FINAL REPORT

Asian Development Bank

National Capital Region Planning Board

Capacity Development of the
National Capital Region Planning Board
Package 2 Component B
TA No. 7055-IND

Volume V-C1:Main Report
Model DPR for Bus Terminal at Ghaziabad

WilburSmith
ASSOCIATES

July 2010

NCR Planning Board
Asian Development Bank

Capacity Development of the National Capital Region Planning Board (NCRPB) – Component B

(TA No. 7055-IND)

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Volume V-C1: DPR for Bus Terminal in Ghaziabad

Main Report

July 2010

Wilbur Smith Associates
Engineers Planners Economists

Abbreviations

ADB	Asian Development Bank
BIS	Bureau of Indian Standard
BOQ	Bill of Quantities
CBR	California Bearing Ratio
CMSA	Cumulative number of Million Standard Axles
DFR	Draft Final Report
DL	Deal Load
DPR	Detailed Project Report
ECS	Equivalent Car Space
FR	Final Report
GDA	Ghaziabad Development Authority
INR	Indian Rupees
IRC	Indian Road Congress
IS	Indian Standard
KMPH	Kilometer per Hour
LCV	Light Commercial Vehicle
LL	Live Load
MAV	Multi-axle Vehicle
MORT&H	Ministry of Road Transport and Highways
NCR	National Capital Region
NCRPB	National Capital Region Planning Board
NH	National Highway
RCC	Reinforced Cement Concrete
ROW	Right of Way
SP	Standard Procedure
TA	Technical Assistance
UP	Uttar Pradesh
UPSRTC	Uttar Pradesh State Road Transport Corporation

Contents

List of Tables

List of Figures

List of Appendices

Appendix 1: Geotechnical Report
Appendix 2: Architectural Drawings
Appendix 3: STAAD Model
Appendix 4: STAAD Input
Appendix 5: Analysis Model for Flat Slab
Appendix 6: Design of Footing
Appendix 7: Design of Column
Appendix 8: Design of Plinth Beam
Appendix 9: Design of Roof Beam (Ground Floor)
Appendix 10: Design of Roof Beam (First Floor)
Appendix 11: Design of Roof Beam (Bus Bay)
Appendix 12: Design of Slab
Appendix 13: Design of Staircase
Appendix 14: Structural Drawings
Appendix 15: BOQs and Detailed Quantity Estimates
Appendix 16: Outline Development Specifications

Compendium Volumes

Besides this Volume V-C1, the DPR for Bus Terminal has following Volumes appended separately.

Volume V-C2: Financial & Economic Analysis
Volume V-C3: Initial Environmental Examination
Volume V-C4: Short Resettlement Plan

1. INTRODUCTION

A. Background

1. The National Capital Region Planning Board, constituted in 1985 under the provisions of NCRPB Act, 1985, is a statutory body functioning under the Ministry of Urban Development, Government of India. NCRPB has a mandate to systematically develop the National Capital Region (NCR) of India. It is one of the functions of the Board to arrange and oversee the financing of selected development projects in the NCR through Central and State Plan funds and other sources of revenue.

2. On Government of India's request, Asian Development Bank (ADB) has formulated the technical assistance (TA) to enhance the capacities of National Capital Region Planning Board and its associated implementing agencies. The TA has been designed in three components: Component A relates to improving the business processes in NCRPB; Component B relates to improving the capacity of the implementing agencies in project identification, feasibility studies and preparing detailed engineering design; and Component C relates to urban planning and other activities.

3. ADB has appointed M/s Wilbur Smith Associates to perform consultancy services envisaged under Component B. In the context of this contract, the first deliverable – Inception Report, was submitted in October 2008. The second deliverable –Interim Report comprising Master Plan for sewerage in Hapur, Master Plan for Water Supply for Panipat, Master Plan for Drainage for Hapur, Master Plan for Solid Waste management for Ghaziabad, Traffic and Transport analysis for Ghaziabad, Socio-Economic base line survey result in 3 sample project towns and proceedings of workshop 1 was submitted in January 2009. The four Master Plans as stated above are also made available on NCRPB web site for use of the implementing agencies.

4. The third deliverable Draft Final Report (DFR) comprising Detailed Project Report (DPR) for water supply in Panipat, DPR for sewerage in Hapur, DPR for drainage in Hapur, DPR for drainage in Sonipat, DPR for solid waste management in Ghaziabad, DPR for four selected transport components (Flyover, Road widening, Multi-level Parking and Bus Terminal) in Ghaziabad, and a Report on Capacity Building Activities were submitted.

5. Now, this is the Final Report (FR) and is the fourth and final deliverable. The comments/feedback on Draft Final Report received from ADB, NCRPB and respective implementing agencies were duly incorporated and final DPRs for components of Water Supply, Sewerage, Drainage, Solid Waste Management, and Transport are submitted as part of this Final Report. This is the Detailed Project Report for Transport Component of Multi-level Parking in Ghaziabad.

B. Overview of this ADB TA

6. *Objectives*. The objective of this TA is to strengthen the capacity at NCRPB, state-level NCR cells, and other implementing agencies in the area of planning for urban infrastructure and to impart necessary skills to conceive, design, develop, appraise and implement good quality infrastructure projects for planned development of NCR. The increased institutional capacity of the NCRPB and the implementing agencies will lead to effective and time scaling-up of urban infrastructure to (i) improve quality of basic urban services in the NCR; (ii) develop counter magnet towns; (iii) reduce in migration into Delhi and orderly development of NCR; and (iv) accelerate economic growth in the NCR.

7. The TA – Capacity Development of the NCRPB, Component B focuses on strengthening the capacities of NCRPB and implementing agencies relating to project feasibility studies and preparation, and detailed engineering design in the implementing agencies. Specifically this component B of the TA will support the project preparation efforts of the implementing agencies by preparing demonstration feasibility studies that include all due diligence documentation required for processing of the project in accordance with best practices, including ADB's policies and guidelines.

8. *Scope of Work*. According to the terms of reference of the TA assignment, the following activities are envisaged in component B of the TA:

(i) Conduct technical, institutional, economic and financial feasibility analysis of identified subprojects in the six sample implementing agencies;
(ii) Conduct safeguards due diligence on the subprojects, including environmental assessment report and resettlement plan for all subprojects covered in the sample implementing agencies;
(iii) Prepare environmental assessment framework and resettlement framework; and
(iv) Develop a capacity building and policy reform program for the implementing agencies, including governance strengthening, institutional development and financial management.

9. Besides, this component of the TA will also:

(i) help in assessing the current practices and procedures of project identification and preparation of detailed project reports including technical, financial, economic and social safeguard due diligence;
(ii) support preparation of standard procedure manuals for project identification and preparation of detailed project reports including technical, financial, economic and social safeguard due diligence;
(iii) train the implementing agencies in the preparation of detailed project reports by using the sample subprojects, reports on deficiency of current practices and standard protocol manuals; and
(iv) help in developing a user-friendly web-page where different manuals and guidelines for preparation of DPRs will be made available for the implementing agencies.

C. About the Final Report

10. At Interim Report stage of the TA, the Master Plans for Water Supply in Panipat, Sewerage system in Hapur, Drainage for Hapur and Municipal Solid Waste Management for Ghaziabad were prepared. The Master Plans provided 100 percent coverage of population and the area likely to be in planning horizon year 2031/2041. All works required up to planning horizon year were conceptualized, broadly designed and block cost was estimated. The Master Plans also provided phasing of investment such that under phase 1 works required to cover present spread of city were proposed.

11. At draft final report stage of the TA the Detailed Project Reports (DPRs) were prepared for Phase 1 works as suggested in the Master Plans. For preparation of DPRs, engineering surveys and investigations were conducted and various possible and feasible alternatives evaluated. Finally for the selected options the DPRs prepared with detailed designs, item wise detailed cost estimate, work specifications, implementation process and proposed implementation arrangements. Further, according to ADB procedures these DPRs in addition to technical analysis included institutional, financial and economic feasibility analysis and environmental and social safeguards due diligence – environmental assessment and resettlement plans.

12. The DPR's submitted as part of Draft Final Report was reviewed by the implementing agencies, NCRPB and the ADB. Now this Final Report comprising DPR's modified in light of comments of IA's is being submitted. The draft DPR for water supply in Panipat was reviewed by PHED Haryana. Detailed discussions were held with Superintending Engineer (Urban), Executive Engineer (Urban), Superintending Engineer (Karnal) and Executive Engineer Panipat. The comments made by PHED have been suitably incorporated in this Final Report.

13. These DPRs are proposed to be made available to the ULBs and other implementing agencies of the state governments as model DPRs so that they may replicate the methodology/approach in the future DPRs prepared by them for obtaining finances from the NCRPB.

14. *Organization of this Final Report*. The Final Report of the TA Component B is organized in following Seven Volumes:

Volume I: Detailed Project Report for Water Supply System in Panipat

Volume II: Detailed Project Report for Rehabilitation and Augmentation of Sewerage System in Hapur

Volume III: Detailed Project Report for Rehabilitation of Major Drains in Hapur

Volume IV: Detailed Project Report for Improvement of Solid Waste Management System in Ghaziabad

Volume V: Detailed Project Reports for Four Transport Components in Ghaziabad

Volume VI: Capacity Building Activities

Volume VII: Detailed Project Reports Rehabilitation of Drainage in Sonipat

D. Structure of Volume V Report

15. The DPRs for all four transport components are compiled in Volume V. This is Volume V is presented **four** volumes:

(i) **Volume V-A**: DPR for Mohan Nagar Flyover
(ii) **Volume V-B**: DPR for Road Widening
(iii) **Volume V-C**: DPR for Bus Terminal
(iv) **Volume V-D**: DPR for Multi-level Parking

1. Structure of this Volume V-C Report

16. This DPR for Bus Terminal in Ghaziabad is compiled in following four sub-volumes (**Volumes V-C1 to V-C4**) including this Main Report:

Volume V-C1: Main Report:

- **Section 1** Introduction
- **Section 2** presents bus terminal studies and proposals
- **Section 3** presents planning and design of the proposed bus terminal
- **Section 4** presents cost estimates

Volume V-C2: Financial & Economic Analysis
Volume V-C3: Initial Environmental Examination
Volume V-C4: Short Resettlement Plan

2. BUS TERMINAL STUDIES & PROPOSALS

A. Overview

17. The existing bus stand in Ghaziabad is located in the centre of the city at Navyug Market. The is major centre and is CBD of Ghaziabad busy with various activities; in addition to bus stand, a number of commercial establishments, markets, government offices (Ghaziabad Nagar Nigam and Ghaziabad Development Authority) situated here. Roads around the area are congested with vehicles, pedestrian, squatter, vendors and illegal and haphazard parking all along the roads.

18. Recognizing the importance of decongesting this area, Ghaziabad Master Plan -2021, has identified and earmarked a site near Loni Road and NH 24 junction for shifting the existing Bus Stand and constructing a new Bus Terminal. Accordingly, this DPR study is being carried out for developing a Bus Terminal at the proposed site.

18. The proposed site for the Bus Terminal as per the Ghaziabad Master Plan 2012 is located adjacent to Loni Road and behind the existing truck terminal that is located on G.T. Road. Location of proposed site is shown **Figure 2-1**.

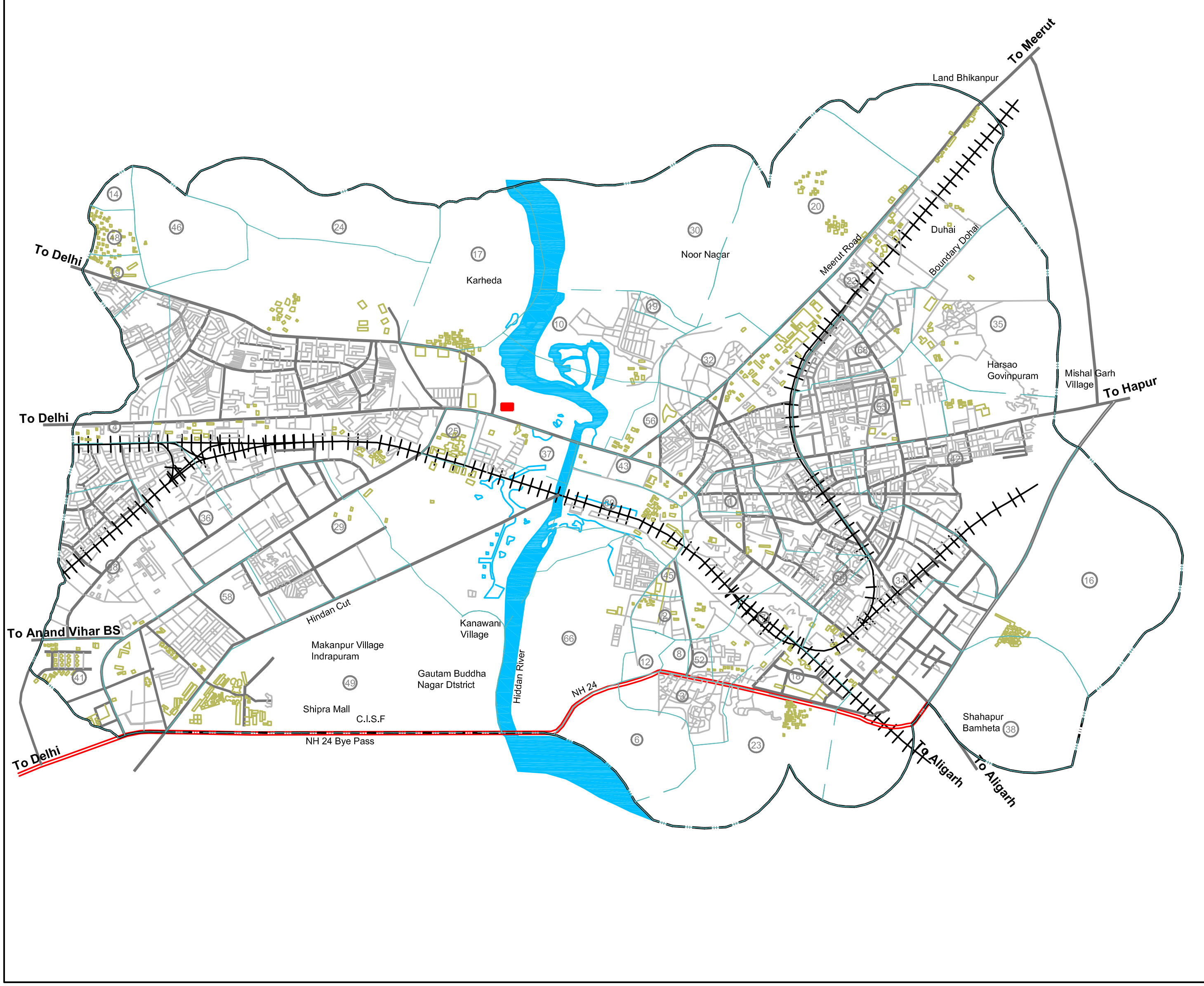
B. Profile of the Proposed Site

19. *Access Roads*. The proposed site is located adjacent to Loni Road and G T Road. The site is an open terrain located behind the commercial tax office / Truck Terminal. The main entrance is through the Loni Road. However, in the due course of time, certain unauthorized structures like small industrial sheds have come up bordering the land under consideration that block the entrance from Loni Road.

20. Loni road is a four lane two-way divided road, which has high movement of traffic flow especially the trucks. The G T Road on the other side is a National Highway (NH 24) which has the maximum traffic load. Road network around the site is shown in **Figure 2-2**.

Capcity Development of the NCRPB: Component B (ADB TA-7055)

Location of Proposed Bus Terminal Site in Ghaziabad



Legend

- Municipal Boundary
- Ward Boundary
- Ward Number
- National Highway
- Other Roads
- Buildings
- River, Stream
- Location of Proposed Bus Terminal

Client

Asian Development Bank
National Capital Region Planning Board

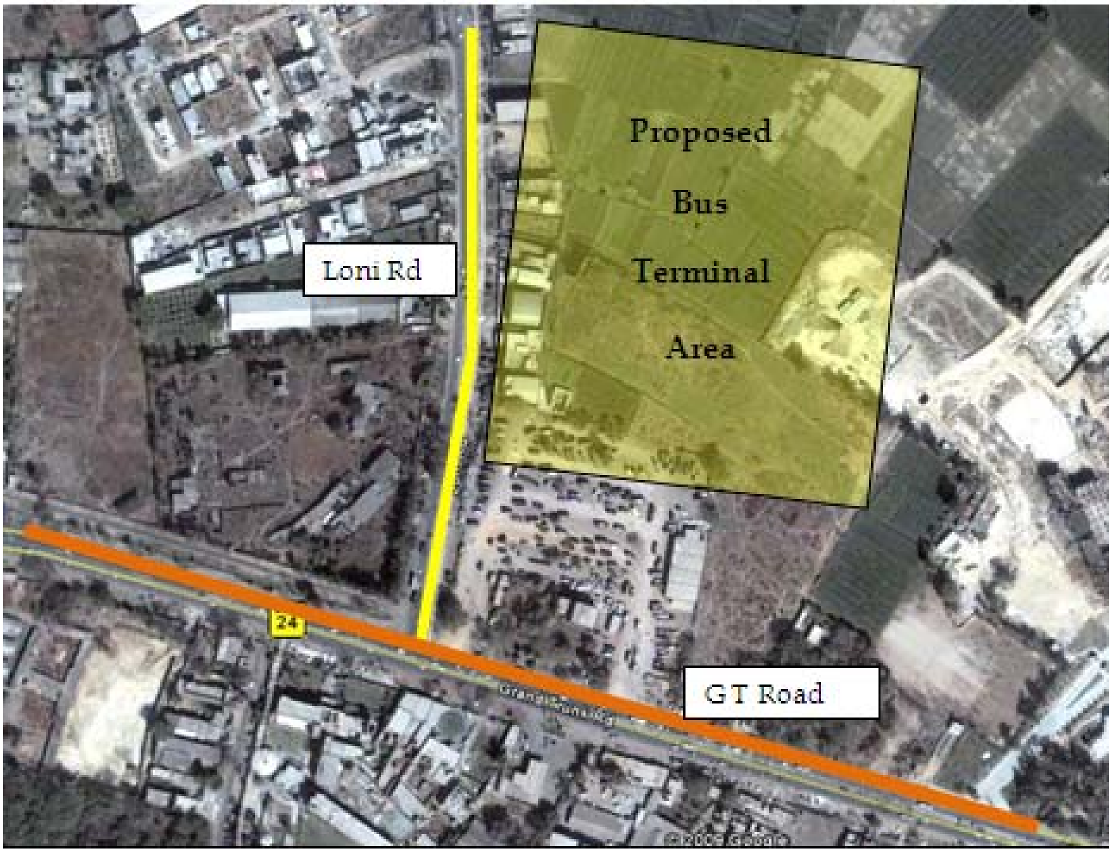
Consultant

Wilbur Smith Associates

Drawn:SK	Checked: SKG
Date: August. 2009	Approved: NSS
Scale: NTS	

Figure 2-1

Figure 2-2: Proposed Site and Adjoining Road Network



C. Detailed Traffic Surveys

1. Site Reconnaissance Survey

21. Taking into the consideration of the Master plan, site reconnaissance was carried out in presence of GDA officials. The entrance from Loni Road has many unauthorized buildings which need to be removed, to give way for the entry and exit of buses and other facilities for the proposed bus terminal. The right hand side of the site is the commercial tax office which has the entrance through the G T Road.

22. The actual available land for the proposed terminal is not known (which may be approximately 25 to 30 acres), but considering the demand required for the current bus terminal, 12 acres of land is enough and topographic surveys were carried out for 12 acres only.

2. Bus Count Survey

23. In order to get the parking demand for the buses, bus counts were done at all the entry and exits of existing old bus stand for the period of 16 hours for two days. Schedule of Surveys is given below.

Table 2-1: Survey Schedule – Bus Count

Type	Schedule	
	Date	**Day**
Bus Count Surveys	17-08-09	Monday
Bus Count Surveys	18-08-09	Tuesday

3. *Pedestrian Count Survey*

24. In order to get the demand of footfall at the bus stand for providing the passenger facilities at the bus terminal, pedestrian counts were done at all the entry and exits of existing old bus stand for the period 16 hours for two days. Schedule of Surveys is given below.

Table 2-2: Survey Schedule – Pedestrian Count

Type	Schedule	
	Date	**Day**
Pedestrian Count	17-08-09	Thursday
Pedestrian Count	18-08-09	Friday

D. Bus Terminal Demand Assessment

25. *Roadway Inventory (Carriage way and ROW) and Issues at the proposed site for Bus Terminal*. The roadway details near the site are as follows:

- All the roads at the vicinity of the site are two way divided roads
- The entrance form Loni Road has lot of encroachments which needs to be removed
- An auxiliary lane has to be provided on Loni Road for the free movement of other vehicles which use the bus terminal

26. *Bus Terminal Supply*. The total count obtained from the bus count survey with respect to the gates at that particular day is presented in the following **Table 2-3**. Bus count surveys were carried out for three days at the entry and the exit points of the existing old bus stand for a period of 16 hours.

Table 2-3: Results of Bus Count Survey

S. No	Day	Gate 1 Entry	Gate 1 Exit	Gate 2 Entry	Gate 2 Exit	Gate 3 Entry	Gate 3 Exit	Total Entry	Total Exit	Difference
1	1	103	164	2	262	261	0	366	426	60
2	2	99	166	4	240	267	0	368	416	48

27. Number of buses counted at entry and exit for day one was 366 and 426. Similarly, for day

two, it was 370 at the entry and 406 at the exit. Thus, the maximum difference in the entry and exit has been 60 buses. The current demand for the buses is estimated to be around 60 which is then projected to the year 2030, considering the vehicular growth pattern.

28. *Parking Demand Forecast*. The demand is projected for the year 2030 with respect to the vehicular growth as mentioned below. The projected demand is about 75 buses for the year 2030.

Table 2-4: Parking Demand Forecast

Base year Parking Demand	Projected Parking Demand (16 Hour surveys)
Base year 2010	60
2010 – 2020	64
2020 – 2025	68
2025 – 2030	75

Notes:

(i) Econometric modeling is used to derive the Growth Factor. To obtain the Growth Factor we consider the data related to Population, Per Capita Income (PCI), Net State Domestic Product (NSDP) and Gross Domestic Product (GDP).

(ii) The influence area of the study includes the state of Uttar Pradesh and Delhi.

(iii) An econometric model measures past relationships among various variables and then tries to forecast how changes in some variables will affect the future course of others.

(iv) Formula Recommended by IRC (108 – 1996) is:

logeP = Ao + A1 logeGDP + A2 logeNSDP +A3 logePopulation + A4 loge PCI

Where,

P = Traffic Volume

A0 = Regression Constant

A1, A2, A3, A4 are the Elasticity Coefficients

(v) The time series data of traffic at the study area and the corresponding data on GDP, NSDP, Population and PCI are tabulated.

(vi) Multiple Regression Analysis is done to arrive at the following equation

logeP = Ao + A1 logeGDP + A2 logeNSDP +A3 logePopulation + A4 loge PCI

The values of A1, A2, A3, A4 are found

(vii) Growth rate of traffic = (A1 * Expected Growth rate of GDP) + (A2 * Expected Growth rate of NSDP)

(A3 * Expected Growth rate of Population) + (A4 * Expected Growth rate of PCI)

(viii) The growth of the traffic is projected with the obtained growth factors.

(ix) The growth rates obtained are

6.5 For the period from 2009 to 2020

6.0 For the period from 2020 to 2025

5.7 For the period from 2025 to 2030

(x) The reason behind the variation of growth factor periodically is because of the predicted periodic changes in factors considered in the regression equation.

E. Proposed Bus Terminal Facility

29. The site proposed for the Bus Terminal is shown but the area to be utilized for the construction is not been specified. Hence as per the demand, 12 acres of land is been considered for planning the bus terminal.

30. The proposed Bus terminal will accommodate car parking, two wheeler parking and auto rickshaw stand with pick up and drop off areas. The Bus Terminal building will include bus parking spaces, passenger waiting areas, ticket booking offices, eating places, rest rooms and other basic amenities. Adequate provision is made in terms of reserving space for fire station, workshop, water service station, gas station, and store room etc. for future expansion.

Photo 1: View of the Proposed Site

Photo 2: View of the Proposed Site

3. PLANNING & DESIGN OF BUS TERMINAL

A. General

31. The proposed site for the Bus Terminal is located adjacent to Loni Road and behind the existing truck terminal that is located on G.T. Road. A reconnaissance survey was carried out to gather basic information about the site, type of area like commercial or residential, climate etc. from different sources. Primary and secondary data available were also collected for further studies.

32. The following site surveys were carried out for the finalization of the structure:
    - Location Survey
    - Topographic Survey
    - Traffic surveys
    - Geotechnical Investigations

33. Due to busy activities in the existing Bus terminal the Consultant was not able to carry out geotechnical investigations at the site. Hence the geotechnical details taken for the proposed Bus Terminal building is considered for the design of Multilevel Car Parking. The lowest value of SBC at a depth of 3m given in the area of Bus Terminal is 225 KN/m2 and this value is considered for design. It is also recommended to take adequate number of confirmatory bore holes during execution. This item is included in the cost estimate of the work.

1. Topographical Survey

34. The basic objective of the topographical survey was to collect the essential ground features of the area using Total Station so as to develop a Digital Terrain Model (DTM), to take care of design requirements. The data collected will result in the final design and is also used for the computation of earthwork and other quantities required.

35. As first step of the field study, satellite imagery maps of the location were collected and examined thoroughly to have first hand information about the area and to decide on the possible improvement options. It also helped out in finalizing the extent of topographical survey.

36. Spot levels were taken along the proposed area at regular intervals to understand the ground variation. The utility services present along the existing area were also plotted. Topographic survey was carried out using Total Station of 5-sec accuracy for detailed mapping and with higher accuracy total station during the traversing (min 3 sec). The existing features surveyed were directly imported into Computer Aided Software and the details of the same has been plotted and presented for ready reference.

2. Geo Technical Investigations for foundation of structure

37. The geotechnical investigations were carried out to appreciate the subsoil layers and their properties to facilitate finalizing the foundation type, depth, size and configuration. Subsoil condition is analyzed along with evaluation of field and laboratory data for determination of necessary physical and chemical characteristic of the in-situ soil strata. Bore holes were taken at five locations (one at each corner and one at centre) for a depth of 25m. In general, the sub soil strata comprises of silty sand and sandy silt up to 10.0 and 10.0 - 18.0m depth respectively. Thin layers of clayey silt and sandy silt with clay are also present. Below this depth the subsoil strata consists of fine sand. SBC value of 225kN/m2 is considered at a depth of 2.5m below ground level. It is also recommended to take adequate number of confirmatory bore holes during execution. This item is included in the cost estimate of the work. The bore logs details, test results and recommendations are given in **Appendix 1: Geotechnical Investigation Report**.

38. In order to prepare the plan of the Bus terminal the following technical factors were taken into consideration.

- Land use requirement for various activities
- Planning norms and regulations
- Topographical and geotechnical factors such as ground features and slope, type of soil, ground water level etc.
- Standards for provision of parking requirement
- Traffic growth trend and future demand
- Water, drainage, power, communication and transport facilities
- Seismic zone and wind direction
- Safety and security

B. Planning considerations

39. The proposed site is located adjacent to Loni Road and G T Road. The site is an open terrain located behind the commercial tax office / Truck Terminal. The main entrance is through the Loni Road which is a four lane two-way divided road, with has high movement of traffic flow especially the trucks. The G T Road on the other side is a National Highway (NH 24) which has the maximum traffic load. The actual available land for the proposed terminal area is not known (which may be approximately 25 to 30 acres), but considering the demand required for the current bus terminal, 12 acres of land is enough and topographic surveys were carried out for 12 acres only. Bus count surveys were carried out for three days at the entry and the exit points of the existing old bus stand for a period of 16 hours. Based on the results, the current demand for the buses is estimated to be around 60 which is then projected to 75 buses for the year 2030, considering the vehicular growth pattern.

40. *General Approach*. Apart from provided 75 bus bays (with a provision to add 75 more in the future), the proposed Bus terminal accommodate car parking, two wheeler parking and auto rickshaw stand with pick up and drop off areas. The Bus Terminal building accommodates bus parking spaces, passenger waiting areas, ticket booking offices, eating places, rest rooms and other basic amenities. Adequate provision is made in terms of reserving space for fire station, water service station, gas station, and store room etc. for future expansion.

41. *Conceptual Plan*. The bus terminal is designed to provide all necessary passenger and commuter facilities for an enhanced user experience. The main aspect of the terminal is to provide proper bus circulation and well designed and comfortable passenger terminal facilities.

(i) Bus circulation: The bus circulation is designed to be unidirectional with busses entering to the left side of the terminal and exiting to the right side of terminal. The driveways are designed to avoid any crossing of busses and to avoid any U turns in the terminal. The busses will be parked at 45 degrees to the terminal.

(ii) Taxi and private vehicles: The cars and private vehicles parking will be limited to the front of the terminal building, without any conflict with the movement of the busses. The 7mts lane in front of the terminal building will facilitate all necessary queue length for all cars and autos without affecting the road traffic.

(iii) Passenger circulation: The total length of the terminal is around 200 m long. The entrances of the terminal are located in three zones, the left, right and the center. The terminal building is located in the front of the site covering the frontage to the road.

(iv) Terminal Building: The terminal building is designed to take the peak traffic and capacity of the 108 bay terminal building. The passenger waiting areas are designed to facilitate clear and smooth movement of pedestrians without needing to cross over the bus movement areas.

(v) Facilities in the Passenger terminal area: These include: entrance lobby, administrative area, passenger utilities, commercial retail & office area, restaurant, passenger waiting area, car & auto parking.

(vi) The Architecture: the architecture of the terminal building reflects the trends in development of public buildings in the country. The façade is treated with modern materials like aluminum composite panels and with stone cladding to achieve a modern and a low maintenance building. The front of the building is designed with ample landscape and paved area for commuter’s movement and a good ambiance in the terminal. Glass is suggested as a material for the entrance lobby to allow ample light and to highlight the entrances.

(vii) Building orientation: The building is oriented to the west of the site to allow for shading of the passenger waiting area from the evening sun. Diffused natural light is used to light up the terminal building. Landscaping in the western side will allow for some passive cooling of the western façade. Punch windows are designed to the western façade of the terminal building in the first floor level (commercial office spaces). The building is designed as an open structure for ample air circulation and ventilation.

42. Typical floor plans are presented in **Figure 3-1** and **Figure 3-2**. Detailed floor plans, sections and elevations are presented in **Appendix 2**.

43. Area statement of the proposed facility is presented in the following Table

Table 3-1: Particulars of Proposed Bus Terminal

S. No.	Parameter	Unit	Value
	Site		
1	Site area	Sq. m	50,410
2	Built up area	Sq. m	15,492
	Ground Floor		
1	Commercial/Retail	Sq. m	1,033
2	Terminal	Sq. m	10,910
3	Driveway	Sq. m	17,808
4	Surface Auto/Car park	Sq. m	3,470
5	Service Station	Sq. m	1,799
	First Floor		
1	Commercial/Retail	Sq. m	1,750
	Parking		
1	Provision for commercial area	No. s	40
2	Provision for Bus Terminal (as per demand)	No. s	60
3	Auto parking	No. s	36
4	Bus bays	No. s	75

Figure 3-1: Ground Floor Plan of the Proposed Bus Terminal

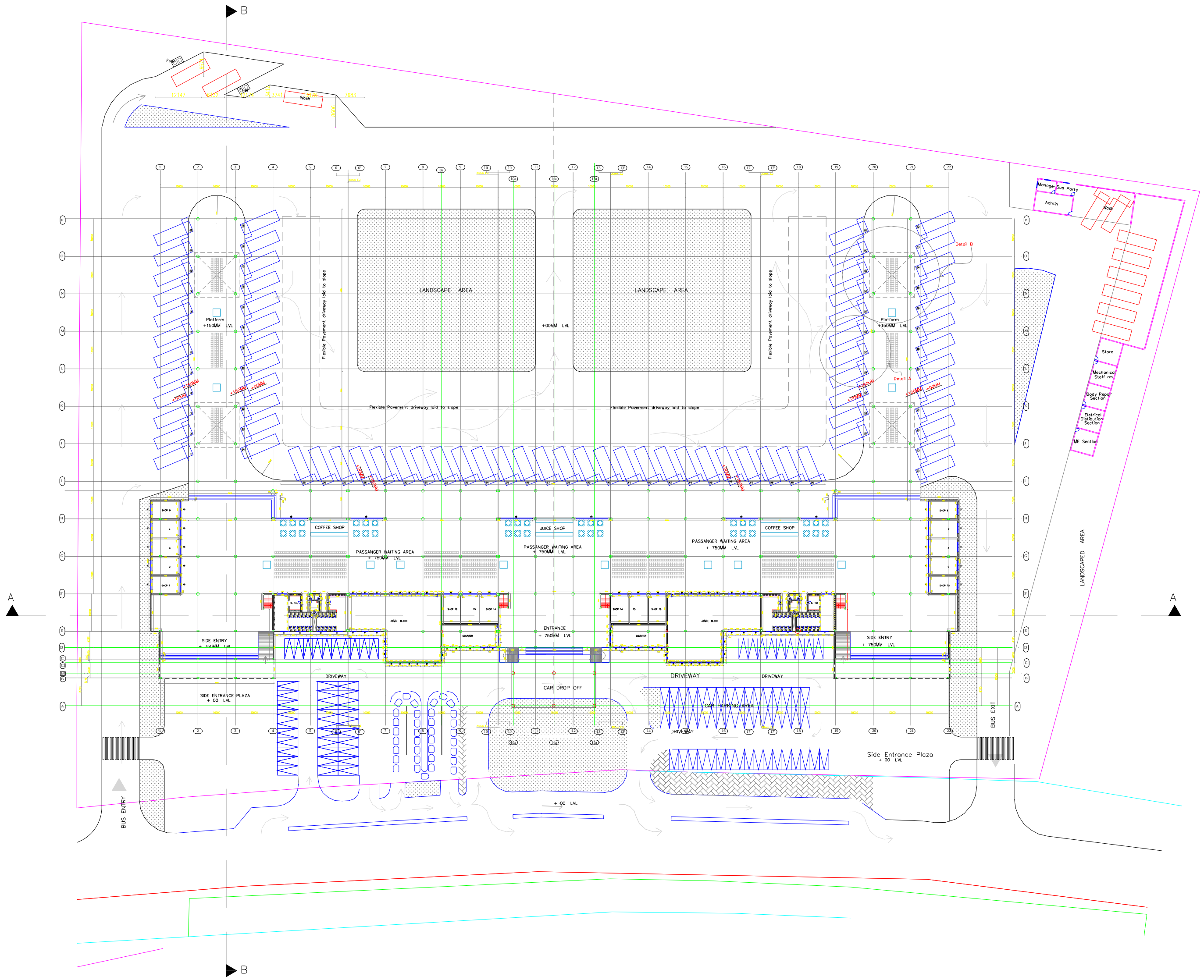
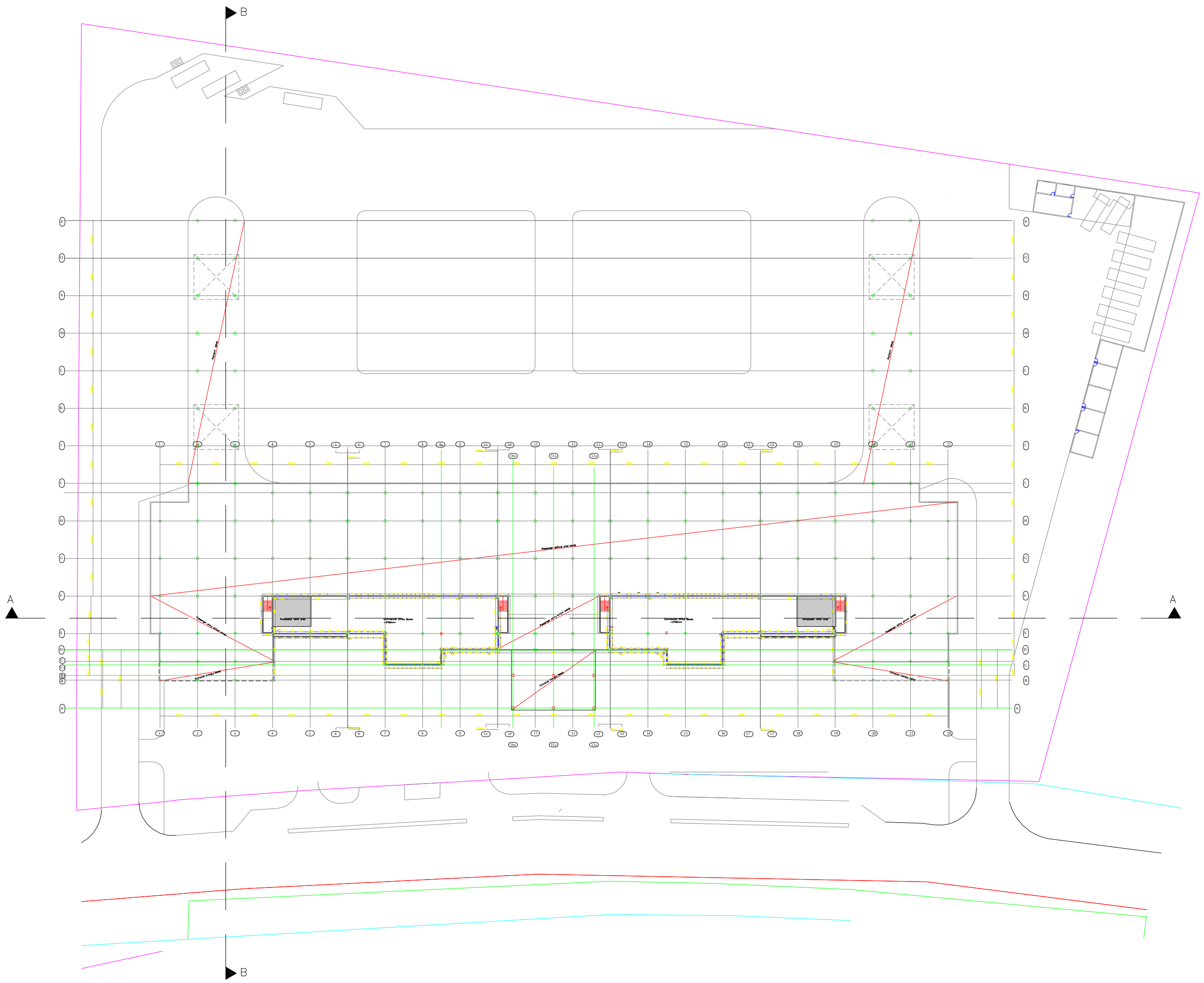


Figure 3-2: First Floor Plan of the Proposed Bus Terminal



C. Structural System

44. The proposed building is 210.079m long and 134.275m wide with a plinth area of 12,722 sq. m for ground floor and 1,720sq. m for first floor. The floor height for Atrium block and Canopy at the main entrance as well as side entrance shall be 7m and 4m respectively. For the administration block the height for each floor shall be 3m. The floor height for the passenger waiting area shall be 6m and for the platform shall be 5m. A combination of column beam/slab beam arrangement is proposed for the building. Ordinary beam slab arrangement is proposed for the administration block and restaurant area. For the remaining portions flat slab is proposed. Large column spacing of 10.0m is adopted along length and breadth for the main area. The flat slab area shall have circular columns and where beam slab arrangement is given, columns shall be rectangular as per requirements. Mild condition of exposure is considered in design. Isolated rectangular or square footings are provided as foundations except at one location where combined footing is given. The minimum depth of foundation shall generally be 2.5 m below ground.

45. Salient features of the building are:

- Length 210.079m
- Breadth 134.275m
- Column spacing (along the length): 10.0m.
- Column spacing (along the breadth):10.0m
- Plinth area: 12722 sq.m for ground floor
- Plinth area: 1720 sq.m for first floor

46. *Design Criterion.*

- Exposure Condition - Mild (as per IS 456 – Table Clause 8.2.2.1 & 5.3.2)
- Grade of Concrete – M30 (as per IS 456 – Table 5 Clause 6.1.2, 8.2.4.1 & 9.1.2)
- Reinforcing Steel - Fe 415 conforming to IS 1786.
- Safe Bearing Capacity of the soil considered – 225 KN/m2
- Depth of foundation – 2.5m below ground

47. *Design Codes and Standards.*

48. The structural design is carried out as per the latest versions of Indian Standard codes published by Bureau of Indian Standards. Various design codes and standards referred are:

- IS 456 for Plain and Reinforced Concrete.
- IS 875 Part 1,2,3 & 5 for dead load, live load, wind load and combinations
- SP 34 for detailing of reinforcement

49. Ghaziabad being in seismic zone IV, the earthquake resistant design became mandatory. The codes followed are:

- IS 1893 Part I for earthquake resistant design and
- IS 13920 for ductile detailing of reinforced concrete subjected to seismic forces.

50. *Loads considered*.

(i) Self Weight of members
(ii) Wall Load
(iii) Slab Live Load (3kN/m2 as per IS 875 Part II)
(iv) Stair Load
(v) Load due to Wind

51. For wind load the four Cases considered are:

- Wind force acting in X direction
- Wind acting in -X direction
- Wind force acting in Z direction
- Wind acting in -Z direction

52. *Wind Load Analysis*. General load combinations considered in the design are: (as per IS 456 – Table 18 Clause 18.2.3.1, 36.4 & B-4.3)

- 1.5 * (DL+WX)
- 1.5 * (DL-WX)
- 1.5 * (DL+WZ)
- 1.5 * (DL-WZ)
- 1.2 * (DL+LL+WX)
- 1.2 * (DL+LL-WX)
- 1.2 * (DL+LL+WZ)
- 1.2 * (DL+LL-WZ)
- 0.9 * DL+ 1.5 * WX
- 0.9 * DL - 1.5 * WX
- 0.9 * DL+ 1.5 * WZ
- 0.9 * DL - 1.5 * WZ

53. *Load due to Earthquake*. The two cases considered are: (i) force acting in X direction, and (ii) force acting in Z direction: Load combinations considered are:

- 1.5 * (DL+LL)
- 1.5 * (DL+EQX)
- 1.5 * (DL-EQX)
- 1.5 * (DL+EQZ)
- 1.5 * (DL-EQZ)
- 1.2 * (DL+LL+EQX)
- 1.2 * (DL+LL-EQX)
- 1.2 * (DL+LL+EQZ)
- 1.2 * (DL+LL-EQZ)
- 0.9 * DL+ 1.5 * EQX
- 0.9 * DL - 1.5 * EQX
- 0.9 * DL+ 1.5 * EQZ
- 0.9 * DL - 1.5 * EQZ

54. Following densities and load values are considered for design:

(i)	Density of Reinforced concrete	: 24 kN/m3
(ii)	Density of brick masonry	: 18.85 kN/m3
(iii)	Density of earth	: 18 kN/m3
(iv)	Superimposed Live Load for Floor	: 3 kN/m2
(iv)	Floor Finishes	: 1 kN/m2

55. *Data for wind load design*.

(i) Basic wind speed – Ghaziabad 47 m/sec (Appendix A Clause 5.2)
(ii) Wind Intensity – 1.73 kN/m2

56. *Criteria for Earthquake Resistant Design of Structures*. (IS 1893-2002) Clause 6.3.1.2 Partial safety factors for limit state design of reinforced concrete and prestressed concrete structures.

57. In the limit state design of reinforced concrete structures, the following load combinations are to be accounted for:

(i) 1.5(DL+IL)
(ii) 1.2(DL+IL±EL)
(iii) 1.5(DL±EL)
(iv) 0.9DL±1.5EL

58. *Factors Considered for Earth Quake Analysis*.

- Ghaziabad is Located in Zone IV
- Zone Factor : 0.24
- Importance Factor : 1.5
- Response Reduction Factor : 3.0
- Rock & Soil Site Factor : 1.0
- Damping Ratio : 0.5
- Suitable increase in SBC is considered as per IS 1893-2002

Ref: [Table1 Percentage of Permissible Increase in Allowable Bearing Pressure or Resistance of Soils (clause6.3.5.2)]

For Medium soil - Percentage of Permissible Increase is 25% for isolated RCC footing without tie beams, or unreinforced strip foundations.

59. *Clear cover to reinforcement*. The following clear cover to the outer reinforcement shall be adopted:

- For Foundation : 50 mm.
- For Beams : 30 mm.
- For Slabs : 20mm.
- For columns : 40 mm.

60. The framed system is analyzed as a 3D structure using STAAD Pro 2007. The member forces and moments from the STAAD output are taken for the design. The beams are designed as singly reinforced as well as doubly reinforced depending upon the requirement. The columns are designed as square or rectangular in shape. The slabs supported by beams and columns are designed using the method specified in Annexure D of IS 456:2000 and the flat slab is designed according to clause 31 of IS 456. The various structural elements are designed for the worst combination of loads

D. Analysis of Bus Terminal

61. Bus terminal has a plinth area of 12722 sq.m with length of 210.079 and width of 134.275m. STAAD Pro 2007 is used for the modeling of the structure. For the accuracy of results the whole structure has been split into number of units & modeled separately such as for portions having different heights, staircase & also for different panels within the structure.

62. To take care of temperature stresses in slab an expansion joint of 20 mm is provided along the width of the structure. Four expansion joints are provided forming a total of five sections of 50.010m, 40.020m, 30.020m, 40.020m & 50.010m.

63. Based on the axial load following types of footings are designed:

- Isolated footings of 6 different sizes.
- Combined Footings of 2 different sizes.

64. Details are given in the structural drawings. All footings shall be founded at a minimum depth of 2.5m from ground level based on the bearing capacity requirement of the soil.

65. Columns are designed for biaxial bending considering axial Load & moments in X & Y directions. There are about 10 different types of columns with in the structure considering span & load.

66. *Seismic Analysis*. Static Equivalent Method is used for the seismic analysis utilizing the rules of IS: 1893(part 1) – 2002.

67. *Methodology*. In seismic load generation using a static equivalent approach, encompassed in code IS 1893, the weights in the structure are specified. There are three methods for specifying the weights: self weight, joint weight and member weight. Weights, which could be treated as being lumped at a node, could be assigned using Joint Weight the same has been used during this analysis. The joint loads at all the nodes are obtained from the initial analysis by assuming pinned supports at all the beam column joints. These loads are applied as weight for the seismic analysis.

68. Analysis of this system for all the loads/load combinations is carried out. Please refer following volumes appended this DPR Main Report of Multi-level Parking Facility in Ghaziabad.

Appendix 3: STAAD Model
Appendix 4: STAAD Input
Appendix 5: Analysis Model for Flat Slab
Appendix 6: Design of Footing
Appendix 7: Design of Column
Appendix 8: Design of Plinth Beam
Appendix 9: Design of Roof Beam (Ground Floor)
Appendix 10: Design of Roof Beam (First Floor)
Appendix 11: Design of Roof Beam (Bus Bay)
Appendix 12: Design of Slab
Appendix 13: Design of Staircase
Appendix 14: Structural Drawings

4. COST ESTIMATES

A. Rate Analysis

69. The unit rates shall be arrived by considering the basic rates, lead distances, man power, machinery, and materials. The unit rate for every individual item is arrived based on Uttar Pradesh Lok Nirman Vibhag (UP Public Works Department), Schedule of Rates for Ghaziabad District 2008 and Central Public Works Department Delhi, Schedule of rates 2007. For items of work with no rates specified in the schedule of rates, market rates are obtained and used.

B. Bill of Quantities & Cost Estimates

70. Total item wise quantities are calculated as per the detailed drawings. Separate heads for all different items of work is included in the BOQ. The major work items considered are

- Earth work excavation
- Concrete
  - PCC leveling Course
  - Reinforced Cement concrete M30
  - Foundation
  - For Walls, columns, beams, slab etc
- Steel
  - Reinforcement
  - Foundation
  - For Walls, columns, beams, slab etc

71. Apart from the civil cost, provision for the following are also made

- Pavement cost
- Electrical cost
- Costs for plumbing, sanitation along with storage facilities
- Costs for office room, seating arrangement and other passenger amenities

72. The total project cost works out to INR 285.6 million. Detailed cost estimates are presented in **Appendix 15**. General development specifications are given in **Appendix 16.**

Appendix 1

PART-II

GEOTECHNICAL INVESTIGATION WORK FOR PROPOSED BUS TERMINAL AT MOHAN NAGAR

REPORT ON

GEOTECHNICAL INVESTIGATION WORK FOR PROPOSED BUS TERMINAL AT MOHAN NAGAR

CONTENTS

REPORT ON
GEOTECHNICAL INVESTIGATION WORK FOR PROPOSED BUS TERMINAL AT MOHAN NAGAR

Summary of Borehole:

Sl. No.	Bore Hole No.	Ground R.L.	Depth of Overburden soil	Total Depth (m)	Depth of Ground Water Table (m)
1.	BH-1	99.650	25.0	25.0	8.50
2.	BH-2	99.712	25.0	25.0	8.50
3.	BH-3	99.708	25.0	25.0	8.50
4.	BH-4	99.703	25.0	25.0	8.50
5.	BH-5	99.685	25.0	25.0	8.50

1.0 FINDINGS OF GEOTECHNICAL INVESTIGATION

1.1 The classification of subsoil strata met at this site was done according to IS:1498-1970. From the bore log enclosed with the report, the test results can be summarized as below-

BH-1 (G.R.L. 99.650)

The subsoil strata from 0.0 to 4.0m depth consists of depth consists of silty sand classified as SM, from 4.0m to 5.0m & 10.0m to 14.0m depths consist of clayey silt classified as CL, from 5.0m to 10.0m depth consists of sandy silt classified as ML, from 14.0m to 17.0m depth consists of sandy silt with clay classified as ML-CL and from 17.0m to 25.0m depth consists of fine sand classified as SP-SM.

BH-2 (G.R.L. 99.712)

The subsoil strata from 0.0 to 3.0m & 17.0m to 25.0m depths consist of silty sand classified as SM, from 3.0m to 7.0m & 9.0m to 17.0m depths consist of sandy silt with clay classified as ML-CL and from 7.0m to 9.0m depth consists of fine sand classified as SP-SM.

REPORT ON GEOTECHNICAL NVESTIGATION WORK FOR PROPOSED BUS TERMINAL AT MOHAN NAGAR

BH-3 (G.R.L. 99.708)

The subsoil strata from 0.0 to 10.5m depth consists of silty sand classified as SM, and from 10.5m to 25.0m depth consists of fine sand classified as SP-SM.

BH-4 (G.R.L. 99.703)

The subsoil strata from 0.0 to 5.0m & 13.0m to 18.0m depths consist of silty sand classified as SM, from 5.0m to 11.0m depth consists of fine sand classified as SP-SM, from 11.0m to 13.0m depth consists of sandy silt classified as ML and from 18.0m to 25.0m depth consists of fine sand with gravel classified as SP-SM.

BH-5 (G.R.L. 99.685)

The subsoil strata from 0.0 to 4.0m & 6.0m to 10.0m depths consist of silty sand classified as SM, from 4.0m to 6.0m depth consists of clayey silt classified as CL, from 10.0m to 15.0m depth consists of sandy silt classified as ML and from 15.0m to 25.0m depth consists of fine sand classified as SP-SM.

In general the subsoil strata at this site comprise of silty sand and sandy silt up to 10.0-18.0m depth, thin layers of clayey silt & sandy silt with clay are also present . Below this depth the subsoil strata consists of fine sand.

The subsoil strata are medium dense to dense up to the depth of exploration.

The Detail description of subsoil strata encountered along with various laboratory test results are presented in the respective bore log enclosed with this report.

The subsoil profile depicting the distribution of the various subsoil strata along with N values (observed/corrected) and other strength parameters with depth are given in subsoil profile enclosed with this report. The SPT Curves & Tables (No/Nc), Grain Size Analysis Curves, etc. are enclosed with this report.

The layer wise properties of the encountered subsoil strata at this site may be adopted from the following table no. 1.

Table no.1 layer wise properties of subsoil strata at the site

Sl. No.	Depth (m)		c	φ	γ_{eff}	K_0	Ka	Kp
	From	To	Kg/cm2	degree	gm/cc			
1.	0.0	4.0	0.10	29.5	1.65	0.507	0.340	2.94

2.	4.0	8.0	0.0	31.5	1.68	0.478	0.314	3.19
3.	8.0	13.0	0.56	10.0	0.97	0.826	0.704	1.42
4.	13.0	20.0	0.0	33.0	1.0	0.455	0.295	3.39
5.	20.0	25.0	0.0	33.5	1.0	0.448	0.289	3.46

Where

C & φ – Shear Parameters

K_0, K_a, K_p – Earth Pressure Coefficients at rest, in active case & in passive Case.

The depth wise lowest SPT values 'N' (observed/corrected) at the site may be adopted from the following table no.4.

Table No.2 Depth wise lowest observed/corrected SPT Values at the site

Sl. No.	**Depth below existing ground level (m)**	**Lowest SPT Values**		**Effective density gm/cc**
		Observed	**Corrected**	
1	1.5	14	20.6	1.65
2	3.0	17	21.0	1.65
3	4.5	19	20.9	1.65
4	6.0	20	20.0	1.68
5	7.5	22	20.3	1.68
6	9.0	24	20.7	1.68
7	10.5	25	19.9	0.97
8	12.0	29	21.3	0.97
9	13.5	31	21.6	0.97
10	15.0	32	21.4	1.0
11	16.5	34	21.7	1.0
12	18.0	36	22.0	1.0
13	19.5	38	22.3	1.0
14	21.0	40	22.6	1.0
15	22.5	41	22.5	1.0

16	24.0	44	23.1	1.0
17	25.0	49	24.5	1.0

The results of chemical analysis of subsoil sample are enclosed with this report

The result of chemical analysis of subsoil sample indicate that the pH value, sulphate content, chloride content are within permissible limit and the RCC work prepared with Ordinary Portland Cement shall not be deteriorated when placed over/within site subsoil.

The result of chemical analysis tests on ground water sample is annexed with the report.

The results indicate that the pH Value & Sulphate Contents are within permissible limits, the chloride content is on higher sides hence as per IS: 456, at the time of placing the concrerte it should be ensured that total amount of chloride (Cl) of all constituents of concrete shall be as per Table 7 of IS;456-2000.

1.2 GROUND WATER

The ground water table was encountered at 8.50m depth below existing ground level in the borehole during boring activities at site. The measured ground water level may fluctuate due to variation in climatic conditions and rate of surface evapotranspiration. However, for design purposes the ground water table may be considered at 5.0m depth below general existing ground level as the ground water level may rise in heavy rainy season/due to unforeseen reasons.

2.0 PROPOSED DEPTH & TYPE OF FOUNDATIONS

Depending upon the visual examination of soil & field strata, field and laboratory test results and the type of structures proposed at this site, the safe bearing capacity of sub-soil strata for isolated and strip footings have been analyzed. The details of the proposed foundations are presented in the following paragraphs:

a) Isolated footings of dimensions 1.0m x 1.0m, 2.0m x 2.0m, 3.0m x 3.0m & 4.0m x 4.0m with base of foundations at 1.0, 2.0m, 3.0m & 4.0m depth below natural ground surface.

b) Strip footings of width 1.0m, 2.0m, 3.0m & 4.0m with base of foundations at 1.0, 2.0m, 3.0m & 4.0m depth below natural ground surface.

3.0 COMPUTATION OF SAFE /ALLOWABLE BEARING CAPACITY:

Shear and settlement failure criteria as per IS: 6403- 1981 , IS : 8009 (part-1)-1976 and IS: 1904-1986 have been considered to compute the safe / allowable bearing capacity of underlying soil strata for isolated and strip footings. The safe/allowable bearing capacity from both criteria is given as follows:-

3.1 SHEAR FAILURE CRITERION:

The net safe bearing capacity of sub-soil strata has been computed by using the following equation for calculating the net ultimate bearing capacity.

Qnu = CN'c scdcic + q (Nq'–1) sqdqiq + 1/2 rBNr'srdrirx W',

The shear parameters are selected from table no.1 according to the depth of foundations

Average Shear Parameters are computed by the following equation by iteration:

Cav = (C1h1 + C2h2 + ---- + Cnhn)/h

tan Ø av = (h1 tan Ø 1 + h2 tan Ø 2+----+ hn tan Ø n)/h

where h =0.5xBxtan(45+ Øav/2) below foundation level

and Ci, Øi, hi-cohesion, angle of friction and thickness of ith layer below foundation level and up to thickness h respectively.

Shape factors have been taken as follows:-

Sc = 1.3, Sq = 1.2 & Sr = 0.8 (for isolated footing)

Sc = 1.0, Sq = 1.0 & Sr = 1.0 (for strip footing)

ic = iq = ir = 1.0 (for vertical loads)

Effective density – as per table no.1& 2.

Depth factors:

dc=1+0.2xof/B tan (45º+ Øav/2)

dq=dr=1 + 0.1xDf/B tan (45º+ Ø av/2)

Water correction factor (w)' = 0.5(1+dw/B)

Where dw = depth of water table from the base of foundation.

In present case, w' = 0.5 (for worst subsoil condition)

Factor of safety F.O.S=2.5

3.2 SETTLEMENT FAILURE CRITERION:

The settlement of cohesion less / less cohesive layers below the foundation level and up to the zone of Influence are computed by using the chart of settlement Vs SPT 'N' given on page 17 of IS 8009, part-I.

For Isolated and strip footings, the zone of influence below the foundation depth is considered equal to 2.0B, where B is the width of foundation.

The following total permissible settlements have been considered

for Isolated footing = 50mm

for Strip footing = 60mm

The soil parameters (SPT values observed/corrected) have been adopted from the table no. 2

The values of settlement obtained as above are corrected applying the Fox's depth correction factor

4.0 CONCLUSION WITH RECOMMENDATIONS:

On the basis of above Geotechnical investigation the following recommendations are suggested:

4.1 The subsoil strata at this site have been described in detail for in clause 1.0

4.2 On the basis of field and laboratory test results and analysis in section 3.0, the lower of the values of net safe bearing capacity obtained from shear failure criterion and net allowable pressure intensity obtained from settlement failure criterion can be adopted for design purposes. The recommended values of net safe bearing capacities/ net allowable pressure intensities for design purposes, are given in the following table no. 3.

Table no. 3: Recommended Values of Net SBC/API

Depth of foundation below natural	Type of foundation (m)	Size/width of foundation (m)	Net SBC in Shear (t/m^2)	Net Allowable Pressure	Net SBC/API (t/m^2)

ground level (m)				**intensity (t/m^2)**	
1.0	isolated	1.0 x 1.0	13.2	38.3	13.2
		2.0x2.0	12.8	18.4	12.8
		3.0 x 3.0	13.3	15.0	13.3
		4.0x4.0	13.4	15.3	13.4
2.0	isolated	1.0 x 1.0	21.1	44.4	21.1
		2.0x2.0	19.4	19.2	19.2
		3.0 x 3.0	18.5	21.8	18.5
		4.0x4.0	18.2	17.8	17.8
3.0	isolated	1.0 x 1.0	29.2	49.3	29.2
		2.0x2.0	25.2	27.1	25.2
		3.0 x 3.0	23.9	22.2	22.2
		4.0x4.0	23.7	29.0	23.7
4.0	isolated	1.0 x 1.0	34.6	49.6	34.6
		2.0x2.0	31.3	28.6	28.6
		3.0 x 3.0	30.0	24.7	24.7
		4.0x4.0	29.9	20.3	20.3
1.0	strip	1.0	9.6	46.0	9.6
		2.0	10.6	22.1	10.6
		3.0	10.5	28.0	10.5
		4.0	11.0	18.4	11.0
2.0	strip	1.0	15.5	53.3	15.5
		2.0	15.5	23.0	15.5
		3.0	15.3	26.1	15.3
		4.0	15.8	21.4	15.8
3.0	strip	1.0	22.5	59.1	22.5
		2.0	19.8	32.5	19.8
		3.0	20.4	26.7	20.4
		4.0	19.6	22.8	19.6

4.0	strip	1.0	28.7	59.5	28.7
		2.0	23.0	34.3	23.0
		3.0	24.5	29.6	24.5
		4.0	22.3	24.3	22.3

The net SBC/API for intermediate widths & depths may be interpolated from above values.

4.3 The ground water table was encountered at 8.50m depth below existing ground level in the borehole during boring activities at site. The measured ground water level may fluctuate due to variation in climatic conditions and rate of surface evapotranspiration. However, for design purposes the ground water table may be considered at 5.0m depth below general existing ground level as the ground water level may rise in heavy rainy season/due to unforeseen reasons.

4.4 Layer wise properties of the encountered subsoil strata may be adopted from table no. 1 & 2 given in clause 1.0.

4.5 The slope of the excavated pit may be kept at 26^0 with horizontal with factor of safety of 1.25 during excavation. However, if space is constraint then suitably designed bracing and strutting system should be adopted.

4.6 The result of chemical analysis of subsoil sample indicate that the pH value, sulphate content, chloride content are within permissible limit and the RCC work prepared with Ordinary Portland Cement shall not be deteriorated when placed over/within site subsoil.

The results of chemical analysis on ground water indicate that the pH Value & Sulphate Contents are within permissible limits, the chloride content is on higher sides hence as per IS: 456, at the time of placing the concrerte it should be ensured that total amount of chloride (Cl) of all constituents of concrete shall be as per Table 7 of IS;456-2000.

4.7 The above recommendations have been made on the basis of in situ tests and laboratory tests conducted on the samples collected from limited number of bore holes bored at the locations given by the client. If during excavation, any unusual or abnormal features are noticed, these may be brought to the attention of Maverick Engineers for further suggestions.

S0IL PROFILE | **PROJECT:** SUB SOIL INVESTIGATION WORK FOR PROPOSED BUS TERMINAL AT MOHAN NAGAR | **SHEET NO 55**

GROUND R.L.	BOREHOLE NO	BORING DATE	TERMINAL DEPTH (m)	WATER TABLE (m)
99.650	BH-1	20/09/2009	25.00	8.50

N VALUES	R.L.	DEPTH	SAMPLE	DESCRIPTION OF SOIL	IS CLASSIF -ICATION	GRAIN SIZE ANALYSIS				LIQUID LIMIT	PLASTIC LIMIT	DRY/BULK DENSITY	MOIST. CONT	SHEAR PARAMETER			SPECIFIC GRAVITY
		m				GRAVEL %	SAND %	SILT %	CLAY %	%	%	gm/cc	%	TEST TYPE	C kg/cm^2	ϕ deg.	
	99.15	0.5	DS-1	Silty Sand	SM	0	55	45	0	N	P						2.64
15	98.15	1.5	SPT-1														
	97.15	2.5	UDS-1	Silty Sand	SM	0	54	46	0	N	P	1.54/1.61	4.46	DST	0.05	30.0	2.64
18	96.65	3.0	SPT-2														
19	95.15	4.5	SPT-3	Clayey silt	CL	0	21	62	17								2.68
	94.65	5.0	UDS-2	Sandy silt	ML	7	40	53	0	N	P	1.58/1.65	4.52	DST	0.10	29.5	2.65
20	93.65	6.0	SPT-4														
22	92.15	7.5	SPT-5														
	91.65	8.0	UDS-3	Sandy silt	ML	7	41	52	0	N	P						2.65
24	90.65	9.0	SPT-6														
25	89.15	10.5	SPT-7														
	88.65	11.0	UDS-4	Clayey silt	CL	4	22	58	16	32	21	1.63/1.97	20.65	UUT	0.56	10.0	2.69
29	87.65	12.0	SPT-8														
31	86.15	13.5	SPT-9														
	85.65	14.0	UDS-5	Sandy silt with clay	ML-CL	3	25	59	13	29	20						2.67
33	84.65	15.0	SPT-10														
36	83.15	16.5	SPT-11														
	82.65	17.0	UDS-6	Fine sand	SP-SM	0	91	9	0	N	P			DST	0.0	33.0	2.63
38	81.65	18.0	SPT-12														
41	80.15	19.5	SPT-13														
	79.65	20.0	UDS-7	Fine sand	SP-SM	0	93	7	0	N	P	1.69/1.97	16.56	DST	0.0	33.5	2.64
45	78.65	21.0	SPT-14														
46	77.15	22.5	SPT-15														
	76.65	23.0	UDS-8	Fine sand	SP-SM	0	92	8	0	N	P			DST	0.0	34.0	2.64
47	75.65	24.0	SPT-16														
	74.65	25.0	SPT-17														

S0IL PROFILE

PROJECT: SUB SOIL INVESTIGATION WORK FOR PROPOSED BUS TERMINAL AT MOHAN NAGAR

SHEET NO 56

GROUND R.L.	BOREHOLE NO	BORING DATE	TERMINAL DEPTH (m)	WATER TABLE (m)
99.712	BH-2	22/09/2009	25.00	8.50

N VALUES	R.L.	DEPTH	SAMPLE	DESCRIPTION OF SOIL	IS CLASSIF -ICATION	GRAIN SIZE ANALYSIS				LIQUID LIMIT	PLASTIC LIMIT	DRY/BULK DENSITY	MOIST. CONT	SHEAR PARAMETER			SPECIFIC GRAVITY
		m				GRAVEL %	SAND %	SILT %	CLAY %	%	%	gm/cc	%	TEST TYPE	C kg/cm^2	φ deg.	
	99.212	0.5	DS-1	Silty Sand	SM	0	55	45	0	N	P						
16	98.212	1.5	SPT-1														
	97.212	2.5	UDS-1	Silty Sand	SM	0	57	43	0	N	P	1.55/1.62	4.65	DST	0.0	31.0	2.64
17	96.712	3.0	SPT-2														
19	95.212	4.5	SPT-3														
	94.712	5.0	UDS-2	Sandy silt with clay	ML-CL	3	22	64	11	28	21	1.60/1.68	5.12	UUT	0.38	13.0	2.68
22	93.712	6.0	SPT-4														
25	92.212	7.5	SPT-5														
	91.712	8.0	UDS-3	Fine sand	SP-SM	2	92	6	0	N	P	1.64/1.91	16.55	DST	0.0	32.0	2.63
27	90.712	9.0	SPT-6														
30	89.212	10.5	SPT-7														
	88.712	11.0	UDS-4	Sandy silt with clay	ML-CL	0	22	66	12	29	22	1.65/2.0	21.28	UUT	0.64	14.0	2.67
31	87.712	12.0	SPT-8														
33	86.212	13.5	SPT-9														
	85.712	14.0	UDS-5	Sandy silt with clay	ML-CL	0	20	70	10	28	21	1.65/1.99	20.86	UUT	0.72	14.0	2.67
35	84.712	15.0	SPT-10														
37	83.212	16.5	SPT-11														
	82.712	17.0	UDS-6	Silty Sand	SM	2	62	36	0	N	P	1.68/1.95	16.26	DST	0.0	33.0	2.65
41	81.712	18.0	SPT-12														
47	80.212	19.5	SPT-13														
	79.712	20.0	UDS-7	Silty Sand	SM	0	58	42	0	N	P	1.70/1.97	15.82	DST			2.64
50	78.712	21.0	SPT-14														
55	77.212	22.5	SPT-15														
	76.712	23.0	UDS-8	Silty Sand	SM	0	64	36	0	N	P	1.72/1.97	14.76	DST	0.0	34.5	2.65
60	75.712	24.0	SPT-16														
	74.712	25.0	SPT-17														

					S0IL PROFILE	PROJECT: SUB SOIL INVESTIGATION WORK FOR PROPOSED BUS TERMINAL AT MOHAN NAGAR										SHEET NO 57			
					GROUND R.L. 99.708	BOREHOLE NO BH-3			BORING DATE 23/09/2009			TERMINAL DEPTH (m) 25.00				WATER TABLE (m) 8.50			
N VALUES	R.L.	DEPTH	SAMPLE	DESCRIPTION OF SOIL	IS CLASSIF -ICATION	GRAIN SIZE ANALYSIS				LIQUID LIMIT	PLASTIC LIMIT	DRY/BULK DENSITY	MOIST. CONT	SHEAR PARAMETER			SPECIFIC GRAVITY		
		m				GRAVEL %	SAND %	SILT %	CLAY %	%	%	gm/cc	%	TEST TYPE	C kg/cm^2	φ deg.			
	99.208	0.5	DS-1	Silty sand	SM	0	56	44	0	N	P								
14	98.208	1.5	SPT-1																
	97.208	2.5	UDS-1	Silty sand	SM	0	68	32	0	N	P	1.55/1.62	4.54	DST	0.0	31.0	2.64		
18	96.708	3.0	SPT-2																
20	95.208	4.5	SPT-3																
	94.708	5.0	UDS-2	Silty sand	SM	0	56	44	0	N	P								
22	93.708	6.0	SPT-4																
24	92.208	7.5	SPT-5																
	91.708	8.0	UDS-3	Silty sand & gravel	SM	6	52	42	0	N	P	1.64/1.93	17.65	DST	0.0	32.5	2.65		
26	90.708	9.0	SPT-6																
29	89.208	10.5	SPT-7																
	88.708	11.0	UDS-4	Fine sand	SP-SM	0	91	9	0	N	P								
33	87.708	12.0	SPT-8																
36	86.208	13.5	SPT-9																
	85.708	14.0	UDS-5	Fine sand	SP-SM	0	93	7	0	N	P	1.67/1.95	16.64	DST	0.0	33.5	2.63		
39	84.708	15.0	SPT-10																
37	83.208	16.5	SPT-11																
	82.708	17.0	UDS-6	Fine sand	SP-SM	0	92	8	0	N	P								
38	81.708	18.0	SPT-12																
40	80.208	19.5	SPT-13																
	79.708	20.0	UDS-7	Fine sand	SP-SM	0	90	10	0	N	P	1.70/1.96	15.12	DST	0.0	34.0	2.64		
45	78.708	21.0	SPT-14																
50	77.208	22.5	SPT-15																
	76.708	23.0	UDS-8	Fine sand	SP-SM	0	92	8	0	N	P								
49	75.708	24.0	SPT-16																
54	74.708	25.0	SPT-17																

S0IL PROFILE

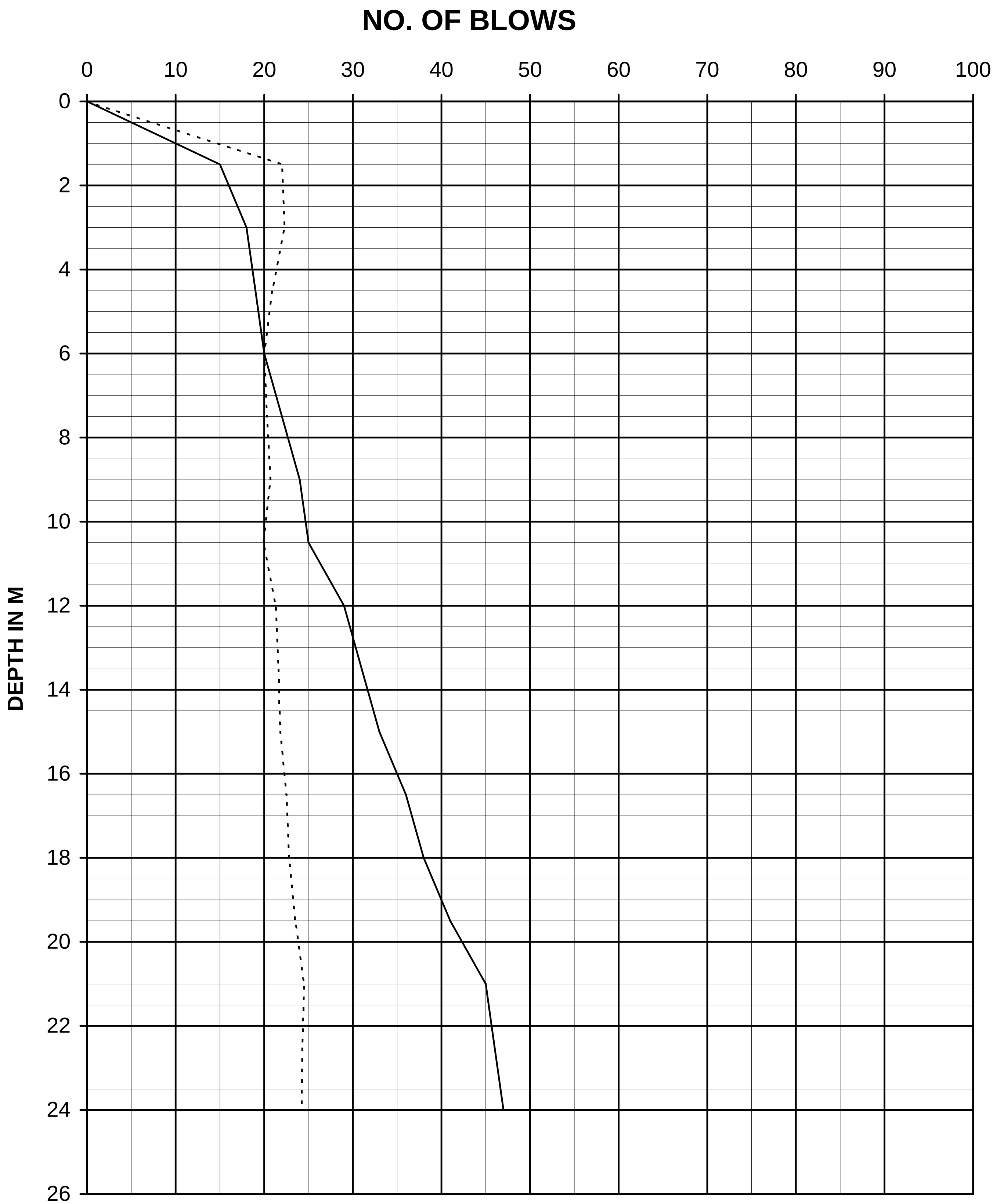
PROJECT: SUB SOIL INVESTIGATION WORK FOR PROPOSED BUS TERMINAL AT MOHAN NAGAR

SHEET NO 58

GROUND R.L.	BOREHOLE NO	BORING DATE	TERMINAL DEPTH (m)	WATER TABLE (m)
99.703	BH-4	25/09/2009	25.00	8.50

N VALUES	R.L.	DEPTH	SAMPLE	DESCRIPTION OF SOIL	IS CLASSIF -ICATION	GRAIN SIZE ANALYSIS				LIQUID LIMIT	PLASTIC LIMIT	DRY/BULK DENSITY	MOIST. CONT	SHEAR PARAMETER			SPECIFIC GRAVITY
						GRAVEL	SAND	SILT	CLAY					TEST TYPE	C	ϕ	
		m				%	%	%	%	%	%	gm/cc	%		kg/cm^2	deg.	
	99.203	0.5	DS-1	Silty sand	SM	0	58	42	0	N	P						
16	98.203	1.5	SPT-1														
	97.203	2.5	UDS-1	Silty sand	SM	0	60	40	0	N	P	1.57/1.64	4.72	DST	0.0	31.0	2.65
18	96.703	3.0	SPT-2														
20	95.203	4.5	SPT-3														
	94.703	5.0	UDS-2	Fine sand	SP-SM	0	88	12	0	N	P	1.60/1.68	5.18	DST	0.0	31.5	2.65
24	93.703	6.0	SPT-4														
28	92.203	7.5	SPT-5														
	91.703	8.0	UDS-3	Fine sand	SP-SM	0	88	12	0	N	P						
32	90.703	9.0	SPT-6														
30	89.203	10.5	SPT-7														
	88.703	11.0	UDS-4	Sandy silt	ML	3	26	68	3	21	18	1.65/1.94	17.78	DST	0.05	30.5	2.66
34	87.703	12.0	SPT-8														
39	86.203	13.5	SPT-9														
	85.703	14.0	UDS-5	Silty sand	SM	0	82	18	0	N	P						
32	84.703	15.0	SPT-10														
34	83.203	16.5	SPT-11														
	82.703	17.0	UDS-6	Silty sand	SM	0	89	11	0	N	P	1.66/1.94	16.85	DST	0.0	33.5	2.62
36	81.703	18.0	SPT-12														
38	80.203	19.5	SPT-13														
	79.703	20.0	UDS-7	Fine sand	SP-SM	2	90	8	0	N	P						
41	78.703	21.0	SPT-14														
43	77.203	22.5	SPT-15														
	76.703	23.0	UDS-8	Fine sand with gravel	SP-SM	6	80	14	0	N	P	1.69/1.95	15.65	DST	0.0	34.0	2.63
49	75.703	24.0	SPT-16														
55	74.703	25.0	SPT-17														

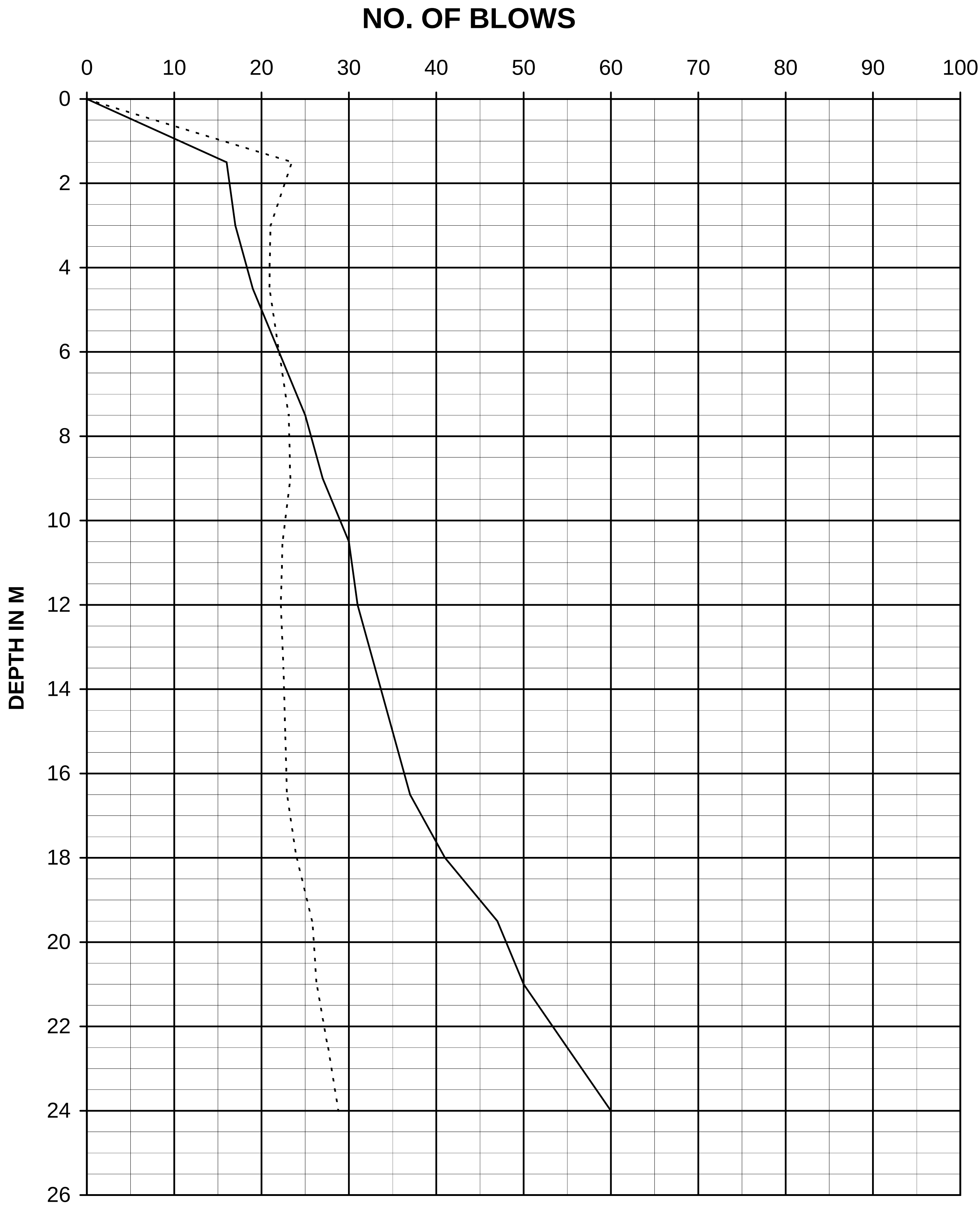
					S0IL PROFILE	PROJECT: SUB SOIL INVESTIGATION WORK FOR PROPOSED BUS TERMINAL AT MOHAN NAGAR											SHEET NO 59			
					GROUND R.L. 99.685	BOREHOLE NO BH-5			BORING DATE 26/09/2009			TERMINAL DEPTH (m) 25.00					WATER TABLE (m) 8.50		
N VALUES	R.L.	DEPTH	SAMPLE	DESCRIPTION OF SOIL	IS CLASSIF -ICATION	GRAIN SIZE ANALYSIS				LIQUID LIMIT	PLASTIC LIMIT	DRY/BULK DENSITY	MOIST. CONT	SHEAR PARAMETER			SPECIFIC GRAVITY
						GRAVEL	SAND	SILT	CLAY					TEST TYPE	C	ϕ	
		m				%	%	%	%	%	%	gm/cc	%		kg/cm^2	deg.	
	99.185	0.5	DS-1	Silty sand	SM	0	53	47	0	N	P						
17	98.185	1.5	SPT-1														
	97.185	2.5	UDS-1	Silty sand	SM	0	66	34	0	N	P	1.58/1.68	6.65	DST	0.0	31.0	2.64
19	96.685	3.0	SPT-2														
21	95.185	4.5	SPT-3														
	94.685	5.0	UDS-2	Clayey silt	CL	2	12	70	16	32	21	1.61/1.74	8.40				2.68
23	93.685	6.0	SPT-4														
26	92.185	7.5	SPT-5														
	91.685	8.0	UDS-3	Silty sand	SM	0	56	44	0	N	P	1.65/1.94	17.82	DST	0.0	32.0	2.65
28	90.685	9.0	SPT-6														
30	89.185	10.5	SPT-7														
	88.685	11.0	UDS-4	Sandy silt	ML	2	34	61	3	21	18						
32	87.685	12.0	SPT-8														
38	86.185	13.5	SPT-9														
	85.685	14.0	UDS-5	Sandy silt	ML	0	23	72	5	24	20	1.67/1.95	16.86	DST	0.08	30.5	2.66
41	84.685	15.0	SPT-10														
36	83.185	16.5	SPT-11														
	82.685	17.0	UDS-6	Fine sand	SP-SM	2	88	10	0	N	P						
39	81.685	18.0	SPT-12														
40	80.185	19.5	SPT-13														
	79.685	20.0	UDS-7	Fine sand	SP-SM	0	89	11	0	N	P	1.69/1.95	15.70	DST	0.0	33.5	2.63
40	78.685	21.0	SPT-14														
41	77.185	22.5	SPT-15														
	76.685	23.0	UDS-8	Fine sand	SP-SM	0	90	10	0	N	P						
44	75.685	24.0	SPT-16														
49	74.685	25.0	SPT-17														



SPT CURVE

BH-1

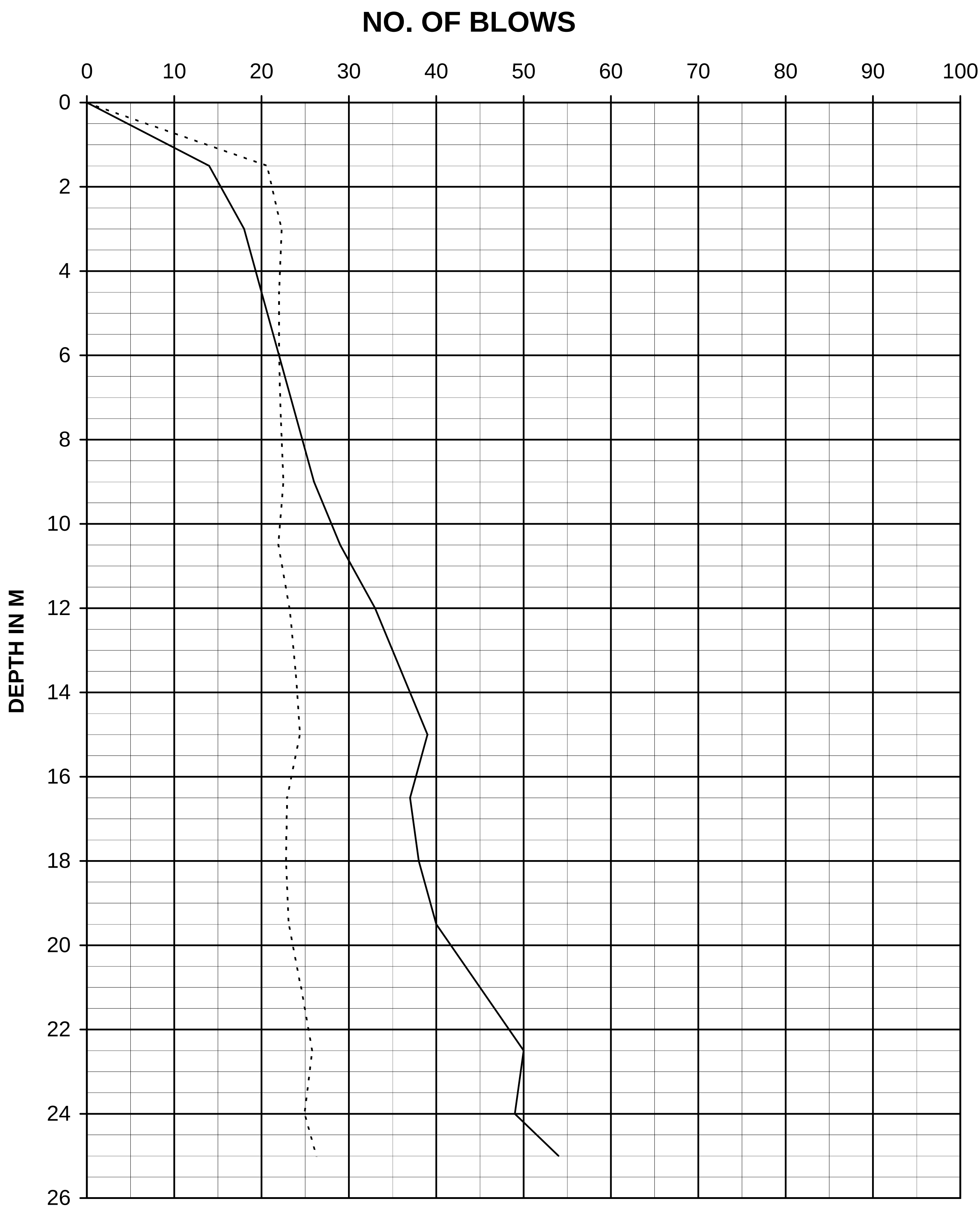
Continuous line - Observed SPT, Dotted Line - Corrected SPT



SPT CURVE

BH-2

Continuous line - Observed SPT, Dotted Line - Corrected SPT

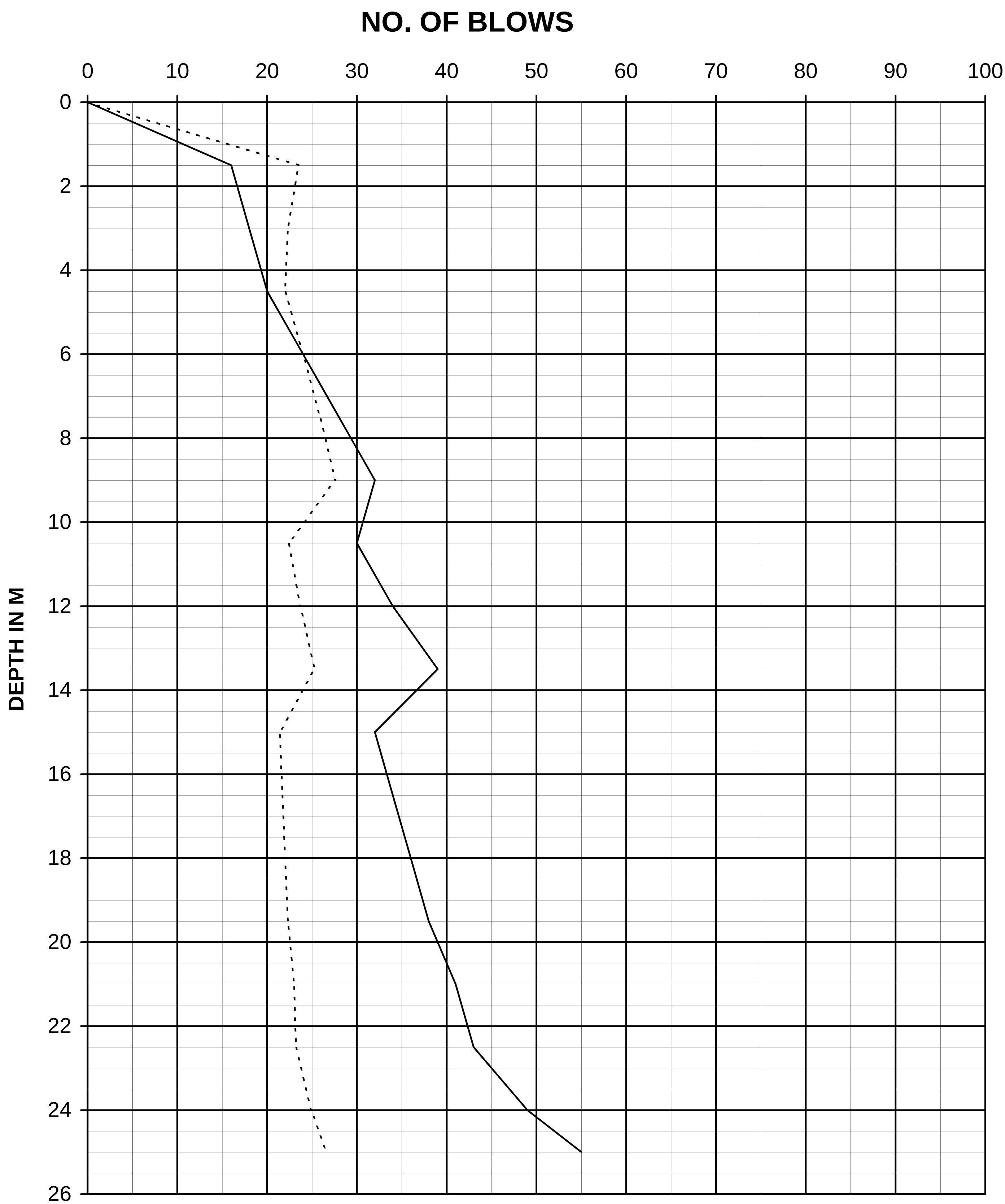


SPT CURVE

BH-3

Continuous line - Observed SPT, Dotted Line - Corrected SPT

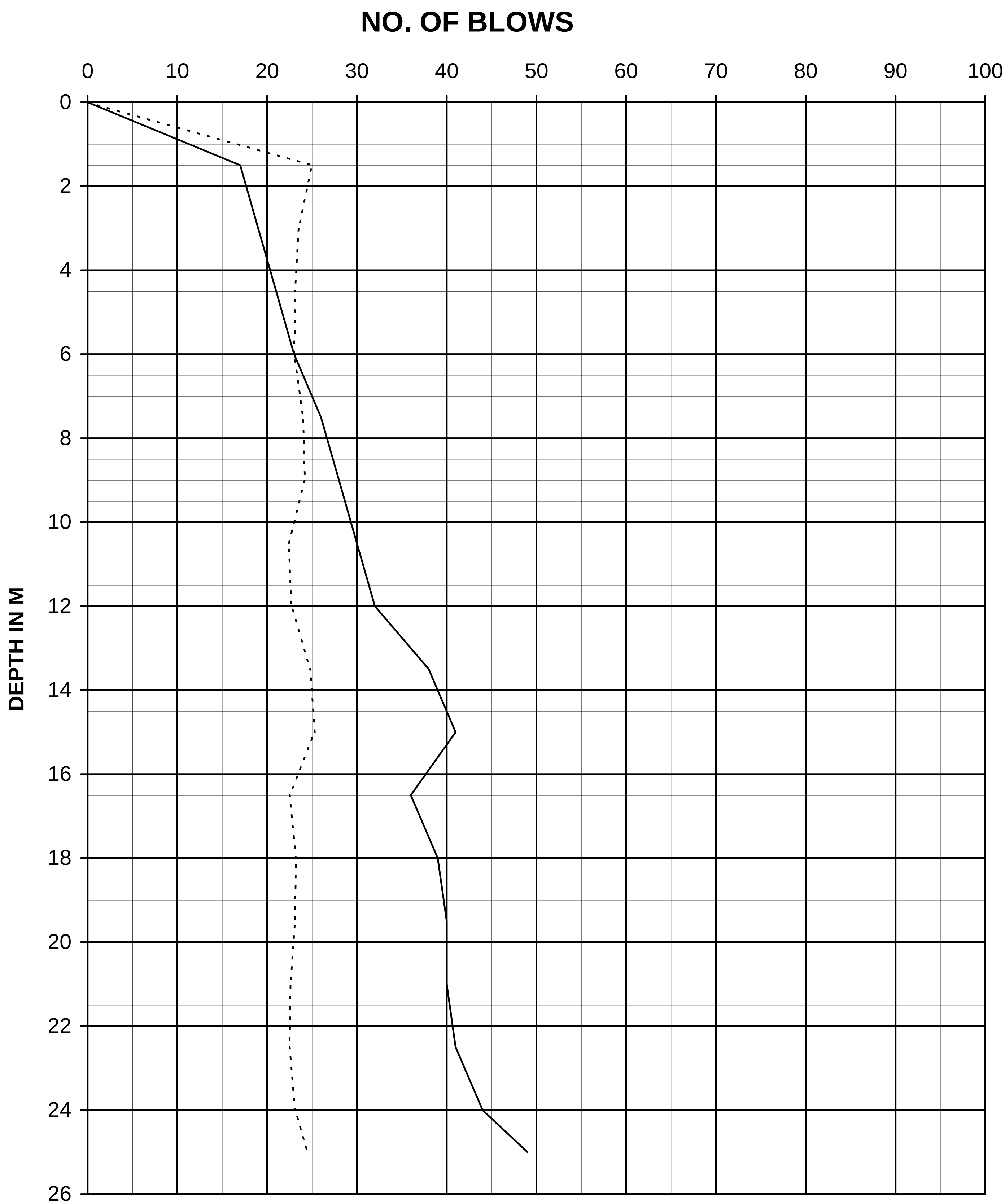
SHEET NO. 63



SPT CURVE

BH-4

Continuous line - Observed SPT, Dotted Line - Corrected SPT



SPT CURVE

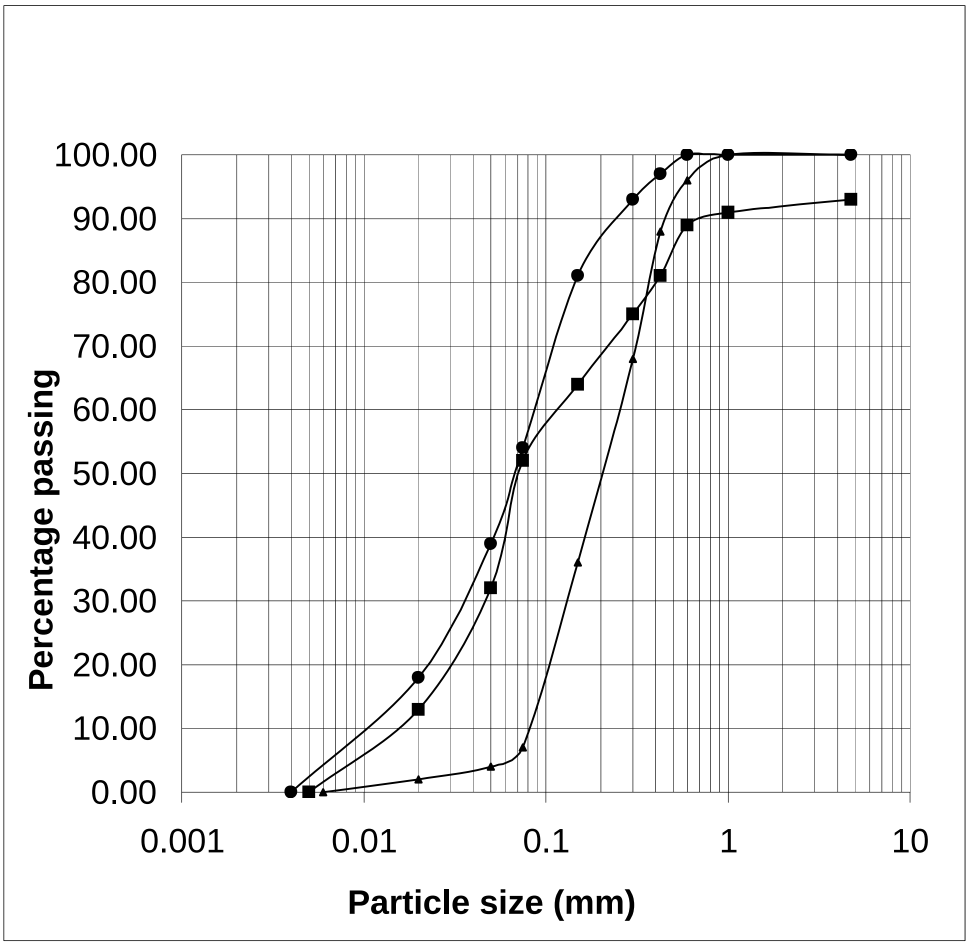
BH-5

Continuous line - Observed SPT, Dotted Line - Corrected SPT

GRAIN SIZE ANALYSIS

Project: Geotechnical Investigation for Proposed Bus Terminal at Mohan Nagar

Bore Hole No. BH - 1

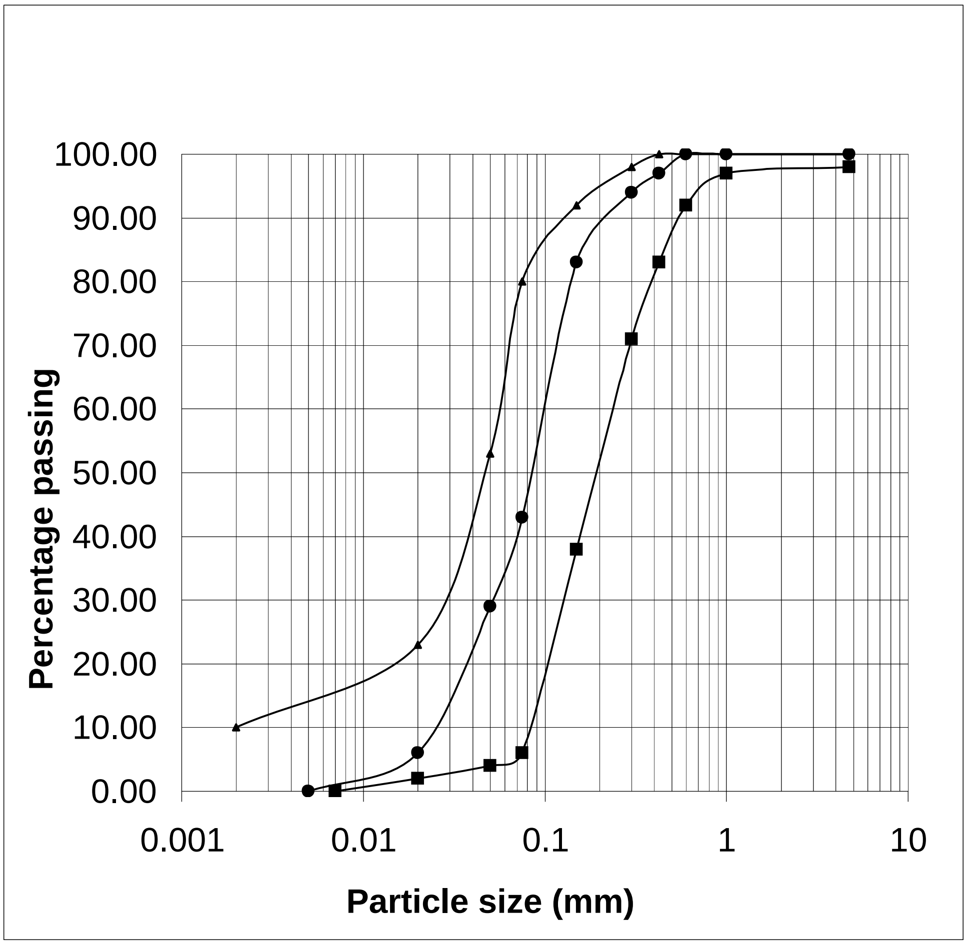


Symbol	Description of soil	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
●	Silty sand	2.50	0	54	46	0
■	Sandy silt	8.00	7	41	52	0
▲	Fine sand	20.00	0	93	7	0

GRAIN SIZE ANALYSIS

Project: Geotechnical Investigation for Proposed Bus Terminal at Mohan Nagar

Bore Hole No. BH - 2

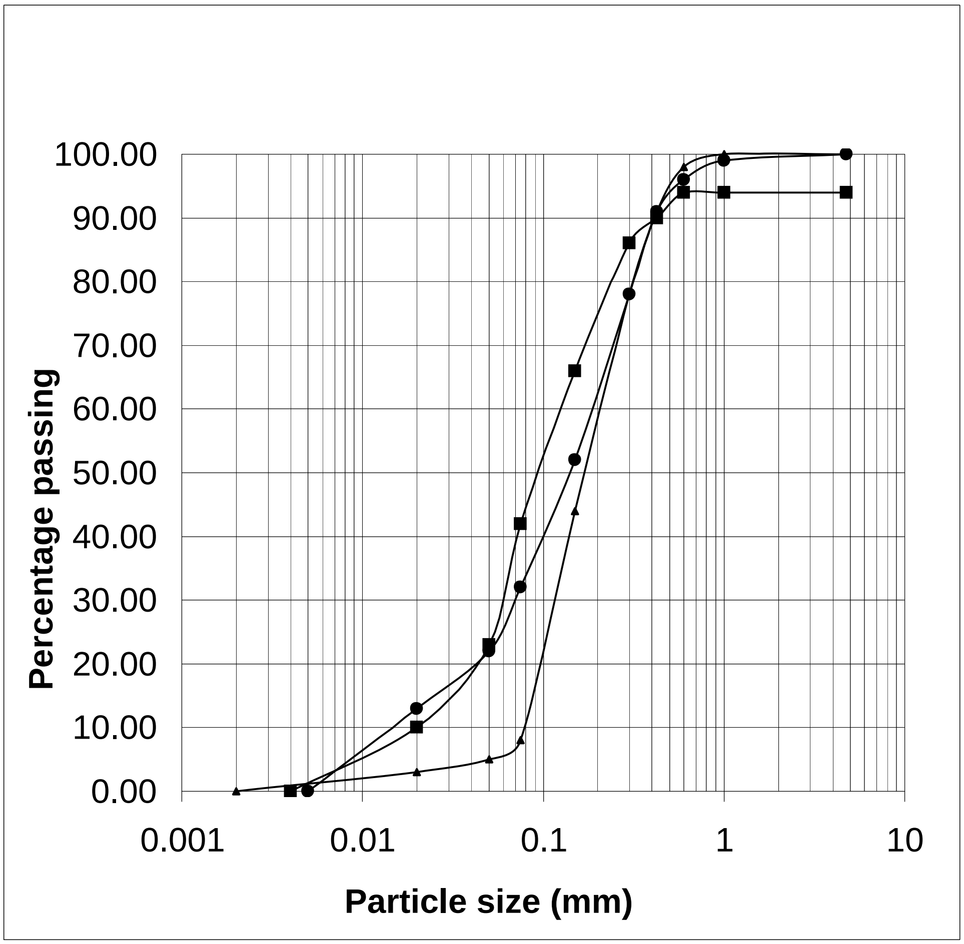


Symbol	Description of soil	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
●	Silty sand	2.50	0	57	43	0
■	Fine sand	8.00	2	92	6	0
▲	Sandy silt with clay	14.00	0	20	70	10

GRAIN SIZE ANALYSIS

Project: Geotechnical Investigation for Proposed Bus Terminal at Mohan Nagar

Bore Hole No. BH - 3



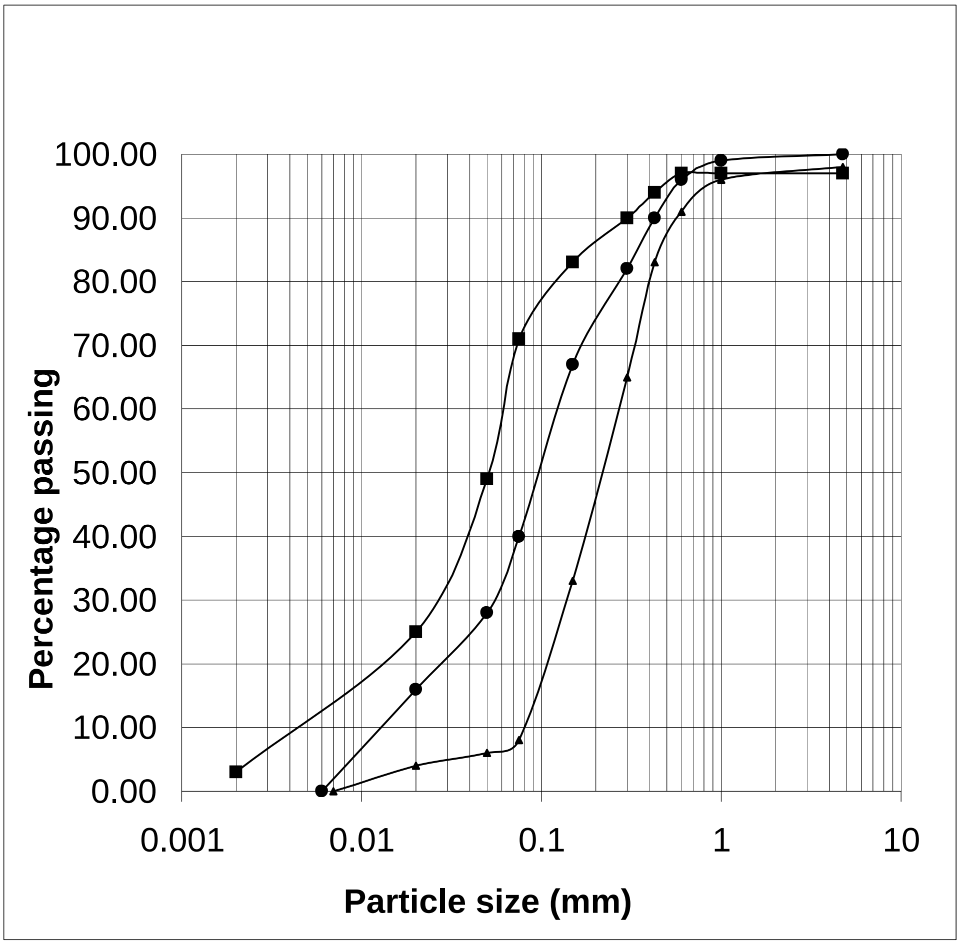
Symbol	Description of soil	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
●	Silty sand	2.50	0	68	32	0
■	Silty sand & gravel	8.00	6	52	42	0
▲	Fine sand	17.00	0	92	8	0

SHEET NO. 68

GRAIN SIZE ANALYSIS

Project: Geotechnical Investigation for Proposed Bus Terminal at Mohan Nagar

Bore Hole No. BH - 4



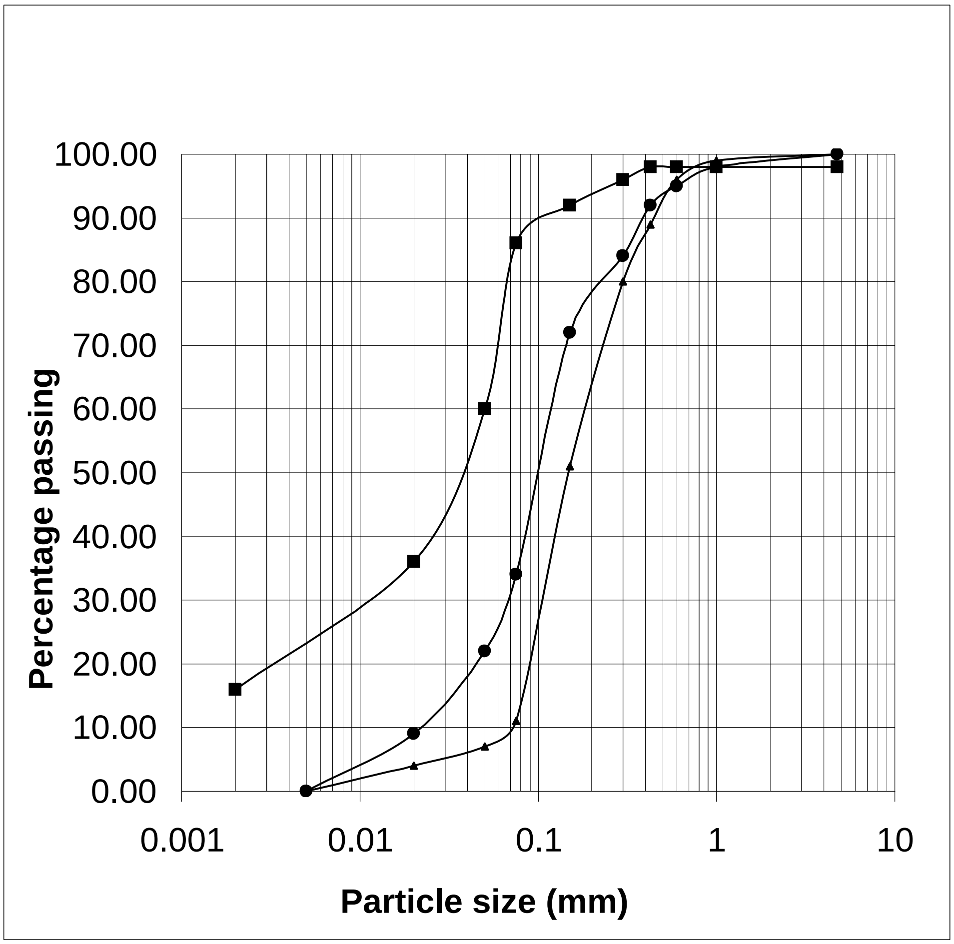
Symbol	Description of soil	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
●	Silty sand	2.50	0	60	40	0
■	Sandy silt	11.00	3	26	68	3
▲	Fine sand	20.00	2	90	8	0

	SHEET NO. 69

GRAIN SIZE ANALYSIS

Project: Geotechnical Investigation for Proposed Bus Terminal at Mohan Nagar

Bore Hole No. BH - 5



Symbol	Description of soil	Depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
●	Clayey silt	5.00	2	12	70	16
■	Sandy silt	14.00	0	23	72	5
▲	Fine sand	20.00	0	89	11	0

.

SAMPLE CALCULATION FOR GEOTECHNICAL INVESTIGATION FOR BUS STAND AT MOHAN NAGAR

Type of Foundation – Isolated Footing
Depth of Foundation – 2.0 m below NGL
Size of Foundation– 3.0 m x 3.0 m (B=3.0 m)
Allowable Settlement S = 50 mm

2.0 SETTLE MENT CRITERION AS PER IS: 8009, Pt.I

Influence Zone is considered 2.0B below foundation level
Properties of strata below depth of exploration have been considered same as at depth of exploration.
The settlement of cohesive layers below foundation level is computed
$S = \Delta H x Cc/ (1+e_0) \times \log_{10} ((P_0+\Delta P)/P_0)$
Where e_0 = initial voids ratio

P_0 = initial stress at centre of layer

ΔP = increase in stress due to imposed load on footing

C_c = Compression Index

ΔH = Thickness of layer

The settlement of cohesion less layers below the foundation level and up to the zone of Influence are computed by using the chart of settlement Vs SPT ‘N’ given on page 17 of IS 8009, part-I.

For pressure intensity of 10.0 T/m^2 at base of foundation

From 2.0m-8.0m depth…Cohesion less layer

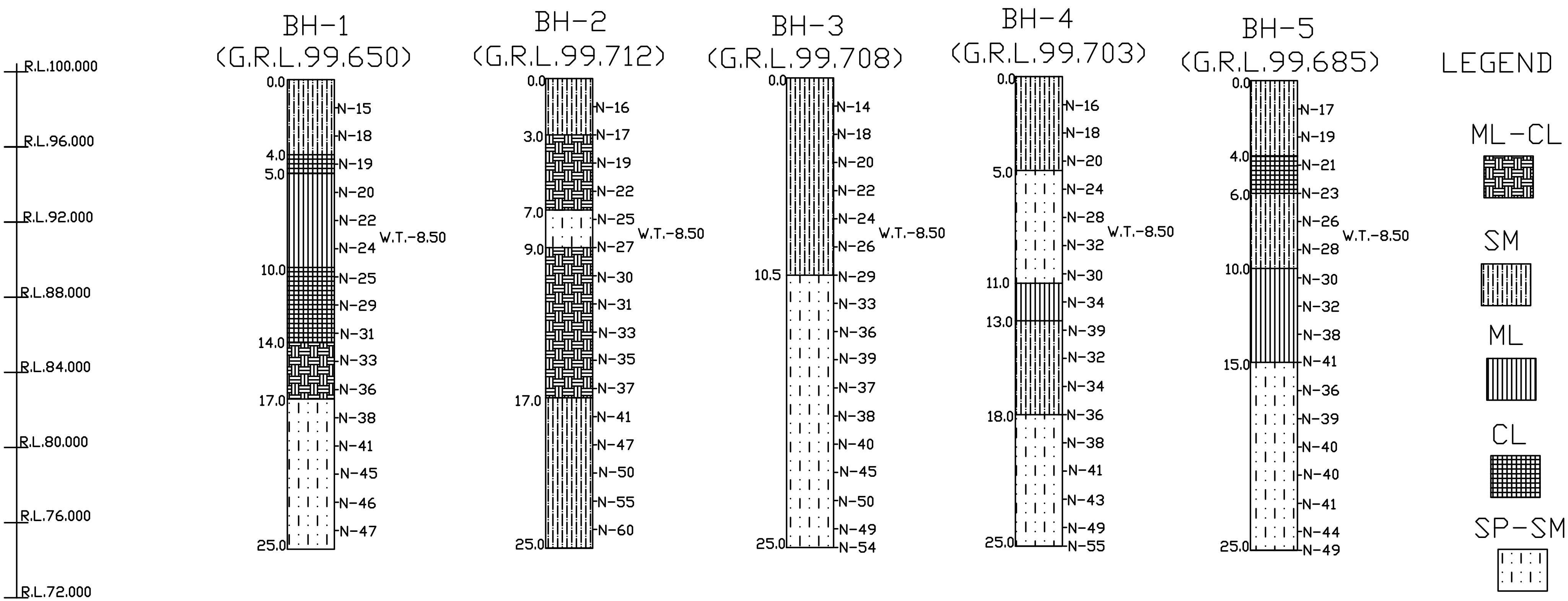
Average N value	**Pressure at top of layer (T/m2)**	**Settlement from graph (mm)**	**Water Corr. factor**	**Corrected Settlement 1 (mm)**
20.6	10.0	17	0.5	34.0

Computation of API:

S_1 (mm)	**Total Settlement (mm)**	**Fox’s depth factor**	**Rigidity Factor**	**Corrected Settlement (mm)**	**Permissible Settlement (mm)**	**Net API (T/m2)**
34	34	0.675	1.0	22.95	50	21.8

RECOMMENDATION:

Lower of the Values OF Net SBC obtained from Shear Failure Criterion and Settlement Failure Criterion i.e.18.5 T/m2 for 50 mm settlement may be adopted for design purposes



SUBSOIL PROFILE

Name of Work:- Sub Soil Investigation work for Proposed bus terminal at mohan nagar

SHEET NO. 71

CHEMICAL TEST REPORT OF GROUND WATER SAMPLE

Location: Geotechnical Investigation for Bus Terminal at Mohan Nagar

SAMPLE NO: 1 **BORE HOLE NO: BH-3**

SL.NO.	Name of test	Observed values	Permissible values
1	pH value	6.8	>6
2	Chloride content	716mg/l	500 mg/l
3	Sulphate content (as $SO3^{--}$)	54.3mg/l	400 mg/l

CHEMICAL TEST REPORT OF SUBSOIL SAMPLE

Location: Geotechnical Investigation for Bus Terminal at Mohan Nagar

SAMPLE NO: 1 **BORE HOLE NO: BH-5**

DEPTH: 3.0m

SL.NO.	Name of test	Observed values	Permissible values
1	pH value	6.9	>6
2	Chloride content	0.017%	0.2%
3	Sulphate content (as $SO3^{--}$)	0.073%	0.16 %

ARCHITECTURAL DRAWING LIST

1	GROUND FLOOR PLAN	ST-002 -01
2	FRIST FLOOR PLAN	ST-002 -02
3	TYPICAL FLOOR PLAN	ST-002 -03
4	SECTIONS & ELEVATION	ST-002 -04

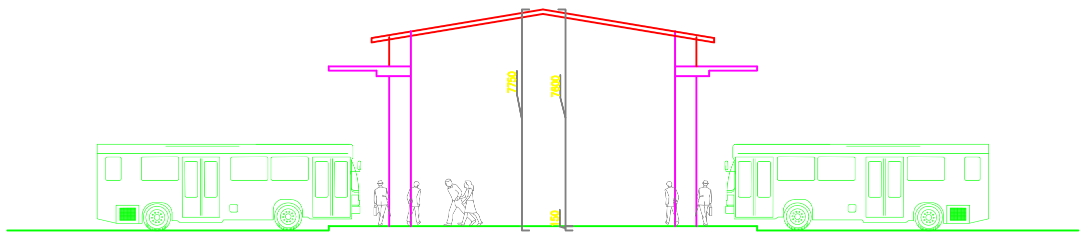
Capcity Development of the NCRPB: Component B (ADB TA-7055)

Client:
Asian Development Bank
National Capital Region Planning Board

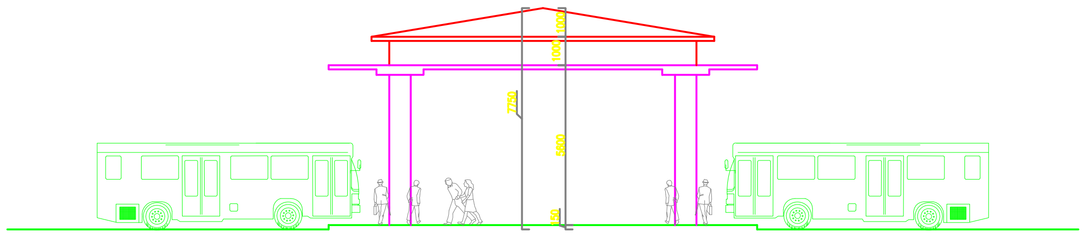
Consultant:
Wilbur Smith Associates

Drawn: SHAN	Checked: APK	Sheet No.
Date: Dec.2009	Approved: AN	
Scale: As shown	ST-001 -00	

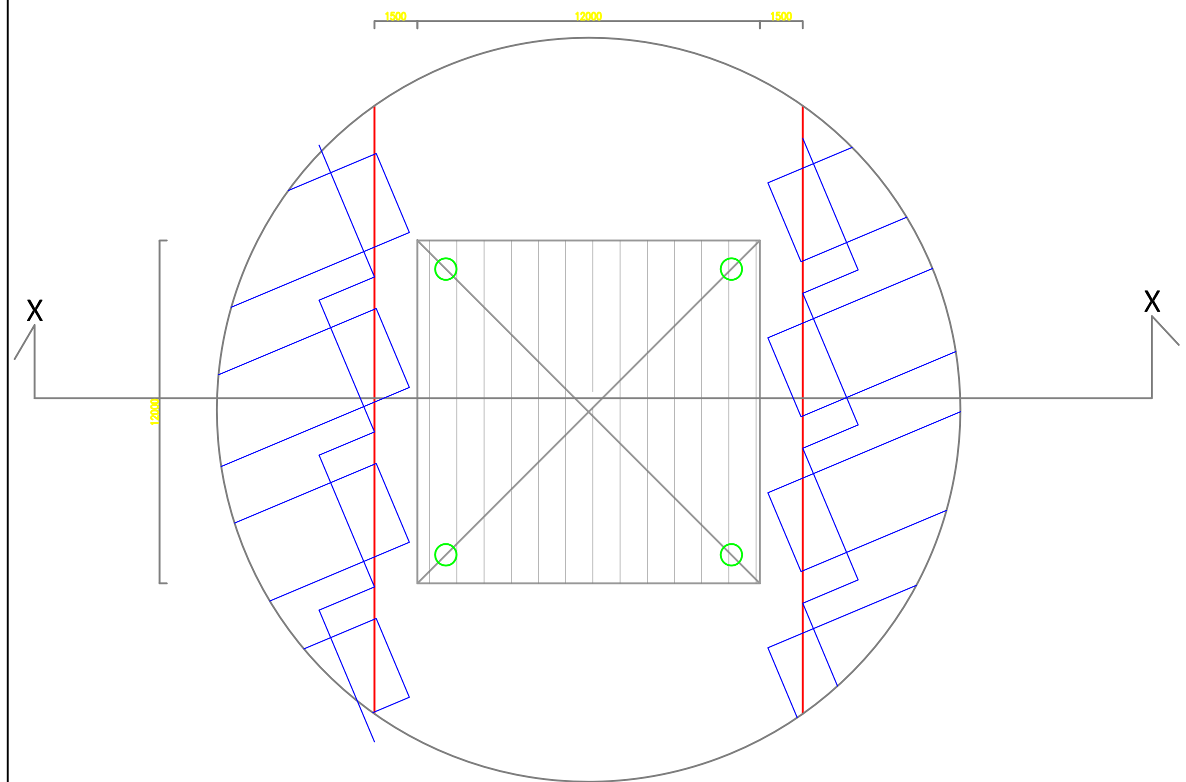
Drawing No:
(MULTI LEVEL PARKING)
DRAWING LIST



Section

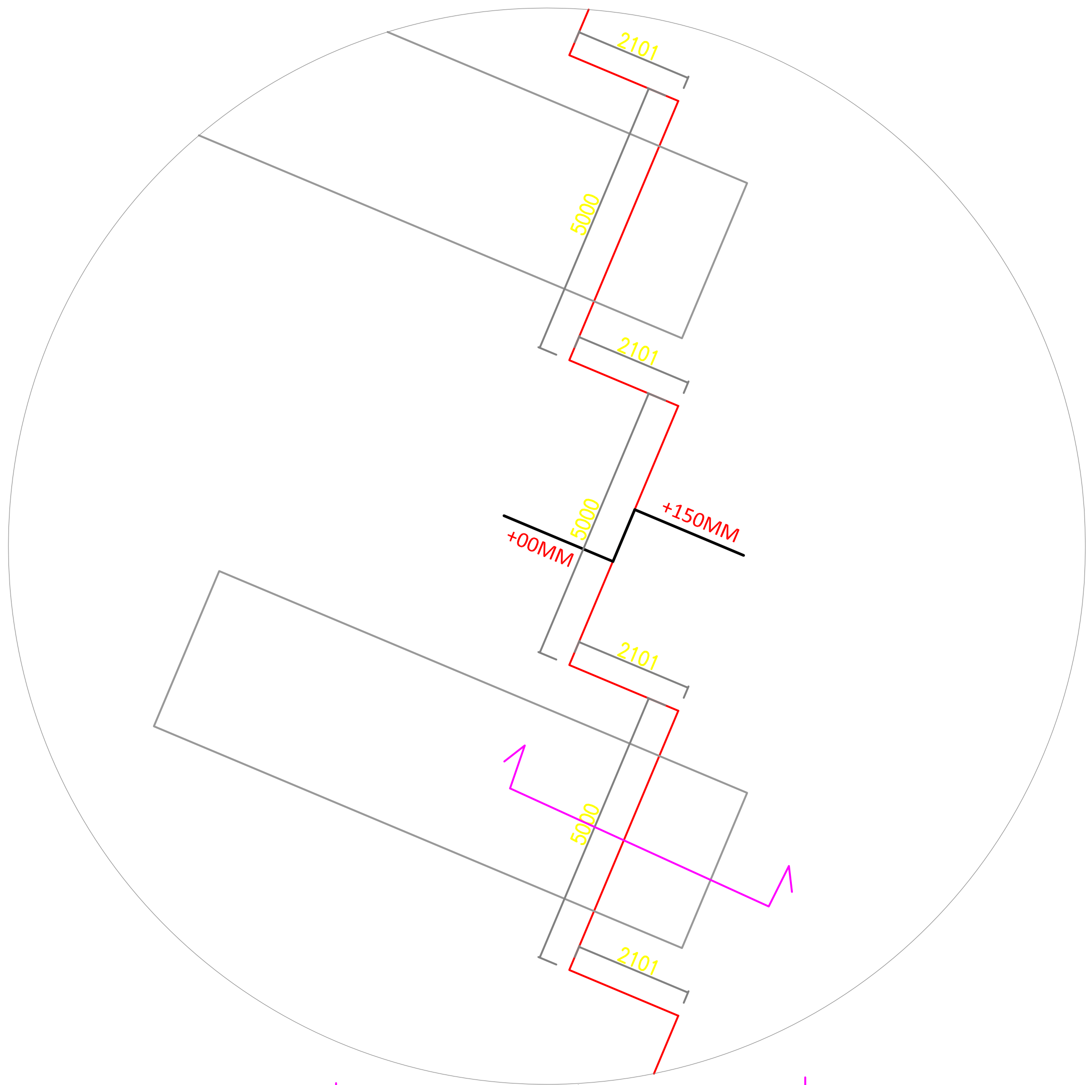


Elevation

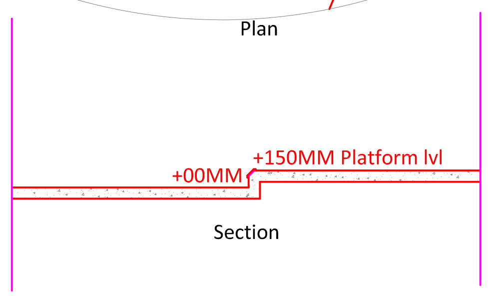


Plan of Pyramid roof

FP Detail @ B
Scale -1:100



Plan

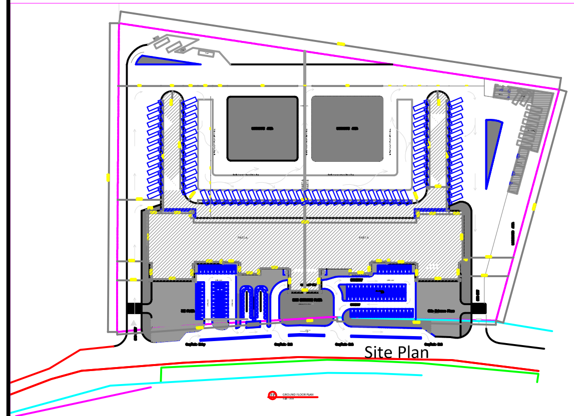


Section

FP Detail @ A
Scale -1:100

Capacity Development of the NCRPB: Component B (ADB TA-7055)

BUS TERMINAL BUILDING DETAILED DRAWINGS



Site Plan

Schedule of openings

Type	Description	Sizes
Wooden doors		
D	Door	1050x2100
D1	Door	900x2100
D2	Toilet Door	750x2100
Windows/Ventilators		
W1	Aluminium window	1800x1200
W2	Aluminium window	1200x1200
GW	Aluminium window	3700X8500
V	Aliminium ventilator	2700x500
V1	Aliminium ventilator	600x600
Windows/Ventilators		
RS	Rolling Shutter	4000x2400

Note:
All dimensions are in millimeters
Any discrepancy must be brought to the notice of the consultant

Rev. No.	Revision	Date

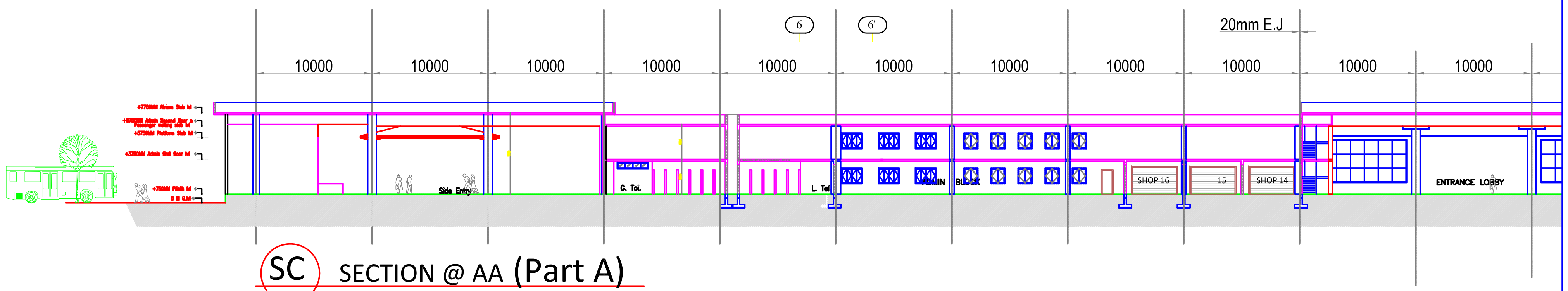
Client:
Asian Development Bank
National Capital Region Planning Board

Consultant:
Wilbur Smith Associates

Drawn: Shan | Checked: APK
Design: Yunus | Approved: AN | Sheet No.
Date: April 2010
Scale: As shown
Drawing No: ST-002 -07

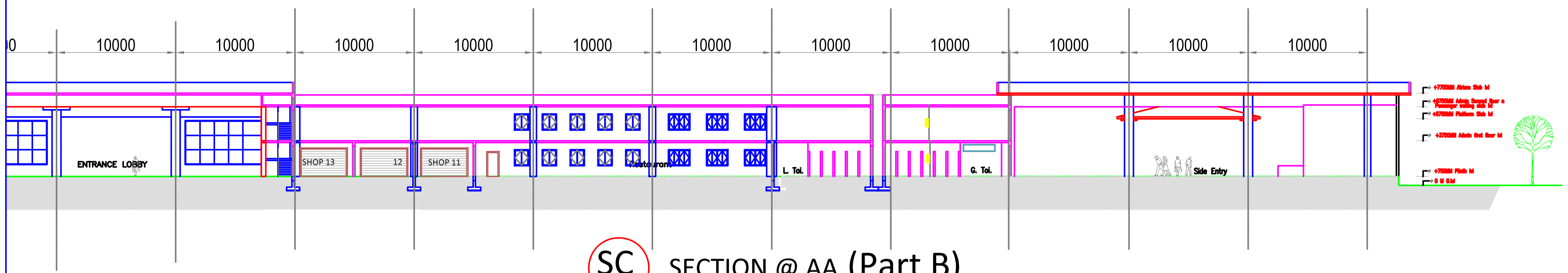
Capacity Development of the NCRPB: Component B (ADB TA-7055)

BUS TERMINAL BUILDING SECTIONS



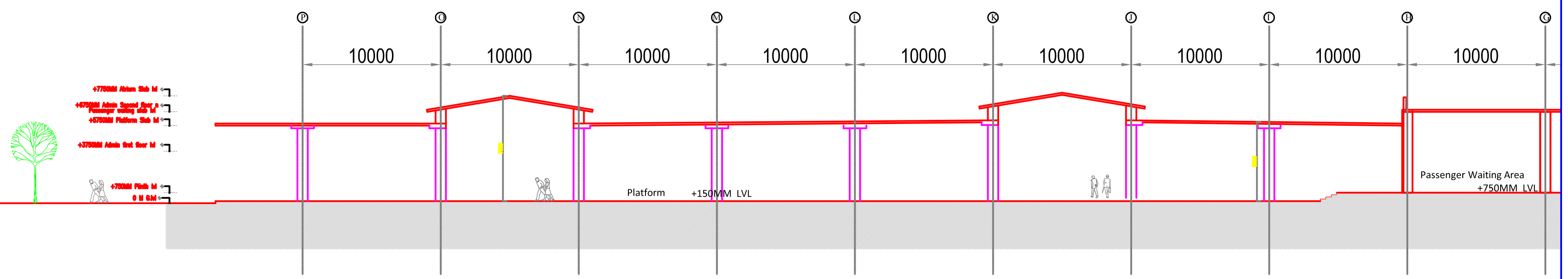
SC SECTION @ AA (Part A)

Scale -1:250



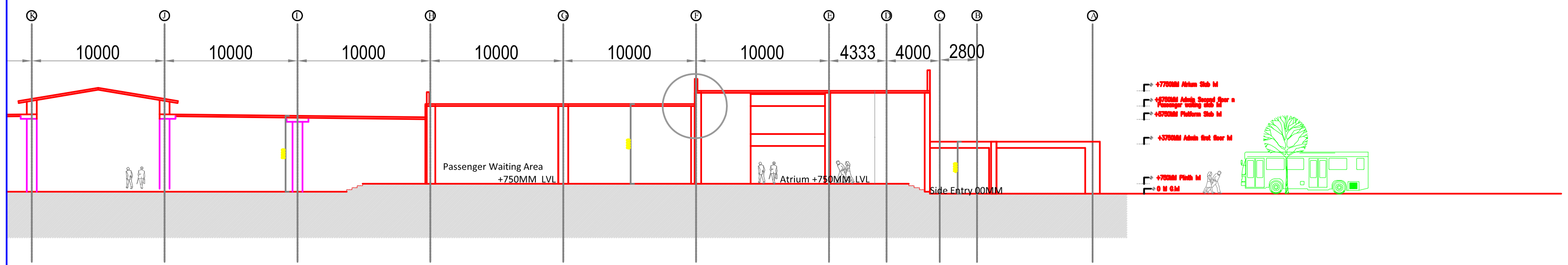
SC SECTION @ AA (Part B)

Scale -1:250



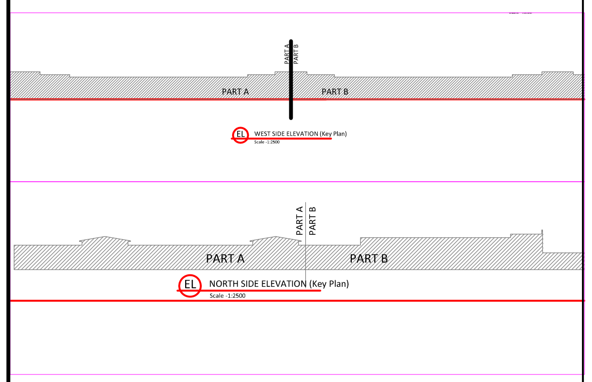
SC SECTION @ BB (Part A)

Scale -1:250



SC SECTION @ BB (Part B)

Scale -1:250



Schedule of openings

Type	Description	Sizes
Wooden doors		
D	Door	1050x2100
D1	Door	900x2100
D2	Toilet Door	750x2100
Windows/Ventilators		
W1	Aluminium window	1800x1200
W2	Aluminium window	1200x1200
GW	Aluminium window	3700X8500
V	Aliminium ventilator	2700x500
V1	Aliminium ventilator	600x600
Windows/Ventilators		
RS	Rolling Shutter	4000x2400

Note:
All dimensions are in millimeters
Any discrepancy must be brought to the notice of the consultant

Rev. No.	Revision	Date

Client:

Asian Development Bank
National Capital Region Planning Board

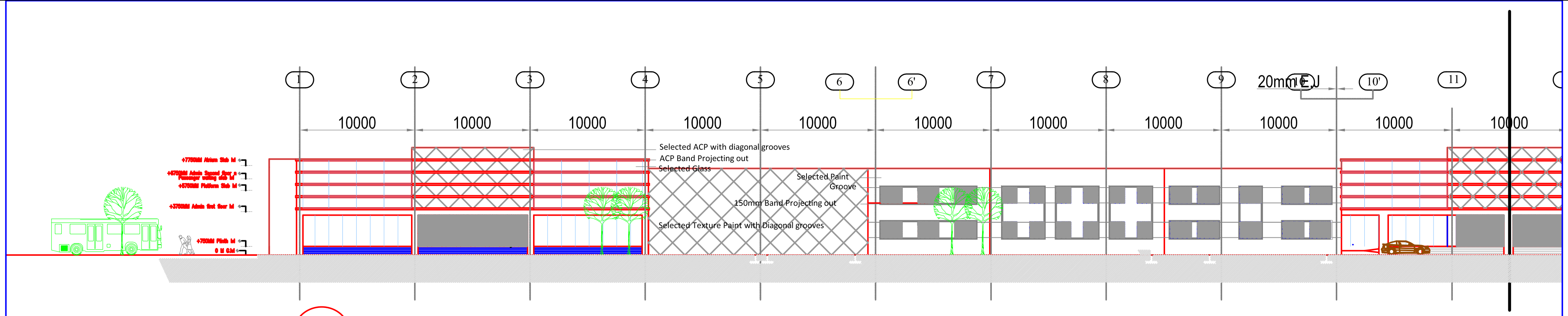
Consultant:

Wilbur Smith Associates

Drawn: Shan | Checked: APK
Design: Yunus | Approved: AN | Sheet No.
Date: April 2010

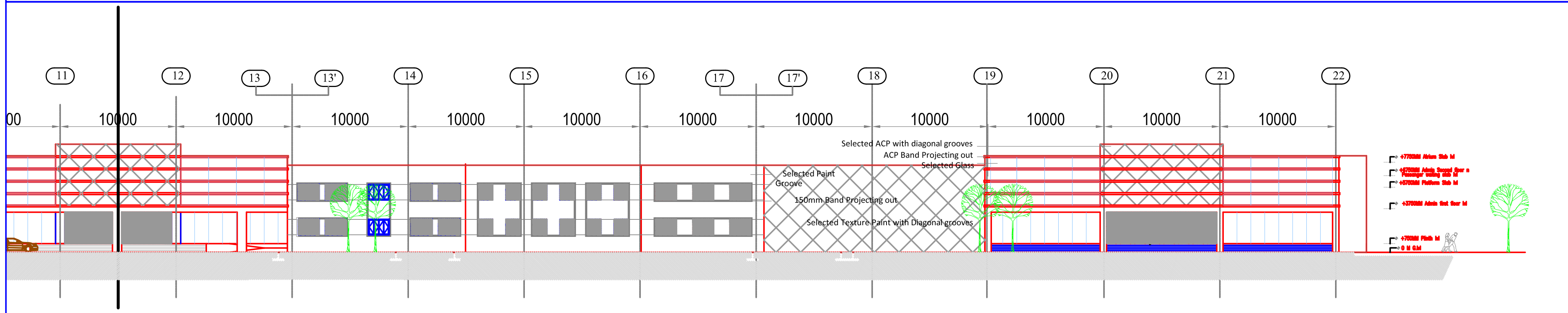
Scale: As shown

Drawing Title: ST-002 -06



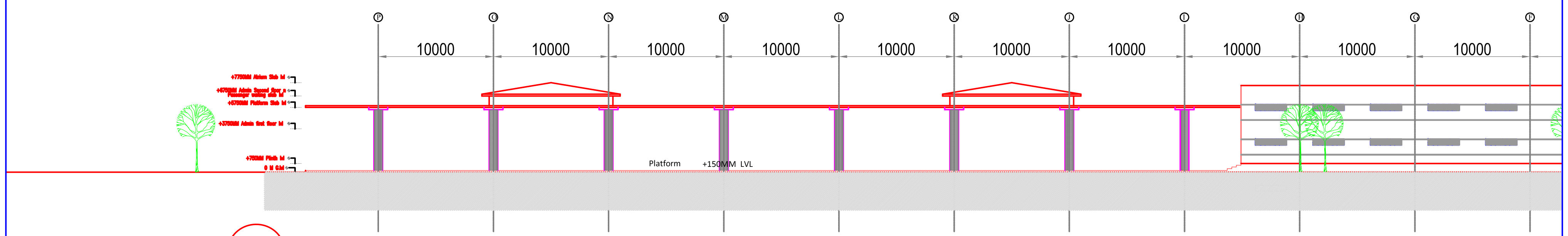
EL WEST SIDE (Part A) ELEVATION

Scale -1:250



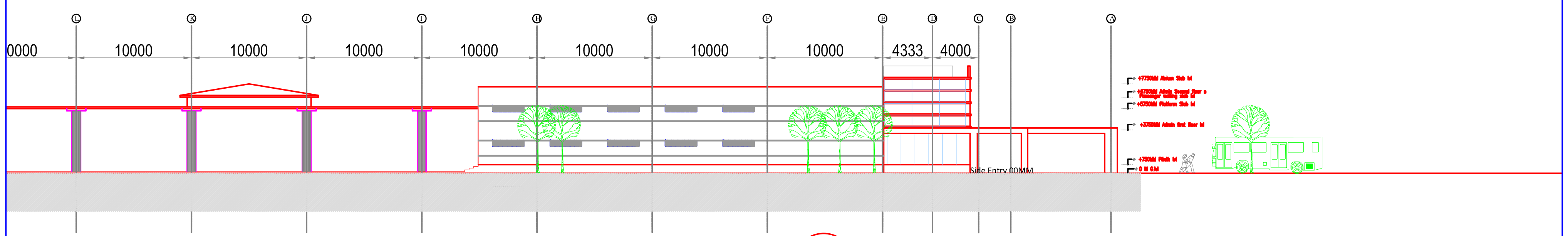
EL WEST SIDE (Part B) ELEVATION

Scale -1:250



EL NORTH SIDE(Part A) ELEVATION

Scale -1:250

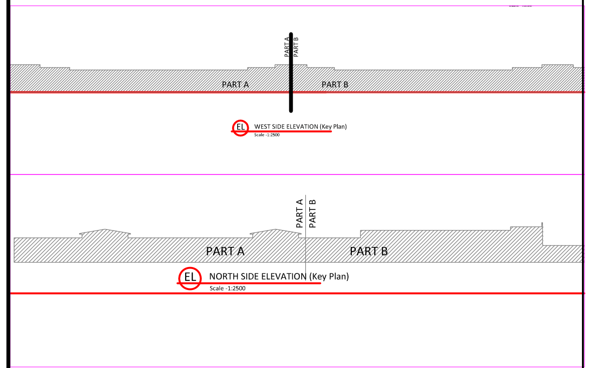


EL NORTH SIDE(Part B) ELEVATION

Scale -1:250

Capacity Development of the NCRPB: Component B (ADB TA-7055)

BUS TERMINAL BUILDING ELEVATIONS



Schedule of openings

Type	Description	Sizes
Wooden doors		
D	Door	1050x2100
D1	Door	900x2100
D2	Toilet Door	750x2100
Windows/Ventilators		
W1	Aluminium window	1800x1200
W2	Aluminium window	1200x1200
GW	Aluminium window	3700X8500
V	Aliminium ventilator	2700x500
V1	Aliminium ventilator	600x600
Windows/Ventilators		
RS	Rolling Shutter	4000x2400

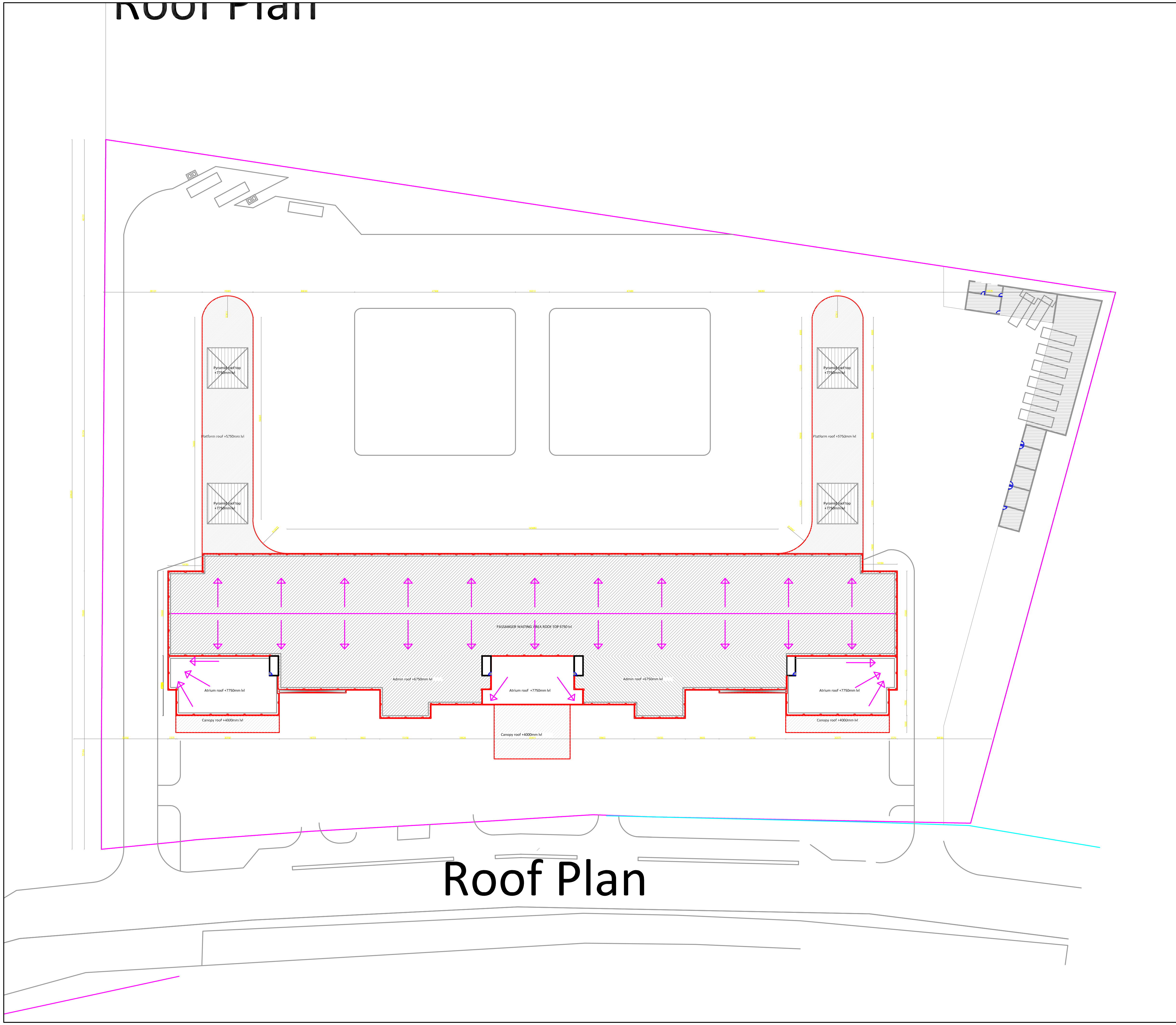
Note:
All dimensions are in millimeters
Any discrepancy must be brought to the notice of the consultant

Rev. No.	Revision	Date

Client:
Asian Development Bank
National Capital Region Planning Board

Consultant:
Wilbur Smith Associates

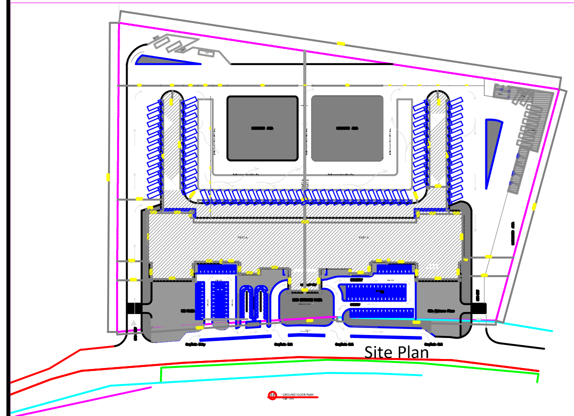
Drawn: Shan | Checked: APK
Design: Yunus | Approved: AN | Sheet No.
Date: April 2010
Scale: As shown
Drawing No: ST-002 -05



Roof Plan

Capacity Development of the NCRPB: Component B (ADB TA-7055)

BUS TERMINAL BUILDING
Roof Plan



Site Plan

Schedule of openings

Type	Description	Sizes
Wooden doors		
D	Door	1050x2100
D1	Door	900x2100
D2	Toilet Door	750x2100
Windows/Ventilators		
W1	Aluminium window	1800x1200
W2	Aluminium window	1200x1200
GW	Aluminium window	3700X8500
V	Aliminium ventilator	2700x500
V1	Aliminium ventilator	600x600
Windows/Ventilators		
RS	Rolling Shutter	4000x2400

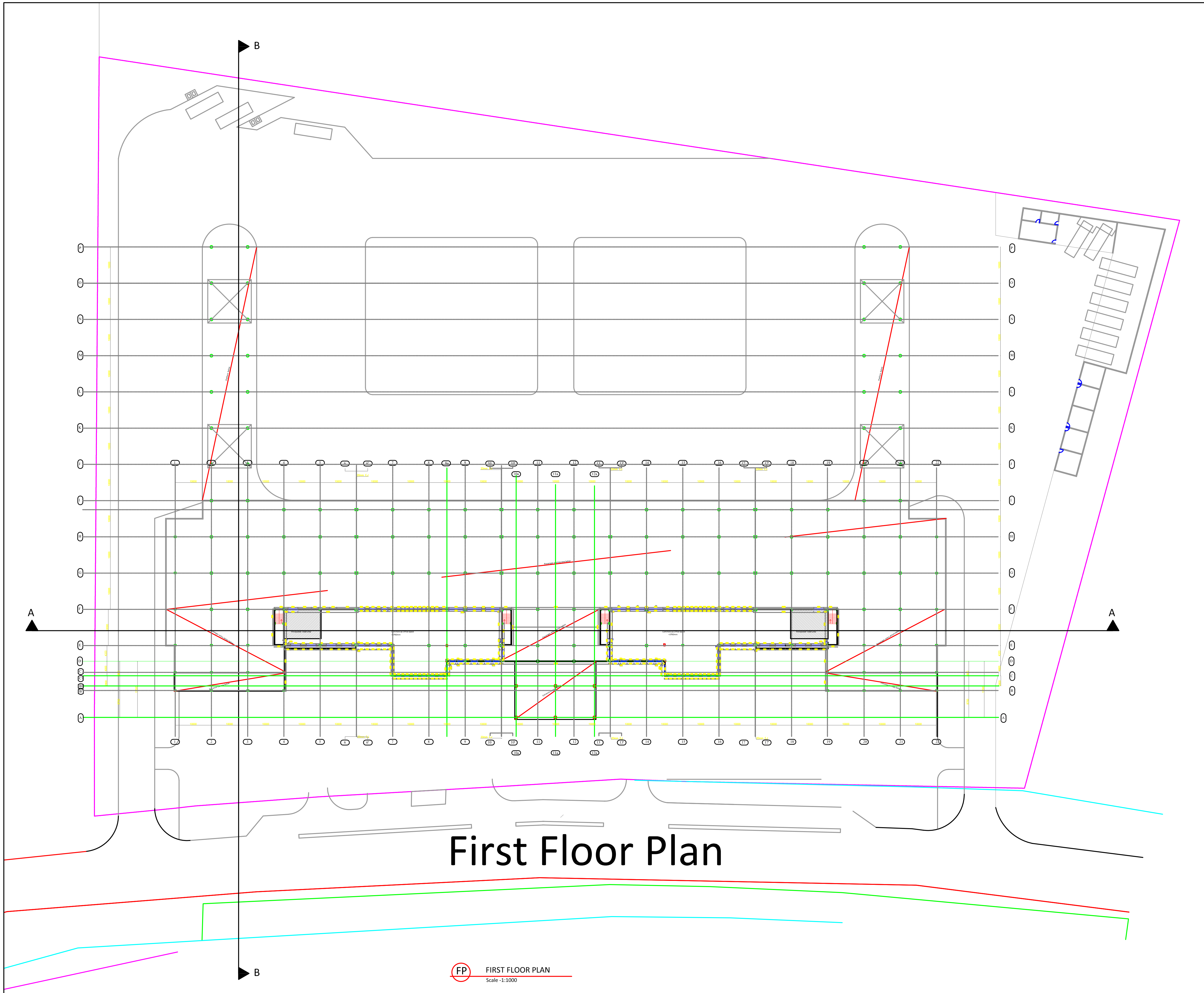
Note:
All dimensions are in millimeters
Any discrepancy must be brought to the notice of the consultant

Rev. No.	Revision	Date

Client:
Asian Development Bank
National Capital Region Planning Board

Consultant:
Wilbur Smith Associates

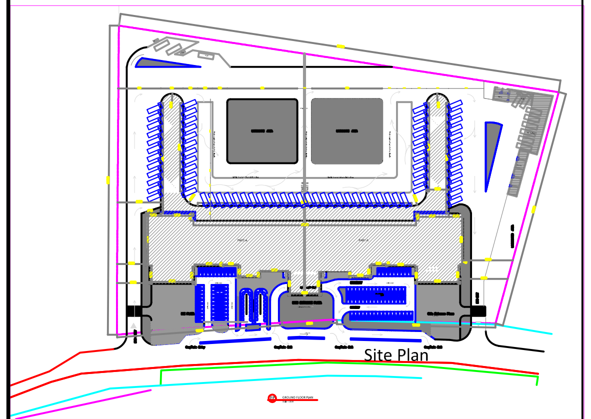
Drawn: Shan
Design: Yunus
Checked: APK
Approved: AN
Sheet No.
Date: April 2010
Scale: As shown
Drawing No: ST-002 -04



First Floor Plan

Capacity Development of the NCRPB: Component B (ADB TA-7055)

BUS TERMINAL BUILDING
First Floor Plan



Schedule of openings

Type	Description	Sizes
Wooden doors		
D	Door	1050x2100
D1	Door	900x2100
D2	Toilet Door	750x2100
Windows/Ventilators		
W1	Aluminium window	1800x1200
W2	Aluminium window	1200x1200
GW	Aluminium window	3700X8500
V	Aliminium ventilator	2700x500
V1	Aliminium ventilator	600x600
Windows/Ventilators		
RS	Rolling Shutter	4000x2400

Note:
All dimensions are in millimeters
Any discrepancy must be brought to the notice of the consultant

Rev. No.	Revision	Date

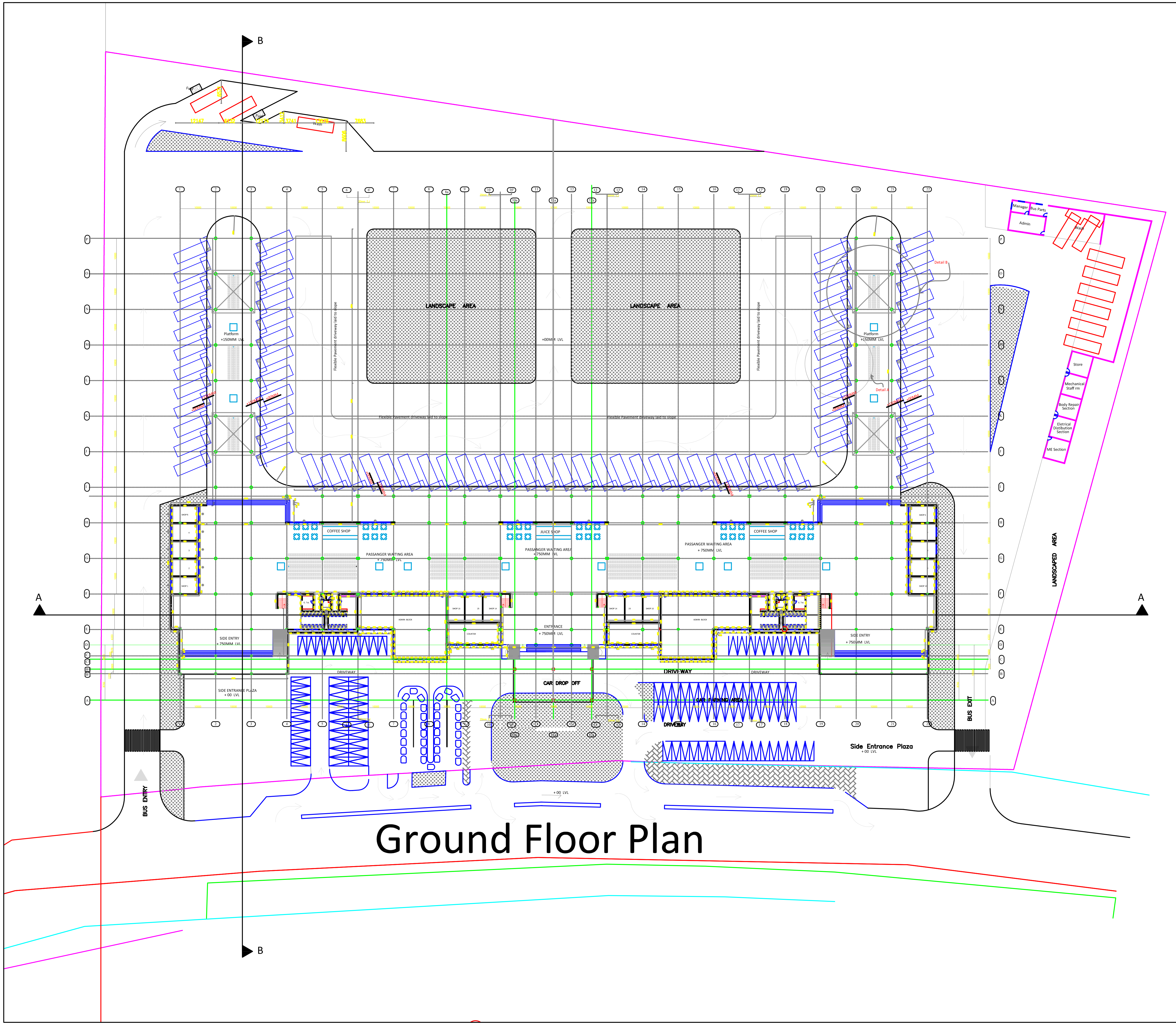
Client:

Asian Development Bank
National Capital Region Planning Board

Consultant:

Wilbur Smith Associates

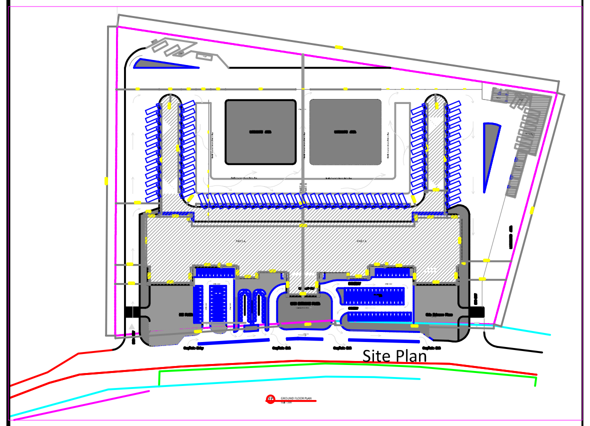
Drawn: Shan
Design: Yunus
Checked: APK
Approved: AN
Sheet No.
Date: April 2010
Scale: As shown
Drawing No: ST-002 -03



Ground Floor Plan

Capacity Development of the NCRPB: Component B (ADB TA-7055)

BUS TERMINAL BUILDING
Ground Floor Plan



Schedule of openings

Type	Description	Sizes
Wooden doors		
D	Door	1050x2100
D1	Door	900x2100
D2	Toilet Door	750x2100
Windows/Ventilators		
W1	Aluminium window	1800x1200
W2	Aluminium window	1200x1200
GW	Aluminium window	3700X8500
V	Aliminium ventilator	2700x500
V1	Aliminium ventilator	600x600
Windows/Ventilators		
RS	Rolling Shutter	4000x2400

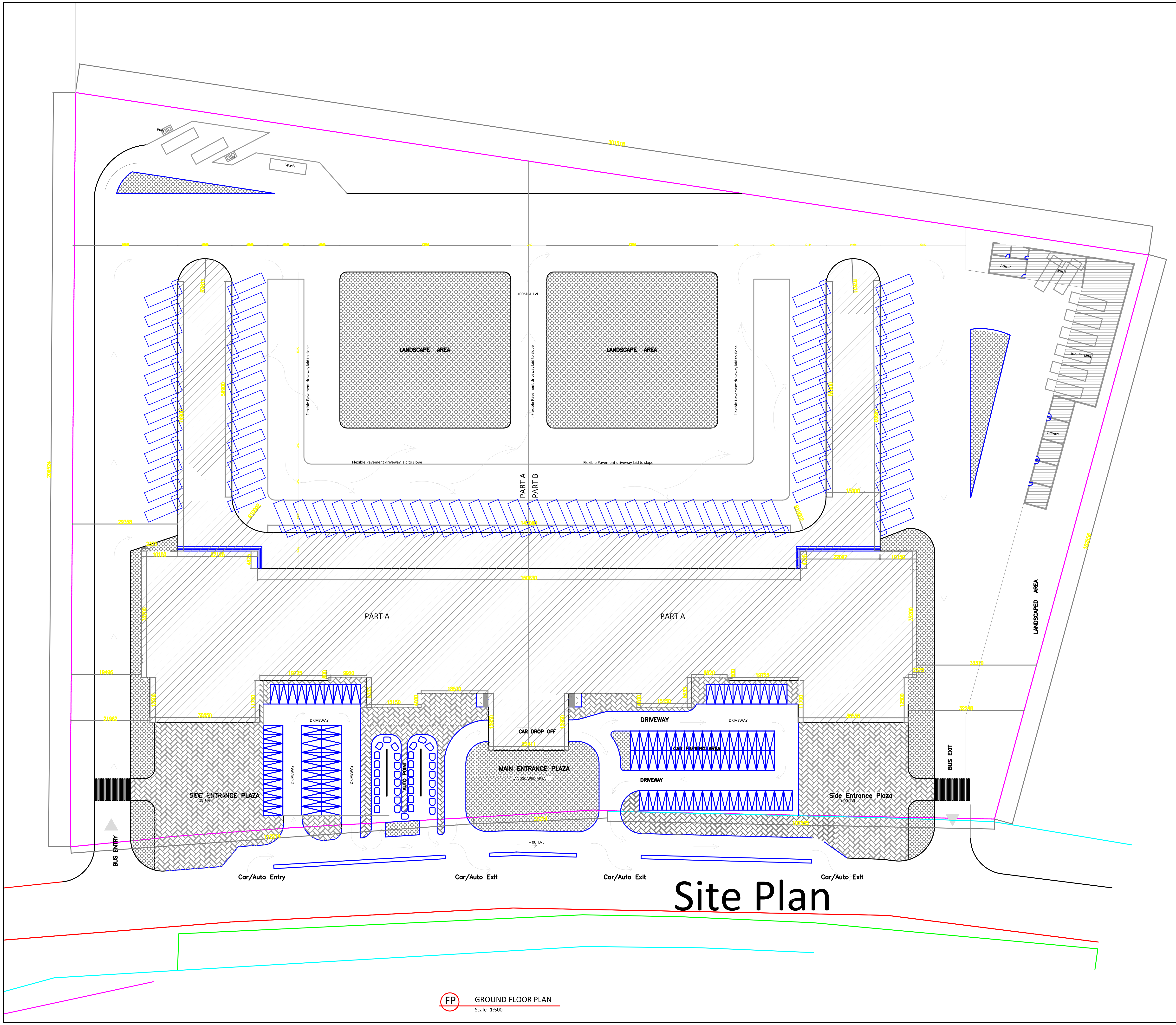
Note:
All dimensions are in millimeters
Any discrepancy must be brought to the notice of the consultant

Rev. No.	Revision	Date

Client:
Asian Development Bank
National Capital Region Planning Board

Consultant:
Wilbur Smith Associates

Drawn: Shan
Design: Yunus
Checked: APK
Approved: AN
Sheet No.
Date: April 2010
Scale: As shown
Drawing No: ST-002 -02



Site Plan

Capacity Development of the NCRPB: Component B (ADB TA-7055)

BUS TERMINAL BUILDING SITE PLAN

Legend	
(dotted)	Land scape area
(cross-hatched)	Paved Area
(hatched)	Built Up Area

Client:

Asian Development Bank
National Capital Region Planning Board

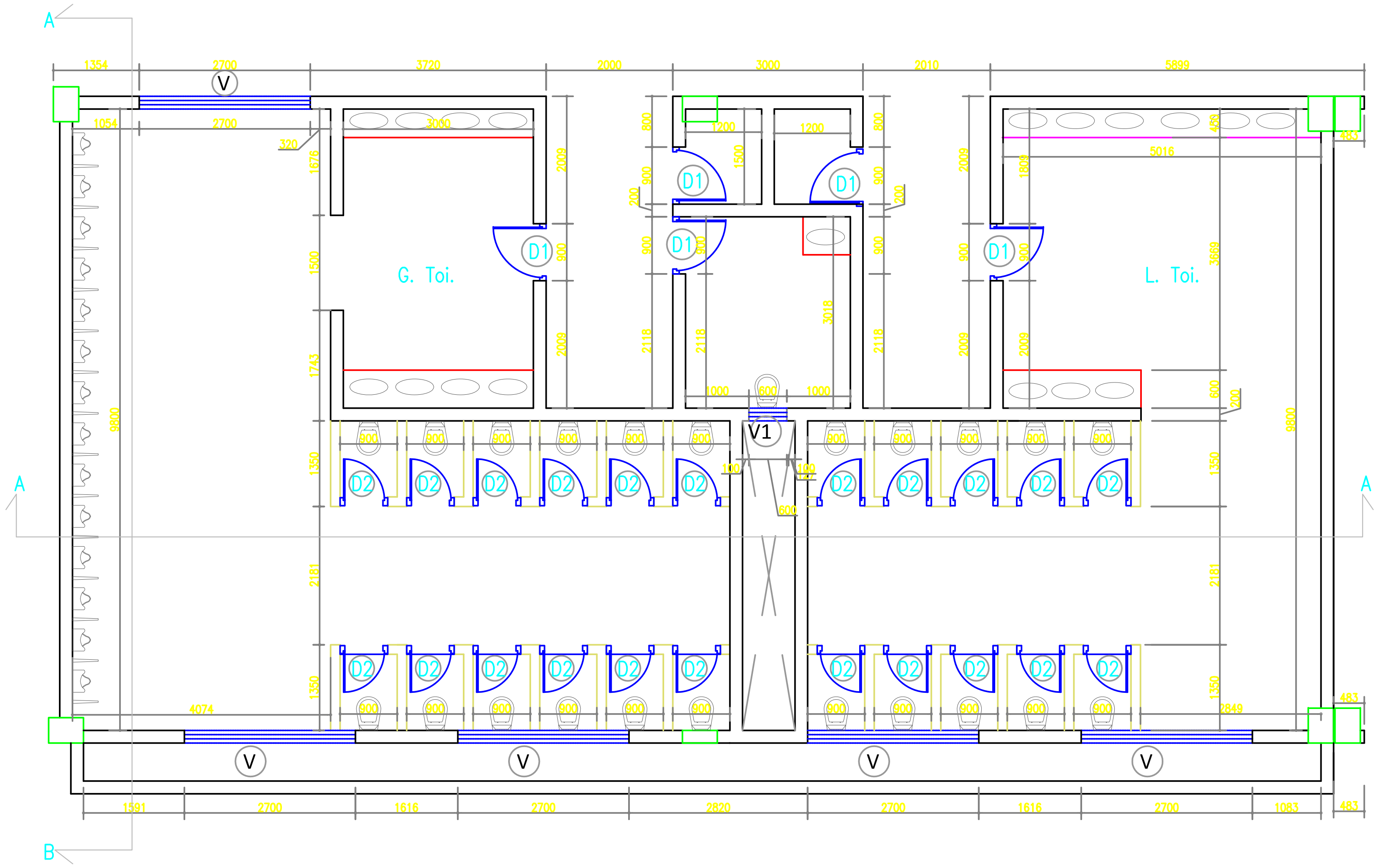
Consultant:

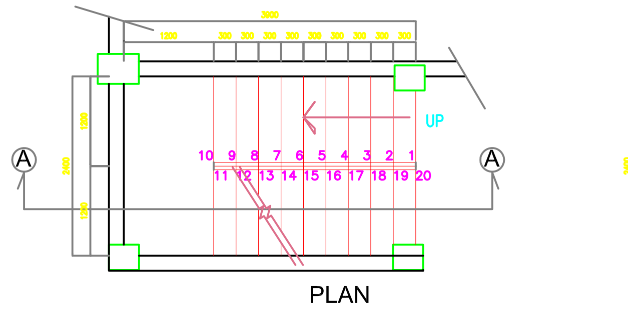
Wilbur Smith Associates

Drawn: Shan	Checked: APK	
Design: Yunus	Approved: AN	Sheet No.
Date: April 2010		
Scale: As shown		
Drawing No: ST-002 -01		

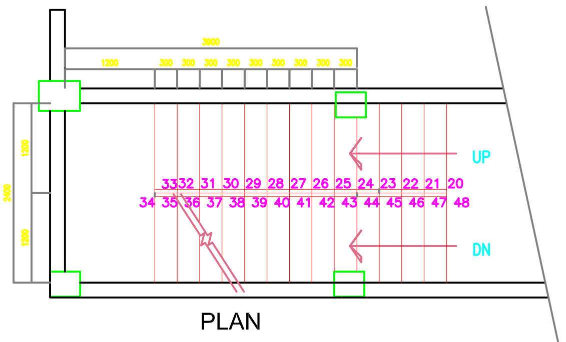
Capacity Development of the NCRPB: Component B (ADB TA-7055)

BUS TERMINAL BUILDING DETAILED DRAWINGS

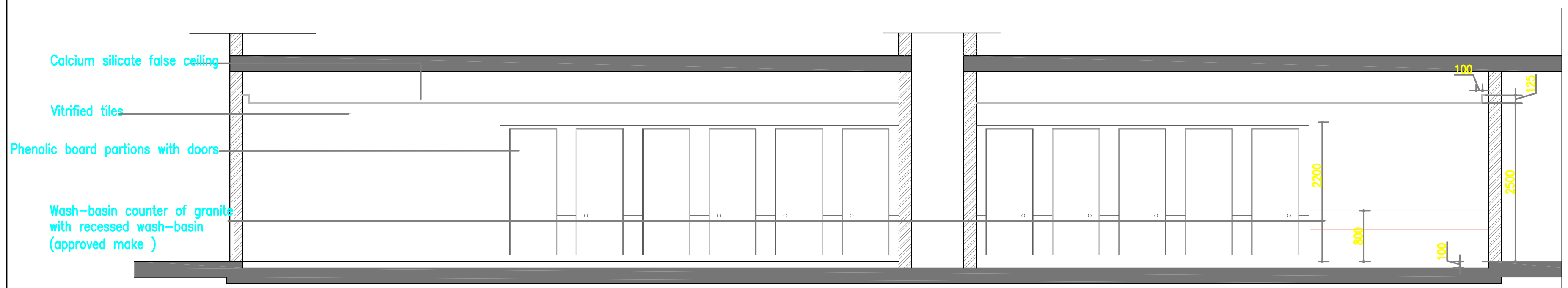


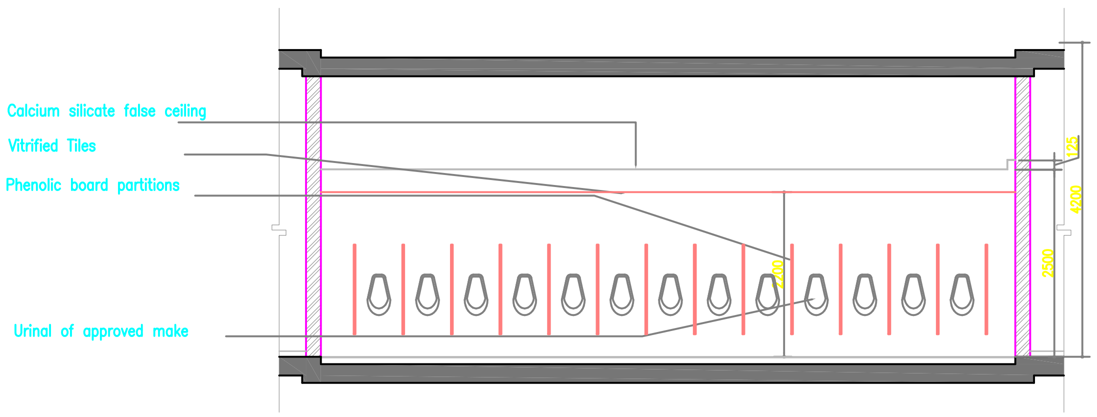


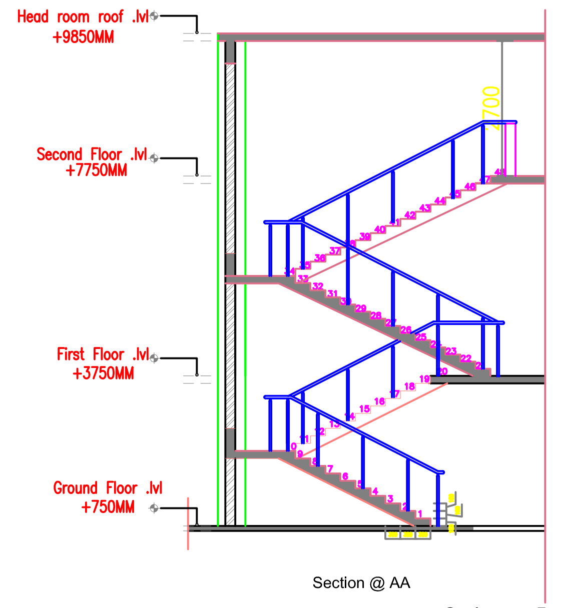
From Ground Floor to First Floor
Floor Height : 3000M
No of Treads : 18
No of Risers : 20
No of Landings : 1
Riser Height : 150MM
Tread Width : 1200MM
Tread Depth : 300MM



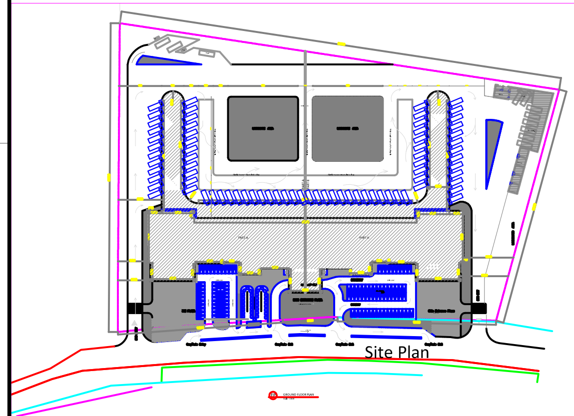
From First Floor to Second Floor
Floor Height : 3000M
No of Treads : 26
No of Risers : 28
No of Landings : 1
Riser Height : 150MM
Tread Width : 1200MM
Tread Depth : 300MM







Staircase Detail



Schedule of openings

Type	Description	Sizes
Wooden doors		
D	Door	1050x2100
D1	Door	900x2100
D2	Toilet Door	750x2100
Windows/Ventilators		
W1	Aluminium window	1800x1200
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GW	Aluminium window	3700X8500
V	Aliminium ventilator	2700x500
V1	Aliminium ventilator	600x600
Windows/Ventilators		
RS	Rolling Shutter	4000x2400

Note:
All dimensions are in millimeters
Any discrepancy must be brought to the notice of the consultant

Rev. No.	Revision	Date

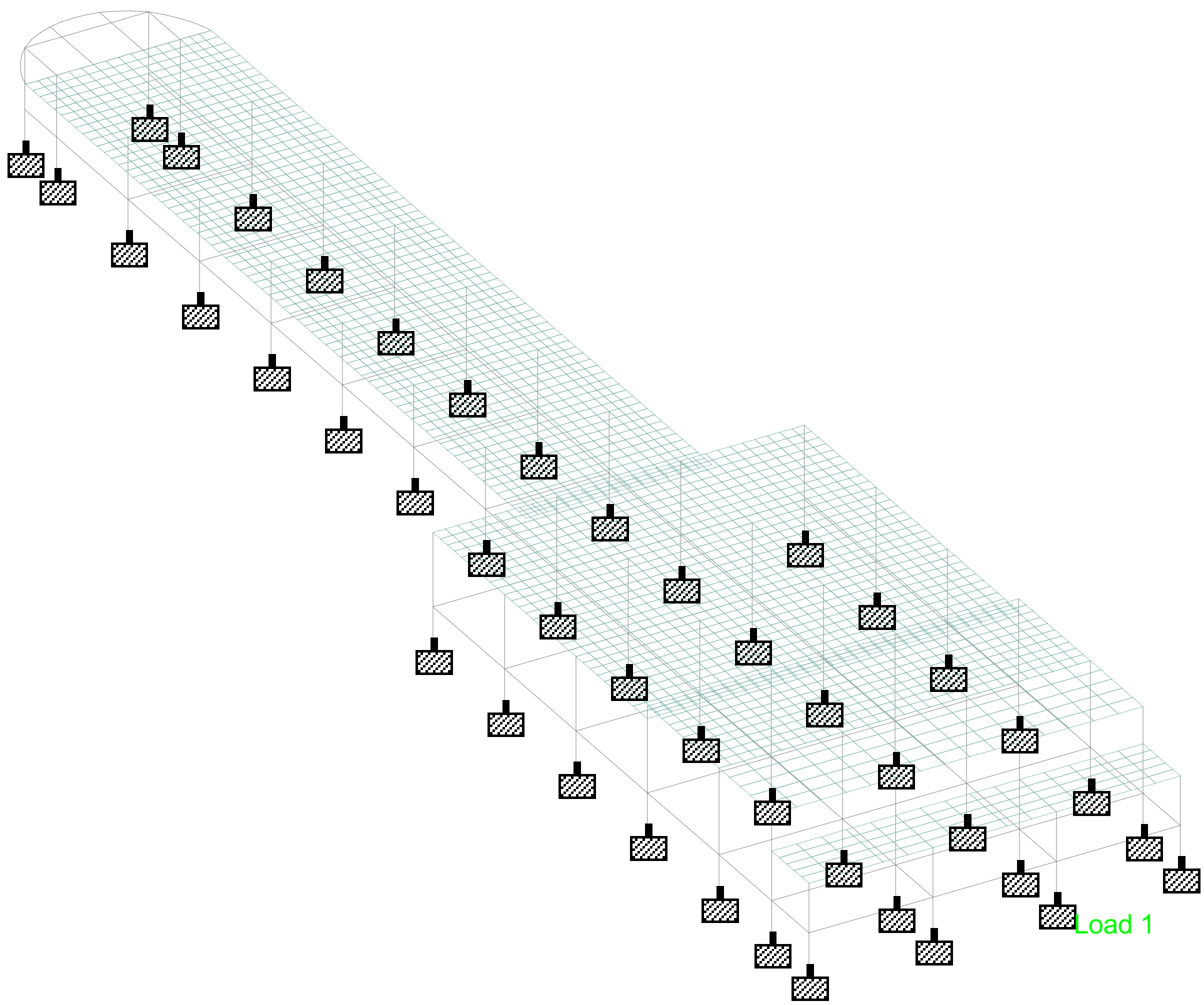
Client:
Asian Development Bank
National Capital Region Planning Board

Consultant:
Wilbur Smith Associates

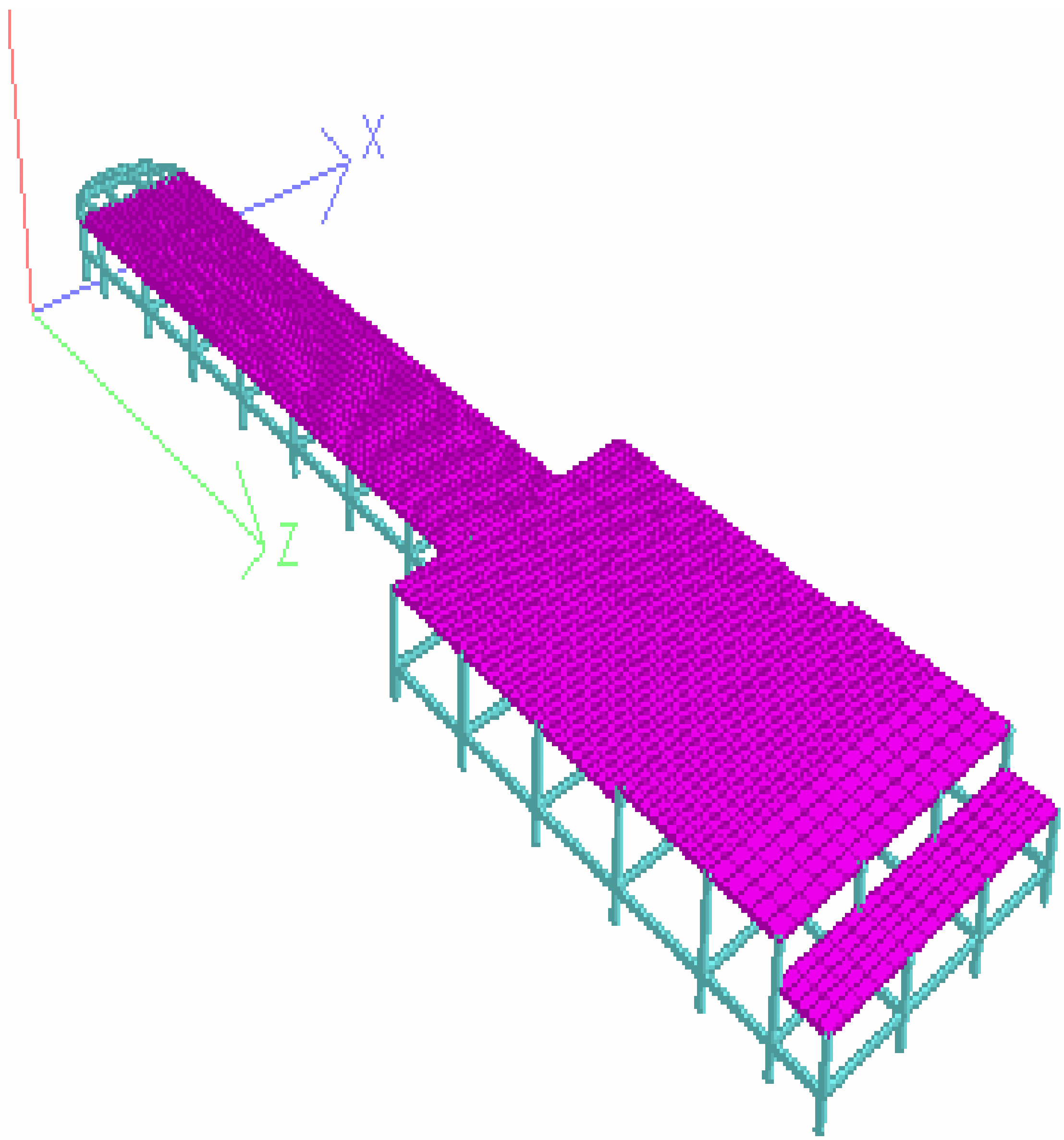
Drawn: Shan | Checked: APK
Design: Yunus | Approved: AN | Sheet No.
Date: April 2010
Scale: As shown
Drawing No: ST-002 -08

STAAD MODEL

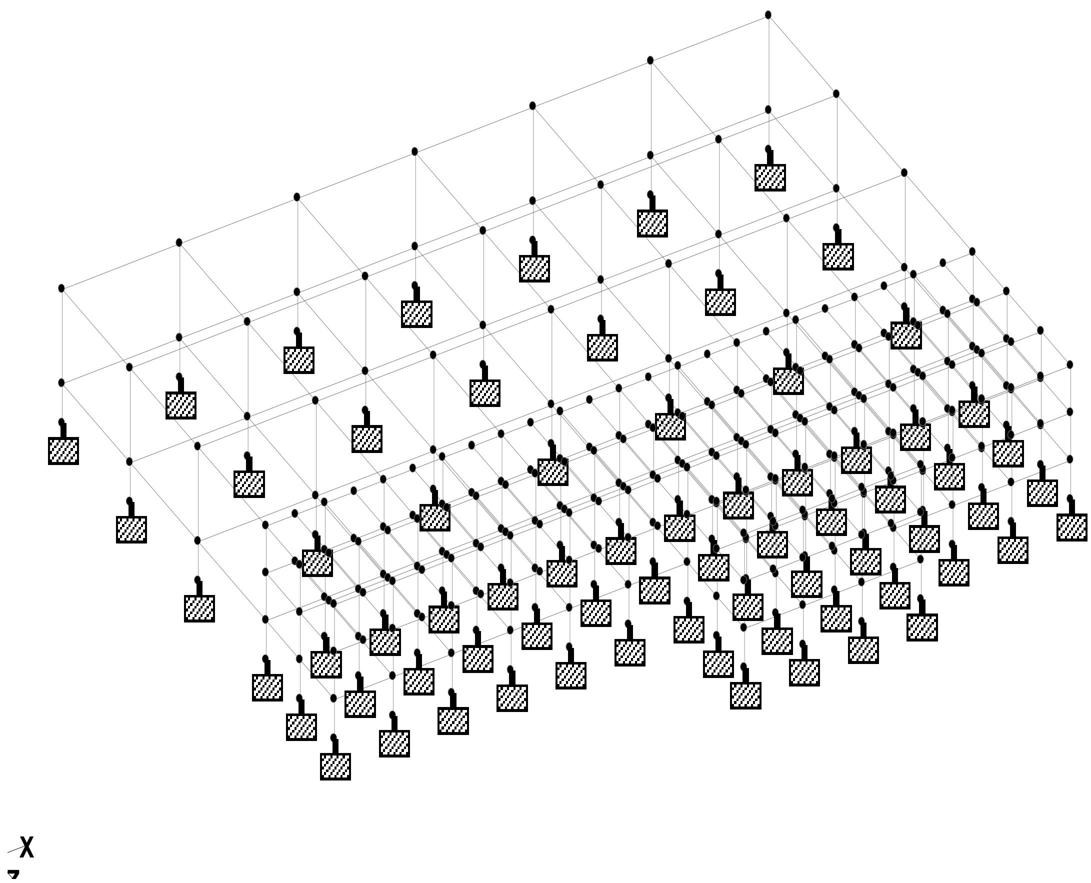
Bus Terminal Platform



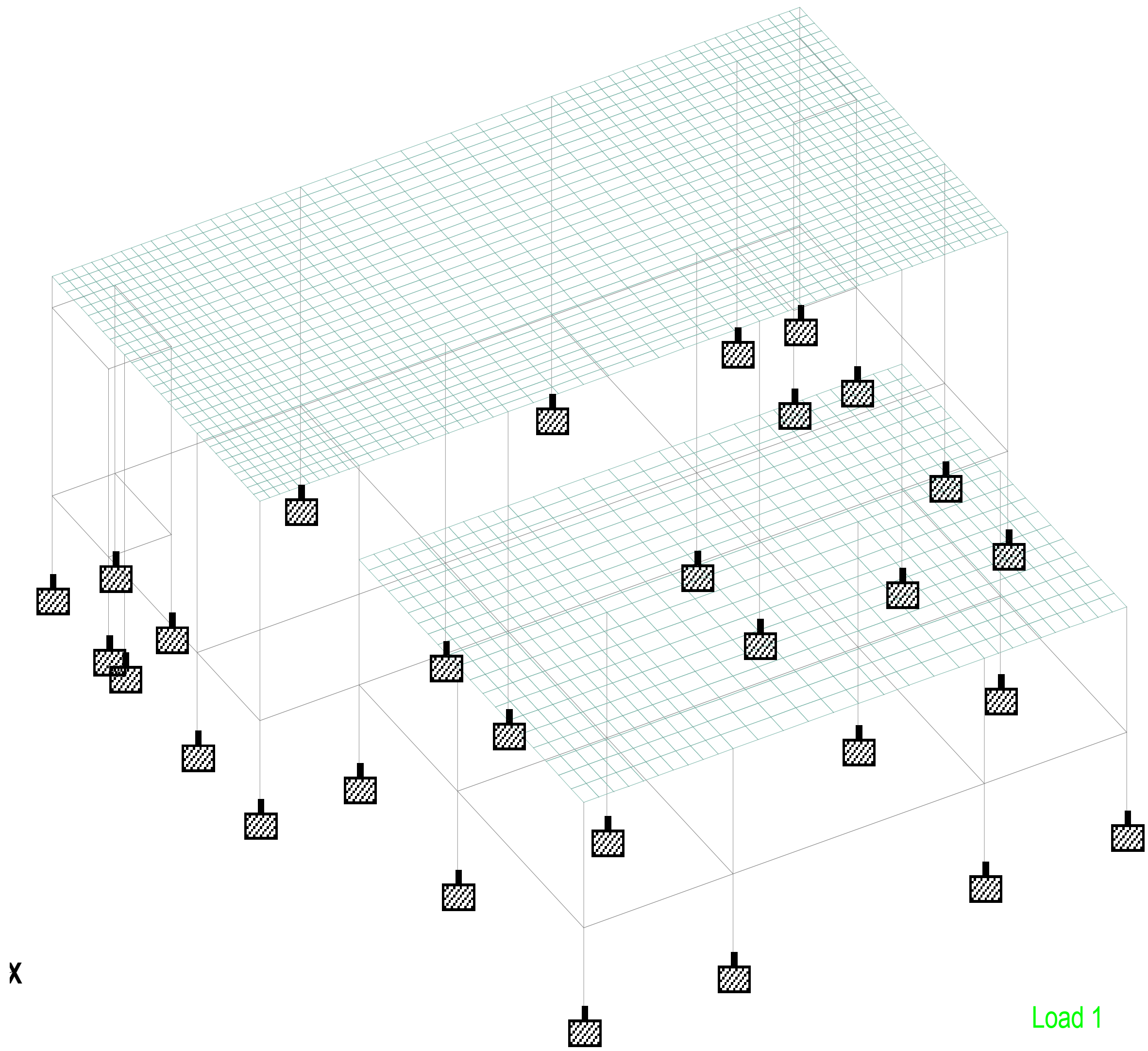
3D Model



Admin Building



Bus Terminal Entrance



STAAD INPUT

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STAAD SPACE
START JOB INFORMATION
ENGINEER DATE 04-Feb-10
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
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14 0 7 -20; 15 0 7 -10; 16 0 7 0; 17 0 7 5; 18 0 7 10; 19 2.5 7 0; 20 2.5 7 5;
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DEFINE MATERIAL START
ISOTROPIC CONCRETE
E 2.17185e+007
POISSON 0.17
DENSITY 23.5616
ALPHA 1e-005
DAMP 0.05
END DEFINE MATERIAL
MEMBER PROPERTY AMERICAN
4 15 58 69 112 123 166 181 248 263 327 340 395 408 430 436 442 448 458 468 -
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476 PRIS YD 0.6 ZD 0.45
6 17 33 35 39 41 60 71 87 89 93 95 114 125 141 143 147 149 168 TO 170 183 -
184 TO 185 209 211 TO 213 219 221 TO 223 250 TO 252 265 TO 267 291 -
293 TO 295 301 303 TO 305 329 330 342 343 363 365 366 371 373 374 397 398 -
410 411 432 433 435 438 439 441 444 445 447 450 TO 453 455 TO 457 -
460 TO 463 465 TO 467 470 TO 472 474 475 478 479 PRIS YD 0.4 ZD 0.25
7 TO 11 26 27 36 TO 38 48 49 61 TO 65 80 81 90 TO 92 102 103 115 TO 119 134 -
135 144 TO 146 156 157 171 TO 177 198 199 214 TO 218 234 235 253 TO 259 280 -
281 296 TO 300 315 316 331 TO 336 354 355 367 TO 370 383 384 399 TO 404 640 -
641 TO 651 PRIS YD 0.65 ZD 0.25
21 22 28 29 43 44 50 51 75 76 82 83 97 98 104 105 129 130 136 137 151 152 -
158 159 189 TO 192 200 TO 203 225 TO 228 236 TO 239 271 TO 274 282 TO 285 -
307 TO 310 317 TO 319 347 TO 349 356 TO 358 376 TO 378 385 TO 387 -
415 TO 417 480 481 485 486 490 491 495 496 500 501 505 506 510 511 515 516 -
520 521 525 526 530 531 535 536 540 TO 543 549 TO 552 558 TO 561 567 TO 570 -
576 TO 579 585 TO 588 594 TO 597 602 TO 604 609 TO 611 616 TO 618 -
623 TO 625 630 TO 632 637 TO 639 PRIS YD 0.5 ZD 0.23
1 TO 3 12 TO 14 55 TO 57 66 TO 68 109 TO 111 120 TO 122 163 TO 165 -
178 TO 180 245 TO 247 260 TO 262 324 TO 326 337 TO 339 392 TO 394 -
405 TO 407 PRIS YD 0.7
23 TO 25 30 TO 32 45 TO 47 52 TO 54 77 TO 79 84 TO 86 99 TO 101 106 TO 108 -
131 TO 133 138 TO 140 153 TO 155 160 TO 162 193 TO 197 204 TO 208 -
229 TO 233 240 TO 244 275 TO 279 286 TO 290 311 TO 314 320 TO 323 -
350 TO 353 359 TO 362 379 TO 382 388 TO 391 482 TO 484 487 TO 489 -
492 TO 494 497 TO 499 502 TO 504 507 TO 509 512 TO 514 517 TO 519 -
522 TO 524 527 TO 529 532 TO 534 537 TO 539 544 TO 548 553 TO 557 -
562 TO 566 571 TO 575 580 TO 584 589 TO 593 598 TO 601 605 TO 608 -
612 TO 615 619 TO 622 626 TO 629 633 TO 636 PRIS YD 0.3 ZD 0.23
18 TO 20 42 72 TO 74 96 126 TO 128 150 186 TO 188 224 268 TO 270 306 -
344 TO 346 375 412 TO 414 418 TO 428 -
429 PRIS AX 0.001 IX 0.001 IY 0.001 IZ 0.001
MEMBER PROPERTY
5 16 34 40 59 70 88 94 113 124 142 148 167 182 210 220 249 264 292 302 328 -
341 364 372 396 409 431 434 437 440 443 446 449 454 459 464 469 473 -
477 PRIS YD 0.45 ZD 0.3
CONSTANTS
MATERIAL CONCRETE ALL
SUPPORTS
1 TO 6 22 TO 24 34 TO 39 55 TO 57 67 TO 72 88 TO 90 100 TO 107 129 TO 133 -
149 TO 156 178 TO 182 197 TO 203 222 TO 225 238 TO 244 FIXED
DEFINE WIND LOAD
TYPE 1
INT 1.73 1.73 1.73 1.73 1.73 HEIG  3.3  6.6  9.9  13.2  16.5
EXP 1 JOINT 12 18 21 27 30 33 45 51 54 60 63 66 78 84 87 93 96 99 113 114 -
121 122 128 138 143 148 164 172 177 181 186 187 191 192 196 210 217 221 229 -
233 237 251 258 261 264 267 270 273 276 279 282 285 288 291 294 297 298 304 -
309 314 319 324 328 329 333 337 341 345 349 353
DEFINE 1893 LOAD
ZONE 0.24 RF 3 I 1.5 SS 1 DM 0.05 DT 2.5
JOINT WEIGHT
1 WEIGHT 14.66
2 WEIGHT 14.66
3 WEIGHT 14.66
4 WEIGHT 11.928
5 WEIGHT 4.418
6 WEIGHT 4.418
7 WEIGHT 112.427
8 WEIGHT 139.036
9 WEIGHT 142.794
10 WEIGHT 167.141
11 WEIGHT 129.693
12 WEIGHT 107.527
13 WEIGHT 457.786
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14 WEIGHT 893.799
15 WEIGHT 892.586
16 WEIGHT 378.827
17 WEIGHT 115.126
18 WEIGHT 66.835
22 WEIGHT 4.418
23 WEIGHT 4.418
24 WEIGHT 4.418
25 WEIGHT 95.631
26 WEIGHT 42.632
27 WEIGHT 140.973
28 WEIGHT 417.291
29 WEIGHT 286.624
30 WEIGHT 115.501
34 WEIGHT 14.66
35 WEIGHT 14.66
36 WEIGHT 14.66
37 WEIGHT 11.928
38 WEIGHT 4.418
39 WEIGHT 4.418
40 WEIGHT 138.991
41 WEIGHT 152.115
42 WEIGHT 160.915
43 WEIGHT 93.255
44 WEIGHT 34.134
45 WEIGHT 133.933
46 WEIGHT 893.916
47 WEIGHT 1779.22
48 WEIGHT 1776.7
49 WEIGHT 735.969
50 WEIGHT 212.174
51 WEIGHT 122.921
55 WEIGHT 4.418
56 WEIGHT 4.418
57 WEIGHT 4.418
58 WEIGHT 93.108
59 WEIGHT 42.203
60 WEIGHT 134.36
61 WEIGHT 416.188
62 WEIGHT 281.598
63 WEIGHT 112.944
67 WEIGHT 14.66
68 WEIGHT 14.66
69 WEIGHT 14.66
70 WEIGHT 11.928
71 WEIGHT 4.418
72 WEIGHT 4.418
73 WEIGHT 142.099
74 WEIGHT 158.926
75 WEIGHT 167.73
76 WEIGHT 187.895
77 WEIGHT 34.115
78 WEIGHT 133.954
79 WEIGHT 889.061
80 WEIGHT 1769.66
81 WEIGHT 1767.14
82 WEIGHT 736.177
83 WEIGHT 212.563
84 WEIGHT 123.3
88 WEIGHT 4.418
89 WEIGHT 4.418
90 WEIGHT 4.418
91 WEIGHT 134.186

92 WEIGHT 42.012
93 WEIGHT 141.638
94 WEIGHT 416.339
95 WEIGHT 281.232
96 WEIGHT 111.277
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101 WEIGHT 14.66
102 WEIGHT 14.66
103 WEIGHT 11.928
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105 WEIGHT 4.418
106 WEIGHT 4.418
107 WEIGHT 4.418
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109 WEIGHT 158.324
110 WEIGHT 167.094
111 WEIGHT 185.426
112 WEIGHT 28.63
113 WEIGHT 122.455
114 WEIGHT 114.44
115 WEIGHT 96.348
116 WEIGHT 889.236
117 WEIGHT 1770.01
118 WEIGHT 1767.46
119 WEIGHT 737.417
120 WEIGHT 200.78
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122 WEIGHT 107.899
123 WEIGHT 54.3
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130 WEIGHT 4.418
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133 WEIGHT 4.418
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135 WEIGHT 40.339
136 WEIGHT 36.089
137 WEIGHT 35.362
138 WEIGHT 137.389
139 WEIGHT 416.447
140 WEIGHT 268.419
141 WEIGHT 231.1
142 WEIGHT 217.668
143 WEIGHT 99.384
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150 WEIGHT 14.66
151 WEIGHT 14.66
152 WEIGHT 11.928
153 WEIGHT 4.418
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157 WEIGHT 142.099
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159 WEIGHT 167.712
160 WEIGHT 184.733
161 WEIGHT 31.813
162 WEIGHT 38.28
163 WEIGHT 34.803
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166 WEIGHT 1769.66
167 WEIGHT 1767.11

168 WEIGHT 737.302
169 WEIGHT 196.439
170 WEIGHT 244.598
171 WEIGHT 211.791
172 WEIGHT 99.692
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182 WEIGHT 4.418
183 WEIGHT 134.612
184 WEIGHT 41.131
185 WEIGHT 31.673
186 WEIGHT 124.964
187 WEIGHT 100.277
188 WEIGHT 416.537
189 WEIGHT 268.895
190 WEIGHT 231.669
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192 WEIGHT 51.081
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213 WEIGHT 1776.68
214 WEIGHT 737.216
215 WEIGHT 196.819
216 WEIGHT 252.712
217 WEIGHT 97.531
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226 WEIGHT 137.313
227 WEIGHT 40.122
228 WEIGHT 38.356
229 WEIGHT 138.11
230 WEIGHT 417.561
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307 WEIGHT 132.699
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309 WEIGHT 64.326
315 WEIGHT 83.605
316 WEIGHT 156.706
317 WEIGHT 129.361
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319 WEIGHT 64.225
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327 WEIGHT 133.266
328 WEIGHT 99.549
329 WEIGHT 40.393
334 WEIGHT 83.587
335 WEIGHT 157.467
336 WEIGHT 132.521
337 WEIGHT 66.985
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LOAD 1 LOADTYPE Seismic  TITLE EQX
1893 LOAD X 1
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LOAD 2 LOADTYPE Seismic  TITLE EQZ
1893 LOAD Z 1
LOAD 3 LOADTYPE Wind  TITLE WIND X
WIND LOAD X 1 TYPE 1 XR 0 65 YR 1 7 ZR 0 20 OPEN
LOAD 4 LOADTYPE Wind  TITLE WIND Z
WIND LOAD Z 1 TYPE 1 XR 0 60 YR 1 7 ZR 0 20 OPEN
LOAD 5 LOADTYPE Wind  TITLE WIND -X
WIND LOAD -X -1 TYPE 1 XR 0 60 YR 1 7 ZR 0 20 OPEN
LOAD 6 LOADTYPE Wind  TITLE WIND -Z
WIND LOAD -Z -1 TYPE 1 XR 0 60 YR 1 7 ZR 0 20 OPEN
LOAD 7 LOADTYPE None  TITLE SW
SELFWEIGHT Y -1
LOAD 8 LOADTYPE None  TITLE WL
MEMBER LOAD
10 11 26 27 49 81 102 103 134 135 156 157 176 177 198 199 234 235 280 281 -
300 315 316 354 355 383 384 402 TO 404 UNI GY -11.1
LOAD 9 LOADTYPE None  TITLE SLAB DL
FLOOR LOAD
YRANGE 4 4.2 FLOAD -3 XRANGE 0 60  ZRANGE 0 10  GY
YRANGE 4 4.2 FLOAD -3 XRANGE 30 60  ZRANGE 10 14.33  GY
YRANGE 4 4.2 FLOAD -3 XRANGE 30 45  ZRANGE 14.33 18.33  GY
YRANGE 7 7.2 FLOAD -3 XRANGE 0 60  ZRANGE 0 10  GY
YRANGE 7 7.2 FLOAD -3 XRANGE 30 60  ZRANGE 10 14.33  GY
YRANGE 7 7.2 FLOAD -3 XRANGE 30 45  ZRANGE 14.33 18.33  GY
YRANGE 7 7.2 FLOAD -13 XRANGE 0 60  ZRANGE -30 0  GY
LOAD 10 LOADTYPE None  TITLE SLAB LL
FLOOR LOAD
YRANGE 4 4.2 FLOAD -2 XRANGE 0 60  ZRANGE 0 10  GY
YRANGE 4 4.2 FLOAD -2 XRANGE 30 60  ZRANGE 10 14.33  GY
YRANGE 4 4.2 FLOAD -2 XRANGE 30 45  ZRANGE 14.33 18.33  GY
YRANGE 7 7.2 FLOAD -2 XRANGE 0 60  ZRANGE 0 10  GY
YRANGE 7 7.2 FLOAD -2 XRANGE 30 60  ZRANGE 10 14.33  GY
YRANGE 7 7.2 FLOAD -2 XRANGE 30 45  ZRANGE 14.33 18.33  GY
YRANGE 7 7.2 FLOAD -2 XRANGE 0 60  ZRANGE -30 0  GY
LOAD COMB 11 1.5 * (DL+LL)
7 1.5 8 1.5 9 1.5 10 1.5
LOAD COMB 12 1.5 * (DL+EQX)
7 1.5 8 1.5 9 1.5 1 1.5
LOAD COMB 13 1.5 * (DL-EQX)
7 1.5 8 1.5 9 1.5 1 -1.5
LOAD COMB 14 1.5 * (DL+EQZ)
7 1.5 8 1.5 9 1.5 2 1.5
LOAD COMB 15 1.5 * (DL-EQZ)
7 1.5 8 1.5 9 1.5 2 -1.5
LOAD COMB 16 1.2 * (DL+LL+EQX)
7 1.2 8 1.2 9 1.2 10 1.2 1 1.2
LOAD COMB 17 1.2 * (DL+LL-EQX)
7 1.2 8 1.2 9 1.2 10 1.2 1 -1.2
LOAD COMB 18 1.2 * (DL+LL+EQZ)
7 1.2 8 1.2 9 1.2 10 1.2 2 1.2
LOAD COMB 19 1.2 * (DL+LL-EQZ)
7 1.2 8 1.2 9 1.2 10 1.2 1 -1.2
LOAD COMB 20 0.9 * DL + 1.5 * EQX
7 0.9 8 0.9 9 0.9 1 1.5
LOAD COMB 21 0.9 * DL - 1.5 * EQX
7 0.9 8 0.9 9 0.9 1 -1.5
LOAD COMB 22 0.9 * DL+ 1.5 * EQZ
7 0.9 8 0.9 9 0.9 2 1.5
LOAD COMB 23 0.9 * DL - 1.5 * EQZ
7 0.9 8 0.9 9 0.9 2 -1.5
LOAD COMB 24 1.5 * (DL+WX)
7 1.5 8 1.5 9 1.5 3 1.5
LOAD COMB 25 1.5 * (DL-WX)
```

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7 1.5 8 1.5 9 1.5 5 -1.5
LOAD COMB 26 1.5 * (DL+WZ)
7 1.5 8 1.5 9 1.5 4 1.5
LOAD COMB 27 1.5 * (DL-WZ)
7 1.5 8 1.5 9 1.5 6 -1.5
LOAD COMB 28 1.2 * (DL+LL+WX)
7 1.2 8 1.2 9 1.2 10 1.2 3 1.2
LOAD COMB 29 1.2 * (DL+LL-WX)
7 1.2 8 1.2 9 1.2 10 1.2 5 -1.2
LOAD COMB 30 1.2 * (DL+LL+WZ)
7 1.2 8 1.2 9 1.2 10 1.2 4 1.2
LOAD COMB 31 1.2 * (DL+LL-WZ)
7 1.2 8 1.2 9 1.2 10 1.2 6 -1.2
LOAD COMB 32 0.9 * DL+ 1.5 * WX
7 0.9 8 0.9 9 0.9 3 1.5
LOAD COMB 33 0.9 * DL - 1.5 * WX
7 0.9 8 0.9 9 0.9 5 -1.5
LOAD COMB 34 0.9 * DL+ 1.5 * WZ
7 0.9 8 0.9 9 0.9 4 1.5
LOAD COMB 35 0.9 * DL - 1.5 * WZ
7 0.9 8 0.9 9 0.9 6 -1.5
PERFORM ANALYSIS PRINT ALL
FINISH
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STAAD SPACE
START JOB INFORMATION
ENGINEER DATE 04-Feb-10
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
2 10 -1.5 0; 3 20 -1.5 0; 6 10 1 0; 7 20 1 0; 10 10 -1.5 10; 11 20 -1.5 10;
14 10 1 10; 15 20 1 10; 18 10 -1.5 20; 19 20 -1.5 20; 22 10 1 20; 23 20 1 20;
26 10 -1.5 30; 27 20 -1.5 30; 30 10 1 30; 31 20 1 30; 34 10 -1.5 40;
35 20 -1.5 40; 38 10 1 40; 39 20 1 40; 42 10 -1.5 50; 43 20 -1.5 50;
46 10 1 50; 47 20 1 50; 50 10 -1.5 60; 51 20 -1.5 60; 54 10 1 60; 55 20 1 60;
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85 0 1 100; 86 10 1 100; 87 20 1 100; 88 30 1 100; 89 0 -1.5 110;
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104 30 1 117.4; 105 0 -1.5 122.6; 106 10 -1.5 122.6; 107 20 -1.5 122.6;
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167 0 5 121.56; 168 2 5 121.56; 169 2 5 122.6; 170 4 5 118.44; 171 4 5 117.4;
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2716 2535 2795 2796 2537; 2717 2537 2796 2797 2539; 2718 2539 2797 2798 2541;
2719 2541 2798 2735 2388;
ELEMENT PROPERTY
210 211 213 TO 216 218 219 230 231 233 TO 235 239 240 244 250 254 255 259 -
260 264 265 269 275 279 280 284 TO 286 292 TO 296 302 TO 304 365 366 373 -
374 TO 376 383 TO 386 393 TO 396 403 404 465 466 473 TO 476 483 TO 486 493 -
494 TO 496 503 504 565 566 573 TO 576 583 TO 589 605 614 630 634 635 639 655 -
659 676 677 684 TO 687 694 695 756 757 764 TO 767 774 TO 777 784 TO 787 794 -
795 856 857 864 TO 867 874 TO 877 884 TO 887 894 895 956 957 964 TO 967 974 -
975 TO 977 984 TO 987 994 995 1056 TO 1058 1064 TO 1068 1074 TO 1078 1084 -
1085 TO 1088 1094 1095 1156 TO 1158 1162 1165 TO 1168 1175 TO 1178 -
1185 TO 1188 1195 1228 1256 TO 1258 1264 TO 1268 1274 TO 1277 1285 TO 1287 -
1295 1356 1357 1365 TO 1367 1375 TO 1377 1385 TO 1387 1395 1456 1457 1465 -
1466 TO 1467 1475 TO 1477 1485 TO 1487 1495 1556 1557 1565 TO 1567 1575 1586 -
1587 1594 TO 1597 1604 1605 1666 1667 1674 TO 1677 1684 TO 1687 1694 TO 1697 -
1704 1705 1766 1767 1774 TO 1777 1784 TO 1787 1794 TO 1797 1804 1805 1866 -
1867 1874 TO 1877 1884 TO 1887 1894 TO 1897 1904 1905 1966 1967 1974 TO 1977 -
1984 TO 1987 1994 TO 1997 2004 2005 2066 2067 2074 TO 2077 2084 TO 2087 2094 -
2095 TO 2097 2104 2105 2166 2167 2174 TO 2177 2184 TO 2187 2194 TO 2197 2204 -
2205 THICKNESS 0.75
2266 2267 2274 TO 2277 2284 2285 2300 TO 2303 2316 TO 2323 2336 TO 2343 2356 -
2357 TO 2363 2376 TO 2383 2396 TO 2403 2416 TO 2423 2436 TO 2443 2456 TO 2461 -
2468 TO 2471 2478 TO 2481 2488 TO 2491 2498 TO 2501 2508 TO 2511 -
2518 TO 2521 2528 TO 2531 2538 TO 2541 2548 TO 2551 2558 TO 2561 -
2568 TO 2571 2578 2579 THICKNESS 0.75
212 217 220 TO 229 232 236 TO 238 241 TO 243 245 TO 249 251 TO 253 -
256 TO 258 261 TO 263 266 TO 268 270 TO 274 276 TO 278 281 TO 283 -
287 TO 291 297 TO 301 305 TO 364 367 TO 372 377 TO 382 387 TO 392 -
397 TO 402 405 TO 464 467 TO 472 477 TO 482 487 TO 492 497 TO 502 -
505 TO 564 567 TO 572 577 TO 582 590 TO 604 606 TO 613 615 TO 629 -
631 TO 633 636 TO 638 640 TO 654 656 TO 658 678 TO 683 688 TO 693 -
696 TO 755 758 TO 763 768 TO 773 778 TO 783 788 TO 793 796 TO 855 -
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858 TO 863 868 TO 873 878 TO 883 888 TO 893 896 TO 955 958 TO 963 -
968 TO 973 978 TO 983 988 TO 993 996 TO 1055 1059 TO 1063 1069 TO 1073 1079 -
1080 TO 1083 1089 TO 1093 1096 TO 1155 1159 TO 1161 1163 1164 1169 TO 1174 -
1179 TO 1184 1189 TO 1194 1196 TO 1227 1229 TO 1255 1259 TO 1263 -
1269 TO 1273 1278 TO 1284 1288 TO 1294 1296 TO 1355 1358 TO 1364 -
1368 TO 1374 1378 TO 1384 1388 TO 1394 1396 TO 1455 1458 TO 1464 -
1468 TO 1474 1478 TO 1484 1488 TO 1494 1496 TO 1555 1558 TO 1564 -
1568 TO 1574 1588 TO 1593 1598 TO 1603 1606 TO 1665 1668 TO 1673 -
1678 TO 1683 1688 TO 1693 1698 TO 1703 1706 TO 1765 1768 TO 1773 -
1778 TO 1783 1788 TO 1793 1798 TO 1803 1806 THICKNESS 0.35
1807 TO 1865 1868 TO 1873 1878 TO 1883 1888 TO 1893 1898 TO 1903 1906 TO 1965 -
1968 TO 1973 1978 TO 1983 1988 TO 1993 1998 TO 2003 2006 TO 2065 -
2068 TO 2073 2078 TO 2083 2088 TO 2093 2098 TO 2103 2106 TO 2165 -
2168 TO 2173 2178 TO 2183 2188 TO 2193 2198 TO 2203 2206 TO 2265 -
2268 TO 2273 2278 TO 2283 2304 TO 2315 2324 TO 2335 2344 TO 2355 -
2364 TO 2375 2384 TO 2395 2404 TO 2415 2424 TO 2435 2444 TO 2455 -
2462 TO 2467 2472 TO 2477 2482 TO 2487 2492 TO 2497 2502 TO 2507 -
2512 TO 2517 2522 TO 2527 2532 TO 2537 2542 TO 2547 2552 TO 2557 -
2562 TO 2567 2572 TO 2577 2580 TO 2719 THICKNESS 0.35
DEFINE MATERIAL START
ISOTROPIC CONCRETE
E 2.17185e+007
POISSON 0.17
DENSITY 23.5616
ALPHA 1e-005
DAMP 0.05
END DEFINE MATERIAL
MEMBER PROPERTY AMERICAN
5 6 12 13 19 20 26 27 33 34 40 41 47 48 53 TO 56 60 TO 63 67 TO 70 74 TO 76 -
81 TO 84 88 TO 91 95 TO 98 151 TO 153 155 TO 178 180 TO 194 196 198 200 660 -
662 664 1576 1578 2720 TO 2723 PRIS YD 0.7
9 16 23 30 37 44 50 TO 52 57 TO 59 64 TO 66 71 TO 73 78 TO 80 85 TO 87 92 -
93 TO 94 100 101 104 105 108 109 112 113 116 117 120 121 124 125 127 TO 150 -
2724 2725 PRIS YD 0.6 ZD 0.3
MEMBER PROPERTY AMERICAN
2731 TO 2739 2755 TO 2762 2788 TO 2790 PRIS YD 0.75 ZD 0.3
2783 TO 2786 PRIS YD 0.55 ZD 0.3
2727 TO 2729 2740 TO 2742 2763 TO 2782 PRIS YD 0.5 ZD 0.3
2744 TO 2753 PRIS YD 0.4 ZD 0.25
MEMBER PROPERTY
77 154 666 PRIS YD 0.65 ZD 0.55
CONSTANTS
MATERIAL CONCRETE ALL
SUPPORTS
2 3 10 11 18 19 26 27 34 35 42 43 50 51 57 TO 60 65 TO 68 73 TO 76 81 TO 84 -
89 TO 92 97 TO 100 105 TO 108 2799 2800 FIXED
DEFINE WIND LOAD
TYPE 1
INT 1.73 1.73 1.73 1.73 1.73 HEIG  3.3  6.6  9.9  13.2  16.5
EXP 1 JOINT 6 14 22 30 38 46 54 61 69 77 85 93 101 109 113 117 121 125 129 -
133 137 142 144 146 148 150 152 154 156 657 2801 2803
DEFINE 1893 LOAD
ZONE 0.24 RF 3 I 1.5 SS 1 DM 0.05 DT 2.5
JOINT WEIGHT
2 WEIGHT 14.66
3 WEIGHT 14.66
6 WEIGHT 119.144
7 WEIGHT 119.141
10 WEIGHT 14.66
11 WEIGHT 14.66
14 WEIGHT 138.456
15 WEIGHT 138.456
18 WEIGHT 14.66
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19 WEIGHT 14.66
22 WEIGHT 139.761
23 WEIGHT 139.761
26 WEIGHT 14.66
27 WEIGHT 14.66
30 WEIGHT 139.338
31 WEIGHT 139.338
34 WEIGHT 14.66
35 WEIGHT 14.66
38 WEIGHT 139.312
39 WEIGHT 139.312
42 WEIGHT 14.66
43 WEIGHT 14.66
46 WEIGHT 139.832
47 WEIGHT 139.832
50 WEIGHT 14.66
51 WEIGHT 14.66
54 WEIGHT 138.522
55 WEIGHT 138.521
57 WEIGHT 14.66
58 WEIGHT 14.66
59 WEIGHT 14.66
60 WEIGHT 14.66
61 WEIGHT 115.469
62 WEIGHT 168.986
63 WEIGHT 169.008
64 WEIGHT 115.49
65 WEIGHT 14.66
66 WEIGHT 14.66
67 WEIGHT 14.66
68 WEIGHT 14.66
69 WEIGHT 146.078
70 WEIGHT 177.248
71 WEIGHT 177.411
72 WEIGHT 146.078
73 WEIGHT 14.66
74 WEIGHT 14.66
75 WEIGHT 14.66
76 WEIGHT 14.66
77 WEIGHT 146.39
78 WEIGHT 174.91
79 WEIGHT 174.807
80 WEIGHT 146.38
81 WEIGHT 14.66
82 WEIGHT 14.66
83 WEIGHT 14.66
84 WEIGHT 14.66
85 WEIGHT 144.465
86 WEIGHT 176.974
87 WEIGHT 176.8
88 WEIGHT 144.425
89 WEIGHT 14.66
90 WEIGHT 14.66
91 WEIGHT 14.66
92 WEIGHT 14.66
93 WEIGHT 144.778
94 WEIGHT 176.606
95 WEIGHT 176.607
96 WEIGHT 144.778
97 WEIGHT 14.66
98 WEIGHT 14.66
99 WEIGHT 14.66
100 WEIGHT 14.66

101 WEIGHT 170.803
102 WEIGHT 140.572
103 WEIGHT 140.606
104 WEIGHT 170.933
105 WEIGHT 14.66
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107 WEIGHT 14.66
108 WEIGHT 14.66
109 WEIGHT 145.353
110 WEIGHT 117.785
111 WEIGHT 117.727
112 WEIGHT 145.404
113 WEIGHT 345.874
114 WEIGHT 766.578
115 WEIGHT 766.059
116 WEIGHT 345.977
117 WEIGHT 699.302
118 WEIGHT 1785.1
119 WEIGHT 1781.08
120 WEIGHT 675.106
121 WEIGHT 259.945
122 WEIGHT 442.81
123 WEIGHT 485.41
124 WEIGHT 240.536
125 WEIGHT 218.904
126 WEIGHT 474.448
127 WEIGHT 468.28
128 WEIGHT 210.19
129 WEIGHT 338.023
130 WEIGHT 745.134
131 WEIGHT 743.963
132 WEIGHT 337.362
133 WEIGHT 731.663
134 WEIGHT 1869.72
135 WEIGHT 1878.22
136 WEIGHT 740.589
137 WEIGHT 724.146
138 WEIGHT 1891.9
139 WEIGHT 1852.16
140 WEIGHT 729.966
142 WEIGHT 869.335
143 WEIGHT 869.347
144 WEIGHT 1304.76
145 WEIGHT 1304.76
146 WEIGHT 1214.6
147 WEIGHT 1214.6
148 WEIGHT 1234.43
149 WEIGHT 1234.43
150 WEIGHT 1235.6
151 WEIGHT 1235.6
152 WEIGHT 1210.52
153 WEIGHT 1210.53
154 WEIGHT 1321.07
155 WEIGHT 1321.06
156 WEIGHT 250.329
157 WEIGHT 502.493
158 WEIGHT 496.049
159 WEIGHT 240.842
657 WEIGHT 366.146
658 WEIGHT 767.429
659 WEIGHT 772.503
660 WEIGHT 366.475
1606 WEIGHT 563.89

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1607 WEIGHT 563.906
2799 WEIGHT 14.66
2800 WEIGHT 14.66
2801 WEIGHT 93.207
2802 WEIGHT 93.21
2803 WEIGHT 282.327
2804 WEIGHT 282.239
LOAD 1 LOADTYPE Seismic  TITLE EQX
1893 LOAD X 1
LOAD 2 LOADTYPE Seismic  TITLE EQZ
1893 LOAD Z 1
LOAD 3 LOADTYPE Wind  TITLE WIND X
WIND LOAD X 1 TYPE 1 XR 0 32.4 YR 1 15.5 ZR 0 10.8 OPEN
LOAD 4 LOADTYPE Wind  TITLE WIND Z
WIND LOAD Z 1 TYPE 1 XR 0 25.2 YR 1 15.5 OPEN
LOAD 5 LOADTYPE Wind  TITLE WIND -X
WIND LOAD -X -1 TYPE 1 XR 0 32.4 YR 1 16.5 OPEN
LOAD 6 LOADTYPE Wind  TITLE WIND -Z
WIND LOAD -Z -1 TYPE 1 XR 0 25.2 YR 1 16.5 OPEN
LOAD 7 LOADTYPE None  TITLE SW
SELFWEIGHT Y -1
LOAD 8 LOADTYPE None  TITLE WL
MEMBER LOAD
147 150 UNI GY -15.4
ELEMENT LOAD
210 215 220 225 230 255 TO 259 280 TO 284 PR GY -11
LOAD 9 LOADTYPE Dead  TITLE SLAB DL
FLOOR LOAD
YRANGE 6 6.3 FLOAD -3.6 XRANGE 7.5 22.5  ZRANGE -6.358 0  GY
LOAD 10 LOADTYPE Roof Live REDUCIBLE TITLE SLAB LL
FLOOR LOAD
YRANGE 6 6.5 FLOAD -3 XRANGE 7.5 22.5  ZRANGE -6.358 0  GY
ELEMENT LOAD
210 TO 659 676 TO 1575 1586 TO 2285 2300 TO 2719 PR GY -3
LOAD COMB 11 1.5 * (DL+LL)
7 1.5 8 1.5 9 1.5 10 1.5
LOAD COMB 12 1.5 * (DL+EQX)
7 1.5 8 1.5 9 1.5 1 1.5
LOAD COMB 13 1.5 * (DL-EQX)
7 1.5 8 1.5 9 1.5 1 -1.5
LOAD COMB 14 1.5 * (DL+EQZ)
7 1.5 8 1.5 9 1.5 2 1.5
LOAD COMB 15 1.5 * (DL-EQZ)
7 1.5 8 1.5 9 1.5 2 -1.5
LOAD COMB 16 1.2 * (DL+LL+EQX)
7 1.2 8 1.2 9 1.2 10 1.2 1 1.2
LOAD COMB 17 1.2 * (DL+LL-EQX)
7 1.2 8 1.2 9 1.2 10 1.2 1 -1.2
LOAD COMB 18 1.2 * (DL+LL+EQZ)
7 1.2 8 1.2 9 1.2 10 1.2 2 1.2
LOAD COMB 19 1.2 * (DL+LL-EQZ)
7 1.2 8 1.2 9 1.2 10 1.2 1 -1.2
LOAD COMB 20 0.9 * DL + 1.5 * EQX
7 0.9 8 0.9 9 0.9 1 1.5
LOAD COMB 21 0.9 * DL - 1.5 * EQX
7 0.9 8 0.9 9 0.9 1 -1.5
LOAD COMB 22 0.9 * DL+ 1.5 * EQZ
7 0.9 8 0.9 9 0.9 2 1.5
LOAD COMB 23 0.9 * DL - 1.5 * EQZ
7 0.9 8 0.9 9 0.9 2 -1.5
LOAD COMB 24 1.5 * (DL+WX)
7 1.5 8 1.5 9 1.5 3 1.5
LOAD COMB 25 1.5 * (DL-WX)
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7 1.5 8 1.5 9 1.5 5 -1.5
LOAD COMB 26 1.5 * (DL+WZ)
7 1.5 8 1.5 9 1.5 4 1.5
LOAD COMB 27 1.5 * (DL-WZ)
7 1.5 8 1.5 9 1.5 6 -1.5
LOAD COMB 28 1.2 * (DL+LL+WX)
7 1.2 8 1.2 9 1.2 10 1.2 3 1.2
LOAD COMB 29 1.2 * (DL+LL-WX)
7 1.2 8 1.2 9 1.2 10 1.2 5 -1.2
LOAD COMB 30 1.2 * (DL+LL+WZ)
7 1.2 8 1.2 9 1.2 10 1.2 4 1.2
LOAD COMB 31 1.2 * (DL+LL-WZ)
7 1.2 8 1.2 9 1.2 10 1.2 6 -1.2
LOAD COMB 32 0.9 * DL+ 1.5 * WX
7 0.9 8 0.9 9 0.9 3 1.5
LOAD COMB 33 0.9 * DL - 1.5 * WX
7 0.9 8 0.9 9 0.9 5 -1.5
LOAD COMB 34 0.9 * DL+ 1.5 * WZ
7 0.9 8 0.9 9 0.9 4 1.5
LOAD COMB 35 0.9 * DL - 1.5 * WZ
7 0.9 8 0.9 9 0.9 6 -1.5
PERFORM ANALYSIS PRINT ALL
FINISH
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STAAD SPACE
START JOB INFORMATION
ENGINEER DATE 12-Feb-10
END JOB INFORMATION
INPUT WIDTH 79
UNIT METER KN
JOINT COORDINATES
1 0 0 0; 2 5.94 0 0; 3 15.94 0 0; 4 21.605 0 0; 5 0 0 6.8; 7 21.605 0 6.8;
8 0 0 15.502; 10 21.605 0 15.502; 11 5.94 0 6.8; 12 15.94 0 6.8;
25 5.94 0 -4.333; 26 15.94 0 -4.333; 27 -3.945 0 0; 28 -3.945 0 -4.33;
29 25.82 0 0; 30 25.82 0 -4.333; 31 -3.945 0 -10.43; 32 -1.445 0 -10.43;
33 25.82 0 -10.43; 34 23.32 0 -10.43; 35 -3.945 0 -14.33; 36 -1.445 0 -14.33;
37 5.94 0 -14.333; 38 15.94 0 -14.333; 39 25.82 0 -14.33; 40 23.32 0 -14.33;
41 -3.945 0 -9.33; 42 -3.945 0 -6.33; 43 0 -2.5 0; 44 5.94 -2.5 0;
45 15.94 -2.5 0; 46 21.605 -2.5 0; 47 0 -2.5 6.8; 49 21.605 -2.5 6.8;
50 0 -2.5 15.502; 52 21.605 -2.5 15.502; 53 5.94 -2.5 6.8; 54 15.94 -2.5 6.8;
55 5.94 -2.5 -4.333; 56 15.94 -2.5 -4.333; 57 -3.945 -2.5 0;
58 -3.945 -2.5 -4.33; 59 25.82 -2.5 0; 60 25.82 -2.5 -4.333;
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ELEMENT PROPERTY
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1941 TO 1945 1952 TO 1957 1964 TO 1969 1976 TO 1981 2012 TO 2016 2024 TO 2028 -
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POISSON 0.17
DENSITY 23.5616
ALPHA 1e-005
DAMP 0.05
END DEFINE MATERIAL
MEMBER PROPERTY AMERICAN
75 TO 78 80 84 102 TO 104 106 110 1246 PRIS YD 0.35 ZD 0.35
57 TO 61 63 64 66 TO 70 81 82 91 TO 94 107 108 148 TO 152 154 155 157 TO 159 -
3139 3141 3143 3144 3147 3148 3156 3157 PRIS YD 0.65
1 TO 3 6 8 TO 11 13 14 27 30 TO 32 34 TO 42 44 TO 51 53 55 56 87 TO 90 3151 -
3152 TO 3155 PRIS YD 0.25 ZD 0.65
MEMBER PROPERTY AMERICAN
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1248 1249 1251 1252 1254 1255 1257 1259 PRIS YD 0.15 ZD 0.15
SUPPORTS
43 TO 47 49 50 52 TO 71 2553 2555 FIXED
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CONSTANTS
MATERIAL CONCRETE ALL
DEFINE WIND LOAD
TYPE 1
INT 1.47 1.47 1.47 1.47 HEIG 0 2 4 7
EXP 1 JOINT 8 10 27 29 73 TO 76 79 81 98 TO 101 105 107 110 112 2551 2554
DEFINE 1893 LOAD
ZONE 0.24 RF 3 I 1.5 SS 1 ST 1 DM 0.05 DT 3
JOINT WEIGHT
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2 WEIGHT 76.617
3 WEIGHT 76.049
4 WEIGHT 141.942
5 WEIGHT 186.648
7 WEIGHT 186.142
8 WEIGHT 165.239
10 WEIGHT 162.513
11 WEIGHT 85.071
12 WEIGHT 84.547
25 WEIGHT 93.205
26 WEIGHT 93.122
27 WEIGHT 109.67
28 WEIGHT 108.369
29 WEIGHT 111.287
30 WEIGHT 151.48
31 WEIGHT 73.197
32 WEIGHT 24.515
33 WEIGHT 114.893
34 WEIGHT 25.499
35 WEIGHT 75.843
36 WEIGHT 126.084
37 WEIGHT 218.794
38 WEIGHT 218.768
39 WEIGHT 72.016
40 WEIGHT 125.635
41 WEIGHT 62.348
42 WEIGHT 48.431
43 WEIGHT 9.773
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56 WEIGHT 9.773
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60 WEIGHT 7.952
61 WEIGHT 3.608
62 WEIGHT 3.608
63 WEIGHT 3.608
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65 WEIGHT 7.952
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69 WEIGHT 7.952
70 WEIGHT 3.608
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74 WEIGHT 0.273
75 WEIGHT 17.782
76 WEIGHT 204.763
77 WEIGHT 1124.78
78 WEIGHT 1166.77
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81 WEIGHT 36.635
82 WEIGHT 421.783
87 WEIGHT 111.072
89 WEIGHT 481.475
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91 WEIGHT 219.74
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2551 WEIGHT 196.258
2553 WEIGHT 9.773
2554 WEIGHT 193.669
2555 WEIGHT 9.773
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1893 LOAD X 1
LOAD 2 LOADTYPE SEISMIC  TITLE EQZ
1893 LOAD Z 1
LOAD 7 LOADTYPE NONE  TITLE SW
SELFWEIGHT Y -1
LOAD 8 LOADTYPE NONE  TITLE WL
MEMBER LOAD
6 8 TO 11 34 TO 36 40 42 44 46 49 TO 51 55 56 87 88 90 3153 3154 UNI GY -15.4
LOAD 9 LL
ELEMENT LOAD
1283 1285 1287 1289 1291 1293 1295 1297 1299 1301 1303 TO 1311 1313 -
1315 TO 1323 1325 1327 TO 1335 1337 1339 TO 1347 1349 1351 TO 1359 1361 1363 -
1364 TO 1371 1373 1375 TO 1383 1385 1387 TO 1395 1397 1399 1401 1403 1405 -
1407 1409 1411 1413 1415 1416 1419 1421 1423 1425 1427 1429 1431 1433 1435 -
1437 TO 1446 1448 TO 1457 1459 TO 1468 1470 TO 1479 1481 TO 1490 -
1492 TO 1501 1503 TO 1512 1514 TO 1523 1525 1527 1529 1531 1533 1535 1537 -
1539 1541 1543 1544 1559 1561 1563 1565 1567 1569 1571 1573 1575 -
1577 TO 1586 1588 TO 1597 1599 TO 1608 1610 TO 1619 1621 TO 1630 -
1632 TO 1641 1643 TO 1652 1654 TO 1663 1665 1667 1669 1671 1673 1675 1677 -
1679 1681 1683 1684 1686 1688 1690 1692 1694 1696 1698 1700 1702 -
```

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1704 TO 1713 1715 TO 1724 1726 TO 1735 1737 TO 1746 1748 TO 1757 -
1759 TO 1768 1770 TO 1779 1781 TO 1790 1792 1794 1796 1798 1800 1802 1804 -
1806 1808 1810 1811 1813 1815 1817 1819 1821 1823 1825 1827 1829 -
1831 TO 1840 1842 TO 1851 1853 TO 1862 1864 TO 1873 1875 TO 1884 -
1886 TO 1895 1897 TO 1906 1908 TO 1917 1919 1921 1923 1925 1927 1929 1931 -
1933 1935 1937 1938 1940 TO 1948 1950 1952 TO 1960 1962 1964 TO 1972 1974 -
1976 TO 1984 1986 1988 TO 1996 1998 2000 TO 2008 2010 2012 TO 2020 2022 2024 -
2025 TO 2032 2034 2036 TO 2044 2046 2048 2050 2052 2054 2056 2058 2060 2062 -
2064 TO 2074 2076 TO 2085 2087 PR GY -2
2088 TO 2096 2098 TO 2107 2109 TO 2118 2120 TO 2129 2131 TO 2140 2142 TO 2151 -
2153 TO 2162 2164 2166 2168 2170 2172 2174 2176 2178 2180 2182 TO 2192 2194 -
2195 TO 2203 2205 TO 2214 2216 TO 2225 2227 TO 2236 2238 TO 2247 2249 TO 2258 -
2260 TO 2269 2271 TO 2280 2282 2284 2286 2288 2290 2292 2294 2296 2298 2300 -
2301 TO 2310 2312 TO 2321 2323 TO 2332 2334 TO 2343 2345 TO 2354 2356 TO 2365 -
2367 TO 2376 2378 TO 2387 2389 TO 2398 2400 2402 2404 2406 2408 2410 2412 -
2414 2416 2418 TO 2428 2430 TO 2439 2441 TO 2450 2452 TO 2461 2463 TO 2472 -
2474 TO 2483 2485 TO 2494 2496 TO 2505 2507 TO 2516 2518 2520 2522 2524 2526 -
2528 2530 2532 2534 2536 2537 2539 TO 2547 2549 2551 TO 2559 2561 -
2563 TO 2571 2573 2575 TO 2583 2585 2587 TO 2595 2597 2599 TO 2607 2609 2611 -
2612 TO 2619 2621 2623 TO 2631 2633 2635 TO 2643 2645 2647 2649 2651 2653 -
2655 2657 2659 2661 2663 TO 2673 2675 TO 2684 2686 TO 2695 2697 TO 2706 2708 -
2709 TO 2717 2719 TO 2728 2730 TO 2739 2741 TO 2750 2752 TO 2761 2763 2765 -
2767 2769 2771 2773 2775 2777 2779 2781 TO 2791 2793 TO 2802 2804 TO 2813 -
2815 TO 2824 2826 TO 2835 2837 TO 2846 2848 TO 2857 2859 TO 2868 -
2870 TO 2879 2881 2883 2885 2887 2889 2891 2893 2895 2897 2899 TO 2909 2911 -
2912 TO 2920 2922 TO 2931 2933 TO 2942 2944 TO 2953 2955 TO 2964 2966 TO 2975 -
2977 TO 2986 PR GY -2
2988 TO 2997 2999 3001 3003 3005 3007 3009 3011 3013 3015 3017 TO 3027 3029 -
3030 TO 3038 3040 TO 3049 3051 TO 3060 3062 TO 3071 3073 TO 3082 3084 TO 3093 -
3095 TO 3104 3106 TO 3115 3117 3119 3121 3123 3125 3127 3129 3131 3133 3135 -
3136 3183 3185 3187 3189 3191 3193 3195 3197 3199 3201 3203 TO 3211 3213 -
3215 TO 3223 3225 3227 TO 3235 3237 3239 TO 3247 3249 3251 TO 3259 3261 3263 -
3264 TO 3271 3273 3275 TO 3283 3285 3287 TO 3295 3297 3299 3301 3303 3305 -
3307 3309 3311 3313 3315 3316 3318 3320 3322 3324 3326 3328 3330 3332 3334 -
3336 TO 3345 3347 TO 3356 3358 TO 3367 3369 TO 3378 3380 TO 3389 -
3391 TO 3400 3402 TO 3411 3413 TO 3422 3424 3426 3428 3430 3432 3434 3436 -
3438 3440 3442 3443 3445 3447 3449 3451 3453 3455 3457 3459 3461 -
3463 TO 3472 3474 TO 3483 3485 TO 3494 3496 TO 3505 3507 TO 3516 -
3518 TO 3527 3529 TO 3538 3540 TO 3549 3551 3553 3555 3557 3559 3561 3563 -
3565 3567 3569 3570 3572 TO 3580 3582 3584 TO 3592 3594 3596 TO 3604 3606 -
3608 TO 3616 3618 3620 TO 3628 3630 3632 TO 3640 3642 3644 TO 3652 3654 3656 -
3657 TO 3664 3666 3668 TO 3676 3678 3680 3682 3684 3686 3688 3690 3692 3694 -
3696 TO 3706 3708 TO 3717 3719 TO 3728 3730 TO 3739 3741 TO 3750 -
3752 TO 3761 3763 TO 3772 3774 TO 3783 3785 TO 3794 3796 3798 3800 3802 3804 -
3806 3808 3810 3812 3814 TO 3824 3826 TO 3835 3837 TO 3846 3848 PR GY -2
3849 TO 3857 3859 TO 3868 3870 TO 3879 3881 TO 3890 3892 TO 3901 3903 TO 3912 -
3914 3916 3918 3920 3922 3924 3926 3928 3930 3932 3933 PR GY -2
LOAD COMB 10 1.5 * (DL+LL)
7 1.5 8 1.5 9 1.5
LOAD COMB 11 1.5 * (DL+EQX)
7 1.5 8 1.5 1 1.5
LOAD COMB 12 1.5 * (DL-EQX)
7 1.5 8 1.5 1 -1.5
LOAD COMB 13 1.5 * (DL+EQZ)
7 1.5 8 1.5 2 1.5
LOAD COMB 14 1.5 * (DL-EQZ)
7 1.5 8 1.5 2 -1.5
LOAD COMB 15 1.2 * (DL+LL+EQX)
7 1.2 8 1.2 9 1.2 1 1.2
LOAD COMB 16 1.2 * (DL+LL-EQX)
7 1.2 8 1.2 9 1.2 1 -1.2
LOAD COMB 17 1.2 * (DL+LL+EQZ)
7 1.2 8 1.2 9 1.2 2 1.2
```

```
LOAD COMB 18 1.2 * (DL+LL-EQZ)
7 1.2 8 1.2 9 1.2 1 -1.2
LOAD COMB 19 0.9 * DL + 1.5 * EQX
7 0.9 8 0.9 1 1.5
LOAD COMB 20 0.9 * DL - 1.5 * EQX
7 0.9 8 0.9 1 -1.5
LOAD COMB 21 0.9 * DL+ 1.5 * EQZ
7 0.9 8 0.9 2 1.5
LOAD COMB 22 0.9 * DL - 1.5 * EQZ
7 0.9 8 0.9 2 -1.5
LOAD COMB 23 1.5 * (DL+WX)
7 1.5 8 1.5
LOAD COMB 24 1.5 * (DL-WX)
7 1.5 8 1.5
LOAD COMB 25 1.5 * (DL+WZ)
7 1.5 8 1.5
LOAD COMB 26 1.5 * (DL-WZ)
7 1.5 8 1.5
LOAD COMB 27 1.2 * (DL+LL+WX)
7 1.2 8 1.2 9 1.2
LOAD COMB 28 1.2 * (DL+LL-WX)
7 1.2 8 1.2 9 1.2
LOAD COMB 29 1.2 * (DL+LL+WZ)
7 1.2 8 1.2 9 1.2
LOAD COMB 30 1.2 * (DL+LL-WZ)
7 1.2 8 1.2 9 1.2
LOAD COMB 31 0.9 * DL+ 1.5 * WX
7 0.9 8 0.9
LOAD COMB 32 0.9 * DL - 1.5 * WX
7 0.9 8 0.9
LOAD COMB 33 0.9 * DL+ 1.5 * WZ
7 0.9 8 0.9
LOAD COMB 34 0.9 * DL - 1.5 * WZ
7 0.9 8 0.9
PERFORM ANALYSIS PRINT ALL
START CONCRETE DESIGN
CODE INDIAN
BRACE 3 MEMB 57 TO 61 63 64 66 TO 85 91 TO 94 97 TO 100 102 TO 111 -
148 TO 152 154 155 157 TO 159 1246 1247 1256 3139 3141 3143 3144 3147 3148 -
3156 3157
ELY 0.85 MEMB 57 TO 61 63 64 66 TO 85 91 TO 94 97 TO 100 102 TO 111 -
148 TO 152 154 155 157 TO 159 1246 1247 1256 3139 3141 3143 3144 3147 3148 -
3156 3157
ELZ 0.7 MEMB 57 TO 61 63 64 66 TO 85 91 TO 94 97 TO 100 102 TO 111 -
148 TO 152 154 155 157 TO 159 1246 1247 1256 3139 3141 3143 3144 3147 3148 -
3156 3157
FC 30000 MEMB 57 TO 61 63 64 66 TO 85 91 TO 94 97 TO 100 102 TO 111 -
148 TO 152 154 155 157 TO 159 1246 1247 1256 3139 3141 3143 3144 3147 3148 -
3156 3157
FYMAIN 415000 MEMB 57 TO 61 63 64 66 TO 85 91 TO 94 97 TO 100 102 TO 111 148 -
149 TO 152 154 155 157 TO 159 1246 1247 1256 3139 3141 3143 3144 3147 3148 -
3156 3157
MAXMAIN 20 MEMB 57 TO 61 63 64 66 TO 85 91 TO 94 97 TO 100 102 TO 111 148 -
149 TO 152 154 155 157 TO 159 1246 1247 1256 3139 3141 3143 3144 3147 3148 -
3156 3157
MINMAIN 10 MEMB 57 TO 61 63 64 66 TO 85 91 TO 94 97 TO 100 102 TO 111 148 -
149 TO 152 154 155 157 TO 159 1246 1247 1256 3139 3141 3143 3144 3147 3148 -
3156 3157
RATIO 4 MEMB 57 TO 61 63 64 66 TO 85 91 TO 94 97 TO 100 102 TO 111 -
148 TO 152 154 155 157 TO 159 1246 1247 1256 3139 3141 3143 3144 3147 3148 -
3156 3157
REINF 0 MEMB 57 TO 61 63 64 66 TO 85 91 TO 94 97 TO 100 102 TO 111 -
148 TO 152 154 155 157 TO 159 1246 1247 1256 3139 3141 3143 3144 3147 3148 -
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3156 3157
RFACE 4 MEMB 57 TO 61 63 64 66 TO 85 91 TO 94 97 TO 100 102 TO 111 -
148 TO 152 154 155 157 TO 159 1246 1247 1256 3139 3141 3143 3144 3147 3148 -
3156 3157
TRACK 1 MEMB 57 TO 61 63 64 66 TO 85 91 TO 94 97 TO 100 102 TO 111 -
148 TO 152 154 155 157 TO 159 1246 1247 1256 3139 3141 3143 3144 3147 3148 -
3156 3157
DESIGN COLUMN 57 TO 61 63 64 66 TO 85 91 TO 94 97 TO 100 102 TO 111 -
148 TO 152 154 155 157 TO 159 1246 1247 1256 3139 3141 3143 3144 3147 3148 -
3156 3157
END CONCRETE DESIGN
FINISH
LOAD 1 LOADTYPE SEISMIC  TITLE EQX
1893 LOAD X 1
LOAD 2 LOADTYPE SEISMIC  TITLE EQZ
1893 LOAD Z 1
LOAD 8 SELF WEIGHT
SELFWEIGHT Y -1
LOAD 9 LOADTYPE NONE  TITLE WL
MEMBER LOAD
6 8 TO 11 34 TO 36 40 42 44 46 49 TO 51 55 56 87 88 90 3153 3154 UNI GY -15.4
LOAD 10 LL
ELEMENT LOAD
1283 1285 1287 1289 1291 1293 1295 1297 1299 1301 1303 TO 1311 1313 -
1315 TO 1323 1325 1327 TO 1335 1337 1339 TO 1347 1349 1351 TO 1359 1361 1363 -
1364 TO 1371 1373 1375 TO 1383 1385 1387 TO 1395 1397 1399 1401 1403 1405 -
1407 1409 1411 1413 1415 1416 1419 1421 1423 1425 1427 1429 1431 1433 1435 -
1437 TO 1446 1448 TO 1457 1459 TO 1468 1470 TO 1479 1481 TO 1490 -
1492 TO 1501 1503 TO 1512 1514 TO 1523 1525 1527 1529 1531 1533 1535 1537 -
1539 1541 1543 1544 1559 1561 1563 1565 1567 1569 1571 1573 1575 -
1577 TO 1586 1588 TO 1597 1599 TO 1608 1610 TO 1619 1621 TO 1630 -
1632 TO 1641 1643 TO 1652 1654 TO 1663 1665 1667 1669 1671 1673 1675 1677 -
1679 1681 1683 1684 1686 1688 1690 1692 1694 1696 1698 1700 1702 -
1704 TO 1713 1715 TO 1724 1726 TO 1735 1737 TO 1746 1748 TO 1757 -
1759 TO 1768 1770 TO 1779 1781 TO 1790 1792 1794 1796 1798 1800 1802 1804 -
1806 1808 1810 1811 1813 1815 1817 1819 1821 1823 1825 1827 1829 -
1831 TO 1840 1842 TO 1851 1853 TO 1862 1864 TO 1873 1875 TO 1884 -
1886 TO 1895 1897 TO 1906 1908 TO 1917 1919 1921 1923 1925 1927 1929 1931 -
1933 1935 1937 1938 1940 TO 1948 1950 1952 TO 1960 1962 1964 TO 1972 1974 -
1976 TO 1984 1986 1988 TO 1996 1998 2000 TO 2008 2010 2012 TO 2020 2022 2024 -
2025 TO 2032 2034 2036 TO 2044 2046 2048 2050 2052 2054 2056 2058 2060 2062 -
2064 TO 2074 2076 TO 2085 2087 PR GY -2
2088 TO 2096 2098 TO 2107 2109 TO 2118 2120 TO 2129 2131 TO 2140 2142 TO 2151 -
2153 TO 2162 2164 2166 2168 2170 2172 2174 2176 2178 2180 2182 TO 2192 2194 -
2195 TO 2203 2205 TO 2214 2216 TO 2225 2227 TO 2236 2238 TO 2247 2249 TO 2258 -
2260 TO 2269 2271 TO 2280 2282 2284 2286 2288 2290 2292 2294 2296 2298 2300 -
2301 TO 2310 2312 TO 2321 2323 TO 2332 2334 TO 2343 2345 TO 2354 2356 TO 2365 -
2367 TO 2376 2378 TO 2387 2389 TO 2398 2400 2402 2404 2406 2408 2410 2412 -
2414 2416 2418 TO 2428 2430 TO 2439 2441 TO 2450 2452 TO 2461 2463 TO 2472 -
2474 TO 2483 2485 TO 2494 2496 TO 2505 2507 TO 2516 2518 2520 2522 2524 2526 -
2528 2530 2532 2534 2536 2537 2539 TO 2547 2549 2551 TO 2559 2561 -
2563 TO 2571 2573 2575 TO 2583 2585 2587 TO 2595 2597 2599 TO 2607 2609 2611 -
2612 TO 2619 2621 2623 TO 2631 2633 2635 TO 2643 2645 2647 2649 2651 2653 -
2655 2657 2659 2661 2663 TO 2673 2675 TO 2684 2686 TO 2695 2697 TO 2706 2708 -
2709 TO 2717 2719 TO 2728 2730 TO 2739 2741 TO 2750 2752 TO 2761 2763 2765 -
2767 2769 2771 2773 2775 2777 2779 2781 TO 2791 2793 TO 2802 2804 TO 2813 -
2815 TO 2824 2826 TO 2835 2837 TO 2846 2848 TO 2857 2859 TO 2868 -
2870 TO 2879 2881 2883 2885 2887 2889 2891 2893 2895 2897 2899 TO 2909 2911 -
2912 TO 2920 2922 TO 2931 2933 TO 2942 2944 TO 2953 2955 TO 2964 2966 TO 2975 -
2977 TO 2986 PR GY -2
2988 TO 2997 2999 3001 3003 3005 3007 3009 3011 3013 3015 3017 TO 3027 3029 -
3030 TO 3038 3040 TO 3049 3051 TO 3060 3062 TO 3071 3073 TO 3082 3084 TO 3093 -
3095 TO 3104 3106 TO 3115 3117 3119 3121 3123 3125 3127 3129 3131 3133 3135 -
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3136 3183 3185 3187 3189 3191 3193 3195 3197 3199 3201 3203 TO 3211 3213 -
3215 TO 3223 3225 3227 TO 3235 3237 3239 TO 3247 3249 3251 TO 3259 3261 3263 -
3264 TO 3271 3273 3275 TO 3283 3285 3287 TO 3295 3297 3299 3301 3303 3305 -
3307 3309 3311 3313 3315 3316 3318 3320 3322 3324 3326 3328 3330 3332 3334 -
3336 TO 3345 3347 TO 3356 3358 TO 3367 3369 TO 3378 3380 TO 3389 -
3391 TO 3400 3402 TO 3411 3413 TO 3422 3424 3426 3428 3430 3432 3434 3436 -
3438 3440 3442 3443 3445 3447 3449 3451 3453 3455 3457 3459 3461 -
3463 TO 3472 3474 TO 3483 3485 TO 3494 3496 TO 3505 3507 TO 3516 -
3518 TO 3527 3529 TO 3538 3540 TO 3549 3551 3553 3555 3557 3559 3561 3563 -
3565 3567 3569 3570 3572 TO 3580 3582 3584 TO 3592 3594 3596 TO 3604 3606 -
3608 TO 3616 3618 3620 TO 3628 3630 3632 TO 3640 3642 3644 TO 3652 3654 3656 -
3657 TO 3664 3666 3668 TO 3676 3678 3680 3682 3684 3686 3688 3690 3692 3694 -
3696 TO 3706 3708 TO 3717 3719 TO 3728 3730 TO 3739 3741 TO 3750 -
3752 TO 3761 3763 TO 3772 3774 TO 3783 3785 TO 3794 3796 3798 3800 3802 3804 -
3806 3808 3810 3812 3814 TO 3824 3826 TO 3835 3837 TO 3846 3848 PR GY -2

3849 TO 3857 3859 TO 3868 3870 TO 3879 3881 TO 3890 3892 TO 3901 3903 TO 3912 -
3914 3916 3918 3920 3922 3924 3926 3928 3930 3932 3933 PR GY -2
LOAD COMB 11 1.5 * (DL+LL)
8 1.5 9 1.5 10 1.5
LOAD COMB 12 1.5 * (DL+EQX)
8 1.5 9 1.5 1 1.5
LOAD COMB 14 1.5 * (DL-EQX)
8 1.5 9 1.5 1 -1.5
LOAD COMB 15 1.5 * (DL+EQZ)
8 1.5 9 1.5 2 1.5
LOAD COMB 16 1.5 * (DL-EQZ)
8 1.5 9 1.5 2 -1.5
LOAD COMB 17 1.2 * (DL+LL+EQX)
8 1.2 9 1.2 1 1.2 10 1.2
LOAD COMB 18 1.2 * (DL+LL-EQX)
8 1.2 9 1.2 1 1.2 10 -1.2
LOAD COMB 19 1.2 * (DL+LL+EQZ)
8 1.2 9 1.2 2 1.2 10 1.2
LOAD COMB 20 1.2 * (DL+LL-EQZ)
8 1.2 9 1.2 2 1.2 10 -1.2
LOAD COMB 21 0.9 * DL+ 1.5 * EQX
8 0.9 9 0.9 1 1.5
LOAD COMB 22 0.9 * DL - 1.5 * EQX
8 0.9 9 0.9 1 -1.5
LOAD COMB 23 0.9 * DL+ 1.5 * EQZ
8 0.9 9 0.9 2 1.5
LOAD COMB 24 0.9 * DL - 1.5 * EQZ
8 0.9 9 0.9 2 -1.5
PERFORM ANALYSIS PRINT ALL
PRINT SUPPORT REACTION
```

ANALYSIS MODEL FOR FLAT SLAB

Model Definition

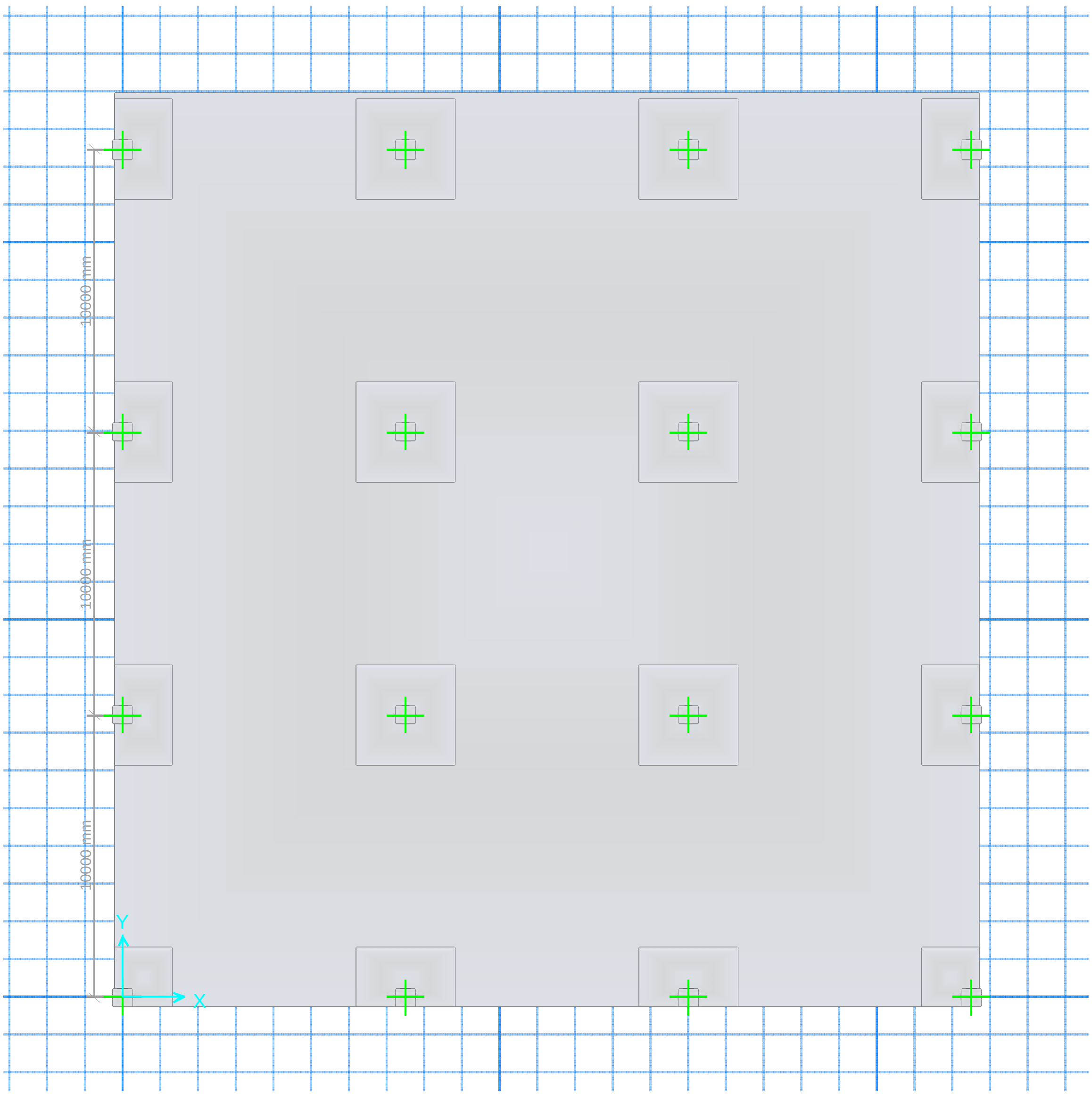


Figure 1: Finite element model

1. Model geometry

This section provides model geometry information, including items such as joint coordinates, joint restraints, and element connectivity.

1.1. Connectivity

Table 1: Concrete Slab Design Summary 02 - Span Definition Data

Table 1: Concrete Slab Design Summary 02 - Span Definition Data

Strip	SpanID	SpanLength	StartDist	GlobalX1	GlobalY1	GlobalX2	GlobalY2
		mm	mm	mm	mm	mm	mm
CSA1	Span 1	10000.00	300.00	0.00	0.00	10000.00	0.00
CSA1	Span 2	10000.00	10300.00	10000.00	0.00	20000.00	0.00
CSA1	Span 3	10000.00	20300.00	20000.00	0.00	30000.00	0.00
CSA2	Span 1	10000.00	300.00	0.00	10000.00	10000.00	10000.00
CSA2	Span 2	10000.00	10300.00	10000.00	10000.00	20000.00	10000.00
CSA2	Span 3	10000.00	20300.00	20000.00	10000.00	30000.00	10000.00
CSA3	Span 1	10000.00	300.00	0.00	20000.00	10000.00	20000.00
CSA3	Span 2	10000.00	10300.00	10000.00	20000.00	20000.00	20000.00
CSA3	Span 3	10000.00	20300.00	20000.00	20000.00	30000.00	20000.00
CSA4	Span 1	10000.00	300.00	0.00	30000.00	10000.00	30000.00
CSA4	Span 2	10000.00	10300.00	10000.00	30000.00	20000.00	30000.00
CSA4	Span 3	10000.00	20300.00	20000.00	30000.00	30000.00	30000.00
CSB1	Span 1	10000.00	300.00	0.00	0.00	0.00	10000.00
CSB1	Span 2	10000.00	10300.00	0.00	10000.00	0.00	20000.00
CSB1	Span 3	10000.00	20300.00	0.00	20000.00	0.00	30000.00
CSB2	Span 1	10000.00	300.00	10000.00	0.00	10000.00	10000.00
CSB2	Span 2	10000.00	10300.00	10000.00	10000.00	10000.00	20000.00
CSB2	Span 3	10000.00	20300.00	10000.00	20000.00	10000.00	30000.00
CSB3	Span 1	10000.00	300.00	20000.00	0.00	20000.00	10000.00
CSB3	Span 2	10000.00	10300.00	20000.00	10000.00	20000.00	20000.00
CSB3	Span 3	10000.00	20300.00	20000.00	20000.00	20000.00	30000.00
CSB4	Span 1	10000.00	300.00	30000.00	0.00	30000.00	10000.00
CSB4	Span 2	10000.00	10300.00	30000.00	10000.00	30000.00	20000.00
CSB4	Span 3	10000.00	20300.00	30000.00	20000.00	30000.00	30000.00
MSA1	Span 1	30600.00	0.00	-300.00	5000.00	30300.00	5000.00
MSA2	Span 1	30600.00	0.00	-300.00	15000.00	30300.00	15000.00
MSA3	Span 1	30600.00	0.00	-300.00	25000.00	30300.00	25000.00
MSB1	Span 1	32300.00	0.00	5000.00	-300.00	5000.00	32000.00
MSB2	Span 1	32300.00	0.00	15000.00	-300.00	15000.00	32000.00
MSB3	Span 1	32300.00	0.00	25000.00	-300.00	25000.00	32000.00

2. Model properties

This section provides model properties, including items such as material properties, section properties, and support properties.

2.1. Material properties

Table 2: Material Properties 03 - Concrete

Table 2: Material Properties 03 - Concrete

Material	E	U	A	UnitWt	Fc	LtWtConc
	N/mm2		1/C	N/mm3	N/mm2	
C30	26667.31	0.200000	9.9000E-06	2.3563E-05	30.00	No

Table 3: Material Properties 04 - Rebar

Table 3: Material Properties 04 - Rebar

Material	E	UnitWt	Fy	Fu
	N/mm2	N/mm3	N/mm2	N/mm2
CSA-G30.18Gr400	300000.00	7.6973E-05	415.00	500.00

Table 4: Material Properties 05 - Tendon

Table 4: Material Properties 05 - Tendon

Material	E	UnitWt	Fy	Fu
	N/mm2	N/mm3	N/mm2	N/mm2
A416MGr186	196500.60	7.6973E-05	1690.00	1860.00

2.2. Section properties

Table 5: Slab Properties 02 - Solid Slabs

Table 5: Slab Properties 02 - Solid Slabs

Slab	Type	MatProp	Thickness	Ortho
			mm	
DROP	Drop	C30	750.000	No
SLAB	Slab	C30	350.000	No
STIFF	Stiff	C30	750.000	No

Table 6: Tendon Properties

Table 6: Tendon Properties

TendonProp	MatProp	StrandArea
		mm2
TENDON1	A416MGr186	98.71

Table 7: Column Properties 03 - Circular

Table 7: Column Properties 03 - Circular

Column	MatProp	Diameter mm	AutoRigid	AutoDrop	IncludeCap
COLUMN	C30	650.000	Yes	No	No

2.3. Support properties

Table 8: Soil Properties

Table 8: Soil Properties

Soil	Subgrade N/mm3
SOIL1	2.0000E-02

Table 9: Spring Properties - Point

Table 9: Spring Properties - Point

Spring	Ux N/mm	Uy N/mm	Uz N/mm	Rx N-mm/rad	Ry N-mm/rad	Rz N-mm/rad	NonlinOpt
PSPR1	0.00	0.00	1.00	0.00	0.00	0.00	None (Linear)

Table 10: Spring Properties - Line

Table 10: Spring Properties - Line

Spring	VertStiff N/mm/mm	RotStiff N/rad	NonlinOpt
LSPR1	1.0000	1.00	None (Linear)

3. Model assignments

This section provides model assignments, including assignments to slabs, beams, and joints.

3.1. Slab assignments

Table 11: Slab Property Assignments

Table 11: Slab Property Assignments

Area	SlabProp
34	STIFF
35	STIFF
36	STIFF
37	STIFF
38	STIFF
39	STIFF
40	STIFF
41	STIFF
42	STIFF
43	STIFF
44	STIFF
45	STIFF
46	STIFF
47	STIFF
48	STIFF
49	STIFF
SLAB	SLAB
DROP1	DROP
DROP2	DROP
DROP3	DROP
DROP4	DROP
DROP5	DROP
DROP6	DROP
DROP7	DROP
DROP8	DROP
DROP9	DROP
DROP10	DROP
DROP11	DROP
DROP12	DROP
DROP13	DROP
DROP14	DROP
DROP15	DROP
DROP16	DROP

3.2. Column assignments

Table 12: Column Property Assignments

Table 12: Column Property Assignments

Line	ColProp
1	COLUMN
2	COLUMN
3	COLUMN
4	COLUMN
5	COLUMN
6	COLUMN
7	COLUMN
8	COLUMN
9	COLUMN
10	COLUMN
11	COLUMN
12	COLUMN
13	COLUMN
14	COLUMN
15	COLUMN
16	COLUMN

3.3. Support assignments

Table 13: Point Restraint Assignments

Table 13: Point Restraint Assignments

Point	Ux	Uy	Uz	Rx	Ry	Rz
68	Yes	Yes	Yes	Yes	Yes	Yes
70	Yes	Yes	Yes	Yes	Yes	Yes
72	Yes	Yes	Yes	Yes	Yes	Yes
74	Yes	Yes	Yes	Yes	Yes	Yes
76	Yes	Yes	Yes	Yes	Yes	Yes
78	Yes	Yes	Yes	Yes	Yes	Yes
80	Yes	Yes	Yes	Yes	Yes	Yes
82	Yes	Yes	Yes	Yes	Yes	Yes
84	Yes	Yes	Yes	Yes	Yes	Yes
86	Yes	Yes	Yes	Yes	Yes	Yes
88	Yes	Yes	Yes	Yes	Yes	Yes
90	Yes	Yes	Yes	Yes	Yes	Yes
92	Yes	Yes	Yes	Yes	Yes	Yes
94	Yes	Yes	Yes	Yes	Yes	Yes
96	Yes	Yes	Yes	Yes	Yes	Yes
98	Yes	Yes	Yes	Yes	Yes	Yes

4. Model loading

This section provides model loading information, including load patterns, load cases, and load combinations.

4.1. Load patterns

Table 14: Load Patterns

Table 14: Load Patterns

LoadPat	Type	SelfWtMult
DEAD	DEAD	1.000000
LIVE	LIVE	0.000000
PATTERN	AUTO PATTERN LIVE	0.000000

Table 15: Load Assignments - Surface Loads

Table 15: Load Assignments - Surface Loads

Area	LoadPat	Dir	UnifLoad	A	B	C
			N/mm2	N/mm3	N/mm3	N/mm2
SLAB	DEAD	Gravity	0.0010	0.0000E+00	0.0000E+00	0.0000
SLAB	LIVE	Gravity	0.0010	0.0000E+00	0.0000E+00	0.0000

4.2. Load cases

Table 16: Load Cases 02 - Static

Table 16: Load Cases 02 - Static

LoadCase	InitialCond	AType
DEAD	Zero	Linear
LIVE	Zero	Linear

Table 17: Load Cases 03 - Multistep Static

Table 17: Load Cases 03 - Multistep Static

LoadCase	InitialCond	ResType
APAT	Zero	Range

Table 18: Load Cases 06 - Loads Applied

Table 18: Load Cases 06 - Loads Applied

LoadCase	LoadPat	SF
DEAD	DEAD	1.000000

Table 18: Load Cases 06 - Loads Applied

LoadCase	LoadPat	SF
LIVE	LIVE	1.000000

4.3. Load combinations

Table 19: Load Combinations

Table 19: Load Combinations

Combo	Load	SF	Type	DSStrength	DSServInit	DSServNorm	DSServLong
DCONU1	DEAD	1.400000	Linear Add	Yes	No	No	No
DCONU2	DEAD	1.200000	Linear Add	Yes	No	No	No
DCONU2	LIVE	1.600000					
DCONU3	DEAD	1.200000	Linear Add	Yes	No	No	No
DCONU3	APAT	1.200000					

Analysis Results

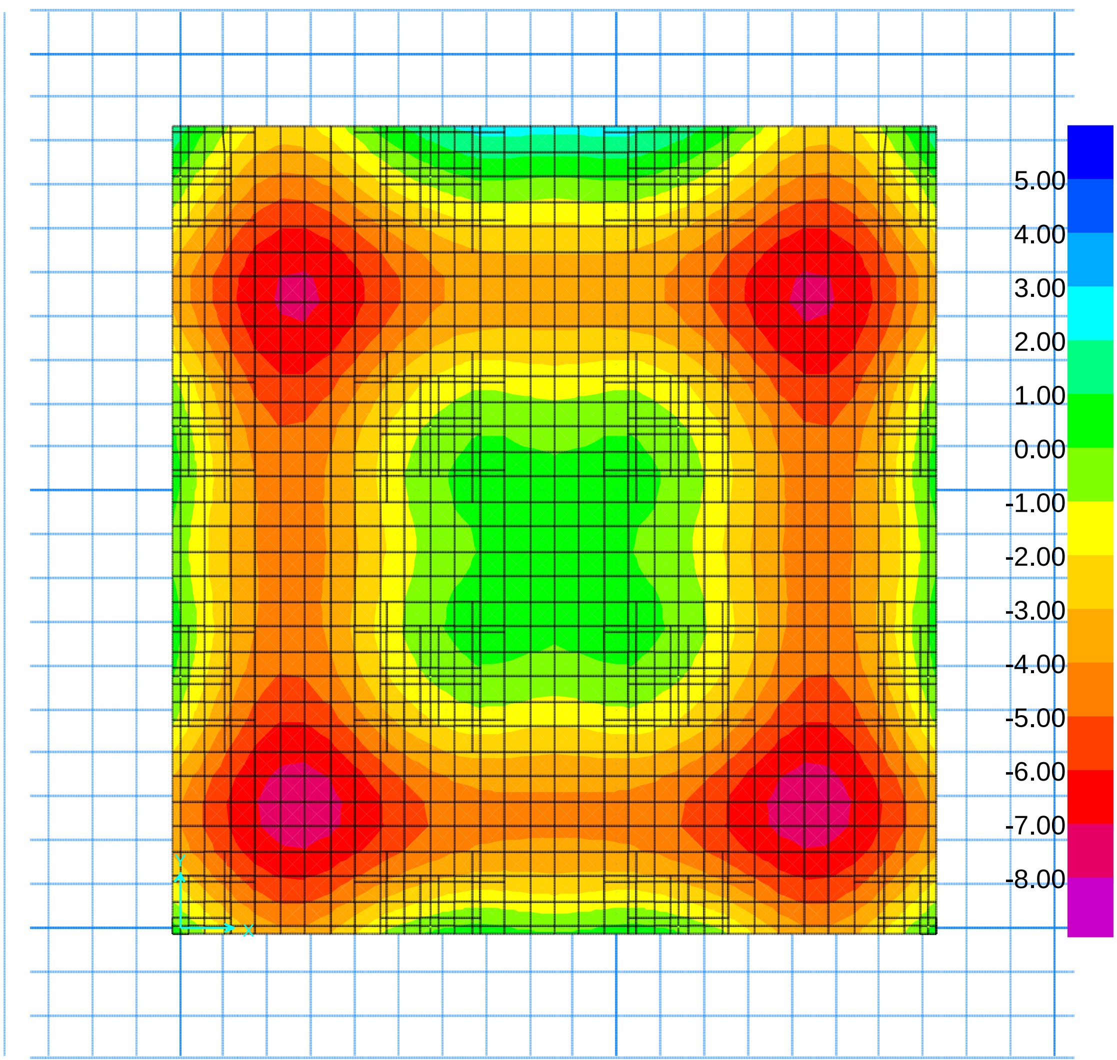
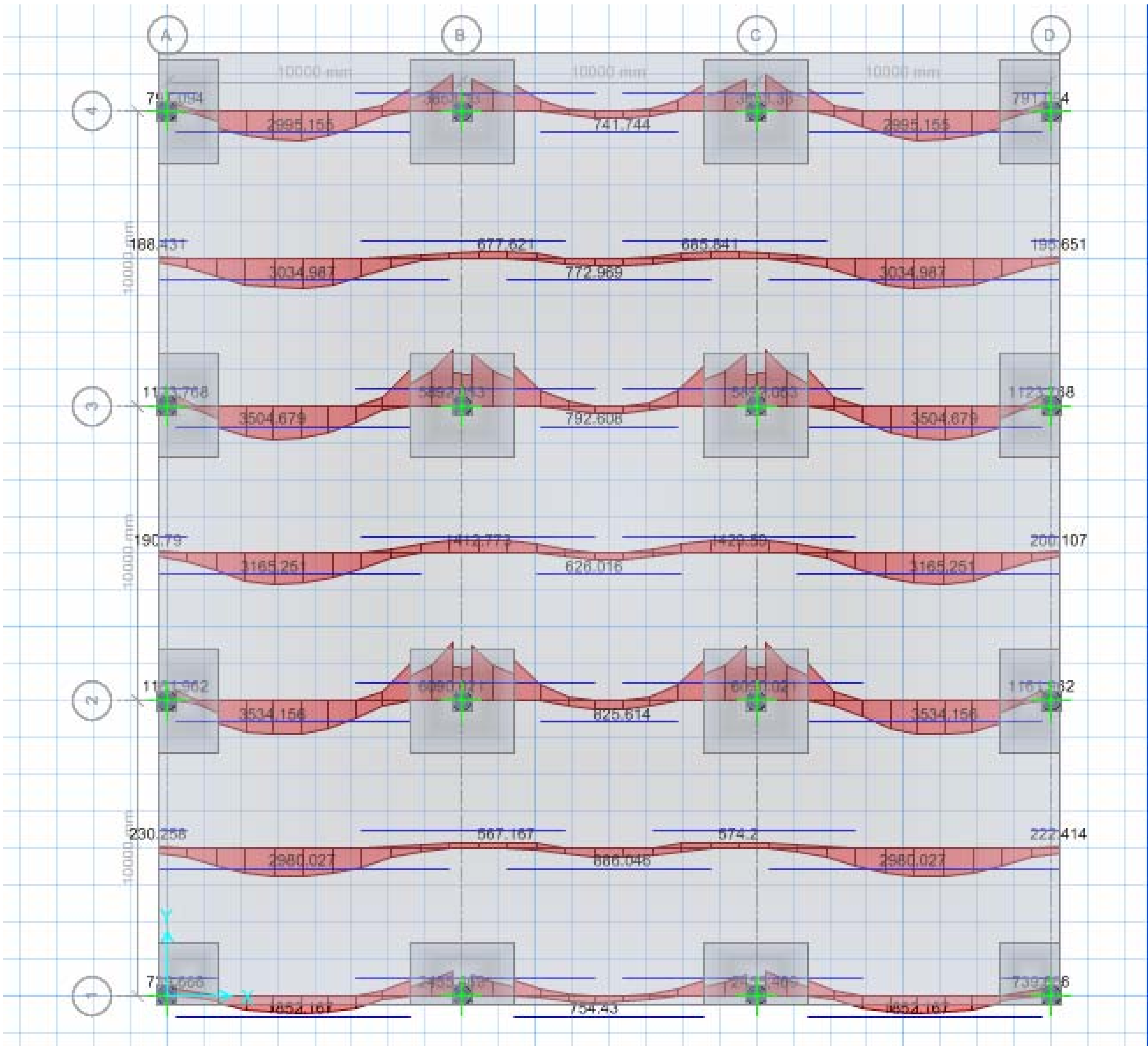
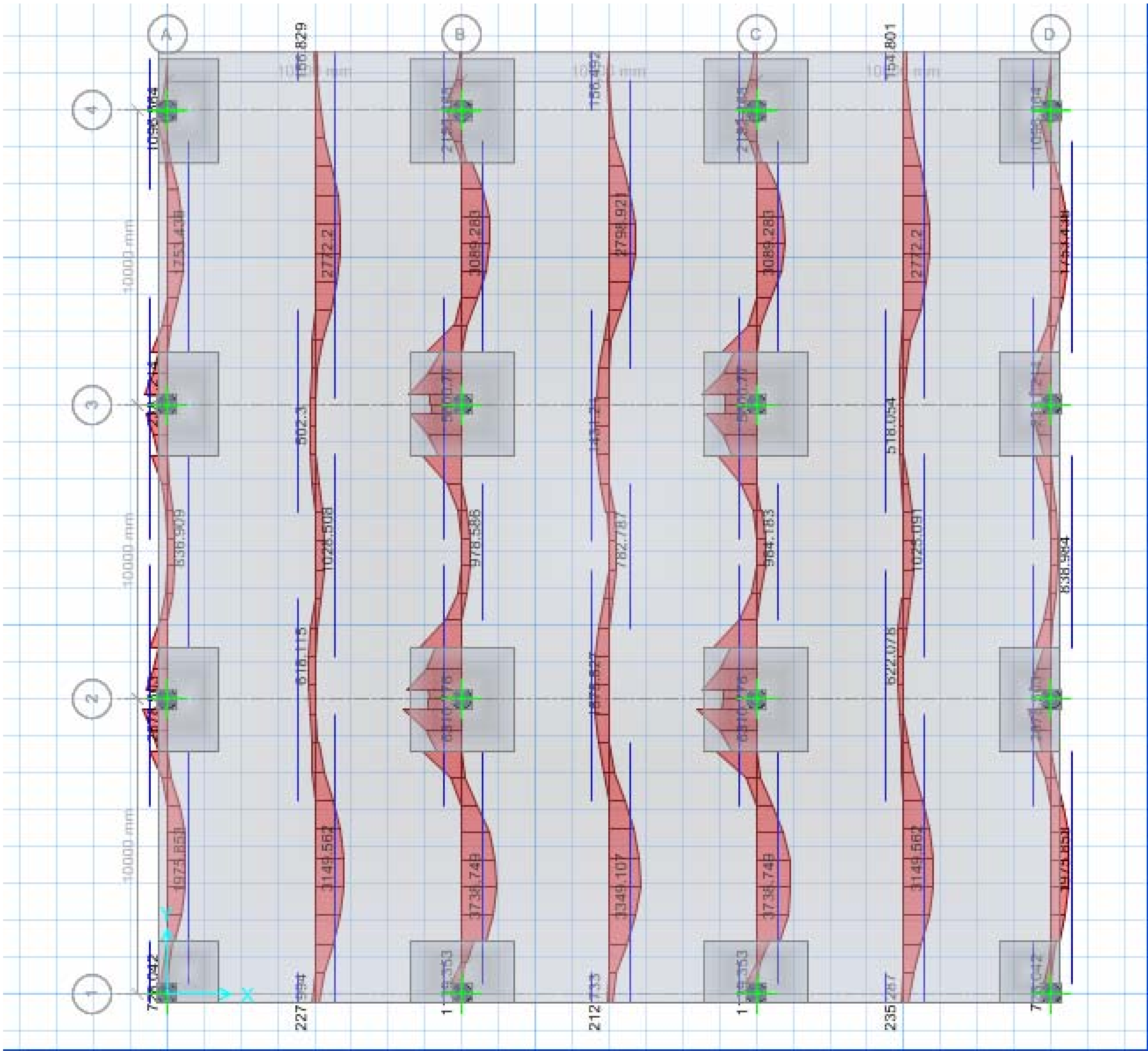


Figure 2: Deformed shape

Reinforcement Details along X Direction



Reinforcement Details along Y Direction



Design Summary For Bus Terminal

Footing

Footing No	Axial Load	Length	Breadth	d	D	Reinforcement	
F1	Pu = 566	1400	1400	-	300	12 @ 150 c/c	12 @ 150 c/c
F2	Pu = 1290	2100	2100	200	500	16 @ 100 c/c	16 @ 100 c/c
F3	Pu = 2250	2800	2800	500	1000	16 @ 100 c/c	16 @ 100 c/c
F4	Pu = 802	1700	1700	-	350	16 @ 150 c/c	16 @ 150 c/c
F5	Pu = 1530	2400	2200	200	600	16 @ 120 c/c	16 @ 120 c/c
F6	Pu = 678	1600	1500	200	520	12 @ 120 c/c	12 @ 120 c/c
F7	Pu = 889	1800	1800	-	350	16 @ 150 c/c	16 @ 150 c/c

Combined Footing

Footing No	Axial Load	Length	Breadth	d	D	L	Reinforcement	
CF1	Pu = 1875	2500	1500	-	500	5000	16 @ 120 c/c	16 @ 120 c/c
CF2	Pu = 1490.42	2500	2000	200	400	-	16 @ 100 c/c	16 @ 100 c/c

Columns

Column No	Load Case	Axial Force	Moment X	Moment Y	Size of column	Reinforcement	Stirrups
C1	1.5(DL+EQX)	213.18	182.17	261.48	650 Dia	12 of 25	8 @ 200 c/c
C2	1.5(DL+EQX)	638.67	291.17	741.29	650 Dia	12 of 32	8 @ 200 c/c
C3	1.5(DL-EQX)	625.93	347.26	551.45	650 Dia	16 of 32	8 @ 200 c/c
C4	1.2(DL+LL-EQX)	676.24	227.44	579.67	650 Dia	14 of 32	8 @ 200 c/c
C5	1.5(DL-EQX)	274.18	201.13	356.29	650 Dia	14 of 25	8 @ 200 c/c
C6	1.2(DL+LL-EQX)	595.94	1.44	512.86	450 x 600	10 of 32	8 @ 200 c/c
C7	1.5(DL-EQX)	125	92.14	116.56	350 x 350	6 of 25	8 @ 200 c/c
C8	1.5(DL-EQX)	304.5	91.72	232.66	400 x 550	12 of 25	8 @ 200 c/c
C9	1.5(DL-EQX)	342.07	2.44	54.88	400 x 250	10 of 20	8 @ 200 c/c
C10	1.5(DL-EQX)	108.11	1.46	170.54	400 x 300	8 of 25	8 @ 200 c/c

Plinth Beams

Beam No	Load Case	Moments		Shear		B	D	Ast Top	Ast Bottom	Shear Rft
		Support	Midspan	Support	Midspan					
PB1	1.5(DL+EQX)	355	255	165	166	250	650	5 of 25	3 of 25	8 @ 200
PB2	1.5(DL-EQX)	177	90	90	30	250	650	3 of 25	3 of 16	8 @ 200
PB1a	1.5(DL-EQX)	275	189	165	122	250	650	4 of 25	2 of 25 + 1 OF 20	8 @ 200

GF Roof Beams

Beam No	Load Case	Moments		Torsion	Shear		B	D	Ast Top	Ast Bottom	Shear Rft	Legs
		Support	Midspan		Support	Midspan						
GRB1	1.5(DL+EQX)	150	76	0	189	20	230	450	5 of 20	3 of 16	8 @ 200	2
GRB2	1.5(DL+EQZ)	175	80	0	75	55	230	500	5 of 20	4 of 16	8 @ 200	2
GRB3	1.5(DL-EQZ)	190	85	0	75	35	230	500	6 of 20	4 of 16	8 @ 200	2
GRB4	1.5(DL+EQX)	55	52	0	65	40	230	350	3 of 16	4 of 16	8 @ 200	2

FF Roof Beams

Beam No	Load Case	Moments		Torsion	Shear		B	D	Ast Top	Ast Bottom	Shear Rft	Legs
		Support	Midspan		Support	Midspan						
FRB1	1.5(DL+EQX)	66	32	0	43	20	230	400	4 of 16	2 of 12+ 1 of 16	8 @ 200	2
FRB2	1.5(DL+EQZ)	93	80	0	82	51	230	450	3 of 20	4 of 16	8 @ 200	2
FRB3	1.5(DL-EQZ)	139	67	0	75	20	230	500	4 of 20	4 of 16	8 @ 200	2
FRB4	1.5(DL+EQX)	35	47	0	51	40	230	300	3 of 16	4 of 16	8 @ 200	2

SLAB Plat Form

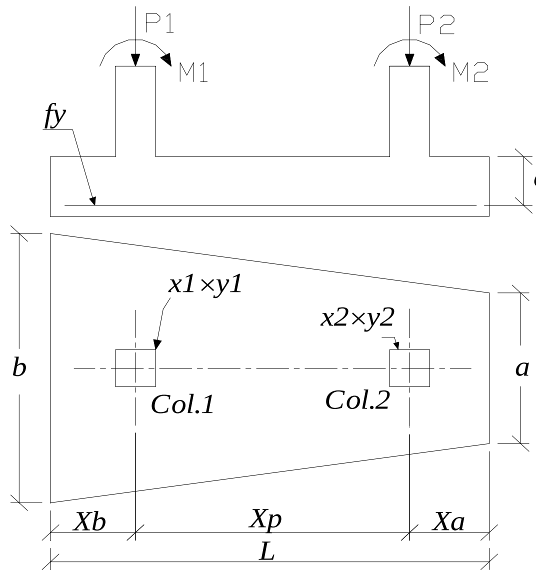
	Thickness	Rft
GF	150	12 @ 150 c/c

SLAB Admin Roof

	Thickness	Rft
GF,FF	120	12 @ 150 c/c

DESIGN OF FOOTING

Combined Footing Analysis and Design		Issue:	Design	Page
		Date:		1 of 1
Project:	CF1	Revised by:		
		Checked by:		



Dimensions:

	Col.1	Col.2
Length, x (m)	0.576	0.576
Width, y (m)	0.576	0.576

Distance, Xp (m)	2.5	Left width, b (m)	2.5
Distance, Xb (m)	1.25	Right width, a (m)	1.5
Distance, Xa (m)	1.25	Length, L (m)	5
Eff. depth, d (m)	0.4	Area, (m2)	10

Material Properties:

Conc comp strength f'c, (Mpa)	30
Steel comp strength fy, (Mpa)	415
Allow soil pressure, qa (kPa)	281.25

Loads:

	Working loads			
Col. Load	Dead	Live	Wind	Seismic
P1 (kN)	1607.14	0	0	0
P2 (kN)	1071.43	0	0	0
M1 (kN.m)	0	0	0	0
M2 (kN.m)	0	0	0	0

Checkings:

Allowable soil pressure, qa (kPa)	281.25	
Maximum soil pressure, qmax (kPa)	280.395	(qmax < qa) Ok
Minimum soil pressure, qmin (kPa)	189.78	(qmin > 0) Ok
Maximum wide beam shear, Vw (kN/m width)	249.839	
Maximum punching shear, Vp (kN/m width)	1493.08	
Wide beam shear strength, Vc1 (kN/m width)	365.148	Vw < Vc1, OK
Punching shear strength, Vc2 (kN/m width)	3999.06	Vp < Vc2, OK

Area of Steel:

Use area of steel, As (cm2)	13.5	for bottom reinforcement
As (cm2)	15.3013	for top reinforcement

Details:

x	V, kN	M, kN-m	b, m	As, cm2/m
0	0	0	2.5	13.494
0.5	478.548	120.646	2.4	13.494
1	933.064	474.543	2.3	14.2215
1.5	-886.07	487.269	2.2	15.3013
2	-478.47	147.096	2.1	13.494
2.5	-93.75	4.98682	2	13.494
3	268.468	49.5957	1.9	13.494
3.5	608.569	269.769	1.8	13.494
4	-573.06	279.543	1.7	13.494
4.5	-276.05	68.147	1.6	13.494
5	0.00	0.00	1.5	13.494

DESIGN OF ISOLATED FOOTING

Load Case 15 1.5(DL - EQX) **CF2**

Design Parameters

Maximum factored axial load coming on footing =	**1490.42**	kN
Safe Bearing capacity of the soil =	**225**	kN/ m^2
Grade of Concrete	**M30**	
Grade of Steel	**Fe415**	
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**	
Characteristic yield strength of steel , f_y (N/mm^2)	**415**	
Unit weight of concrete , γ_c (kN/m^3)	**24**	
Partial safety factor for concrete	**1.5**	
Nominal Cover to exposure condition(mm)	**50**	
Diameter of bars (mm)	**16**	

Column Dimensions

Breadth of the column (mm) B =	**550**	
Depth of the column (mm) D =	**820**	

Design

Maximum axial load coming on footing =		993.61	kN
Add 10% toward the self-weight of footing	=	99.36	kN
Total load	=	1092.98	kN

SBC of Soil : 225 kN/m2 is considered in the design of foundations.

Area of footing required =	1092.98	/	225	
		=	4.858	m^2
	L	=	2.49	m
	B	=	2.00	m

Provide footing of size 2.5 m x 2 m

Projection beyond Column Faces	=	0.84	m
Net Upward Pressure on the foundation	=	306.798	kN/m^2
B.M @ Section XX = Mx	=	266.31	kNm
Factored Moment = Mux	=	399.47	kNm
Equating Mu,lim to Mux = 0.138fckbd^2 = Mux			
$M_{u,lim}$	=	3394.8 d^2	
		343	mm
B.M @ Section YY = My	=	214	kNm
Factored Moment = Muy	=	321	kNm
Equating Mu,lim to Muy = 0.138fckbd^2 = Muy			
$M_{u,lim}$	=	2277 d^2	
		375	mm

Effective cover to lower layer of steel = 50 mm + 8 mm = 58 mm
Effective cover to upper layer of steel = 58 mm + 16 mm = 74 mm
Overall depth required = 375 mm + 74 mm = 449 mm

The overall depth may be increased by 30% to limit the shear stress

Overall depth reqd = 590 mm

Effective depth for short span = 590 mm - 58 mm = 532 mm
Effective depth for long span = 590 mm - 74 mm = 516 mm

Steel Reqd for Longer Direction

Muy / bd^2 = 2.191
% of steel = 0.669 %

Area of steel required = 1899 mm^2

Provide 10 bars of 16 mm dia
Spacing of 16 mm dia bars 105 mm c/c

Steel Reqd for Shorter Direction

Mux / bd^2 = 1.721
% of steel = 0.513 %

Area of steel required = 2240 mm^2

Reinforcment Reqd for central band of 2.29 m = 1995 mm^2

Provide 12 bars of 16 mm dia
Spacing of 16 mm dia bars 100 mm c/c

Check For Shear

Critical section X1 X1 is considered at a distance equal to the effective depth from the face of the column, i.e at a distance of 532 mm from the face of the column

Shear force at this critical section X1 X1

	V	=	231	kN
Factored Shear	Vu	=	347	kN
Overall depth of the critical section	D'	=	342	mm
Effective deph of the critical section	d'	=	284	mm
Breadth of the footing @ tp @this critical section	b'	=	1884	mm
Nominal shear stress	τ_v	=	0.65	N/mm^2

Percentage of steel provided = 0.45 %
Permissible punching shear stress = 0.25 x sqrt(fck)

1.37 N/mm^2 > 0.65 N/mm2

Provided Section is adequate.

DESIGN OF ISOLATED FOOTING

Load Case 15 1.5(DL - EQX) **F1**

Design Parameters

Maximum factored axial load coming on footing =	**566**	kN
Safe Bearing capacity of the soil =	**225**	kN/ m^2
Grade of Concrete	**M30**	
Grade of Steel	**Fe415**	
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**	
Characteristic yield strength of steel , f_y (N/mm^2)	**415**	
Unit weight of concrete , γ_c (kN/m^3)	**24**	
Partial safety factor for concrete	**1.5**	
Nominal Cover to exposure condition(mm)	**50**	
Diameter of bars (mm)	**12**	

Column Dimensions

Breadth of the column (mm) B = **665**

Depth of the column (mm) D = **665**

Design

Maximum axial load coming on footing =		377.33	kN
Add 10% toward the self-weight of footing	=	37.73	kN
Total load	=	415.07	kN

SBC of Soil : 225 kN/m2 is considered in the design of foundations.

Area of footing required =	415.07	/	225	
		=	1.845	m^2
	L	=	1.36	m
	B	=	1.36	m

Provide footing of size 1.4 m x 1.4 m

Projection beyond Column Faces	=	0.35	m
Net Upward Pressure on the foundation	=	306.776	kN/m^2
B.M @ Section XX = Mx	=	25.04	kNm
Factored Moment = Mux	=	37.56	kNm
Equating Mu,lim to Mux = 0.138fckbd^2 = Mux			
$M_{u,lim}$	=	2753.1 d^2	
		117	mm
B.M @ Section YY = My	=	25	kNm
Factored Moment = Muy	=	38	kNm
Equating Mu,lim to Muy = 0.138fckbd^2 = Muy			
$M_{u,lim}$	=	2753.1 d^2	
		117	mm

Effective cover to lower layer of steel = 50 mm + 6 mm = 56 mm

Effective cover to upper layer of steel = 56 mm + 12 mm = 68 mm

Overall depth required = 117 mm + 68 mm = 185 mm

The overall depth may be increased by 30% to limit the shear stress

Overall depth reqd = 250 mm

Effective depth for short span = 250 mm - 56 mm = 194 mm
Effective depth for long span = 250 mm - 68 mm = 182 mm

Steel Reqd for Longer Direction

Muy / bd^2 = 1.705
% of steel = 0.508 %

Area of steel required = 615 mm^2

Provide 6 bars of 12 mm dia
Spacing of 12 mm dia bars 183 mm c/c

Steel Reqd for Shorter Direction

Mux / bd^2 = 1.501
% of steel = 0.443 %

Area of steel required = 571 mm^2

Reinforcment Reqd for central band of 1.16 m = 681 mm^2

Provide 9 bars of 12 mm dia
Spacing of 12 mm dia bars 166 mm c/c

Check For Shear

Critical section X1 X1 is considered at a distance equal to the effective depth from the face of the column, i.e at a distance of 194 mm from the face of the column

Shear force at this critical section X1 X1

	V	=	64	kN
Factored Shear	Vu	=	95	kN
Overall depth of the critical section	D'	=	166	mm
Effective deph of the critical section	d'	=	110	mm
Breadth of the footing @ tp @this critical section	b'	=	1053	mm
Nominal shear stress	τ_v	=	0.82	N/mm^2
Percentage of steel provided		=	0.88	%
Permissible punching shear stress		=	0.25 x sqrt(fck)	

1.37 N/mm^2 > 0.82 N/mm2

Provided Section is adequate.

DESIGN OF ISOLATED FOOTING

Load Case 16 1.5(DL+LL+EQX) **F2**

Design Parameters

Maximum factored axial load coming on footing =	**1290**	kN
Safe Bearing capacity of the soil =	**225**	kN/ m^2
Grade of Concrete	**M30**	
Grade of Steel	**Fe415**	
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**	
Characteristic yield strength of steel , f_y (N/mm^2)	**415**	
Unit weight of concrete , γ_c (kN/m^3)	**24**	
Partial safety factor for concrete	**1.5**	
Nominal Cover to exposure condition(mm)	**50**	
Diameter of bars (mm)	**16**	

Column Dimensions

Breadth of the column (mm) B =	**665**
Depth of the column (mm) D =	**665**

Design

Maximum axial load coming on footing =			860.00	kN
Add 10% toward the self-weight of footing		=	86.00	kN
Total load		=	946.00	kN

SBC of Soil : 225 kN/m2 is considered in the design of foundations.

Area of footing required =	946	/	225	
		=	4.205	m^2
	L	=	2.05	m
	B	=	2.05	m

Provide footing of size 2.1 m x 2.1 m

Projection beyond Column Faces	=	0.69	m
Net Upward Pressure on the foundation	=	306.778	kN/m^2
B.M @ Section XX = Mx	=	150.97	kNm
Factored Moment = Mux	=	226.46	kNm
Equating Mu,lim to Mux = 0.138fckbd^2 = Mux			
$M_{u,lim}$	=	2753.1 d^2	
		287	mm
B.M @ Section YY = My	=	151	kNm
Factored Moment = Muy	=	226	kNm
Equating Mu,lim to Muy = 0.138fckbd^2 = Muy			
$M_{u,lim}$	=	2753.1 d^2	
		287	mm

Effective cover to lower layer of steel = 50 mm + 8 mm = 58 mm

Effective cover to upper layer of steel = 58 mm + 16 mm = 74 mm

Overall depth required = 287 mm + 74 mm = 361 mm

The overall depth may be increased by 30% to limit the shear stress

Overall depth reqd		=	470	mm

Effective depth for short span = 470 mm - 58 mm = 412 mm
Effective depth for long span = 470 mm - 74 mm = 396 mm

Steel Reqd for Longer Direction

Muy / bd^2	=	2.172	
% of steel	=	0.662 %	
Area of steel required	=	1745	mm^2

Provide 9 bars of 16 mm dia
Spacing of 16 mm dia bars 115 mm c/c

Steel Reqd for Shorter Direction

Mux / bd^2	=	2.006	
% of steel	=	0.607 %	
Area of steel required	=	1663	mm^2
Reinforcment Reqd for central band of 1.85 m	=	1642	mm^2

Provide 11 bars of 16 mm dia
Spacing of 16 mm dia bars 122 mm c/c

Check For Shear

Critical section X1 X1 is considered at a distance equal to the effective depth from the face of the column, i.e at a distance of 412 mm from the face of the column

Shear force at this critical section X1 X1

	V	=	177	kN
Factored Shear	Vu	=	265	kN
Overall depth of the critical section	D'	=	309	mm
Effective deph of the critical section	d'	=	251	mm
Breadth of the footing @ tp @this critical section	b'	=	1489	mm
Nominal shear stress	τ_υ	=	0.71	N/mm^2
Percentage of steel provided		=	0.59	%
Permissible punching shear stress		=	0.25 x sqrt(fck)	

1.37 N/mm^2 > 0.71 N/mm2

Provided Section is adequate.

DESIGN OF ISOLATED FOOTING

Load Case 11 1.5(DL+LL) **F3**

Design Parameters

Maximum factored axial load coming on footing =	**2250**	kN
Safe Bearing capacity of the soil =	**225**	kN/ m^2
Grade of Concrete	**M30**	
Grade of Steel	**Fe415**	
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**	
Characteristic yield strength of steel , f_y (N/mm^2)	**415**	
Unit weight of concrete , γ_c (kN/m^3)	**24**	
Partial safety factor for concrete	**1.5**	
Nominal Cover to exposure condition(mm)	**50**	
Diameter of bars (mm)	**16**	

Column Dimensions

Breadth of the column (mm) B =	**665**
Depth of the column (mm) D =	**665**

Design

Maximum axial load coming on footing =		1500.00	kN
Add 10% toward the self-weight of footing	=	150.00	kN
Total load	=	1650.00	kN

SBC of Soil : 225 kN/m2 is considered in the design of foundations.

Area of footing required =	1650	/	225	
		=	7.334	m^2
	L	=	2.71	m
	B	=	2.71	m

Provide footing of size 2.8 m x 2.8 m

Projection beyond Column Faces	=	1.02	m
Net Upward Pressure on the foundation	=	306.791	kN/m^2
B.M @ Section XX = Mx	=	433.53	kNm
Factored Moment = Mux	=	650.29	kNm
Equating Mu,lim to Mux = 0.138fckbd^2 = Mux			
$M_{u,lim}$	=	2753.1 d^2	
		486	mm
B.M @ Section YY = My	=	434	kNm
Factored Moment = Muy	=	650	kNm
Equating Mu,lim to Muy = 0.138fckbd^2 = Muy			
$M_{u,lim}$	=	2753.1 d^2	
		486	mm

Effective cover to lower layer of steel = 50 mm + 8 mm = 58 mm

Effective cover to upper layer of steel = 58 mm + 16 mm = 74 mm

Overall depth required = 486 mm + 74 mm = 560 mm

The overall depth may be increased by 30% to limit the shear stress

Overall depth reqd = 1000 mm

Effective depth for short span = 1000 mm - 58 mm = 942 mm
Effective depth for long span = 1000 mm - 74 mm = 926 mm

Steel Reqd for Longer Direction

Muy / bd^2 = 1.140
% of steel = 0.331 %

Area of steel required = 2039 mm^2
Provide 11 bars of 16 mm dia
Spacing of 16 mm dia bars 98 mm c/c

Steel Reqd for Shorter Direction

Mux / bd^2 = 1.102
% of steel = 0.319 %

Area of steel required = 2001 mm^2

Reinforcment Reqd for central band of 2.51 m = 1700 mm^2

Provide 11 bars of 16 mm dia
Spacing of 16 mm dia bars 118 mm c/c

Check For Shear

Critical section X1 X1 is considered at a distance equal to the effective depth from the face of the column, i.e at a distance of 942 mm from the face of the column

Shear force at this critical section X1 X1

	V	=	66	kN
Factored Shear	Vu	=	99	kN
Overall depth of the critical section	D'	=	539	mm
Effective deph of the critical section	d'	=	481	mm
Breadth of the footing @ tp @this critical section	b'	=	2549	mm
Nominal shear stress	τ_{υ}	=	0.08	N/mm^2
Percentage of steel provided		=	0.18	%
Permissible punching shear stress		=	0.25 x sqrt(fck)	

1.37 N/mm^2 > 0.08 N/mm2

Provided Section is adequate.

DESIGN OF ISOLATED FOOTING

Load Case 11 1.5(DL+LL) **F4**

Design Parameters

Maximum factored axial load coming on footing =	**802**	kN
Safe Bearing capacity of the soil =	**225**	kN/m^2
Grade of Concrete	**M30**	
Grade of Steel	**Fe415**	
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**	
Characteristic yield strength of steel , f_y (N/mm^2)	**415**	
Unit weight of concrete , γ_c (kN/m^3)	**24**	
Partial safety factor for concrete	**1.5**	
Nominal Cover to exposure condition(mm)	**50**	
Diameter of bars (mm)	**16**	

Column Dimensions

Breadth of the column (mm) B =	**665**
Depth of the column (mm) D =	**665**

Design

Maximum axial load coming on footing =		534.67	kN
Add 10% toward the self-weight of footing	=	53.47	kN
Total load	=	588.14	kN

SBC of Soil : 225 kN/m2 is considered in the design of foundations.

Area of footing required = 588.14	/	225	
	=	2.614	m^2
L	=	1.62	m
B	=	1.62	m

Provide footing of size 1.7 m x 1.7 m

Projection beyond Column Faces	=	0.48	m
Net Upward Pressure on the foundation	=	306.81	kN/m^2
B.M @ Section XX = Mx	=	56.17	kNm
Factored Moment = Mux	=	84.26	kNm

Equating Mu,lim to Mux = 0.138fckbd^2 = Mux

$M_{u,lim}$ = 2753.1 d^2

175 mm

B.M @ Section YY = My	=	56	kNm
Factored Moment = Muy	=	84	kNm

Equating Mu,lim to Muy = 0.138fckbd^2 = Muy

$M_{u,lim}$ = 2753.1 d^2

175 mm

Effective cover to lower layer of steel = 50 mm + 8 mm = 58 mm

Effective cover to upper layer of steel = 58 mm + 16 mm = 74 mm

Overall depth required = 175 mm + 74 mm = 249 mm

The overall depth may be increased by 30% to limit the shear stress

Overall depth reqd		=	330	mm

Effective depth for short span = 330 mm - 58 mm = 272 mm
Effective depth for long span = 330 mm - 74 mm = 256 mm

Steel Reqd for Longer Direction

Muy / bd^2	=	1.933	
% of steel	=	0.583 %	
Area of steel required	=	992	mm^2

Provide 5 bars of 16 mm dia
Spacing of 16 mm dia bars 202 mm c/c

Steel Reqd for Shorter Direction

Mux / bd^2	=	1.713	
% of steel	=	0.511 %	
Area of steel required	=	924	mm^2
Reinforcment Reqd for central band of 1.42 m	=	1021	mm^2

Provide 8 bars of 16 mm dia
Spacing of 16 mm dia bars 196 mm c/c

Check For Shear

Critical section X1 X1 is considered at a distance equal to the effective depth from the face of the column, i.e at a distance of 272 mm from the face of the column

Shear force at this critical section X1 X1

	V	=	101	kN
Factored Shear	Vu	=	152	kN
Overall depth of the critical section	D'	=	199	mm
Effective deph of the critical section	d'	=	141	mm
Breadth of the footing @ tp @this critical section	b'	=	1209	mm
Nominal shear stress	τ_v	=	0.89	N/mm^2
Percentage of steel provided		=	0.95	%
Permissible punching shear stress		=	0.25 x sqrt(fck)	

1.37 N/mm^2 > 0.89 N/mm2

Provided Section is adequate.

DESIGN OF ISOLATED FOOTING

Load Case 15 1.5(DL - EQX) **F5**

Design Parameters

Maximum factored axial load coming on footing =	**1530**	kN
Safe Bearing capacity of the soil =	**225**	kN/m^2
Grade of Concrete	**M30**	
Grade of Steel	**Fe415**	
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**	
Characteristic yield strength of steel , f_y (N/mm^2)	**415**	
Unit weight of concrete , γ_c (kN/m^3)	**24**	
Partial safety factor for concrete	**1.5**	
Nominal Cover to exposure condition(mm)	**50**	
Diameter of bars (mm)	**16**	

Column Dimensions

Breadth of the column (mm) B =	**550**
Depth of the column (mm) D =	**650**

Design

Maximum axial load coming on footing =		1020.00	kN
Add 10% toward the self-weight of footing	=	102.00	kN
Total load	=	1122.00	kN

SBC of Soil : 225 kN/m2 is considered in the design of foundations.

Area of footing required =	1122	/	225	
		=	4.987	m^2
	L	=	2.31	m
	B	=	2.16	m

Provide footing of size 2.4 m x 2.2 m

Projection beyond Column Faces	=	0.85	m
Net Upward Pressure on the foundation	=	306.798	kN/m^2
B.M @ Section XX = Mx	=	258.80	kNm
Factored Moment = Mux	=	388.20	kNm
Equating Mu,lim to Mux = 0.138fckbd^2 = Mux			
$M_{u,lim}$	=	2484 d^2	
		395	mm
B.M @ Section YY = My	=	242	kNm
Factored Moment = Muy	=	363	kNm
Equating Mu,lim to Muy = 0.138fckbd^2 = Muy			
$M_{u,lim}$	=	1863 d^2	
		441	mm

Effective cover to lower layer of steel = 50 mm + 8 mm = 58 mm
Effective cover to upper layer of steel = 58 mm + 16 mm = 74 mm
Overall depth required = 441 mm + 74 mm = 515 mm

The overall depth may be increased by 30% to limit the shear stress

Overall depth reqd		=	680	mm

Effective depth for short span = 680 mm - 58 mm = 622 mm
Effective depth for long span = 680 mm - 74 mm = 606 mm

Steel Reqd for Longer Direction

Muy / bd^2		=	2.196	
% of steel		=	0.671 %	
Area of steel required		=	1830	mm^2

Provide 10 bars of 16 mm dia
Spacing of 16 mm dia bars 109 mm c/c

Steel Reqd for Shorter Direction

Mux / bd^2		=	1.672	
% of steel		=	0.498 %	
Area of steel required		=	1857	mm^2
Reinforcment Reqd for central band of 2.11 m		=	1724	mm^2

Provide 11 bars of 16 mm dia
Spacing of 16 mm dia bars 116 mm c/c

Check For Shear

Critical section X1 X1 is considered at a distance equal to the effective depth from the face of the column, i.e at a distance of 622 mm from the face of the column

Shear force at this critical section X1 X1

	V	=	165	kN
Factored Shear	Vu	=	247	kN
Overall depth of the critical section	D'	=	403	mm
Effective deph of the critical section	d'	=	345	mm
Breadth of the footing @ tp @this critical section	b'	=	1844	mm
Nominal shear stress	τ_v	=	0.39	N/mm^2
Percentage of steel provided		=	0.35	%
Permissible punching shear stress		=	0.25 x sqrt(fck)	

1.37 N/mm^2 > 0.39 N/mm2

Provided Section is adequate.

DESIGN OF ISOLATED FOOTING

Load Case 15 1.5(DL - EQX) **F6**

Design Parameters

Maximum factored axial load coming on footing =	**678**	kN
Safe Bearing capacity of the soil =	**225**	kN/ m^2
Grade of Concrete	**M30**	
Grade of Steel	**Fe415**	
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**	
Characteristic yield strength of steel , f_y (N/mm^2)	**415**	
Unit weight of concrete , γ_c (kN/m^3)	**24**	
Partial safety factor for concrete	**1.5**	
Nominal Cover to exposure condition(mm)	**50**	
Diameter of bars (mm)	**12**	

Column Dimensions

Breadth of the column (mm) B =	**250**	
Depth of the column (mm) D =	**400**	

Design

Maximum axial load coming on footing =		452.00	kN
Add 10% toward the self-weight of footing	=	45.20	kN
Total load	=	497.20	kN

SBC of Soil : 225 kN/m2 is considered in the design of foundations.

Area of footing required = 497.2	/	225	
	=	2.21	m^2
L	=	1.56	m
B	=	1.41	m

Provide footing of size 1.6 m x 1.5 m

Projection beyond Column Faces	=	0.58	m
Net Upward Pressure on the foundation	=	306.788	kN/m^2
B.M @ Section XX = Mx	=	81.17	kNm
Factored Moment = Mux	=	121.75	kNm
Equating Mu,lim to Mux = 0.138fckbd^2 = Mux			
$M_{u,lim}$	=	1656 d^2	
		271	mm
B.M @ Section YY = My	=	73	kNm
Factored Moment = Muy	=	110	kNm
Equating Mu,lim to Muy = 0.138fckbd^2 = Muy			
$M_{u,lim}$	=	1035 d^2	
		326	mm

Effective cover to lower layer of steel = 50 mm + 6 mm = 56 mm
Effective cover to upper layer of steel = 56 mm + 12 mm = 68 mm

Overall depth required = 326 mm + 68 mm	=	394	mm

The overall depth may be increased by 30% to limit the shear stress

Overall depth reqd		=	520	mm

Effective depth for short span = 520 mm - 56 mm = 464 mm
Effective depth for long span = 520 mm - 68 mm = 452 mm

Steel Reqd for Longer Direction

Muy / bd^2	=	2.155	
% of steel	=	0.657 %	
Area of steel required	=	742	mm^2

Provide 7 bars of 12 mm dia
Spacing of 12 mm dia bars 152 mm c/c

Steel Reqd for Shorter Direction

Mux / bd^2	=	1.414	
% of steel	=	0.416 %	
Area of steel required	=	771	mm^2
Reinforcment Reqd for central band of 1.36 m	=	866	mm^2

Provide 10 bars of 12 mm dia
Spacing of 12 mm dia bars 130 mm c/c

Check For Shear

Critical section X1 X1 is considered at a distance equal to the effective depth from the face of the column, i.e at a distance of 464 mm from the face of the column

Shear force at this critical section X1 X1

	V	=	56	kN
Factored Shear	Vu	=	85	kN
Overall depth of the critical section	D'	=	265	mm
Effective deph of the critical section	d'	=	209	mm
Breadth of the footing @ tp @this critical section	b'	=	1328	mm
Nominal shear stress	τ_{υ}	=	0.31	N/mm^2
Percentage of steel provided		=	0.41	%
Permissible punching shear stress		=	0.25 x sqrt(fck)	

1.37 N/mm^2 > 0.31 N/mm2

Provided Section is adequate.

DESIGN OF ISOLATED FOOTING

Load Case 11 1.5(DL+LL) **F7**

Design Parameters

Maximum factored axial load coming on footing =	**889**	kN
Safe Bearing capacity of the soil =	**225**	kN/ m^2
Grade of Concrete	**M30**	
Grade of Steel	**Fe415**	
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**	
Characteristic yield strength of steel , f_y (N/mm^2)	**415**	
Unit weight of concrete , γ_c (kN/m^3)	**24**	
Partial safety factor for concrete	**1.5**	
Nominal Cover to exposure condition(mm)	**50**	
Diameter of bars (mm)	**16**	

Column Dimensions

Breadth of the column (mm) B = **300**

Depth of the column (mm) D = **450**

Design

Maximum axial load coming on footing =		592.67	kN
Add 10% toward the self-weight of footing	=	59.27	kN
Total load	=	651.94	kN

SBC of Soil : 225 kN/m2 is considered in the design of foundations.

Area of footing required =	651.94	/	225	
		=	2.898	m^2
	L	=	1.70	m
	B	=	1.70	m

Provide footing of size 1.8 m x 1.8 m

Projection beyond Column Faces	=	0.52	m
Net Upward Pressure on the foundation	=	306.764	kN/m^2
B.M @ Section XX = Mx	=	70.24	kNm
Factored Moment = Mux	=	105.37	kNm
Equating Mu,lim to Mux = 0.138fckbd^2 = Mux			
$M_{u,lim}$	=	2753.1 d^2	
		196	mm
B.M @ Section YY = My	=	70	kNm
Factored Moment = Muy	=	105	kNm
Equating Mu,lim to Muy = 0.138fckbd^2 = Muy			
$M_{u,lim}$	=	2753.1 d^2	
		196	mm

Effective cover to lower layer of steel = 50 mm + 8 mm = 58 mm

Effective cover to upper layer of steel = 58 mm + 16 mm = 74 mm

Overall depth required = 196 mm + 74 mm = 270 mm

The overall depth may be increased by 30% to limit the shear stress

Overall depth reqd = 360 mm

Effective depth for short span = 360 mm - 58 mm = 302 mm
Effective depth for long span = 360 mm - 74 mm = 286 mm

Steel Reqd for Longer Direction

Muy / bd^2 = 1.937
% of steel = 0.584 %

Area of steel required = 1111 mm^2
Provide 6 bars of 16 mm dia
Spacing of 16 mm dia bars 180 mm c/c

Steel Reqd for Shorter Direction

Mux / bd^2 = 1.737
% of steel = 0.519 %

Area of steel required = 1042 mm^2

Reinforcment Reqd for central band of 1.5 m = 1125 mm^2

Provide 8 bars of 16 mm dia
Spacing of 16 mm dia bars 178 mm c/c

Check For Shear

Critical section X1 X1 is considered at a distance equal to the effective depth from the face of the column, i.e at a distance of 302 mm from the face of the column

Shear force at this critical section X1 X1

	V	=	113	kN
Factored Shear	Vu	=	170	kN
Overall depth of the critical section	D'	=	209	mm
Effective deph of the critical section	d'	=	151	mm
Breadth of the footing @ tp @this critical section	b'	=	1269	mm
Nominal shear stress	τ_v	=	0.89	N/mm^2
Percentage of steel provided		=	0.84	%
Permissible punching shear stress		=	0.25 x sqrt(fck)	

1.37 N/mm^2 > 0.89 N/mm2

Provided Section is adequate.

DESIGN OF COLUMN

Rectangular Short Column with Biaxial bending - C1 Bresler method

Grade of Concrete		**M30**		
Grade of Steel		**Fe415**		
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)		**30**		
Characteristic yield strength of steel , f_y (N/mm^2)		**415**		
Unit weight of concrete , γ_c (kN/m^3)		**25**		
Partial safety factor for concrete		**1.5**		
Exposure condition		**Mild**		
Nominal Cover to exposure condition(mm)		**40**		
Assumed effective cover all around , d' (mm)		**60**		

Dimesions of the Column

Unsupported length of column, L	=	5000	mm	
Least lateral dimension	=	576	mm	
Breadth of the column B (mm)	=	576		
Depth of the Column D (mm)	=	576		
Effective length of the column , l_{ex} , (m)	=	3.25		
Effective length of the column , l_{ey} , (m)	=	3.25		

Check for Slenderness ratio, L/D

Slenderness ratio , λ_{ex}	=	5.64	<12	column is Short
Slenderness ratio , λ_{ey}	=	5.64	<12	column is Short

Design Factors

Factored load, Pu	=	123.18	KN
Factored moment acting parallel to the larger dimension , M_{ux}	=	182.14	KN-m
Factored moment acting parallel to the shorter dimension, M_{uy}	=	261.48	KN-m

1 Check for accidental eccentricity
Equivalent eccentricity of loads is given by

M_{ux}/p_u	=	1478.65	mm
M_{uy}/p_u	=	730.64	mm

Both are more than 20mm minimum

2 Assume percentage of steel
(assuming steel larger than required by P and M_x)

d'/D	=	0.1
$\frac{M_x}{f_{ck} \times b \times D^2}$	=	0.03
$\frac{P_u}{f_{ck} \times b \times D}$	=	0.01

From SP16 chart44

$\frac{P}{f_{ck}}$	=	**0.027**	From table
Assuming a higher value P/fck	=	0.0405	
Assumed , P	=	1.22	per cent
Area of steel, A_s	=	**4031.08**	mm^2

Use **12** no.s of **25** mm

Area of steel provided	=	5888	mm^2

3 Find the moment capacities M_{x1} and M_{y1}

About X-axis

d'/D	=	0.10	
P/fck x b x D^2	=	0.01	
P/fck	=	0.0405	
$M_{x1}/(f_{ck} \times b \times D^2)$	=	**0.07**	From table
M_{x1}	=	401.32	KN-m

About Y-axis

d'/D	=	0.10	
P/fck x b x D^2	=	0.01	
P/fck	=	0.0405	
$M_{y1}/(f_{ck} \times D \times b^2)$	=	**0.07**	From table
M_{y1}	=	401.32	KN-m

4 Calculate α^n

$P_z=0.45f_{ck}A_c+0.75f_yA_s$

Pz	=	6311	KN
P/P_z	=	0.02	

By formula

α^n= 2/3[1+5/2 x P/Pz]

α^n	=	0.70	

5 Criteria for biaxial bending

$(M_x/M_{x1})^{\alpha n} + (M_y/M_{y1})^{\alpha n}$ < or =1.0	=	0.9238	< or = 1

Hence the column is safe

Rectangular Short Column with Biaxial bending -C2 Bresler method

Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**25**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**40**
Assumed effective cover all around , d' (mm)	**60**

Dimesions of the Column

Unsupported length of column, L	=	5000	mm
Least lateral dimension	=	576	mm
Breadth of the column B (mm)	=	576	
Depth of the Column D (mm)	=	576	
Effective length of the column , l_{ex} , (m)	=	3.25	
Effective length of the column , l_{ey} , (m)	=	3.25	

Check for Slenderness ratio, L/D

Slenderness ratio , λ_{ex}	=	5.64	<12	column is Short
Slenderness ratio , λ_{ey}	=	5.64	<12	column is Short

Design Factors

Factored load, Pu	=	638.67	KN
Factored moment acting parallel to the larger dimension , M_{ux}	=	291.17	KN-m
Factored moment acting parallel to the shorter dimension, M_{uy}	=	741.29	KN-m

1 Check for accidental eccentricity
Equivalent eccentricity of loads is given by

M_{ux}/p_u = 455.90 mm

M_{uy}/p_u = 140.92 mm

Both are more than 20mm minimum

2 Assume percentage of steel
(assuming steel larger than required by P and M_x)

d'/D = 0.1

$$\frac{M_x}{f_{ck} \times b \times D^2} = 0.05$$

$$\frac{P_u}{f_{ck} \times b \times D} = 0.06$$

From SP16 chart44

$\frac{P}{f_{ck}}$	=	**0.06**	From table
Assuming a higher value P/fck	=	0.09	
Assumed , P	=	2.70	per cent
Area of steel, A_s	=	**8957.95**	mm^2

Use **12** no.s of **32** mm

Area of steel provided	=	9646	mm^2

3 Find the moment capacities M_{x1} and M_{y1}

About X-axis

d'/D	=	0.10	
P/fck x b x D^2	=	0.06	
P/fck	=	0.09	
$M_{x1}/(f_{ck} \times b \times D^2)$	=	**0.12**	From table
M_{x1}	=	687.97	KN-m

About Y-axis

d'/D	=	0.10	
P/fck x b x D^2	=	0.06	
P/fck	=	0.09	
$M_{y1}/(f_{ck} \times D \times b^2)$	=	**0.12**	From table
M_{y1}	=	687.97	KN-m

4 Calculate α^n

$P_z=0.45f_{ck}A_c+0.75f_yA_s$

Pz	=	7481	KN
P/P_z	=	0.09	

By formula

α^n= 2/3[1+5/2 x P/Pz]

α^n	=	0.81	

5 Criteria for biaxial bending

$(M_x/M_{x1})^{\alpha n} + (M_y/M_{y1})^{\alpha n}$ < or =1.0	=	0.6884	< or = 1

Hence the column is safe

Rectangular Short Column with Biaxial bending -C3 **Bresler method**

Grade of Concrete	M30
Grade of Steel	Fe415
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	30
Characteristic yield strength of steel , f_y (N/mm^2)	415
Unit weight of concrete , γ_c (kN/m^3)	25
Partial safety factor for concrete	1.5
Exposure condition	Mild
Nominal Cover to exposure condition(mm)	40
Assumed effective cover all around , d' (mm)	60

Dimesions of the Column

Unsupported length of column, L	=	5000	mm
Least lateral dimension	=	576	mm
Breadth of the column B (mm)	=	576	
Depth of the Column D (mm)	=	576	
Effective length of the column , l_{ex} , (m)	=	3.25	
Effective length of the column , l_{ey} , (m)	=	3.25	

Check for Slenderness ratio, L/D

Slenderness ratio , λ_{ex}	=	5.64	<12	column is Short
Slenderness ratio , λ_{ey}	=	5.64	<12	column is Short

Design Factors

Factored load, Pu	=	676.24	KN
Factored moment acting parallel to the larger dimension , M_{ux}	=	227.44	KN-m
Factored moment acting parallel to the shorter dimension, M_{uy}	=	579.67	KN-m

1 Check for accidental eccentricity

Equivalent eccentricity of loads is given by

M_{ux}/p_u	=	336.33	mm
M_{uy}/p_u	=	133.09	mm

Both are more than 20mm minimum

2 Assume percentage of steel

(assuming steel larger than required by P and M_x)

d'/D = 0.1

$$\frac{M_x}{f_{ck} \times b \times D^2} = 0.05$$

$$\frac{P_u}{f_{ck} \times b \times D} = 0.07$$

From SP16 chart44

$\frac{P}{f_{ck}}$	=	**0.08**	From table
Assuming a higher value P/fck	=	0.12	
Assumed , P	=	3.60	per cent
Area of steel, A_s	=	**11943.94**	mm^2

Use **16** no.s of **32** mm

Area of steel provided	=	12861	mm^2

3 Find the moment capacities M_{x1} and M_{y1}

About X-axis

d'/D	=	0.10	
P/fck x b x D^2	=	0.07	
P/fck	=	0.12	
$M_{x1}/(f_{ck} \times b \times D^2)$	=	**0.15**	From table
M_{x1}	=	859.96	KN-m

About Y-axis

d'/D	=	0.10	
P/fck x b x D^2	=	0.07	
P/fck	=	0.12	
$M_{y1}/(f_{ck} \times D \times b^2)$	=	**0.15**	From table
M_{y1}	=	859.96	KN-m

4 Calculate α^n

$P_z=0.45f_{ck}A_c+0.75f_yA_s$

Pz	=	8482	KN
P/P_z	=	0.08	

By formula

$\alpha^n= 2/3[1+5/2 \times P/Pz]$

α^n	=	0.80	

5 Criteria for biaxial bending

$(M_x/M_{x1})^{\alpha n} + (M_y/M_{y1})^{\alpha n}$ < or =1.0	=	0.5065	< or = 1

Hence the column is safe

Rectangular Short Column with Biaxial bending - C4 — Bresler method

Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**25**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**40**
Assumed effective cover all around , d' (mm)	**60**

Dimesions of the Column

Unsupported length of column, L	=	5000	mm
Least lateral dimension	=	576	mm
Breadth of the column B (mm)	=	576	
Depth of the Column D (mm)	=	576	
Effective length of the column , l_{ex} , (m)	=	3.25	
Effective length of the column , l_{ey} , (m)	=	3.25	

Check for Slenderness ratio, L/D

Slenderness ratio , λ_{ex}	=	5.64	<12	column is Short
Slenderness ratio , λ_{ey}	=	5.64	<12	column is Short

Design Factors

Factored load, Pu	=	625.93	KN
Factored moment acting parallel to the larger dimension , M_{ux}	=	347.26	KN-m
Factored moment acting parallel to the shorter dimension, M_{uy}	=	551.45	KN-m

1 Check for accidental eccentricity
Equivalent eccentricity of loads is given by

M_{ux}/p_u	=	554.79	mm
M_{uy}/p_u	=	143.79	mm

Both are more than 20mm minimum

2 Assume percentage of steel
(assuming steel larger than required by P and M_x)

d'/D = 0.1

$$\frac{M_x}{f_{ck} \times b \times D^2} = 0.06$$

$$\frac{P_u}{f_{ck} \times b \times D} = 0.06$$

From SP16 chart44

$\frac{P}{f_{ck}}$	=	**0.071**	From table
Assuming a higher value P/fck	=	0.1065	
Assumed , P	=	3.20	per cent
Area of steel, A_s	=	**10600.24**	mm^2

Use **14** no.s of **32** mm

Area of steel provided	=	11254	mm^2

3 Find the moment capacities M_{x1} and M_{y1}

About X-axis

d'/D	=	0.10	
P/fck x b x D^2	=	0.06	
P/fck	=	0.1065	
$M_{x1}/(f_{ck} \times b \times D^2)$	=	**0.12**	From table
M_{x1}	=	687.97	KN-m

About Y-axis

d'/D	=	0.10	
P/fck x b x D^2	=	0.06	
P/fck	=	0.1065	
$M_{y1}/(f_{ck} \times D \times b^2)$	=	**0.12**	From table
M_{y1}	=	687.97	KN-m

4 Calculate α^n

$P_z=0.45f_{ck}A_c+0.75f_yA_s$

Pz	=	7982	KN
P/P_z	=	0.08	

By formula

$\alpha^n= 2/3[1+5/2 \times P/Pz]$

α^n	=	0.80	

5 Criteria for biaxial bending

$(M_x/M_{x1})^{\alpha n} + (M_y/M_{y1})^{\alpha n}$ < or =1.0	=	0.7741	< or = 1

Hence the column is safe

Rectangular Short Column with Biaxial bending -C5 **Bresler method**

Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**25**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**40**
Assumed effective cover all around , d' (mm)	**60**

Dimesions of the Column

Unsupported length of column, L	=	5000	mm
Least lateral dimension	=	576	mm
Breadth of the column B (mm)	=	576	
Depth of the Column D (mm)	=	576	
Effective length of the column , l_{ex} , (m)	=	3.25	
Effective length of the column , l_{ey} , (m)	=	3.25	

Check for Slenderness ratio, L/D

Slenderness ratio , λ_{ex}	=	5.64	<12	column is Short
Slenderness ratio , λ_{ey}	=	5.64	<12	column is Short

Design Factors

Factored load, Pu	=	274.18	KN
Factored moment acting parallel to the larger dimension , M_{ux}	=	201.13	KN-m
Factored moment acting parallel to the shorter dimension, M_{uy}	=	356.29	KN-m

1 Check for accidental eccentricity
Equivalent eccentricity of loads is given by

M_{ux}/p_u	=	733.57	mm
M_{uy}/p_u	=	328.25	mm

Both are more than 20mm minimum

2 Assume percentage of steel
(assuming steel larger than required by P and M_x)

d'/D = 0.1

$$\frac{M_x}{f_{ck} \times b \times D^2} = 0.04$$

$$\frac{P_u}{f_{ck} \times b \times D} = 0.03$$

From SP16 chart44

$\frac{P}{f_{ck}}$	=	**0.04**	From table
Assuming a higher value P/fck	=	0.06	
Assumed , P	=	1.80	per cent
Area of steel, A_s	=	**5971.97**	mm^2

Use **14** no.s of **25** mm

Area of steel provided	=	6869	mm^2

3 Find the moment capacities M_{x1} and M_{y1}

About X-axis

d'/D	=	0.10	
P/fck x b x D^2	=	0.03	
P/fck	=	0.06	
$M_{x1}/(f_{ck} \times b \times D^2)$	=	**0.11**	From table
M_{x1}	=	630.64	KN-m

About Y-axis

d'/D	=	0.10	
P/fck x b x D^2	=	0.03	
P/fck	=	0.06	
$M_{y1}/(f_{ck} \times D \times b^2)$	=	**0.11**	From table
M_{y1}	=	630.64	KN-m

4 Calculate α^n

$P_z=0.45f_{ck}A_c+0.75f_yA_s$

Pz	=	6617	KN
P/P_z	=	0.04	

By formula

α^n= 2/3[1+5/2 x P/Pz]

α^n	=	0.74	

5 Criteria for biaxial bending

$(M_x/M_{x1})^{\alpha n} + (M_y/M_{y1})^{\alpha n}$ < or =1.0	=	0.6666	< or = 1

Hence the column is safe

Rectangular Short Column with Biaxial bending -C6 Bresler method

Grade of Concrete	M30
Grade of Steel	Fe415
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	30
Characteristic yield strength of steel , f_y (N/mm^2)	415
Unit weight of concrete , γ_c (kN/m^3)	25
Partial safety factor for concrete	1.5
Exposure condition	Mild
Nominal Cover to exposure condition(mm)	40
Assumed effective cover all around , d' (mm)	60

Dimesions of the Column

Unsupported length of column, L	=	7000	mm
Least lateral dimension	=	550	mm
Breadth of the column B (mm)	=	550	
Depth of the Column D (mm)	=	650	
Effective length of the column , l_{ex} , (m)	=	4.55	
Effective length of the column , l_{ey} , (m)	=	4.55	

Check for Slenderness ratio, L/D

Slenderness ratio , λ_{ex}	=	10.11	<12	column is Short
Slenderness ratio , λ_{ey}	=	7.58	<12	column is Short

Design Factors

Factored load, Pu	=	767.18	KN
Factored moment acting parallel to the larger dimension , M_{ux}	=	1.37	KN-m
Factored moment acting parallel to the shorter dimension, M_{uy}	=	791.29	KN-m

1 Check for accidental eccentricity
Equivalent eccentricity of loads is given by

M_{ux}/p_u	=	827.95	mm
M_{uy}/p_u	=	254.51	mm

Both are more than 20mm minimum

2 Assume percentage of steel
(assuming steel larger than required by P and M_x)

d'/D = 0.1

$$\frac{M_x}{f_{ck} \times b \times D^2} = 0.09$$

$$\frac{P_u}{f_{ck} \times b \times D} = 0.04$$

From SP16 chart44

$\frac{P}{f_{ck}}$	=	**0.065**	From table
Assuming a higher value P/fck	=	0.0975	
Assumed , P	=	2.93	per cent
Area of steel, A_s	=	**7897.50**	mm^2

Use **12** no.s of **32** mm

Area of steel provided	=	8038	mm^2

3 Find the moment capacities M_{x1} and M_{y1}

About X-axis

d'/D	=	0.10	
P/fck x b x D^2	=	0.04	
P/fck	=	0.0975	
$M_{x1}/(f_{ck} \times b \times D^2)$	=	**0.14**	From table
M_{x1}	=	680.40	KN-m

About Y-axis

d'/D	=	0.13	
P/fck x b x D^2	=	0.04	
P/fck	=	0.0975	
$M_{y1}/(f_{ck} \times D \times b^2)$	=	**0.14**	From table
M_{y1}	=	510.30	KN-m

4 Calculate α^n

$P_z=0.45f_{ck}A_c+0.75f_yA_s$

Pz	=	6147	KN
P/P_z	=	0.06	

By formula

$\alpha^n = 2/3[1+5/2 \times P/Pz]$

α^n	=	0.77	

5 Criteria for biaxial bending

$(M_x/M_{x1})^{\alpha n} + (M_y/M_{y1})^{\alpha n}$ < or =1.0	=	0.7885	< or = 1

Hence the column is safe

Rectangular Short Column with Biaxial bending -C7 **Bresler method**

Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**25**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**40**
Assumed effective cover all around , d' (mm)	**60**

Dimesions of the Column

Unsupported length of column, L	=	6000	mm
Least lateral dimension	=	350	mm
Breadth of the column B (mm)	=	350	
Depth of the Column D (mm)	=	350	
Effective length of the column , l_{ex} , (m)	=	3.9	
Effective length of the column , l_{ey} , (m)	=	3.9	

Check for Slenderness ratio, L/D

Slenderness ratio , λ_{ex}	=	11.14	<12	column is Short
Slenderness ratio , λ_{ey}	=	11.14	<12	column is Short

Design Factors

Factored load, Pu	=	125	KN
Factored moment acting parallel to the larger dimension , M_{ux}	=	92.14	KN-m
Factored moment acting parallel to the shorter dimension, M_{uy}	=	116.56	KN-m

1 Check for accidental eccentricity
Equivalent eccentricity of loads is given by

M_{ux}/p_u	=	737.12	mm
M_{uy}/p_u	=	720.00	mm

Both are more than 20mm minimum

2 Assume percentage of steel
(assuming steel larger than required by P and M_x)

d'/D = 0.2

$$\frac{M_x}{f_{ck} \times b \times D^2} = 0.07$$

$$\frac{P_u}{f_{ck} \times b \times D} = 0.03$$

From SP16 chart44

$\frac{P}{f_{ck}}$	=	**0.035**	From table
Assuming a higher value P/fck	=	0.0525	
Assumed , P	=	1.58	per cent
Area of steel, A_s	=	**1929.38**	mm^2

Use **6** no.s of **25** mm

Area of steel provided	=	2944	mm^2

3 Find the moment capacities M_{x1} and M_{y1}

About X-axis

d'/D	=	0.17	
P/fck x b x D^2	=	0.03	
P/fck	=	0.08	
$M_{x1}/(f_{ck} \times b \times D^2)$	=	**0.14**	From table
M_{x1}	=	180.08	KN-m

About Y-axis

d'/D	=	0.17	
P/fck x b x D^2	=	0.03	
P/fck	=	0.0525	
$M_{y1}/(f_{ck} \times D \times b^2)$	=	**0.14**	From table
M_{y1}	=	180.08	KN-m

4 Calculate α^n

$P_z=0.45f_{ck}A_c+0.75f_yA_s$

Pz	=	2570	KN
P/P_z	=	0.05	

By formula

$\alpha^n= 2/3[1+5/2 \times P/Pz]$

α^n	=	0.75	

5 Criteria for biaxial bending

$(M_x/M_{x1})^{\alpha n} + (M_y/M_{y1})^{\alpha n}$ < or =1.0	=	0.9000	< or = 1

Hence the column is safe

Rectangular Short Column with Biaxial bending -C8 Bresler method

Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**25**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**40**
Assumed effective cover all around , d' (mm)	**60**

Dimesions of the Column

Unsupported length of column, L	=	6000	mm
Least lateral dimension	=	400	mm
Breadth of the column B (mm)	=	400	
Depth of the Column D (mm)	=	555	
Effective length of the column , l_{ex} , (m)	=	3.9	
Effective length of the column , l_{ey} , (m)	=	3.9	

Check for Slenderness ratio, L/D

Slenderness ratio , λ_{ex}	=	9.75	<12	column is Short
Slenderness ratio , λ_{ey}	=	7.03	<12	column is Short

Design Factors

Factored load, Pu	=	304.5	KN
Factored moment acting parallel to the larger dimension , M_{ux}	=	91.72	KN-m
Factored moment acting parallel to the shorter dimension, M_{uy}	=	232.66	KN-m

1 Check for accidental eccentricity
Equivalent eccentricity of loads is given by

M_{ux}/p_u	=	301.22	mm
M_{uy}/p_u	=	295.57	mm

Both are more than 20mm minimum

2 Assume percentage of steel
(assuming steel larger than required by P and M_x)

d'/D = 0.1

$$\frac{M_x}{f_{ck} \times b \times D^2} = 0.02$$

$$\frac{P_u}{f_{ck} \times b \times D} = 0.05$$

From SP16 chart44

$\frac{P}{f_{ck}}$	=	**0.045**	From table
Assuming a higher value P/fck	=	0.0675	
Assumed , P	=	2.03	per cent
Area of steel, A_s	=	**4495.50**	mm^2

Use **12** no.s of **25** mm

Area of steel provided	=	5888	mm^2

3 Find the moment capacities M_{x1} and M_{y1}

About X-axis

d'/D	=	0.11	
P/fck x b x D^2	=	0.05	
P/fck	=	0.0675	
$M_{x1}/(f_{ck} \times b \times D^2)$	=	**0.08**	From table
M_{x1}	=	295.70	KN-m

About Y-axis

d'/D	=	0.15	
P/fck x b x D^2	=	0.05	
P/fck	=	0.0675	
$M_{y1}/(f_{ck} \times D \times b^2)$	=	**0.08**	From table
M_{y1}	=	213.12	KN-m

4 Calculate α^n

$P_z=0.45f_{ck}A_c+0.75f_yA_s$

Pz	=	4829	KN
P/P_z	=	0.06	

By formula

$\alpha^n= 2/3[1+5/2 \times P/Pz]$

α^n	=	0.78	

5 Criteria for biaxial bending

$(M_x/M_{x1})^{\alpha n} + (M_y/M_{y1})^{\alpha n}$ < or =1.0	=	0.9158	< or = 1

Hence the column is safe

Rectangular Short Column with Biaxial bending -C9 Bresler method

Grade of Concrete		**M30**		
Grade of Steel		**Fe415**		
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)		**30**		
Characteristic yield strength of steel , f_y (N/mm^2)		**415**		
Unit weight of concrete , γ_c (kN/m^3)		**25**		
Partial safety factor for concrete		**1.5**		
Exposure condition		**Mild**		
Nominal Cover to exposure condition(mm)		**40**		
Assumed effective cover all around , d' (mm)		**50**		

Dimesions of the Column

Unsupported length of column, L	=	3000	mm	
Least lateral dimension	=	250	mm	
Breadth of the column B (mm)	=	250		
Depth of the Column D (mm)	=	400		
Effective length of the column , l_{ex} , (m)	=	1.95		
Effective length of the column , l_{ey} , (m)	=	1.95		

Check for Slenderness ratio, L/D

Slenderness ratio , λ_{ex}	=	7.80	<12	column is Short
Slenderness ratio , λ_{ey}	=	4.88	<12	column is Short

Design Factors

Factored load, Pu	=	342.07	KN
Factored moment acting parallel to the larger dimension , M_{ux}	=	2.44	KN-m
Factored moment acting parallel to the shorter dimension, M_{uy}	=	54.88	KN-m

1 Check for accidental eccentricity
Equivalent eccentricity of loads is given by

M_{ux}/p_u	=	7.13	mm
M_{uy}/p_u	=	263.10	mm

Both are more than 20mm minimum

2 Assume percentage of steel
(assuming steel larger than required by P and M_x)

d'/D = 0.1

$$\frac{M_x}{f_{ck} \times b \times D^2} = 0.02$$

$$\frac{P_u}{f_{ck} \times b \times D} = 0.11$$

From SP16 chart44

$\frac{P}{f_{ck}}$	=	**0.065**	From table
Assuming a higher value P/fck	=	0.0975	
Assumed , P	=	2.93	per cent
Area of steel, A_s	=	**2925.00**	mm^2

Use **10** no.s of **20** mm

Area of steel provided	=	3140	mm^2

3 Find the moment capacities M_{x1} and M_{y1}

About X-axis

d'/D	=	0.13	
P/fck x b x D^2	=	0.11	
P/fck	=	0.0975	
$M_{x1}/(f_{ck}$ x b x $D^2)$	=	**0.14**	From table
M_{x1}	=	168.00	KN-m

About Y-axis

d'/D	=	0.20	
P/fck x b x D^2	=	0.11	
P/fck	=	0.0975	
$M_{y1}/(f_{ck}$ x D x $b^2)$	=	**0.14**	From table
M_{y1}	=	105.00	KN-m

4 Calculate α^n

$P_z=0.45f_{ck}A_c+0.75f_yA_s$

Pz	=	2327	KN
P/P_z	=	0.15	

By formula

α^n= 2/3[1+5/2 x P/Pz]

α^n	=	0.92	

5 Criteria for biaxial bending

$(M_x/M_{x1})^{\alpha n} + (M_y/M_{y1})^{\alpha n}$ < or =1.0	=	0.8890	< or = 1

Hence the column is safe

Rectangular Short Column with Biaxial bending -C10 **Bresler method**

Grade of Concrete		**M30**		
Grade of Steel		**Fe415**		
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)		**30**		
Characteristic yield strength of steel , f_y (N/mm^2)		**415**		
Unit weight of concrete , γ_c (kN/m^3)		**25**		
Partial safety factor for concrete		**1.5**		
Exposure condition		**Mild**		
Nominal Cover to exposure condition(mm)		**40**		
Assumed effective cover all around , d' (mm)		**50**		

Dimesions of the Column

Unsupported length of column, L	=	3000	mm	
Least lateral dimension	=	300	mm	
Breadth of the column B (mm)	=	300		
Depth of the Column D (mm)	=	450		
Effective length of the column , l_{ex} , (m)	=	1.95		
Effective length of the column , l_{ey} , (m)	=	1.95		

Check for Slenderness ratio, L/D

Slenderness ratio , λ_{ex}	=	6.50	<12	column is Short
Slenderness ratio , λ_{ey}	=	4.88	<12	column is Short

Design Factors

Factored load, Pu	=	108.11	KN
Factored moment acting parallel to the larger dimension , M_{ux}	=	1.46	KN-m
Factored moment acting parallel to the shorter dimension, M_{uy}	=	170.54	KN-m

1 Check for accidental eccentricity
Equivalent eccentricity of loads is given by

M_{ux}/p_u	=	13.50	mm
M_{uy}/p_u	=	832.49	mm

Both are more than 20mm minimum

2 Assume percentage of steel
(assuming steel larger than required by P and M_x)

d'/D = 0.1

$$\frac{M_x}{f_{ck} \times b \times D^2} = 0.03$$

$$\frac{P_u}{f_{ck} \times b \times D} = 0.06$$

From SP16 chart44

$\frac{P}{f_{ck}}$	=	**0.06**	From table
Assuming a higher value P/fck	=	0.09	
Assumed , P	=	2.70	per cent
Area of steel, A_s	=	**3240.00**	mm^2

Use **8** no.s of **25** mm

Area of steel provided	=	3925	mm^2

3 Find the moment capacities M_{x1} and M_{y1}

About X-axis

d'/D	=	0.13	
P/fck x b x D^2	=	0.03	
P/fck	=	0.09	
$M_{x1}/(f_{ck}$ x b x $D^2)$	=	**0.14**	From table
M_{x1}	=	201.60	KN-m

About Y-axis

d'/D	=	0.17	
P/fck x b x D^2	=	0.03	
P/fck	=	0.09	
$M_{y1}/(f_{ck}$ x D x $b^2)$	=	**0.14**	From table
M_{y1}	=	151.20	KN-m

4 Calculate α^n

$P_z=0.45f_{ck}A_c+0.75f_yA_s$

Pz	=	2842	KN
P/P_z	=	0.04	

By formula

α^n= 2/3[1+5/2 x P/Pz]

α^n	=	0.73	

5 Criteria for biaxial bending

$(M_x/M_{x1})^{\alpha n} + (M_y/M_{y1})^{\alpha n}$ < or =1.0	=	0.7103	< or = 1

Hence the column is safe

DESIGN OF PLINTH BEAM

Beam PB1 Support

Design Parameters

Load Case 14 [1.5*(DL + EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	10.00
Breadth of the beam , b (mm)	250
Overall depth of the beam , D (mm)	650

Details of reinforcements

Diameter of tension reinforcement (mm)	25
Diameter of compression reinforcement (mm)	25
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(650-20-8-25/2) =	610

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	355	
Equivalent Bending Moment , M_e (kNm)	355	
Shear force at critical distance , V_{ud} (kN)	165	
Equivalent Shear (kN)	165	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$\text{Mulim} = 0.362\text{fck} * \frac{\text{bxu}_{\text{max}}}{\text{d}} * 0.416\text{xu}_{\text{max}}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\, fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415)

$M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 250 x 609.5^2 / 1000000) = 387.00 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If $M_u > M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If $M_u < M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 355.00 kNm

$M_{u,lim}$ = 387.00 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' ($x_u = x_{u,max}$)

$A_{st} = A_{st,lim} + \Delta A_{st}$

where $A_{st,lim} = p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 250 x 609.5) = 2184 mm^2

- Assuming 25 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 25 / 2) = 40.5 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y \, (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 1963 mm^2

∴ No of tension bars required (#)
(1963 / (Pi / 4 x 25^2) = 5.00

Actual percentage of steel , p_t (%)
(5 x Pi / 4 x 25 ^2 / 250 / 610 x 100) = 1.61

Actual area of steel , A_{st} (mm^2)
(5 x Pi / 4 x 25 ^2) = 2454

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{(0.87\, f_y)(A_{st})}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y \,(p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d'/d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (40.5 / 609.5) = 0.066
  From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 1.61

Actual p_c provided : p_c = 0.32

⇒ p_c^* = (0.87 x 415 x (1.611 - 1.433) / (355.03 - 0.447 x 30))

⇒ p_c^* = 0.19

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1\, F_2$$

where
$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 2028 / 2454) = 198.87 N/mm^2

F = 1.00

F_1 = 0.86

$F_2 =$ 0.86

$\therefore$ $(l/d)_{max} =$ (26 x 1 x 0.86 x 0.86) = 19.29

$(l/d)_{provided} =$ 16.41

$\Rightarrow$ *Hence O.K.*

Check for shear

Shear force at critical distance , V_{ud} (kN) 165

The critical section for shear is at a distance of
610 mm from the face of the support.

- *Check for adequacy of section*

Nominal shear stress , τ_v

(165 x 1000 / (250 x 610)) = 1.08 N/mm^2

The maximum shear stress is given by : $T c \max = 0.62 f c k$

$\Rightarrow$ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

$\Rightarrow$ *Adopted section is adequate*

- *Design shear resistance at critical section*

At critical section , A_{st} is given by 2454 mm^2

Percentage of steel , p_t (%) 1.61

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

$\Rightarrow$ $\tau_c =$ 0.78 N/mm^2

$\Rightarrow$ $V_{uc} =$ (0.78 x 250 x 610 / 1000) = 119 kN

- *Design of " vertical " stirrups*

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

$\Rightarrow$ $V_{us} =$ (165 - 119) = 46 kN

Using 10 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 157

⇒ required spacing sv ≤ (0.87 x 415 x 157 x 610 / (45.83 x 1000))

⇒ Spacing , s_v = 754 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 1.08

Design shear stress , τ_c (N/mm^2) 0.78

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d / 300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 157 / 250) =	567	mm
ii)	≤	(0.75 x 609.5) =	457	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 157 x 610 / (45.83 x 1000)) =	754	mm

Beam PB1 Mid Span

Design Parameters

Load Case 14 [1.5*(DL + EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	10.00
Breadth of the beam , b (mm)	250
Overall depth of the beam , D (mm)	650

Details of reinforcements

Diameter of tension reinforcement (mm)	25
Diameter of compression reinforcement (mm)	25
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(650-20-8-25/2) =	610

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	255	
Equivalent Bending Moment , M_e (kNm)	255	
Shear force at critical distance , V_{ud} (kN)	165	
Equivalent Shear (kN)	165	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\,fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415)

$M_{u,lim}$ □ 0.1389 $f_{ck}\,b\,d^2$

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 250 x 609.5^2 / 1000000) = 387.00 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 255.00 kNm

$M_{u,lim}$ = 387.00 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

  A_{st} = $A_{st,lim}$ + ΔA_{st}

  where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

  ⇒ $A_{st,lim}$ (1.433 / 100 x 250 x 609.5) = 2184 mm^2

- Assuming 25 mm bars for compression steel,

  d' ≈ (20 mm clear cover + 8 mm stirrup + 25 / 2) = 40.5 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y \,(d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 1316 mm^2

∴ No of tension bars required (#)
(1316 / (Pi / 4 x 25^2) = 3.00

Actual percentage of steel , p_t (%)
(3 x Pi / 4 x 25 ^2 / 250 / 610 x 100) = 0.97

Actual area of steel , A_{st} (mm^2)
(3 x Pi / 4 x 25 ^2) = 1473

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\, f_y\, A_{st}}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y \,(p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		$\frac{d'}{d}$		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (40.5 / 609.5) = 0.066
From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 0.97

Actual p_c provided : p_c = 0.64

⇒ p_c^* = (0.87 x 415 x (0.966 - 1.433) / (355.03 - 0.447 x 30))

⇒ p_c^* = -0.49

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1 F_2$$

where

$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 1541 / 1473) = 251.89 N/mm^2

F = 1.00

F_1 = 0.99

F_2 = 1.12

∴ $(l/d)_{max}$ = (26 x 1 x 0.99 x 1.12) = 28.73

$(l/d)_{provided}$ = 16.41

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 165

The critical section for shear is at a distance of
610 mm from the face of the support.

- Check for adequacy of section

Nominal shear stress , τ_v

(165 x 1000 / (250 x 610)) = 1.08 N/mm²

The maximum shear stress is given by : $$Tc\max = 0.62\sqrt{fck}$$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm²

⇒ Adopted section is adequate

- Design shear resistance at critical section

At critical section , A_{st} is given by 1473 mm²

Percentage of steel , p_t (%) 0.97

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.65 N/mm²

⇒ V_{uc} = (0.65 x 250 x 610 / 1000) = 99 kN

- Design of " vertical " stirrups

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (165 - 99) = 66 kN

Using 10 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 157

⇒ required spacing sv ≤ (0.87 x 415 x 157 x 610 / (66.38 x 1000))

⇒ Spacing , s_v = 521 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 1.08

Design shear stress , τ_c (N/mm^2) 0.65

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 157 / 250) =	567	mm
ii)	≤	(0.75 x 609.5) =	457	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 157 x 610 / (66.38 x 1000)) =	521	mm

Beam PB1A Support

Design Parameters

Load Case 14 [1.5*(DL + EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	10.00
Breadth of the beam , b (mm)	250
Overall depth of the beam , D (mm)	650

Details of reinforcements

Diameter of tension reinforcement (mm)	25
Diameter of compression reinforcement (mm)	25
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(650-20-8-25/2) =	610

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	275	
Equivalent Bending Moment , M_e (kNm)	275	
Shear force at critical distance , V_{ud} (kN)	165	
Equivalent Shear (kN)	165	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$\text{Mulim} = 0.362\text{fck} * \frac{\text{bxu}_{\text{max}}}{\text{d}} * 0.416\text{xu}_{\text{max}}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\,fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 250 x 609.5^2 / 1000000) = 387.00 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 275.00 kNm

$M_{u,lim}$ = 387.00 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

  A_{st} = $A_{st,lim}$ + ΔA_{st}

  where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 250 x 609.5) = 2184 mm^2

- Assuming 25 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 25 / 2) = 40.5 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87 \, f_y \, (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87 \, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 1437 mm^2

∴ No of tension bars required (#)

(1437 / (Pi / 4 x 25^2) = 4.00

Actual percentage of steel , p_t (%)

(4 x Pi / 4 x 25 ^2 / 250 / 610 x 100) = 1.29

Actual area of steel , A_{st} (mm^2)

(4 x Pi / 4 x 25 ^2) = 1963

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87 \, f_y \, A_{st}}{f_{sc} - 0.447 \, f_{ck}}$$

or

$$p_c = \frac{0.87 \, f_y \, (p_t - p_{t,lim})}{f_{sc} - 0.447 \, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d'/d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (40.5 / 609.5) = 0.066

From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 1.29

Actual p_c provided : p_c = 0.64

⇒ p_c^* = (0.87 x 415 x (1.289 - 1.433) / (355.03 - 0.447 x 30))

⇒ p_c^* = -0.15

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1 F_2$$

where

$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 1638 / 1963) = 200.85 N/mm^2

F = 1.00

F_1 = 0.97

F_2 = 1.12

∴ $(l / d)_{max}$ = (26 x 1 x 0.97 x 1.12) = 28.30

$(l / d)_{provided}$ = 16.41

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 165

The critical section for shear is at a distance of
610 mm from the face of the support.

- Check for adequacy of section

Nominal shear stress , τ_v

(165 x 1000 / (250 x 610)) = 1.08 N/mm^2

The maximum shear stress is given by : $Tc \max = 0.62 \sqrt{fck}$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- Design shear resistance at critical section

At critical section , A_{st} is given by 1963 mm^2

Percentage of steel , p_t (%) 1.29

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85 \sqrt{0.8 f_{ck}} \left(\sqrt{1 + 5\beta} - 1 \right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.72 N/mm^2

⇒ V_{uc} = (0.72 x 250 x 610 / 1000) = 110 kN

- Design of " vertical " stirrups

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (165 - 110) = 55 kN

Using 10 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 157

$\Rightarrow$ required spacing sv ≤ (0.87 x 415 x 157 x 610 / (55.07 x 1000))

$\Rightarrow$ Spacing , s_v = 628 mm

Check whether $\tau_v > 0.5\ \tau_c$

Nominal shear stress , τ_v (N/mm^2) 1.08

Design shear stress , τ_c (N/mm^2) 0.72

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 157 / 250) =	567	mm
ii)	≤	(0.75 x 609.5) =	457	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 157 x 610 / (55.07 x 1000)) =	628	mm

Beam PB1A Mid Span

Design Parameters

Load Case 14 [1.5*(DL + EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	10.00
Breadth of the beam , b (mm)	250
Overall depth of the beam , D (mm)	650

Details of reinforcements

Diameter of tension reinforcement (mm)	25
Diameter of compression reinforcement (mm)	25
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(650-20-8-25/2) =	610

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	189	
Equivalent Bending Moment , M_e (kNm)	189	
Shear force at critical distance , V_{ud} (kN)	122	
Equivalent Shear (kN)	122	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2 fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 250 x 609.5^2 / 1000000) = 387.00 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 189.00 kNm

$M_{u,lim}$ = 387.00 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

A_{st} = $A_{st,lim}$ + ΔA_{st}

where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 250 x 609.5) = 2184 mm^2

- Assuming 25 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 25 / 2) = 40.5 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y \,(d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 939 mm^2

$\therefore$ No of tension bars required (#)
(939 / (Pi / 4 x 25^2) = 2.00

Actual percentage of steel , p_t (%)
(2 x Pi / 4 x 25 ^2 / 250 / 610 x 100) = 0.64

Actual area of steel , A_{st} (mm^2)
(2 x Pi / 4 x 25 ^2) = 982

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{(0.87\, f_y)(A_{st})}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y \,(p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d'/d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (40.5 / 609.5) = 0.066
  From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t	=	0.64
Actual p_c provided : p_c	=	0.97

⇒ p_c^* = (0.87 x 415 x (0.644 - 1.433) / (355.03 - 0.447 x 30))

⇒ p_c^* = -0.83

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} \times F_1 \times F_2$$

where $\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 1220 / 982) = 299.07 N/mm^2

F = 1.00

F_1 = 1.09

$F_2 =$ 1.25

∴ $(l/d)_{max} =$ (26 x 1 x 1.09 x 1.25) = 35.46

$(l/d)_{provided} =$ 16.41

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 122

The critical section for shear is at a distance of
610 mm from the face of the support.

- Check for adequacy of section

Nominal shear stress , τ_v

(122 x 1000 / (250 x 610)) = 0.80 N/mm²

The maximum shear stress is given by : $\tau_{c\,max} = 0.62\sqrt{fck}$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm²

⇒ Adopted section is adequate

- Design shear resistance at critical section

At critical section , A_{st} is given by 982 mm²

Percentage of steel , p_t (%) 0.64

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ $\tau_c =$ 0.55 N/mm²

⇒ $V_{uc} =$ (0.55 x 250 x 610 / 1000) = 84 kN

- Design of " vertical " stirrups

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ $V_{us} =$ (122 - 84) = 38 kN

Using 10 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 157

⇒ required spacing sv ≤ (0.87 x 415 x 157 x 610 / (38 x 1000))

⇒ Spacing , s_v = 910 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 0.80
Design shear stress , τ_c (N/mm^2) 0.55

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 157 / 250) =	567	mm
ii)	≤	(0.75 x 609.5) =	457	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 157 x 610 / (38 x 1000)) =	910	mm

Beam PB2 Support

Design Parameters

Load Case 14 [1.5*(DL + EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	5.00
Breadth of the beam , b (mm)	250
Overall depth of the beam , D (mm)	500

Details of reinforcements

Diameter of tension reinforcement (mm)	25
Diameter of compression reinforcement (mm)	25
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(500-20-8-25/2) =	460

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	177	
Equivalent Bending Moment , M_e (kNm)	177	
Shear force at critical distance , V_{ud} (kN)	90	
Equivalent Shear (kN)	90	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$\text{Mulim} = 0.362\text{fck} * \frac{\text{bxu}_{\max}}{\text{d}} * 0.416\text{xu}_{\max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\,fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 $f_{ck}\, b\, d^2$

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 250 x 459.5^2 / 1000000) = 219.96 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 177.00 kNm

$M_{u,lim}$ = 219.96 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

A_{st} = $A_{st,lim}$ + ΔA_{st}

where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 250 x 459.5) = 1646 mm^2

- Assuming 25 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 25 / 2) = 40.5 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\ f_y\ (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\ f_y\ \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 1257 mm^2

∴ No of tension bars required (#)
(1257 / (Pi / 4 x 25^2) = 3.00

Actual percentage of steel , p_t (%)
(3 x Pi / 4 x 25 ^2 / 250 / 460 x 100) = 1.28

Actual area of steel , A_{st} (mm^2)
(3 x Pi / 4 x 25 ^2) = 1473

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\ f_y\ A_{st}}{f_{sc} - 0.447\ f_{ck}}$$

or

$$p_c = \frac{0.87\ f_y\ (p_t - p_{t,lim})}{f_{sc} - 0.447\ f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d' / d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (40.5 / 459.5) = 0.088
  From the above table : by interpolation

Design Check

- To ensure $x_u \le x_{u,max}$, it suffices to establish $p_c \ge p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 1.28

Actual p_c provided : p_c = 0.43

⇒ p_c^* = (0.87 x 415 x (1.282 - 1.433) / (353.38 - 0.447 x 30))

⇒ p_c^* = -0.16

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1 F_2$$

where $\left(\frac{l}{d}\right)_{basic}$ = 7 for cantilever spans; 20 for simply supported spans; 26 for continuous spans

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 1362 / 1473) = 222.66 N/mm²

F = 1.00

F_1 = 0.91

F_2 = 0.97

∴ $(l / d)_{max}$ = (26 x 1 x 0.91 x 0.97) = 23.07

$(l / d)_{provided}$ = 10.88

⇒ *Hence O.K.*

Check for shear

Shear force at critical distance , V_{ud} (kN) 90

The critical section for shear is at a distance of
460 mm from the face of the support.

- *Check for adequacy of section*

Nominal shear stress , τ_v

(90 x 1000 / (250 x 460)) = 0.78 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\,fck$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ *Adopted section is adequate*

- *Design shear resistance at critical section*

At critical section , A_{st} is given by 1473 mm^2

Percentage of steel , p_t (%) 1.28

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.72 N/mm^2

⇒ V_{uc} = (0.72 x 250 x 460 / 1000) = 83 kN

- *Design of " vertical " stirrups*

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (90 - 83) = 7 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

$\Rightarrow$ required spacing sv $\leq$ (0.87 x 415 x 101 x 460 / (7.28 x 1000))

$\Rightarrow$ Spacing , s_v = 180 mm

Check whether $\tau_v > 0.5\ \tau_c$

Nominal shear stress , τ_v (N/mm^2) 0.78

Design shear stress , τ_c (N/mm^2) 0.72

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 250) =	363	mm
ii)	$\leq$	(0.75 x 459.5) =	345	mm
iii)	$\leq$	300 mm	300	mm
iv)	$\leq$	(0.87 x 415 x 101 x 460 / (7.28 x 1000)) =	180	mm

Beam PB2 Mid Span

Design Parameters

Load Case 14 [1.5*(DL + EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	5.00
Breadth of the beam , b (mm)	250
Overall depth of the beam , D (mm)	450

Details of reinforcements

Diameter of tension reinforcement (mm)	20
Diameter of compression reinforcement (mm)	20
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(450-20-8-20/2) =	412

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	90	
Equivalent Bending Moment , M_e (kNm)	90	
Shear force at critical distance , V_{ud} (kN)	30	
Equivalent Shear (kN)	30	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\, fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 250 x 412^2 / 1000000) = 176.83 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be
i) get increased by depth or width (preferably depth)
ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 90.00 kNm
$M_{u,lim}$ = 176.83 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

A_{st} = $A_{st,lim}$ + ΔA_{st}

where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 250 x 412) = 1476 mm^2

- Assuming 20 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 20 / 2) = 38 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87 f_y (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87 f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 664 mm^2

∴ No of tension bars required (#)
(664 / (Pi / 4 x 20^2) = 3.00

Actual percentage of steel , p_t (%)
(3 x Pi / 4 x 20 ^2 / 250 / 412 x 100) = 0.92

Actual area of steel , A_{st} (mm^2)
(3 x Pi / 4 x 20 ^2) = 942

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87 f_y A_{st}}{f_{sc} - 0.447 f_{ck}}$$

or

$$p_c = \frac{0.87 f_y (p_t - p_{t,lim})}{f_{sc} - 0.447 f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d'/d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (38 / 412) = 0.092
  From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 0.92

Actual p_c provided : p_c = 0.92

$\Rightarrow$ p_c^* = (0.87 x 415 x (0.915 - 1.433) / (352.91 - 0.447 x 30))

$\Rightarrow$ p_c^* = -0.55

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d} \right)_{max} = \left(\frac{l}{d} \right)_{basic} F_1 F_2$$

where $\left(\frac{l}{d} \right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

$\Rightarrow$ f_{st} = (0.58 x 415 x 833 / 942) = 212.74 N/mm^2

F = 1.00

F_1 = 1.17

F_2 = 1.23

∴ $(l/d)_{max}$ = (26 x 1 x 1.17 x 1.23) = 37.43

$(l/d)_{provided}$ = 12.14

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 30

The critical section for shear is at a distance of
412 mm from the face of the support.

- *Check for adequacy of section*

Nominal shear stress , τ_v

(30 x 1000 / (250 x 412)) = 0.29 N/mm²

The maximum shear stress is given by : $Tc\max = 0.62\, fck$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm²

⇒ Adopted section is adequate

- *Design shear resistance at critical section*

At critical section , A_{st} is given by 942 mm²

Percentage of steel , p_t (%) 0.92

The design shear strength of the concrete , τ_c , is given by :

τ_c □ 0.85 0.8 f 1 5 □ 1 / 6 □

where □ □ $\frac{0.8 f_{ck}}{6.89 p_t}$ 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.63 N/mm²

⇒ V_{uc} = (0.63 x 250 x 412 / 1000) = 65 kN

- *Design of " vertical " stirrups*

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (30 - 65) = -35 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 412 / (-35.27 x 1000))

⇒ Spacing , s_v = 185 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 0.29

Design shear stress , τ_c (N/mm^2) 0.63

$\tau_v > 0.5\ \tau_c$ No

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d / 300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 250) =	363	mm
ii)	≤	(0.75 x 412) =	309	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 412 / (-35.27 x 1000)) =	185	mm

DESIGN OF ROOF BEAM
(GROUND FLOOR)

Beam GRB1 Support

Design Parameters

Load Case 13 [1.5*(DL - EQX)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	5.00
Breadth of the beam , b (mm)	230
Overall depth of the beam , D (mm)	450

Details of reinforcements

Diameter of tension reinforcement (mm)	20
Diameter of compression reinforcement (mm)	20
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(450-20-8-20/2) =	412

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	150	
Equivalent Bending Moment , M_e (kNm)	150	
Shear force at critical distance , V_{ud} (kN)	189	
Equivalent Shear (kN)	189	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2 fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 230 x 412^2 / 1000000) = 162.68 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 150.00 kNm

$M_{u,lim}$ = 162.68 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

  A_{st} = $A_{st,lim}$ + ΔA_{st}

  where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 230 x 412) = 1358 mm^2

- Assuming 20 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 20 / 2) = 38 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y\, (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 1229 mm^2

∴ No of tension bars required (#)
(1229 / (Pi / 4 x 20^2) = 5.00

Actual percentage of steel , p_t (%)
(5 x Pi / 4 x 20 ^2 / 230 / 412 x 100) = 1.66

Actual area of steel , A_{st} (mm^2)
(5 x Pi / 4 x 20 ^2) = 1571

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{(0.87\, f_y)\,(A_{st})}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y\, (p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		$\frac{d'}{d}$		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (38 / 412) = 0.092
From the above table : by interpolation

Design Check

- To ensure $x_u \le x_{u,max}$, it suffices to establish $p_c \ge p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 1.66

Actual p_c provided : p_c = 0.33

$\Rightarrow$ p_c^* = (0.87 x 415 x (1.658 - 1.433) / (352.91 - 0.447 x 30))

$\Rightarrow$ p_c^* = 0.24

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1 F_2$$

where

$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

$\Rightarrow$ f_{st} = (0.58 x 415 x 1264 / 1571) = 193.69 N/mm^2

F = 1.00

F_1 = 0.86

F_2 = 0.87

$\therefore$ $(l/d)_{max}$ = (26 x 1 x 0.86 x 0.87) = 19.53

$(l/d)_{provided}$ = 12.14

$\Rightarrow$ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 189

The critical section for shear is at a distance of
412 mm from the face of the support.

- *Check for adequacy of section*

Nominal shear stress , τ_v

(189 x 1000 / (230 x 412)) = 1.99 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\sqrt{fck}$

$\Rightarrow$ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

$\Rightarrow$ Adopted section is adequate

- *Design shear resistance at critical section*

At critical section , A_{st} is given by 1571 mm^2

Percentage of steel , p_t (%) 1.66

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

$\Rightarrow$ τ_c = 0.79 N/mm^2

$\Rightarrow$ V_{uc} = (0.79 x 230 x 412 / 1000) = 75 kN

- *Design of " vertical " stirrups*

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

$\Rightarrow$ V_{us} = (189 - 75) = 114 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 412 / (114.13 x 1000))

⇒ Spacing , s_v = 280 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 1.99
Design shear stress , τ_c (N/mm^2) 0.79

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 230) =	395	mm
ii)	≤	(0.75 x 412) =	309	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 412 / (114.13 x 1000)) =	280	mm

Beam GRB1 Mid Span

Design Parameters

Load Case 13 [1.5*(DL - EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	5.00
Breadth of the beam , b (mm)	230
Overall depth of the beam , D (mm)	450

Details of reinforcements

Diameter of tension reinforcement (mm)	16
Diameter of compression reinforcement (mm)	16
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(450-20-8-16/2) =	414

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	76	
Equivalent Bending Moment , M_e (kNm)	76	
Shear force at critical distance , V_{ud} (kN)	20	
Equivalent Shear (kN)	20	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

$$\text{Where } fck = \text{Charcteristic Compressive strength of concrete}$$

$$fy = \text{Charcteristic strength of steel}$$

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\, fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 230 x 414^2 / 1000000) = 164.27 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u =	76.00	kNm
$M_{u,lim}$ =	164.27	kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

  A_{st} = $A_{st,lim}$ + ΔA_{st}

  where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

  ⇒ $A_{st,lim}$ (1.433 / 100 x 230 x 414) = 1365 mm^2

- Assuming 16 mm bars for compression steel,

  d' ≈ (20 mm clear cover + 8 mm stirrup + 16 / 2) = 36 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\ f_y\ (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\ f_y\ \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 553 mm^2

∴ No of tension bars required (#)

(553 / (Pi / 4 x 16^2) = 3.00

Actual percentage of steel , p_t (%)

(3 x Pi / 4 x 16 ^2 / 230 / 414 x 100) = 0.63

Actual area of steel , A_{st} (mm^2)

(3 x Pi / 4 x 16 ^2) = 603

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\ f_y\ A_{st}}{f_{sc} - 0.447\ f_{ck}}$$

or

$$p_c = \frac{0.87\ f_y\ (p_t - p_{t,lim})}{f_{sc} - 0.447\ f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d'/d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (36 / 414) = 0.087
  From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 0.63

Actual p_c provided : p_c = 0.84

⇒ p_c^* = (0.87 x 415 x (0.633 - 1.433) / (353.51 - 0.447 x 30))

⇒ p_c^* = -0.85

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1 F_2$$

where $\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 718 / 603) = 286.44 N/mm^2

F = 1.00

F_1 = 1.16

$F_2 =$ 1.21

∴ $(l / d)_{max} =$ (26 x 1 x 1.16 x 1.21) = 36.41

$(l / d)_{provided} =$ 12.08

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 20

The critical section for shear is at a distance of
414 mm from the face of the support.

- Check for adequacy of section

Nominal shear stress , τ_v

(20 x 1000 / (230 x 414)) = 0.21 N/mm²

The maximum shear stress is given by : $Tc\max = 0.62\sqrt{fck}$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm²

⇒ Adopted section is adequate

- Design shear resistance at critical section

At critical section , A_{st} is given by 603 mm²

Percentage of steel , p_t (%) 0.63

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ $\tau_c =$ 0.55 N/mm²

⇒ $V_{uc} =$ (0.55 x 230 x 414 / 1000) = 52 kN

- Design of " vertical " stirrups

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ $V_{us} =$ (20 - 52) = -32 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 414 / (-32.13 x 1000))

⇒ Spacing , s_v = 300 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 0.21

Design shear stress , τ_c (N/mm^2) 0.55

$\tau_v > 0.5\ \tau_c$ No

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 230) =	395	mm
ii)	≤	(0.75 x 414) =	311	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 414 / (-32.13 x 1000)) =	300	mm

Beam GRB2 Support

Design Parameters

Load Case 11 [1.5*(DL + LL)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	5.00
Breadth of the beam , b (mm)	230
Overall depth of the beam , D (mm)	500

Details of reinforcements

Diameter of tension reinforcement (mm)	20
Diameter of compression reinforcement (mm)	20
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm) (500-20-8-20/2) = 462

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	175	
Equivalent Bending Moment , M_e (kNm)	175	
Shear force at critical distance , V_{ud} (kN)	75	
Equivalent Shear (kN)	75	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} \; x \; \frac{Ast}{bd} \; x \; \frac{fck}{2\,fy} \; = \; 4.598 \; \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 230 x 462^2 / 1000000) = 204.57 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 175.00 kNm

$M_{u,lim}$ = 204.57 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

A_{st} = $A_{st,lim}$ + ΔA_{st}

where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 230 x 462) = 1523 mm^2

- Assuming 20 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 20 / 2) = 38 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y \,(d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 1254 mm^2

∴ No of tension bars required (#)

(1254 / (Pi / 4 x 20^2) = 5.00

Actual percentage of steel , p_t (%)

(5 x Pi / 4 x 20 ^2 / 230 / 462 x 100) = 1.48

Actual area of steel , A_{st} (mm^2)

(5 x Pi / 4 x 20 ^2) = 1571

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{(0.87\, f_y)(A_{st})}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y \,(p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d'/d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (38 / 462) = 0.082
  From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 1.48

Actual p_c provided : p_c = 0.30

$\Rightarrow$ p_c^* = (0.87 x 415 x (1.478 - 1.433) / (353.97 - 0.447 x 30))

$\Rightarrow$ p_c^* = 0.05

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1 F_2$$

where

$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

$\Rightarrow$ f_{st} = (0.58 x 415 x 1330 / 1571) = 203.75 N/mm^2

F = 1.00

F_1 = 0.89

F_2 = 0.83

∴ $(l / d)_{max}$ = (26 x 1 x 0.89 x 0.83) = 19.15

$(l / d)_{provided}$ = 10.82

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 75

The critical section for shear is at a distance of
462 mm from the face of the support.

- Check for adequacy of section

Nominal shear stress , τ_v

(75 x 1000 / (230 x 462)) = 0.71 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\,fck$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- Design shear resistance at critical section

At critical section , A_{st} is given by 1571 mm^2

Percentage of steel , p_t (%) 1.48

The design shear strength of the concrete , τ_c , is given by :

τ_c = 0.85 0.8 f_{ck} 1 5 1 / 6

where $\frac{0.8 f_{ck}}{6.89 p_t}$ whichever is greater
1

For (M30 and Fe415)

⇒ τ_c = 0.76 N/mm^2

⇒ V_{uc} = (0.76 x 230 x 462 / 1000) = 81 kN

- Design of " vertical " stirrups

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (75 - 81) = -6 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 462 / (-5.59 x 1000))

⇒ Spacing , s_v = 280 mm

Check whether $\tau_v > 0.5\ \tau_c$

Nominal shear stress , τ_v (N/mm^2) 0.71

Design shear stress , τ_c (N/mm^2) 0.76

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 230) =	395	mm
ii)	≤	(0.75 x 462) =	347	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 462 / (-5.59 x 1000)) =	280	mm

Beam GRB2 Mid Span

Design Parameters

Load Case 11 [1.5*(DL + LL)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	5.00
Breadth of the beam , b (mm)	230
Overall depth of the beam , D (mm)	500

Details of reinforcements

Diameter of tension reinforcement (mm)	16
Diameter of compression reinforcement (mm)	16
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(500-20-8-16/2) =	464

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	80	
Equivalent Bending Moment , M_e (kNm)	80	
Shear force at critical distance , V_{ud} (kN)	55	
Equivalent Shear (kN)	55	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$\text{Mulim} = 0.362\text{fck} * \frac{\text{bxu}_{\text{max}}}{\text{d}} * 0.416\text{xu}_{\text{max}}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\,fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415)

$M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 230 x 464^2 / 1000000) = 206.34 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 80.00 kNm

$M_{u,lim}$ = 206.34 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

  A_{st} = $A_{st,lim}$ + ΔA_{st}

  where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

  ⇒ $A_{st,lim}$ (1.433 / 100 x 230 x 464) = 1529 mm^2

- Assuming 16 mm bars for compression steel,

  d' ≈ (20 mm clear cover + 8 mm stirrup + 16 / 2) = 36 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\ f_y\ (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\ f_y\ \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 511 mm^2

∴ No of tension bars required (#)

(511 / (Pi / 4 x 16^2) = 4.00

Actual percentage of steel , p_t (%)

(4 x Pi / 4 x 16 ^2 / 230 / 464 x 100) = 0.75

Actual area of steel , A_{st} (mm^2)

(4 x Pi / 4 x 16 ^2) = 804

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\ f_y\ A_{st}}{f_{sc} - 0.447\ f_{ck}}$$

or

$$p_c = \frac{0.87\ f_y\ (p_t - p_{t,lim})}{f_{sc} - 0.447\ f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		d'/d		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (36 / 464) = 0.078
  From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 0.75

Actual p_c provided : p_c = 0.94

⇒ p_c^* = (0.87 x 415 x (0.754 - 1.433) / (354.37 - 0.447 x 30))

⇒ p_c^* = -0.72

__Section is not over reinforced__

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1 F_2$$

where $\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 712 / 804) = 213.02 N/mm^2

F = 1.00

F_1 = 1.36

F_2 = 1.24

∴ $(l/d)_{max}$ = (26 x 1 x 1.36 x 1.24) = 43.86

$(l/d)_{provided}$ = 10.78

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 55

The critical section for shear is at a distance of
464 mm from the face of the support.

- **Check for adequacy of section**

Nominal shear stress , τ_v

(55 x 1000 / (230 x 464)) = 0.52 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\sqrt{fck}$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- **Design shear resistance at critical section**

At critical section , A_{st} is given by 804 mm^2

Percentage of steel , p_t (%) 0.75

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89\, p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.59 N/mm^2

⇒ V_{uc} = (0.59 x 230 x 464 / 1000) = 63 kN

- **Design of " vertical " stirrups**

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (55 - 63) = -8 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 464 / (-7.66 x 1000))

⇒ Spacing , s_v = 300 mm

Check whether $\tau_v > 0.5\ \tau_c$

Nominal shear stress , τ_v (N/mm^2) 0.52

Design shear stress , τ_c (N/mm^2) 0.59

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d / 300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 230) =	395	mm
ii)	≤	(0.75 x 464) =	348	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 464 / (-7.66 x 1000)) =	300	mm

Beam GRB3 Support

Design Parameters

Load Case 15 [1.5*(DL - EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	5.00
Breadth of the beam , b (mm)	230
Overall depth of the beam , D (mm)	500

Details of reinforcements

Diameter of tension reinforcement (mm)	20
Diameter of compression reinforcement (mm)	20
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(500-20-8-20/2) =	462

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	190	
Equivalent Bending Moment , M_e (kNm)	190	
Shear force at critical distance , V_{ud} (kN)	75	
Equivalent Shear (kN)	75	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\,fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 230 x 462^2 / 1000000) = 204.57 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 190.00 kNm

$M_{u,lim}$ = 204.57 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' ($x_u = x_{u,max}$)

  $A_{st} = A_{st,lim} + \Delta A_{st}$

  where $A_{st,lim} = p_{t,lim}$ / 100 (b x d)

  ⇒ $A_{st,lim}$ (1.433 / 100 x 230 x 462) = 1523 mm^2

- Assuming 20 mm bars for compression steel,

  d' ≈ (20 mm clear cover + 8 mm stirrup + 20 / 2) = 38 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y \,(d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 1391 mm^2

∴ No of tension bars required (#)

(1391 / (Pi / 4 x 20^2) = 6.00

Actual percentage of steel , p_t (%)

(6 x Pi / 4 x 20 ^2 / 230 / 462 x 100) = 1.77

Actual area of steel , A_{st} (mm^2)

(6 x Pi / 4 x 20 ^2) = 1885

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\, f_y \,(A_{st})}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y \,(p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d'/d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (38 / 462) = 0.082
  From the above table : by interpolation

Design Check

- To ensure $x_u \le x_{u,max}$, it suffices to establish $p_c \ge p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 1.77

Actual p_c provided : p_c = 0.30

⇒ p_c^* = (0.87 x 415 x (1.774 - 1.433) / (353.97 - 0.447 x 30))

⇒ p_c^* = 0.36

Section is over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1 F_2$$

where

$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 1428 / 1885) = 182.30 N/mm^2

F = 1.00

F_1 = 0.85

F_2 = 0.83

∴ $(l/d)_{max}$ = (26 x 1 x 0.85 x 0.83) = 18.42

$(l/d)_{provided}$ = 10.82

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 75

The critical section for shear is at a distance of
462 mm from the face of the support.

- *Check for adequacy of section*

Nominal shear stress , τ_v

(75 x 1000 / (230 x 462)) = 0.71 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\,fck$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- *Design shear resistance at critical section*

At critical section , A_{st} is given by 1885 mm^2

Percentage of steel , p_t (%) 1.77

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \dfrac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.81 N/mm^2

⇒ V_{uc} = (0.81 x 230 x 462 / 1000) = 86 kN

- *Design of " vertical " stirrups*

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (75 - 86) = -11 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 462 / (-10.97 x 1000))

⇒ Spacing , s_v = 180 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 0.71

Design shear stress , τ_c (N/mm^2) 0.81

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d / 300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 230) =	395	mm
ii)	≤	(0.75 x 462) =	347	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 462 / (-10.97 x 1000)) =	180	mm

Beam GRB3 Mid Span

Design Parameters

Load Case 15 [1.5*(DL - EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	5.00
Breadth of the beam , b (mm)	230
Overall depth of the beam , D (mm)	500

Details of reinforcements

Diameter of tension reinforcement (mm)	16
Diameter of compression reinforcement (mm)	16
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(500-20-8-16/2) =	464

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	85	
Equivalent Bending Moment , M_e (kNm)	85	
Shear force at critical distance , V_{ud} (kN)	35	
Equivalent Shear (kN)	35	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

$$\text{Where } b = \text{Breadth of the Section}$$

$$xu_{max} = \text{Limiting depth of Neutral Axis}$$

$$d = \text{Effective depth of the Section}$$

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\,fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415)

$M_{u,lim}$ □ 0.1389 $f_{ck}\, b\, d^2$

$x_{u,max} / d$ = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 230 x 464^2 / 1000000) = 206.34 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If $M_u > M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If $M_u < M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 85.00 kNm

$M_{u,lim}$ = 206.34 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' ($x_u = x_{u,max}$)

  $A_{st} = A_{st,lim} + \Delta A_{st}$

  where $A_{st,lim} = p_{t,lim} / 100 (b \times d)$

  ⇒ $A_{st,lim}$ (1.433 / 100 x 230 x 464) = 1529 mm^2

- Assuming 16 mm bars for compression steel,

  d' ≈ (20 mm clear cover + 8 mm stirrup + 16 / 2) = 36 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\ f_y\ (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\ f_y\ \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 546 mm^2

∴ No of tension bars required (#)
(546 / (Pi / 4 x 16^2) = 4.00

Actual percentage of steel , p_t (%)
(4 x Pi / 4 x 16 ^2 / 230 / 464 x 100) = 0.75

Actual area of steel , A_{st} (mm^2)
(4 x Pi / 4 x 16 ^2) = 804

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\ f_y\ A_{st}}{f_{sc} - 0.447\ f_{ck}}$$

or

$$p_c = \frac{0.87\ f_y\ (p_t - p_{t,lim})}{f_{sc} - 0.447\ f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		$\frac{d'}{d}$		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (36 / 464) = 0.078
  From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87 f_y}{f_{sc} - 0.447 f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 0.75

Actual p_c provided : p_c = 0.94

⇒ p_c^* = (0.87 x 415 x (0.754 - 1.433) / (354.37 - 0.447 x 30))

⇒ p_c^* = -0.72

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1 F_2$$

where

$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58 f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 744 / 804) = 222.71 N/mm^2

F = 1.00

F_1 = 1.31

F_2 = 1.24

∴ $(l/d)_{max}$ = (26 x 1 x 1.31 x 1.24) = 42.07

$(l/d)_{provided}$ = 10.78

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 35

The critical section for shear is at a distance of
464 mm from the face of the support.

- **Check for adequacy of section**

Nominal shear stress , τ_v

(35 x 1000 / (230 x 464)) = 0.33 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\sqrt{fck}$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- **Design shear resistance at critical section**

At critical section , A_{st} is given by 804 mm^2

Percentage of steel , p_t (%) 0.75

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \dfrac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.59 N/mm^2

⇒ V_{uc} = (0.59 x 230 x 464 / 1000) = 63 kN

- **Design of " vertical " stirrups**

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (35 - 63) = -28 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 464 / (-27.66 x 1000))

⇒ Spacing , s_v = 300 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 0.33

Design shear stress , τ_c (N/mm^2) 0.59

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy} \quad When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 230) =	395	mm
ii)	≤	(0.75 x 464) =	348	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 464 / (-27.66 x 1000)) =	300	mm

Beam GRB4 Support

Design Parameters

Load Case 11 [1.5*(DL+LL)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	2.50
Breadth of the beam , b (mm)	230
Overall depth of the beam , D (mm)	350

Details of reinforcements

Diameter of tension reinforcement (mm)	16
Diameter of compression reinforcement (mm)	16
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(350-20-8-16/2) =	314

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	55	
Equivalent Bending Moment , M_e (kNm)	55	
Shear force at critical distance , V_{ud} (kN)	52	
Equivalent Shear (kN)	52	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$\text{Mulim} = 0.362\text{fck} * \frac{\text{bxu}_{\text{max}}}{\text{d}} * 0.416\text{xu}_{\text{max}}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\,fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 230 x 314^2 / 1000000) = 94.50 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 55.00 kNm

$M_{u,lim}$ = 94.50 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

A_{st} = $A_{st,lim}$ + ΔA_{st}

where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 230 x 314) = 1035 mm^2

- Assuming 16 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 16 / 2) = 36 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\ f_y\ (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\ f_y\ \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 541 mm^2

∴ No of tension bars required (#)
(541 / (Pi / 4 x 16^2) = 3.00

Actual percentage of steel , p_t (%)
(3 x Pi / 4 x 16 ^2 / 230 / 314 x 100) = 0.84

Actual area of steel , A_{st} (mm^2)
(3 x Pi / 4 x 16 ^2) = 603

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\ f_y\ A_{st}}{f_{sc} - 0.447\ f_{ck}}$$

or

$$p_c = \frac{0.87\ f_y\ (p_t - p_{t,lim})}{f_{sc} - 0.447\ f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		$\frac{d'}{d}$		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (36 / 314) = 0.115
  From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 0.84

Actual p_c provided : p_c = 0.84

⇒ p_c^* = (0.87 x 415 x (0.835 - 1.433) / (349.61 - 0.447 x 30))

⇒ p_c^* = -0.64

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} \times F_1 \times F_2$$

where
$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 641 / 603) = 255.98 N/mm^2

F = 1.00

F_1 = 1.07

F_2 = 1.20

∴ $(l / d)_{max}$ = (26 x 1 x 1.07 x 1.2) = 33.41

$(l / d)_{provided}$ = 7.96

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 52

The critical section for shear is at a distance of
314 mm from the face of the support.

- *Check for adequacy of section*

Nominal shear stress , τ_v

(52 x 1000 / (230 x 314)) = 0.72 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\sqrt{fck}$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- *Design shear resistance at critical section*

At critical section , A_{st} is given by 603 mm^2

Percentage of steel , p_t (%) 0.84

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.61 N/mm^2

⇒ V_{uc} = (0.61 x 230 x 314 / 1000) = 44 kN

- *Design of " vertical " stirrups*

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (52 - 44) = 8 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 314 / (7.84 x 1000))

⇒ Spacing , s_v = 180 mm

Check whether $\tau_v > 0.5\ \tau_c$

Nominal shear stress , τ_v (N/mm^2) 0.72

Design shear stress , τ_c (N/mm^2) 0.61

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d / 300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 230) =	395	mm
ii)	≤	(0.75 x 314) =	236	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 314 / (7.84 x 1000)) =	180	mm

Beam GRB4 Mid Span

Design Parameters

Load Case 11 [1.5*(DL+LL)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	2.50
Breadth of the beam , b (mm)	230
Overall depth of the beam , D (mm)	350

Details of reinforcements

Diameter of tension reinforcement (mm)	16
Diameter of compression reinforcement (mm)	16
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(350-20-8-16/2) =	314

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	50	
Equivalent Bending Moment , M_e (kNm)	50	
Shear force at critical distance , V_{ud} (kN)	40	
Equivalent Shear (kN)	40	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\, fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 230 x 314^2 / 1000000) = 94.50 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 50.00 kNm

$M_{u,lim}$ = 94.50 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' ($x_u = x_{u,max}$)

$A_{st} = A_{st,lim} + \Delta A_{st}$

where $A_{st,lim} = p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 230 x 314) = 1035 mm^2

- Assuming 16 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 16 / 2) = 36 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\ f_y\ (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\ f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 486 mm^2

∴ No of tension bars required (#)

(486 / (Pi / 4 x 16^2) = 4.00

Actual percentage of steel , p_t (%)

(4 x Pi / 4 x 16 ^2 / 230 / 314 x 100) = 1.11

Actual area of steel , A_{st} (mm^2)

(4 x Pi / 4 x 16 ^2) = 804

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\ f_y\ (A_{st})}{f_{sc} - 0.447\ f_{ck}}$$

or

$$p_c = \frac{0.87\ f_y\ (p_t - p_{t,lim})}{f_{sc} - 0.447\ f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d' / d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (36 / 314) = 0.115

  From the above table : by interpolation

Design Check

- To ensure $x_u \le x_{u,max}$, it suffices to establish $p_c \ge p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 1.11

Actual p_c provided : p_c = 0.84

⇒ p_c^* = (0.87 x 415 x (1.114 - 1.433) / (349.61 - 0.447 x 30))

⇒ p_c^* = -0.34

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1 F_2$$

where $\left(\frac{l}{d}\right)_{basic}$ = 7 for cantilever spans, 20 for simply supported spans, 26 for continuous spans

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 592 / 804) = 177.07 N/mm^2

F = 1.00

F_1 = 1.16

F_2 = 1.20

∴ $(l / d)_{max}$ = (26 x 1 x 1.16 x 1.2) = 36.29

$(l / d)_{provided}$ = 7.96

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 40

The critical section for shear is at a distance of
314 mm from the face of the support.

- Check for adequacy of section

Nominal shear stress , τ_v

(40 x 1000 / (230 x 314)) = 0.55 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\, fck$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- Design shear resistance at critical section

At critical section , A_{st} is given by 804 mm^2

Percentage of steel , p_t (%) 1.11

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.68 N/mm^2

⇒ V_{uc} = (0.68 x 230 x 314 / 1000) = 49 kN

- Design of " vertical " stirrups

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (40 - 49) = -9 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 314 / (-9.34 x 1000))

⇒ Spacing , s_v = 300 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2)	0.55
Design shear stress , τ_c (N/mm^2)	0.68

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy} \quad When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 230) =	395	mm
ii)	≤	(0.75 x 314) =	236	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 314 / (-9.34 x 1000)) =	300	mm

DESIGN OF ROOF BEAM
(FIRST FLOOR)

Beam FRB1 Support

Design Parameters

Load Case 13 [1.5*(DL - EQX)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	5.00
Breadth of the beam , b (mm)	230
Overall depth of the beam , D (mm)	400

Details of reinforcements

Diameter of tension reinforcement (mm)	16
Diameter of compression reinforcement (mm)	16
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(400-20-8-16/2) =	364

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	3	kN-m
Bending Moment Mu(kN-m)	75	
Equivalent Bending Moment , M_e (kNm)	80	
Shear force at critical distance , V_{ud} (kN)	45	
Equivalent Shear (kN)	66	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\,fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 $f_{ck}\, b\, d^2$

$x_{u,max} / d =$ 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 230 x 364^2 / 1000000) = 126.99 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If $M_u > M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If $M_u < M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 79.83 kNm

$M_{u,lim}$ = 126.99 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' ($x_u = x_{u,max}$)

$A_{st} = A_{st,lim} + \Delta A_{st}$

where $A_{st,lim} = p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 230 x 364) = 1200 mm^2

- Assuming 16 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 16 / 2) = 36 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y \,(d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 685 mm^2

∴ No of tension bars required (#)

(685 / (Pi / 4 x 16^2) = 4.00

Actual percentage of steel , p_t (%)

(4 x Pi / 4 x 16 ^2 / 230 / 364 x 100) = 0.96

Actual area of steel , A_{st} (mm^2)

(4 x Pi / 4 x 16 ^2) = 804

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\, f_y \, A_{st}}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y \,(p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d'/d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (36 / 364) = 0.099
  From the above table : by interpolation

Design Check

- To ensure $x_u \le x_{u,max}$, it suffices to establish $p_c \ge p_c^*$

where p_c^* is given by

$$p_c^* = \left(\frac{0.87\ f_y}{f_{sc} - 0.447\ f_{ck}} \right) \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 0.96

Actual p_c provided : p_c = 0.72

⇒ p_c^* = (0.87 x 415 x (0.961 - 1.433) / (352.05 - 0.447 x 30))

⇒ p_c^* = -0.50

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d} \right)_{max} = \left(\frac{l}{d} \right)_{basic} \times F_1 \times F_2$$

where
$$\left(\frac{l}{d} \right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\ f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 802 / 804) = 239.91 N/mm^2

F = 1.00

F_1 = 1.03

F_2 = 1.16

∴ $(l / d)_{max}$ = (26 x 1 x 1.03 x 1.16) = 30.96

$(l / d)_{provided}$ = 13.74

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 65.869565

The critical section for shear is at a distance of
364 mm from the face of the support.

- *Check for adequacy of section*

Nominal shear stress , τ_v

(65.8695652173913 x 1000 / (230 x 364)) 0.79 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\, fck$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- *Design shear resistance at critical section*

At critical section , A_{st} is given by 804 mm^2

Percentage of steel , p_t (%) 0.96

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.65 N/mm^2

⇒ V_{uc} = (0.65 x 230 x 364 / 1000) = 54 kN

- *Design of " vertical " stirrups*

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (66 - 54) = 12 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 364 / (11.81 x 1000))

⇒ Spacing , s_v = 280 mm

Check whether $\tau_v > 0.5\ \tau_c$

Nominal shear stress , τ_v (N/mm^2) 0.79
Design shear stress , τ_c (N/mm^2) 0.65

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy} \quad When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 230) =	395	mm
ii)	≤	(0.75 x 364) =	273	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 364 / (11.81 x 1000)) =	280	mm

Beam FRB1 Mid Span

Design Parameters

Load Case 13 [1.5*(DL - EQZ)]

Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	5.00
Breadth of the beam , b (mm)	230
Overall depth of the beam , D (mm)	400

Details of reinforcements

Diameter of tension reinforcement (mm)	12
Diameter of compression reinforcement (mm)	12
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(400-20-8-12/2) =	366

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	3	kN-m
Bending Moment Mu(kN-m)	40	
Equivalent Bending Moment , M_e (kNm)	45	
Shear force at critical distance , V_{ud} (kN)	20	
Equivalent Shear (kN)	41	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where $b =$ Breadth of the Section

$xu_{max} =$ Limiting depth of Neutral Axis

$d =$ Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2 fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415)

$M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 230 x 366^2 / 1000000) = 128.38 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 44.83 kNm

$M_{u,lim}$ = 128.38 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

  A_{st} = $A_{st,lim}$ + ΔA_{st}

  where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

  ⇒ $A_{st,lim}$ (1.433 / 100 x 230 x 366) = 1206 mm^2

- Assuming 12 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 12 / 2) = 34 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y\, (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 361 mm^2

∴ No of tension bars required (#)
(361 / (Pi / 4 x 12^2) = 4.00

Actual percentage of steel , p_t (%)
(4 x Pi / 4 x 12 ^2 / 230 / 366 x 100) = 0.54

Actual area of steel , A_{st} (mm^2)
(4 x Pi / 4 x 12 ^2) = 452

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\, f_y\, A_{st}}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y\, (p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d'/d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (34 / 366) = 0.093
  From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \left[\frac{0.87 f_y}{f_{sc} - 0.447 f_{ck}}\right]\left[p_t - p_{t,lim}\right]$$

Actual p_t provided : p_t = 0.54

Actual p_c provided : p_c = 0.94

⇒ p_c^* = (0.87 x 415 x (0.537 - 1.433) / (352.83 - 0.447 x 30))

⇒ p_c^* = -0.95

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} \times F_1 \times F_2$$

where

$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58 f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 509 / 452) = 271.00 N/mm²

F = 1.00

F_1 = 1.41

$F_2 =$ 1.24

∴ $(l / d)_{max} =$ (26 x 1 x 1.41 x 1.24) = 45.37

$(l / d)_{provided} =$ 13.66

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 40.8695652

The critical section for shear is at a distance of
366 mm from the face of the support.

- *Check for adequacy of section*

Nominal shear stress , τ_v

(40.8695652173913 x 1000 / (230 x 366)) 0.49 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\sqrt{fck}$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- *Design shear resistance at critical section*

At critical section , A_{st} is given by 452 mm^2

Percentage of steel , p_t (%) 0.54

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ $\tau_c =$ 0.51 N/mm^2

⇒ $V_{uc} =$ (0.51 x 230 x 366 / 1000) = 43 kN

- *Design of " vertical " stirrups*

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ $V_{us} =$ (41 - 43) = -2 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 366 / (-2.22 x 1000))

⇒ Spacing , s_v = 300 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 0.49

Design shear stress , τ_c (N/mm^2) 0.51

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d, 300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 230) =	395	mm
ii)	≤	(0.75 x 366) =	275	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 366 / (-2.22 x 1000)) =	300	mm

Beam FRB2 Support

Design Parameters

Load Case 11 [1.5*(DL + LL)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	5.00
Breadth of the beam , b (mm)	230
Overall depth of the beam , D (mm)	450

Details of reinforcements

Diameter of tension reinforcement (mm)	20
Diameter of compression reinforcement (mm)	20
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(450-20-8-20/2) =	412

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	100	
Equivalent Bending Moment , M_e (kNm)	100	
Shear force at critical distance , V_{ud} (kN)	85	
Equivalent Shear (kN)	85	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$\text{Mulim} = 0.362\text{fck} * \frac{\text{bxu}_{\text{max}}}{\text{d}} * 0.416\text{xu}_{\text{max}}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2 fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 230 x 412^2 / 1000000) = 162.68 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 100.00 kNm

$M_{u,lim}$ = 162.68 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' ($x_u = x_{u,max}$)

$A_{st} = A_{st,lim} + \Delta A_{st}$

where $A_{st,lim} = p_{t,lim} / 100 (b x d)$

⇒ $A_{st,lim}$ (1.433 / 100 x 230 x 412) = 1358 mm^2

- Assuming 20 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 20 / 2) = 38 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y \, (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 756 mm^2

∴ No of tension bars required (#)
(756 / (Pi / 4 x 20^2) = 3.00

Actual percentage of steel , p_t (%)
(3 x Pi / 4 x 20 ^2 / 230 / 412 x 100) = 0.99

Actual area of steel , A_{st} (mm^2)
(3 x Pi / 4 x 20 ^2) = 942

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\, f_y \, A_{st}}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y \, (p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d'/d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = x_{u,max}$, for d' / d = (38 / 412) = 0.092
  From the above table : by interpolation

Design Check

- To ensure $x_u \le x_{u,max}$, it suffices to establish $p_c \ge p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 0.99

Actual p_c provided : p_c = 0.66

⇒ p_c^* = (0.87 x 415 x (0.995 - 1.433) / (352.91 - 0.447 x 30))

⇒ p_c^* = -0.47

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} \times F_1 \times F_2$$

where

$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 894 / 942) = 228.26 N/mm^2

F = 1.00

F_1 = 1.05

F_2 = 1.13

∴ $(l/d)_{max}$ = (26 x 1 x 1.05 x 1.13) = 30.74

$(l/d)_{provided}$ = 12.14

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 85

The critical section for shear is at a distance of
412 mm from the face of the support.

- Check for adequacy of section

Nominal shear stress , τ_v

(85 x 1000 / (230 x 412)) = 0.90 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\sqrt{fck}$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- Design shear resistance at critical section

At critical section , A_{st} is given by 942 mm^2

Percentage of steel , p_t (%) 0.99

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.65 N/mm^2

⇒ V_{uc} = (0.65 x 230 x 412 / 1000) = 62 kN

- Design of " vertical " stirrups

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (85 - 62) = 23 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 412 / (22.99 x 1000))

⇒ Spacing , s_v = 280 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 0.90

Design shear stress , τ_c (N/mm^2) 0.65

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 230) =	395	mm
ii)	≤	(0.75 x 412) =	309	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 412 / (22.99 x 1000)) =	280	mm

Beam FRB2 Mid Span

Design Parameters

Load Case 11 [1.5*(DL + LL)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	5.00
Breadth of the beam , b (mm)	230
Overall depth of the beam , D (mm)	450

Details of reinforcements

Diameter of tension reinforcement (mm)	16
Diameter of compression reinforcement (mm)	16
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(450-20-8-16/2) =	414

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	80	
Equivalent Bending Moment , M_e (kNm)	80	
Shear force at critical distance , V_{ud} (kN)	55	
Equivalent Shear (kN)	55	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where $b =$ Breadth of the Section

$xu_{max} =$ Limiting depth of Neutral Axis

$d =$ Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

$$\text{Where } fck = \text{Charcteristic Compressive strength of concrete}$$

$$fy = \text{Charcteristic strength of steel}$$

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\,fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ $0.1389\ f_{ck}\ b\ d^2$

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 230 x 414^2 / 1000000) = 164.27 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If $M_u > M_{u,lim}$, the section has to be
i) get increased by depth or width (preferably depth)
ii) doubly reinforced

If $M_u < M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 80.00 kNm
$M_{u,lim}$ = 164.27 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' ($x_u = x_{u,max}$)

  $A_{st} = A_{st,lim} + \Delta A_{st}$

  where $A_{st,lim} = p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 230 x 414) = 1365 mm^2

- Assuming 16 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 16 / 2) = 36 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y\, (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 585 mm^2

∴ No of tension bars required (#)
(585 / (Pi / 4 x 16^2) = 4.00

Actual percentage of steel , p_t (%)
(4 x Pi / 4 x 16 ^2 / 230 / 414 x 100) = 0.84

Actual area of steel , A_{st} (mm^2)
(4 x Pi / 4 x 16 ^2) = 804

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\, f_y\, A_{st}}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y\, (p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d'/d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (36 / 414) = 0.087
  From the above table : by interpolation

Design Check

- To ensure $x_u \le x_{u,max}$, it suffices to establish $p_c \ge p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 0.84

Actual p_c provided : p_c = 0.84

⇒ p_c^* = (0.87 x 415 x (0.845 - 1.433) / (353.51 - 0.447 x 30))

⇒ p_c^* = -0.62

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1\, F_2$$

where

$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 747 / 804) = 223.60 N/mm^2

F = 1.00

F_1 = 1.19

F_2 = 1.21

∴ $(l / d)_{max}$ = (26 x 1 x 1.19 x 1.21) = 37.38

$(l / d)_{provided}$ = 12.08

⇒ <u>*Hence O.K.*</u>

<u>*Check for shear*</u>

Shear force at critical distance , V_{ud} (kN) 55

The critical section for shear is at a distance of
414 mm from the face of the support.

- <u>*Check for adequacy of section*</u>

Nominal shear stress , τ_v

(55 x 1000 / (230 x 414)) = 0.58 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\sqrt{fck}$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ <u>*Adopted section is adequate*</u>

- <u>*Design shear resistance at critical section*</u>

At critical section , A_{st} is given by 804 mm^2

Percentage of steel , p_t (%) 0.84

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1 + 5\beta} - 1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.61 N/mm^2

⇒ V_{uc} = (0.61 x 230 x 414 / 1000) = 58 kN

- <u>*Design of " vertical " stirrups*</u>

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (55 - 58) = -3 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 414 / (-3.48 x 1000))

⇒ Spacing , s_v = 300 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 0.58

Design shear stress , τ_c (N/mm^2) 0.61

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 230) =	395	mm
ii)	≤	(0.75 x 414) =	311	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 414 / (-3.48 x 1000)) =	300	mm

Beam FRB3 Support

Design Parameters

Load Case 15 [1.5*(DL - EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	5.00
Breadth of the beam , b (mm)	230
Overall depth of the beam , D (mm)	500

Details of reinforcements

Diameter of tension reinforcement (mm)	20
Diameter of compression reinforcement (mm)	20
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm) (500-20-8-20/2) = 462

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	140	
Equivalent Bending Moment , M_e (kNm)	140	
Shear force at critical distance , V_{ud} (kN)	75	
Equivalent Shear (kN)	75	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$\text{Mulim} = 0.362\text{fck} * \frac{\text{bxu}_{\text{max}}}{\text{d}} * 0.416\text{xu}_{\text{max}}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\,fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 230 x 462^2 / 1000000) = 204.57 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 140.00 kNm

$M_{u,lim}$ = 204.57 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

A_{st} = $A_{st,lim}$ + ΔA_{st}

where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 230 x 462) = 1523 mm^2

- Assuming 20 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 20 / 2) = 38 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\ f_y\ (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\ f_y\ \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 959 mm^2

∴ No of tension bars required (#)
(959 / (Pi / 4 x 20^2) = 4.00

Actual percentage of steel , p_t (%)
(4 x Pi / 4 x 20 ^2 / 230 / 462 x 100) = 1.18

Actual area of steel , A_{st} (mm^2)
(4 x Pi / 4 x 20 ^2) = 1257

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{(0.87\ f_y)(A_{st})}{f_{sc} - 0.447\ f_{ck}}$$

or

$$p_c = \frac{0.87\ f_y\ (p_t - p_{t,lim})}{f_{sc} - 0.447\ f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d' / d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (38 / 462) = 0.082
From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 1.18

Actual p_c provided : p_c = 0.59

⇒ p_c^* = (0.87 x 415 x (1.183 - 1.433) / (353.97 - 0.447 x 30))

⇒ p_c^* = -0.27

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} \times F_1 \times F_2$$

where

$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 1101 / 1257) = 210.89 N/mm^2

F = 1.00

F_1 = 0.99

F_2 = 1.09

∴ $(l / d)_{max}$ = (26 x 1 x 0.99 x 1.09) = 28.14

$(l / d)_{provided}$ = 10.82

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 75

The critical section for shear is at a distance of
462 mm from the face of the support.

- **Check for adequacy of section**

Nominal shear stress , τ_v

(75 x 1000 / (230 x 462)) = 0.71 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\sqrt{fck}$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- **Design shear resistance at critical section**

At critical section , A_{st} is given by 1257 mm^2

Percentage of steel , p_t (%) 1.18

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.70 N/mm^2

⇒ V_{uc} = (0.7 x 230 x 462 / 1000) = 74 kN

- **Design of " vertical " stirrups**

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (75 - 74) = 1 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 462 / (0.74 x 1000))

⇒ Spacing , s_v = 180 mm

Check whether $\tau_v > 0.5\ \tau_c$

Nominal shear stress , τ_v (N/mm^2) 0.71
Design shear stress , τ_c (N/mm^2) 0.70

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 230) =	395	mm
ii)	≤	(0.75 x 462) =	347	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 462 / (0.74 x 1000)) =	180	mm

Beam FRB3 Mid Span

Design Parameters

Load Case 15 [1.5*(DL - EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	5.00
Breadth of the beam , b (mm)	230
Overall depth of the beam , D (mm)	450

Details of reinforcements

Diameter of tension reinforcement (mm)	16
Diameter of compression reinforcement (mm)	16
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(450-20-8-16/2) =	414

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	70	
Equivalent Bending Moment , M_e (kNm)	70	
Shear force at critical distance , V_{ud} (kN)	20	
Equivalent Shear (kN)	20	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where $b =$ Breadth of the Section

$xu_{max} =$ Limiting depth of Neutral Axis

$d =$ Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2 fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 230 x 414^2 / 1000000) = 164.27 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If $M_u > M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If $M_u < M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 70.00 kNm

$M_{u,lim}$ = 164.27 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' ($x_u = x_{u,max}$)

$A_{st} = A_{st,lim} + \Delta A_{st}$

where $A_{st,lim} = p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 230 x 414) = 1365 mm^2

- Assuming 16 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 16 / 2) = 36 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y \,(d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 505 mm^2

∴ No of tension bars required (#)
(505 / (Pi / 4 x 16^2) = 4.00

Actual percentage of steel , p_t (%)
(4 x Pi / 4 x 16 ^2 / 230 / 414 x 100) = 0.84

Actual area of steel , A_{st} (mm^2)
(4 x Pi / 4 x 16 ^2) = 804

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\, f_y \, A_{st}}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y \,(p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d' / d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (36 / 414) = 0.087
  From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\ f_y}{f_{sc} - 0.447\ f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 0.84

Actual p_c provided : p_c = 0.84

⇒ p_c^* = (0.87 x 415 x (0.845 - 1.433) / (353.51 - 0.447 x 30))

⇒ p_c^* = -0.62

<u>*Section is not over reinforced*</u>

<u>*Check for deflection control*</u>

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} \times F_1 \times F_2$$

where

$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\ f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 674 / 804) = 201.67 N/mm^2

F = 1.00

F_1 = 1.30

F_2 = 1.21

∴ $(l / d)_{max}$ = (26 x 1 x 1.3 x 1.21) = 40.82

$(l / d)_{provided}$ = 12.08

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 20

The critical section for shear is at a distance of 414 mm from the face of the support.

- **Check for adequacy of section**

Nominal shear stress , τ_v

(20 x 1000 / (230 x 414)) = 0.21 N/mm²

The maximum shear stress is given by : $$Tc\max = 0.62\,fck$$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm²

⇒ Adopted section is adequate

- **Design shear resistance at critical section**

At critical section , A_{st} is given by 804 mm²

Percentage of steel , p_t (%) 0.84

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89\, p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.61 N/mm²

⇒ V_{uc} = (0.61 x 230 x 414 / 1000) = 58 kN

- **Design of " vertical " stirrups**

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (20 - 58) = -38 kN

Using 8 mm bars and

No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 414 / (-38.48 x 1000))

⇒ Spacing , s_v = 300 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 0.21

Design shear stress , τ_c (N/mm^2) 0.61

$\tau_v > 0.5\ \tau_c$ *No*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d / 300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 230) =	395	mm
ii)	≤	(0.75 x 414) =	311	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 414 / (-38.48 x 1000)) =	300	mm

Beam FRB4 Support

Design Parameters

Load Case 11 [1.5*(DL+LL)]

Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	2.50
Breadth of the beam , b (mm)	230
Overall depth of the beam , D (mm)	300

Details of reinforcements

Diameter of tension reinforcement (mm)	16
Diameter of compression reinforcement (mm)	16
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(300-20-8-16/2) =	264

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	35	
Equivalent Bending Moment , M_e (kNm)	35	
Shear force at critical distance , V_{ud} (kN)	51	
Equivalent Shear (kN)	51	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$\text{Mulim} = 0.362\text{fck} * \frac{\text{bxu}_{\text{max}}}{\text{d}} * 0.416\text{xu}_{\text{max}}$$

$$\text{Where } b = \text{Breadth of the Section}$$

$$\text{xu}_{\text{max}} = \text{Limiting depth of Neutral Axis}$$

$$d = \text{Effective depth of the Section}$$

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\,fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415)

$M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 230 x 264^2 / 1000000) = 66.80 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 35.00 kNm

$M_{u,lim}$ = 66.80 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

A_{st} = $A_{st,lim}$ + ΔA_{st}

where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 230 x 264) = 870 mm^2

- Assuming 16 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 16 / 2) = 36 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y \,(d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 404 mm^2

$\therefore$ No of tension bars required (#)
(404 / (Pi / 4 x 16^2) = 3.00

Actual percentage of steel , p_t (%)
(3 x Pi / 4 x 16 ^2 / 230 / 264 x 100) = 0.99

Actual area of steel , A_{st} (mm^2)
(3 x Pi / 4 x 16 ^2) = 603

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{(0.87\, f_y)\,(A_{st})}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y\,(p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d'/d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (36 / 264) = 0.136
  From the above table : by interpolation

Design Check

- To ensure $x_u \le x_{u,max}$, it suffices to establish $p_c \ge p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 0.99

Actual p_c provided : p_c = 0.99

$\Rightarrow$ p_c^* = (0.87 x 415 x (0.993 - 1.433) / (345.43 - 0.447 x 30))

$\Rightarrow$ p_c^* = -0.48

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} \times F_1 \times F_2$$

where
$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

$\Rightarrow$ f_{st} = (0.58 x 415 x 484 / 603) = 193.09 N/mm^2

F = 1.00

F_1 = 1.19

F_2 = 1.25

∴ $(l/d)_{max}$ = (26 x 1 x 1.19 x 1.25) = 38.67

$(l/d)_{provided}$ = 9.47

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 51

The critical section for shear is at a distance of
264 mm from the face of the support.

- *Check for adequacy of section*

Nominal shear stress , τ_v

(51 x 1000 / (230 x 264)) = 0.84 N/mm²

The maximum shear stress is given by : $Tc\max = 0.62\, fck$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm²

⇒ Adopted section is adequate

- *Design shear resistance at critical section*

At critical section , A_{st} is given by 603 mm²

Percentage of steel , p_t (%) 0.99

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89\, p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.65 N/mm²

⇒ V_{uc} = (0.65 x 230 x 264 / 1000) = 40 kN

- *Design of " vertical " stirrups*

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (51 - 40) = 11 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 264 / (11.28 x 1000))

⇒ Spacing , s_v = 180 mm

Check whether $\tau_v > 0.5\ \tau_c$

Nominal shear stress , τ_v (N/mm^2)	0.84
Design shear stress , τ_c (N/mm^2)	0.65

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d / 300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 230) =	395	mm
ii)	≤	(0.75 x 264) =	198	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 264 / (11.28 x 1000)) =	180	mm

Beam FRB4 Mid Span

Design Parameters

Load Case 11 [1.5*(DL+LL)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	2.50
Breadth of the beam , b (mm)	230
Overall depth of the beam , D (mm)	300

Details of reinforcements

Diameter of tension reinforcement (mm)	16
Diameter of compression reinforcement (mm)	16
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(300-20-8-16/2) =	264

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	50	
Equivalent Bending Moment , M_e (kNm)	50	
Shear force at critical distance , V_{ud} (kN)	40	
Equivalent Shear (kN)	40	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\, fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ $0.1389\ f_{ck}\, b\, d^2$

$x_{u,max} / d =$ 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 230 x 264^2 / 1000000) = 66.80 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If $M_u > M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If $M_u < M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 50.00 kNm

$M_{u,lim}$ = 66.80 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' ($x_u = x_{u,max}$)

  $A_{st} = A_{st,lim} + \Delta A_{st}$

  where $A_{st,lim} = p_{t,lim} / 100\ (b \times d)$

  ⇒ $A_{st,lim}$ (1.433 / 100 x 230 x 264) = 870 mm^2

- Assuming 16 mm bars for compression steel,

  d' ≈ (20 mm clear cover + 8 mm stirrup + 16 / 2) = 36 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y \,(d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 609 mm^2

∴ No of tension bars required (#)
(609 / (Pi / 4 x 16^2) = 4.00

Actual percentage of steel , p_t (%)
(4 x Pi / 4 x 16 ^2 / 230 / 264 x 100) = 1.32

Actual area of steel , A_{st} (mm^2)
(4 x Pi / 4 x 16 ^2) = 804

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{(0.87\, f_y)\, (A_{st})}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y\, (p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d'/d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (36 / 264) = 0.136
  From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 1.32

Actual p_c provided : p_c = 0.66

⇒ p_c^* = (0.87 x 415 x (1.325 - 1.433) / (345.43 - 0.447 x 30))

⇒ p_c^* = -0.12

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1 F_2$$

where
$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 666 / 804) = 199.36 N/mm^2

F = 1.00

F_1 = 0.96

$F_2 =$ 1.13

∴ $(l / d)_{max} =$ (26 x 1 x 0.96 x 1.13) = 28.19

$(l / d)_{provided} =$ 9.47

⇒ *Hence O.K.*

Check for shear

Shear force at critical distance , V_{ud} (kN) 40

The critical section for shear is at a distance of
264 mm from the face of the support.

- *Check for adequacy of section*

Nominal shear stress , τ_v

(40 x 1000 / (230 x 264)) = 0.66 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\, fck$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ *Adopted section is adequate*

- *Design shear resistance at critical section*

At critical section , A_{st} is given by 804 mm^2

Percentage of steel , p_t (%) 1.32

The design shear strength of the concrete , τ_c , is given by :

τ_c = 0.85 … 0.8 f_{ck} … 1 … 5 … 1 / 6

where = $\frac{0.8 f_{ck}}{6.89 p_t}$ whichever is greater 1

For (M30 and Fe415)

⇒ τ_c = 0.73 N/mm^2

⇒ V_{uc} = (0.73 x 230 x 264 / 1000) = 44 kN

- *Design of " vertical " stirrups*

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (40 - 44) = -4 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

$\Rightarrow$ required spacing sv $\leq$ (0.87 x 415 x 101 x 264 / (-4.25 x 1000))

$\Rightarrow$ Spacing , s_v = 300 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 0.66

Design shear stress , τ_c (N/mm^2) 0.73

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d

300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 230) =	395	mm
ii)	$\leq$	(0.75 x 264) =	198	mm
iii)	$\leq$	300 mm	300	mm
iv)	$\leq$	(0.87 x 415 x 101 x 264 / (-4.25 x 1000)) =	300	mm

DESIGN OF ROOF BEAM (BUSBAY)

Beam RB1 Support

Design Parameters

Load Case 13 [1.5*(DL - EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	10.00
Breadth of the beam , b (mm)	300
Overall depth of the beam , D (mm)	750

Details of reinforcements

Diameter of tension reinforcement (mm)	25
Diameter of compression reinforcement (mm)	25
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(750-20-8-25/2) =	710

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	26	kN-m
Bending Moment Mu(kN-m)	300	
Equivalent Bending Moment , M_e (kNm)	354	
Shear force at critical distance , V_{ud} (kN)	175	
Equivalent Shear (kN)	314	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\ fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 300 x 709.5^2 / 1000000) = 629.29 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 353.53 kNm

$M_{u,lim}$ = 629.29 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

A_{st} = $A_{st,lim}$ + ΔA_{st}

where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 300 x 709.5) = 3050 mm^2

- Assuming 25 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 25 / 2) = 40.5 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y\, (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 1533 mm^2

∴ No of tension bars required (#)

(1533 / (Pi / 4 x 25^2) = 4.00

Actual percentage of steel , p_t (%)

(4 x Pi / 4 x 25 ^2 / 300 / 710 x 100) = 0.92

Actual area of steel , A_{st} (mm^2)

(4 x Pi / 4 x 25 ^2) = 1963

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\, f_y\, (A_{st} \ldots)}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y\, (p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d' / d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (40.5 / 709.5) = 0.057
  From the above table : by interpolation

Design Check

- To ensure $x_u \le x_{u,max}$, it suffices to establish $p_c \ge p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 0.92

Actual p_c provided : p_c = 0.69

⇒ p_c^* = (0.87 x 415 x (0.922 - 1.433) / (355.22 - 0.447 x 30))

⇒ p_c^* = -0.54

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1 F_2$$

where
$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 1909 / 1963) = 233.97 N/mm^2

F = 1.00

F_1 = 1.08

$F_2 =$ 1.14

$\therefore$ $(l / d)_{max} =$ (26 x 1 x 1.08 x 1.14) = 32.08

$(l / d)_{provided} =$ 14.09

$\Rightarrow$ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 313.66667

The critical section for shear is at a distance of
710 mm from the face of the support.

- Check for adequacy of section

Nominal shear stress , τ_v

(313.666666666667 x 1000 / (300 x 710)) 1.47 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62 fck$

$\Rightarrow$ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

$\Rightarrow$ Adopted section is adequate

- Design shear resistance at critical section

At critical section , A_{st} is given by 1963 mm^2

Percentage of steel , p_t (%) 0.92

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

$\Rightarrow$ $\tau_c =$ 0.64 N/mm^2

$\Rightarrow$ $V_{uc} =$ (0.64 x 300 x 710 / 1000) = 135 kN

- Design of " vertical " stirrups

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

$\Rightarrow$ $V_{us} =$ (314 - 135) = 178 kN

Using 10 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 157

⇒ required spacing sv ≤ (0.87 x 415 x 157 x 710 / (178.36 x 1000))

⇒ Spacing , s_v = 226 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 1.47

Design shear stress , τ_c (N/mm^2) 0.64

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 157 / 300) =	473	mm
ii)	≤	(0.75 x 709.5) =	532	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 157 x 710 / (178.36 x 1000)) =	226	mm

Beam RB1 Mid Span

Design Parameters

Load Case 13 [1.5*(DL - EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	10.00
Breadth of the beam , b (mm)	300
Overall depth of the beam , D (mm)	750

Details of reinforcements

Diameter of tension reinforcement (mm)	25
Diameter of compression reinforcement (mm)	25
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(750-20-8-25/2) =	710

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	26	kN-m
Bending Moment Mu(kN-m)	290	
Equivalent Bending Moment , M_e (kNm)	344	
Shear force at critical distance , V_{ud} (kN)	30	
Equivalent Shear (kN)	169	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with
width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\, fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 $f_{ck}\, b\, d^2$

$x_{u,max} / d =$ 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 300 x 709.5^2 / 1000000) = 629.29 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If $M_u > M_{u,lim}$, the section has to be
i) get increased by depth or width (preferably depth)
ii) doubly reinforced

If $M_u < M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 343.53 kNm
$M_{u,lim}$ = 629.29 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' ($x_u = x_{u,max}$)

  $A_{st} = A_{st,lim} + \Delta A_{st}$

  where $A_{st,lim} = p_{t,lim} / 100 (b \times d)$

⇒ $A_{st,lim}$ (1.433 / 100 x 300 x 709.5) = 3050 mm^2

- Assuming 25 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 25 / 2) = 40.5 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y \,(d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 1484 mm^2

∴ No of tension bars required (#)
(1484 / (Pi / 4 x 25^2) = 4.00

Actual percentage of steel , p_t (%)
(4 x Pi / 4 x 25 ^2 / 300 / 710 x 100) = 0.92

Actual area of steel , A_{st} (mm^2)
(4 x Pi / 4 x 25 ^2) = 1963

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\, f_y \,(A_{st} - A_{st,lim})}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y \,(p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d'/d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (40.5 / 709.5) = 0.057
  From the above table : by interpolation

Design Check

- To ensure $x_u \le x_{u,max}$, it suffices to establish $p_c \ge p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 0.92

Actual p_c provided : p_c = 0.69

⇒ p_c^* = (0.87 x 415 x (0.922 - 1.433) / (355.22 - 0.447 x 30))

⇒ p_c^* = -0.54

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1 F_2$$

where

$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 1867 / 1963) = 228.90 N/mm^2

F = 1.00

F_1 = 1.10

F_2 = 1.14

∴ $(l/d)_{max}$ = (26 x 1 x 1.1 x 1.14) = 32.65

$(l/d)_{provided}$ = 14.09

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 168.666667

The critical section for shear is at a distance of
710 mm from the face of the support.

- *Check for adequacy of section*

Nominal shear stress , τ_v

(168.666666666667 x 1000 / (300 x 710)) 0.79 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\, fck$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- *Design shear resistance at critical section*

At critical section , A_{st} is given by 1963 mm^2

Percentage of steel , p_t (%) 0.92

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.64 N/mm^2

⇒ V_{uc} = (0.64 x 300 x 710 / 1000) = 135 kN

- *Design of " vertical " stirrups*

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (169 - 135) = 33 kN

Using 10 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 157

⇒ required spacing sv ≤ (0.87 x 415 x 157 x 710 / (33.36 x 1000))

⇒ Spacing , s_v = 1206 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 0.79

Design shear stress , τ_c (N/mm^2) 0.64

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d / 300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 157 / 300) =	473	mm
ii)	≤	(0.75 x 709.5) =	532	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 157 x 710 / (33.36 x 1000)) =	1206	mm

Beam RB2 Support

Design Parameters

Load Case 13 [1.5*(DL - EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	10.00
Breadth of the beam , b (mm)	300
Overall depth of the beam , D (mm)	750

Details of reinforcements

Diameter of tension reinforcement (mm)	25
Diameter of compression reinforcement (mm)	25
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(750-20-8-25/2) =	710

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	29	kN-m
Bending Moment Mu(kN-m)	320	
Equivalent Bending Moment , M_e (kNm)	380	
Shear force at critical distance , V_{ud} (kN)	223	
Equivalent Shear (kN)	378	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$\text{Mulim} = 0.362\text{fck} * \frac{\text{bxu}_{\text{max}}}{\text{d}} * 0.416\text{xu}_{\text{max}}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\, fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415)

$M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 300 x 709.5^2 / 1000000) = 629.29 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be
- i) get increased by depth or width (preferably depth)
- ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 379.71 kNm

$M_{u,lim}$ = 629.29 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

A_{st} = $A_{st,lim}$ + ΔA_{st}

where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 300 x 709.5) = 3050 mm^2

- Assuming 25 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 25 / 2) = 40.5 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\ f_y\ (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\ f_y\ \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 1662 mm^2

∴ No of tension bars required (#)
(1662 / (Pi / 4 x 25^2) = 4.00

Actual percentage of steel , p_t (%)
(4 x Pi / 4 x 25 ^2 / 300 / 710 x 100) = 0.92

Actual area of steel , A_{st} (mm^2)
(4 x Pi / 4 x 25 ^2) = 1963

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\ f_y\ A_{st}}{f_{sc} - 0.447\ f_{ck}}$$

or

$$p_c = \frac{0.87\ f_y\ (p_t - p_{t,lim})}{f_{sc} - 0.447\ f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**$\frac{d'}{d}$**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (40.5 / 709.5) = 0.057
  From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \left(\frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}}\right)\left(p_t - p_{t,lim}\right)$$

Actual p_t provided : p_t	=	0.92
Actual p_c provided : p_c	=	0.69

⇒ p_c^* = (0.87 x 415 x (0.922 - 1.433) / (355.22 - 0.447 x 30))

⇒ p_c^* = -0.54

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1 F_2$$

where

$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 2017 / 1963) = 247.26 N/mm^2

F = 1.00

F_1 = 1.03

F_2 = 1.14

∴ $(l / d)_{max}$ = (26 x 1 x 1.03 x 1.14) = 30.67

$(l / d)_{provided}$ = 14.09

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 377.66667

The critical section for shear is at a distance of
710 mm from the face of the support.

- *Check for adequacy of section*

Nominal shear stress , τ_v

(377.666666666667 x 1000 / (300 x 710)) 1.77 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\, fck$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- *Design shear resistance at critical section*

At critical section , A_{st} is given by 1963 mm^2

Percentage of steel , p_t (%) 0.92

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.64 N/mm^2

⇒ V_{uc} = (0.64 x 300 x 710 / 1000) = 135 kN

- *Design of " vertical " stirrups*

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (378 - 135) = 242 kN

Using 10 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 157

⇒ required spacing sv ≤ (0.87 x 415 x 157 x 710 / (242.36 x 1000))

⇒ Spacing , s_v = 166 mm

Check whether $\tau_v > 0.5\ \tau_c$

Nominal shear stress , τ_v (N/mm^2) 1.77

Design shear stress , τ_c (N/mm^2) 0.64

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 157 / 300) =	473	mm
ii)	≤	(0.75 x 709.5) =	532	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 157 x 710 / (242.36 x 1000)) =	166	mm

Beam RB2 Mid Span

Design Parameters

Load Case 13 [1.5*(DL - EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	10.00
Breadth of the beam , b (mm)	300
Overall depth of the beam , D (mm)	750

Details of reinforcements

Diameter of tension reinforcement (mm)	25
Diameter of compression reinforcement (mm)	25
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(750-20-8-25/2) =	710

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	29	kN-m
Bending Moment Mu(kN-m)	332	
Equivalent Bending Moment , M_e (kNm)	392	
Shear force at critical distance , V_{ud} (kN)	50	
Equivalent Shear (kN)	205	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$\text{Mulim} = 0.362\text{fck} * \frac{\text{bxu}_{\text{max}}}{\text{d}} * 0.416\text{xu}_{\text{max}}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\,fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 300 x 709.5^2 / 1000000) = 629.29 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u =	391.71	kNm
$M_{u,lim}$ =	629.29	kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

  A_{st} = $A_{st,lim}$ + ΔA_{st}

  where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

  ⇒ $A_{st,lim}$ (1.433 / 100 x 300 x 709.5) = 3050 mm^2

- Assuming 25 mm bars for compression steel,

  d' ≈ (20 mm clear cover + 8 mm stirrup + 25 / 2) = 40.5 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y\, (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 1722 mm^2

∴ No of tension bars required (#)

(1722 / (Pi / 4 x 25^2) = 4.00

Actual percentage of steel , p_t (%)

(4 x Pi / 4 x 25 ^2 / 300 / 710 x 100) = 0.92

Actual area of steel , A_{st} (mm^2)

(4 x Pi / 4 x 25 ^2) = 1963

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\, f_y\, (A_{st})}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y\, (p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		d'/d		
	0.05	0.10	0.15	0.20
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (40.5 / 709.5) = 0.057
  From the above table : by interpolation

Design Check

- To ensure $x_u \le x_{u,max}$, it suffices to establish $p_c \ge p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 0.92

Actual p_c provided : p_c = 0.69

⇒ p_c^* = (0.87 x 415 x (0.922 - 1.433) / (355.22 - 0.447 x 30))

⇒ p_c^* = -0.54

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1 F_2$$

where

$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 2067 / 1963) = 253.35 N/mm^2

F = 1.00

F_1 = 1.01

$F_2 =$ 1.14

∴ $(l / d)_{max} =$ (26 x 1 x 1.01 x 1.14) = 30.06

$(l / d)_{provided} =$ 14.09

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 204.666667

The critical section for shear is at a distance of 710 mm from the face of the support.

- Check for adequacy of section

Nominal shear stress , τ_v

(204.666666666667 x 1000 / (300 x 710)) 0.96 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\sqrt{fck}$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- Design shear resistance at critical section

At critical section , A_{st} is given by 1963 mm^2

Percentage of steel , p_t (%) 0.92

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ $\tau_c =$ 0.64 N/mm^2

⇒ $V_{uc} =$ (0.64 x 300 x 710 / 1000) = 135 kN

- Design of " vertical " stirrups

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ $V_{us} =$ (205 - 135) = 69 kN

Using 10 mm bars and

No of legs 2

Area of stirrups , A_{sv} (mm^2) 157

⇒ required spacing sv ≤ (0.87 x 415 x 157 x 710 / (69.36 x 1000))

⇒ Spacing , s_v = 580 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 0.96

Design shear stress , τ_c (N/mm^2) 0.64

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 157 / 300) =	473	mm
ii)	≤	(0.75 x 709.5) =	532	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 157 x 710 / (69.36 x 1000)) =	580	mm

Beam RB3 Support

Design Parameters

Load Case 13 [1.5*(DL - EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	2.50
Breadth of the beam , b (mm)	300
Overall depth of the beam , D (mm)	750

Details of reinforcements

Diameter of tension reinforcement (mm)	25
Diameter of compression reinforcement (mm)	25
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(750-20-8-25/2) =	710

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	50	kN-m
Bending Moment Mu(kN-m)	100	
Equivalent Bending Moment , M_e (kNm)	203	
Shear force at critical distance , V_{ud} (kN)	72	
Equivalent Shear (kN)	339	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

$$\text{Where } b = \text{Breadth of the Section}$$

$$xu_{max} = \text{Limiting depth of Neutral Axis}$$

$$d = \text{Effective depth of the Section}$$

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\,fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 300 x 709.5^2 / 1000000) = 629.29 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 202.94 kNm

$M_{u,lim}$ = 629.29 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

  A_{st} = $A_{st,lim}$ + ΔA_{st}

  where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 300 x 709.5) = 3050 mm^2

- Assuming 25 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 25 / 2) = 40.5 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\ f_y\ (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\ f_y\ \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 838 mm^2

$\therefore$ No of tension bars required (#)

(838 / (Pi / 4 x 25^2) = 2.00

Actual percentage of steel , p_t (%)

(2 x Pi / 4 x 25 ^2 / 300 / 710 x 100) = 0.46

Actual area of steel , A_{st} (mm^2)

(2 x Pi / 4 x 25 ^2) = 982

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\ f_y\ (A_{st} - A_{st,lim})}{f_{sc} - 0.447\ f_{ck}}$$

or

$$p_c = \frac{0.87\ f_y\ (p_t - p_{t,lim})}{f_{sc} - 0.447\ f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		d'/d		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (40.5 / 709.5) = 0.057
  From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^{*}$

where p_c^* is given by

$$p_c^* = \left(\frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \right) \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 0.46

Actual p_c provided : p_c = 0.92

⇒ p_c^* = (0.87 x 415 x (0.461 - 1.433) / (355.22 - 0.447 x 30))

⇒ p_c^* = -1.03

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d} \right)_{max} = \left(\frac{l}{d} \right)_{basic} F_1 F_2$$

where $$\left(\frac{l}{d} \right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 1285 / 982) = 315.09 N/mm²

F = 1.00

F_1 = 1.32

F_2 = 1.23

∴ $(l / d)_{max}$ = (26 x 1 x 1.32 x 1.23) = 42.39

$(l / d)_{provided}$ = 3.52

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 338.66667

The critical section for shear is at a distance of
710 mm from the face of the support.

- Check for adequacy of section

Nominal shear stress , τ_v

(338.666666666667 x 1000 / (300 x 710)) 1.59 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\sqrt{fck}$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- Design shear resistance at critical section

At critical section , A_{st} is given by 982 mm^2

Percentage of steel , p_t (%) 0.46

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.48 N/mm^2

⇒ V_{uc} = (0.48 x 300 x 710 / 1000) = 102 kN

- Design of " vertical " stirrups

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (339 - 102) = 236 kN

Using 10 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 157

⇒ required spacing sv ≤ (0.87 x 415 x 157 x 710 / (236.45 x 1000))

⇒ Spacing , s_v = 170 mm

Check whether $\tau_v > 0.5\ \tau_c$

Nominal shear stress , τ_v (N/mm^2) 1.59
Design shear stress , τ_c (N/mm^2) 0.48

$\tau_v > 0.5\ \tau_c$ Yes

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_v □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 157 / 300) =	473	mm
ii)	≤	(0.75 x 709.5) =	532	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 157 x 710 / (236.45 x 1000)) =	170	mm

Beam RB4 Support

Design Parameters

Load Case 13 [1.5*(DL - EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	4.45
Breadth of the beam , b (mm)	250
Overall depth of the beam , D (mm)	400

Details of reinforcements

Diameter of tension reinforcement (mm)	25
Diameter of compression reinforcement (mm)	25
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(400-20-8-25/2) =	360

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	125	
Equivalent Bending Moment , M_e (kNm)	125	
Shear force at critical distance , V_{ud} (kN)	72	
Equivalent Shear (kN)	72	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\,fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415)

$M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 250 x 359.5^2 / 1000000) = 134.64 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 125.00 kNm

$M_{u,lim}$ = 134.64 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

A_{st} = $A_{st,lim}$ + ΔA_{st}

where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 250 x 359.5) = 1288 mm^2

- Assuming 25 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 25 / 2) = 40.5 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87 f_y (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87 f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 1176 mm^2

∴ No of tension bars required (#)

(1176 / (Pi / 4 x 25^2) = 3.00

Actual percentage of steel , p_t (%)

(3 x Pi / 4 x 25 ^2 / 250 / 360 x 100) = 1.64

Actual area of steel , A_{st} (mm^2)

(3 x Pi / 4 x 25 ^2) = 1473

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{(0.87 f_y) \times A_{st}}{f_{sc} - 0.447 f_{ck}}$$

or

$$p_c = \frac{0.87 f_y (p_t - p_{t,lim})}{f_{sc} - 0.447 f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d' / d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (40.5 / 359.5) = 0.113
  From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \left[\frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}}\right]\left[p_t - p_{t,lim}\right]$$

Actual p_t provided : p_t = 1.64

Actual p_c provided : p_c = 0.55

⇒ p_c^* = (0.87 x 415 x (1.639 - 1.433) / (349.95 - 0.447 x 30))

⇒ p_c^* = 0.22

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} \times F_1 \times F_2$$

where

$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 1204 / 1473) = 196.84 N/mm²

F = 1.00

F_1 = 0.86

$F_2 =$ 1.06

$\therefore$ $(l/d)_{max} =$ (26 x 1 x 0.86 x 1.06) = 23.70

$(l/d)_{provided} =$ 12.38

$\Rightarrow$ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 72

The critical section for shear is at a distance of
360 mm from the face of the support.

- *Check for adequacy of section*

Nominal shear stress , τ_v

(72 x 1000 / (250 x 360)) = 0.80 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\sqrt{fck}$

$\Rightarrow$ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

$\Rightarrow$ Adopted section is adequate

- *Design shear resistance at critical section*

At critical section , A_{st} is given by 1473 mm^2

Percentage of steel , p_t (%) 1.64

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

$\Rightarrow$ $\tau_c =$ 0.79 N/mm^2

$\Rightarrow$ $V_{uc} =$ (0.79 x 250 x 360 / 1000) = 71 kN

- *Design of " vertical " stirrups*

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

$\Rightarrow$ $V_{us} =$ (72 - 71) = 1 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 360 / (1.28 x 1000))

⇒ Spacing , s_v = 10171 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 0.80

Design shear stress , τ_c (N/mm^2) 0.79

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 250) =	363	mm
ii)	≤	(0.75 x 359.5) =	270	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 360 / (1.28 x 1000)) =	10171	mm

Beam RB4 Mid Span

Design Parameters

Load Case 13 [1.5*(DL - EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	4.45
Breadth of the beam , b (mm)	250
Overall depth of the beam , D (mm)	400

Details of reinforcements

Diameter of tension reinforcement (mm)	16
Diameter of compression reinforcement (mm)	16
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(400-20-8-16/2) =	364

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	0	kN-m
Bending Moment Mu(kN-m)	35	
Equivalent Bending Moment , M_e (kNm)	35	
Shear force at critical distance , V_{ud} (kN)	42	
Equivalent Shear (kN)	42	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\, fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 250 x 364^2 / 1000000) = 138.03 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If $M_u > M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If $M_u < M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 35.00 kNm

$M_{u,lim}$ = 138.03 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' ($x_u = x_{u,max}$)

  $A_{st} = A_{st,lim} + \Delta A_{st}$

  where $A_{st,lim} = p_{t,lim}$ / 100 (b x d)

  ⇒ $A_{st,lim}$ (1.433 / 100 x 250 x 364) = 1304 mm^2

- Assuming 16 mm bars for compression steel,

  d' ≈ (20 mm clear cover + 8 mm stirrup + 16 / 2) = 36 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y \, (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 278 mm^2

∴ No of tension bars required (#)
(278 / (Pi / 4 x 16^2) = 2.00

Actual percentage of steel , p_t (%)
(2 x Pi / 4 x 16 ^2 / 250 / 364 x 100) = 0.44

Actual area of steel , A_{st} (mm^2)
(2 x Pi / 4 x 16 ^2) = 402

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\, f_y \, A_{st}}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y \, (p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d' / d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (36 / 364) = 0.099
  From the above table : by interpolation

Design Check

- To ensure $x_u \le x_{u,max}$, it suffices to establish $p_c \ge p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t	=	0.44
Actual p_c provided : p_c	=	1.10

⇒ p_c^* = (0.87 x 415 x (0.442 - 1.433) / (352.05 - 0.447 x 30))

⇒ p_c^* = -1.06

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1 F_2$$

where
$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 434 / 402) = 259.84 N/mm^2

F = 1.00

F_1 = 1.81

F_2 = 1.28

∴ $(l/d)_{max}$ = (26 x 1 x 1.81 x 1.28) = 60.42

$(l/d)_{provided}$ = 12.23

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 42

The critical section for shear is at a distance of 364 mm from the face of the support.

- **Check for adequacy of section**

Nominal shear stress , τ_v

(42 x 1000 / (250 x 364)) = 0.46 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\, fck$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- **Design shear resistance at critical section**

At critical section , A_{st} is given by 402 mm^2

Percentage of steel , p_t (%) 0.44

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.47 N/mm^2

⇒ V_{uc} = (0.47 x 250 x 364 / 1000) = 43 kN

- **Design of " vertical " stirrups**

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (42 - 43) = -1 kN

Using 10 mm bars and

No of legs 2

Area of stirrups , A_{sv} (mm^2) 157

⇒ required spacing sv ≤ (0.87 x 415 x 157 x 364 / (-0.92 x 1000))

⇒ Spacing , s_v = -22402 mm

Check whether $\tau_v > 0.5\ \tau_c$

Nominal shear stress , τ_v (N/mm^2) 0.46
Design shear stress , τ_c (N/mm^2) 0.47

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 157 / 250) =	567	mm
ii)	≤	(0.75 x 364) =	273	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 157 x 364 / (-0.92 x 1000)) =	-22402	mm

Beam RB3 Support

Design Parameters

Load Case 13 [1.5*(DL - EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	2.50
Breadth of the beam , b (mm)	250
Overall depth of the beam , D (mm)	550

Details of reinforcements

Diameter of tension reinforcement (mm)	20
Diameter of compression reinforcement (mm)	20
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(550-20-8-20/2) =	512

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	7	kN-m
Bending Moment Mu(kN-m)	122	
Equivalent Bending Moment , M_e (kNm)	135	
Shear force at critical distance , V_{ud} (kN)	0	
Equivalent Shear (kN)	45	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$\text{Mulim} = 0.362\text{fck} * \frac{\text{bxu}_{\text{max}}}{\text{d}} * 0.416\text{xu}_{\text{max}}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\,fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 250 x 512^2 / 1000000) = 273.09 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 135.18 kNm

$M_{u,lim}$ = 273.09 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

A_{st} = $A_{st,lim}$ + ΔA_{st}

where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 250 x 512) = 1834 mm^2

- Assuming 20 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 20 / 2) = 38 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\, f_y\, (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\, f_y \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 800 mm^2

∴ No of tension bars required (#)

(800 / (Pi / 4 x 20^2) = 3.00

Actual percentage of steel , p_t (%)

(3 x Pi / 4 x 20 ^2 / 250 / 512 x 100) = 0.74

Actual area of steel , A_{st} (mm^2)

(3 x Pi / 4 x 20 ^2) = 942

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{(0.87\, f_y)(A_{st})}{f_{sc} - 0.447\, f_{ck}}$$

or

$$p_c = \frac{0.87\, f_y\, (p_t - p_{t,lim})}{f_{sc} - 0.447\, f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		$\frac{d'}{d}$		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (38 / 512) = 0.074
  From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87 f_y}{f_{sc} - 0.447 f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 0.74

Actual p_c provided : p_c = 0.74

⇒ p_c^* = (0.87 x 415 x (0.736 - 1.433) / (354.61 - 0.447 x 30))

⇒ p_c^* = -0.74

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} \times F_1 \times F_2$$

where

$$\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58 f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 1028 / 942) = 262.66 N/mm^2

F = 1.00

F_1 = 1.14

F_2 = 1.16

∴ $(l / d)_{max}$ = (26 x 1 x 1.14 x 1.16) = 34.44

$(l / d)_{provided}$ = 4.88

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 44.8

The critical section for shear is at a distance of 512 mm from the face of the support.

- Check for adequacy of section

Nominal shear stress , τ_v

(44.8 x 1000 / (250 x 512)) = 0.35 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\sqrt{fck}$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- Design shear resistance at critical section

At critical section , A_{st} is given by 942 mm^2

Percentage of steel , p_t (%) 0.74

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.58 N/mm^2

⇒ V_{uc} = (0.58 x 250 x 512 / 1000) = 74 kN

- Design of " vertical " stirrups

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (45 - 74) = -30 kN

Using 10 mm bars and

No of legs 2

Area of stirrups , A_{sv} (mm^2) 157

⇒ required spacing sv ≤ (0.87 x 415 x 157 x 512 / (-29.66 x 1000))

⇒ Spacing , s_v = -979 mm

Check whether τ_v > 0.5 τ_c

Nominal shear stress , τ_v (N/mm^2) 0.35

Design shear stress , τ_c (N/mm^2) 0.58

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy}\ When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 157 / 250) =	567	mm
ii)	≤	(0.75 x 512) =	384	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 157 x 512 / (-29.66 x 1000)) =	-979	mm

Beam RB6 Support

Design Parameters

Load Case 13 [1.5*(DL - EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	5.12
Breadth of the beam , b (mm)	250
Overall depth of the beam , D (mm)	500

Details of reinforcements

Diameter of tension reinforcement (mm)	20
Diameter of compression reinforcement (mm)	20
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(500-20-8-20/2) =	462

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	20	kN-m
Bending Moment Mu(kN-m)	97	
Equivalent Bending Moment , M_e (kNm)	132	
Shear force at critical distance , V_{ud} (kN)	36	
Equivalent Shear (kN)	164	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

Where fck = Charcteristic Compressive strength of concrete

fy = Charcteristic strength of steel

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} x \frac{Ast}{bd} x \frac{fck}{2\,fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 250 x 462^2 / 1000000) = 222.36 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 132.29 kNm

$M_{u,lim}$ = 222.36 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

  A_{st} = $A_{st,lim}$ + ΔA_{st}

  where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

⇒ $A_{st,lim}$ (1.433 / 100 x 250 x 462) = 1655 mm^2

- Assuming 20 mm bars for compression steel,

d' ≈ (20 mm clear cover + 8 mm stirrup + 20 / 2) = 38 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\ f_y\ (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\ f_y\ \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 887 mm^2

∴ No of tension bars required (#)

(887 / (Pi / 4 x 20^2) = 4.00

Actual percentage of steel , p_t (%)

(4 x Pi / 4 x 20 ^2 / 250 / 462 x 100) = 1.09

Actual area of steel , A_{st} (mm^2)

(4 x Pi / 4 x 20 ^2) = 1257

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{0.87\ f_y\ A_{st}}{f_{sc} - 0.447\ f_{ck}}$$

or

$$p_c = \frac{0.87\ f_y\ (p_t - p_{t,lim})}{f_{sc} - 0.447\ f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		**d'/d**		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (38 / 462) = 0.082
  From the above table : by interpolation

Design Check

- To ensure $x_u \le x_{u,max}$, it suffices to establish $p_c \ge p_c^*$

where p_c^* is given by

$$p_c^* = \left[\frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}}\right]\left[p_t - p_{t,lim}\right]$$

Actual p_t provided : p_t = 1.09

Actual p_c provided : p_c = 0.54

$\Rightarrow$ p_c^* = (0.87 x 415 x (1.088 - 1.433) / (353.97 - 0.447 x 30))

$\Rightarrow$ p_c^* = -0.37

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left[\frac{l}{d}\right]_{max} = \left[\frac{l}{d}\right]_{basic} F_1 F_2$$

where

$$\left[\frac{l}{d}\right]_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

$\Rightarrow$ f_{st} = (0.58 x 415 x 1067 / 1257) = 204.35 N/mm^2

F = 1.00

F_1 = 1.07

F_2 = 1.06

∴ $(l / d)_{max}$ = (26 x 1 x 1.07 x 1.06) = 29.53

$(l / d)_{provided}$ = 11.07

⇒ *Hence O.K.*

Check for shear

Shear force at critical distance , V_{ud} (kN) 164

The critical section for shear is at a distance of
462 mm from the face of the support.

- *Check for adequacy of section*

Nominal shear stress , τ_v

(164 x 1000 / (250 x 462)) = 1.42 N/mm²

The maximum shear stress is given by : $Tc\max = 0.62\, fck$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm²

⇒ *Adopted section is adequate*

- *Design shear resistance at critical section*

At critical section , A_{st} is given by 1257 mm²

Percentage of steel , p_t (%) 1.09

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.68 N/mm²

⇒ V_{uc} = (0.68 x 250 x 462 / 1000) = 78 kN

- *Design of " vertical " stirrups*

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (164 - 78) = 86 kN

Using 8 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 101

⇒ required spacing sv ≤ (0.87 x 415 x 101 x 462 / (85.78 x 1000))

⇒ Spacing , s_v = 195 mm

Check whether $\tau_v > 0.5\ \tau_c$

Nominal shear stress , τ_v (N/mm^2) 1.42

Design shear stress , τ_c (N/mm^2) 0.68

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy} \quad When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

$$s_V \ \square \ \begin{cases} 0.75\ d \\ 300\ mm \end{cases}$$

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 101 / 250) =	363	mm
ii)	≤	(0.75 x 462) =	347	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 101 x 462 / (85.78 x 1000)) =	195	mm

Beam RB6 Mid Span

Design Parameters

Load Case 13 [1.5*(DL - EQZ)]	
Grade of Concrete	**M30**
Grade of Steel	**Fe415**
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	**30**
Characteristic yield strength of steel , f_y (N/mm^2)	**415**
Unit weight of concrete , γ_c (kN/m^3)	**24**
Partial safety factor for concrete	**1.5**
Exposure condition	**Mild**
Nominal Cover to exposure condition(mm)	**20**

Dimensions of the beam

C/C Span of the beam , l , (m)	5.12
Breadth of the beam , b (mm)	250
Overall depth of the beam , D (mm)	500

Details of reinforcements

Diameter of tension reinforcement (mm)	20
Diameter of compression reinforcement (mm)	20
Diameter of stirrups (mm)	8

Effective depth

Effective depth , d (mm)	(500-20-8-20/2) =	462

Design Moment, Shear Force

The moments and shears given below are taken from the STAAD.Pro 2004 output file.
The partial factors of safety are already incorporated into the analysis.

Torsional Moment	36	kN-m
Bending Moment Mu(kN-m)	58	
Equivalent Bending Moment , M_e (kNm)	122	
Shear force at critical distance , V_{ud} (kN)	25	
Equivalent Shear (kN)	255	

Singly reinforced or doubly reinforced section ?

The *limiting moment of resistance* , $M_{u,lim}$ is given by

$$Mulim = 0.362fck * \frac{bxu_{max}}{d} * 0.416xu_{max}$$

Where b = Breadth of the Section

xu_{max} = Limiting depth of Neutral Axis

d = Effective depth of the Section

The limiting percentage of steel , $p_{t,lim}$ is given by

$$Pt_{lim} = 41.61 * \frac{fck}{fy} * \frac{xu_{max}}{d}$$

$$\text{Where } fck = \text{Charcteristic Compressive strength of concrete}$$

$$fy = \text{Charcteristic strength of steel}$$

The area of steel for a singly reinforced section with width , b and depth , d and ultimate moment , M_u is given by :

$$\frac{Pt}{100} \, x \, \frac{Ast}{bd} \, x \, \frac{fck}{2\, fy} = 4.598 \frac{R}{f_{ck}}$$

$$Where \quad R = \frac{Mu}{bd^2}$$

For (M30 and Fe415) $M_{u,lim}$ □ 0.1389 f_{ck} b d^2

$x_{u,max}$ / d = 0.48

⇒ $M_{u,lim}$ = (0.1389 x 30 x 250 x 462^2 / 1000000) = 222.36 kNm

⇒ $p_{t,lim}$ = (41.3 x 30 / 415 x 0.48) = 1.433

If M_u > $M_{u,lim}$, the section has to be

i) get increased by depth or width (preferably depth)

ii) doubly reinforced

If M_u < $M_{u,lim}$, the section can be designed as singly reinforced.

Check for the type of section

M_u = 121.53 kNm

$M_{u,lim}$ = 222.36 kNm

⇒ *Section can be designed as singly reinforced.*

Determining A_{st}

- Considering a ' balanced section ' (x_u = $x_{u,max}$)

  A_{st} = $A_{st,lim}$ + ΔA_{st}

  where $A_{st,lim}$ = $p_{t,lim}$ / 100 (b x d)

  ⇒ $A_{st,lim}$ (1.433 / 100 x 250 x 462) = 1655 mm^2

- Assuming 20 mm bars for compression steel,

  d' ≈ (20 mm clear cover + 8 mm stirrup + 20 / 2) = 38 mm

$$\therefore A_{st} = \frac{M_u - M_{u,lim}}{0.87\ f_y\ (d - d')}$$

$$\therefore \frac{p_t}{100} = \frac{R - R_{lim}}{0.87\ f_y\ \left(1 - \frac{d'}{d}\right)}$$

Mu = 0.87*fy**Ast*d(1-(Ast*fy)/b*d*fck)

Ast Reqd = 806 mm^2

∴ No of tension bars required (#)

(806 / (Pi / 4 x 20^2) = 4.00

Actual percentage of steel , p_t (%)

(4 x Pi / 4 x 20 ^2 / 250 / 462 x 100) = 1.09

Actual area of steel , A_{st} (mm^2)

(4 x Pi / 4 x 20 ^2) = 1257

Determining A_{sc}

The compression steel , A_{sc} , is given by

$$A_{sc} = \frac{(0.87\ f_y)\ (A_{st})}{f_{sc} - 0.447\ f_{ck}}$$

or

$$p_c = \frac{0.87\ f_y\ (p_t - p_{t,lim})}{f_{sc} - 0.447\ f_{ck}}$$

where f_{sc} is the stress in compression steel.

The values of f_{sc} (in MPa units) at $x_u = x_{u,max}$ for various d' / d ratios and different grades of compression steel are given in the table below.

Grade of steel		d'/d		
	0.05	**0.10**	**0.15**	**0.20**
Fe250	217.5	217.5	217.5	217.5
Fe415	355.1	351.9	342.4	329.2
Fe500	423.9	411.3	395.1	370.3

- Assuming $x_u = xu_{,max}$, for d' / d = (38 / 462) = 0.082
  From the above table : by interpolation

Design Check

- To ensure $x_u \leq x_{u,max}$, it suffices to establish $p_c \geq p_c^*$

where p_c^* is given by

$$p_c^* = \frac{0.87\, f_y}{f_{sc} - 0.447\, f_{ck}} \left(p_t - p_{t,lim} \right)$$

Actual p_t provided : p_t = 1.09

Actual p_c provided : p_c = 0.82

⇒ p_c^* = (0.87 x 415 x (1.088 - 1.433) / (353.97 - 0.447 x 30))

⇒ p_c^* = -0.37

Section is not over reinforced

Check for deflection control

For prismatic beams of rectangular sections and slabs of uniform thicknesses and spans upto 10m , the limiting l / d ratios are specified by the Code (Cl. 23.2.1) as :

$$\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} F_1\, F_2$$

where $\left(\frac{l}{d}\right)_{basic} = \begin{cases} 7 \text{ for cantilever spans} \\ 20 \text{ for simply supported spans} \\ 26 \text{ for continuous spans} \end{cases}$

For simply supported and continuous spans over 10 m, these ratios are multiplied by a factor F

$$F = \frac{10}{\text{span in metres}}$$

The modification factors F_1 (which varies with p_t and f_{st}) and F_2 (which varies with p_c) are as given in Fig .4 and Fig .5 of the code.

Code permits an approximate calculation of f_{st} as follows :

The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

⇒ f_{st} = (0.58 x 415 x 997 / 1257) = 190.88 N/mm^2

F = 1.00

F_1 = 1.12

F_2 = 1.20

∴ (l / d)$_{max}$ = (26 x 1 x 1.12 x 1.2) = 34.87

(l / d)$_{provided}$ = 11.07

⇒ Hence O.K.

Check for shear

Shear force at critical distance , V_{ud} (kN) 255.4

The critical section for shear is at a distance of
462 mm from the face of the support.

- **Check for adequacy of section**

Nominal shear stress , τ_v

(255.4 x 1000 / (250 x 462)) = 2.21 N/mm^2

The maximum shear stress is given by : $Tc\max = 0.62\sqrt{fck}$

⇒ $\tau_{c,max}$ (0.62 x Sqrt (30)) = 3.40 N/mm^2

⇒ Adopted section is adequate

- **Design shear resistance at critical section**

At critical section , A_{st} is given by 1257 mm^2

Percentage of steel , p_t (%) 1.09

The design shear strength of the concrete , τ_c , is given by :

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\left(\sqrt{1+5\beta}-1\right)}{6\beta}$$

where $\beta = \frac{0.8 f_{ck}}{6.89 p_t}$ or 1 whichever is greater

For (M30 and Fe415)

⇒ τ_c = 0.68 N/mm^2

⇒ V_{uc} = (0.68 x 250 x 462 / 1000) = 78 kN

- **Design of " vertical " stirrups**

The shear to be resisted by steel , V_{us} is given by : $V_{us} = V_u - V_{uc}$

⇒ V_{us} = (255 - 78) = 177 kN

Using 10 mm bars and
No of legs 2

Area of stirrups , A_{sv} (mm^2) 157

⇒ required spacing sv ≤ (0.87 x 415 x 157 x 462 / (177.18 x 1000))

⇒ Spacing , s_v = 148 mm

Check whether τ_v *> 0.5* τ_c

Nominal shear stress , τ_v (N/mm^2) 2.21

Design shear stress , τ_c (N/mm^2) 0.68

$\tau_v > 0.5\ \tau_c$ *Yes*

The Code (Cl. 26.5.1.6) specifies a minimum shear reinforcement to be provided in the form of stirrups in all beams where the calculated nominal shear stress τ_v exceeds 0.5 τ_c. :

$$\frac{A_{sv}}{b_{sv}} = \frac{0.4}{0.87\ fy} \quad When\ sv = 0.5tc$$

$$sv = \frac{2.175\ fyA_{sv}}{b}$$

The maximum spacing of stirrups should also comply with the requirements mentioned above. For normal " vertical " stirrups, the requirement is

s_V □ 0.75 d
300 mm

Code requirements for maximum spacing..

i)	<	(2.175 x 415 x 157 / 250) =	567	mm
ii)	≤	(0.75 x 462) =	347	mm
iii)	≤	300 mm	300	mm
iv)	≤	(0.87 x 415 x 157 x 462 / (177.18 x 1000)) =	148	mm

DESIGN OF SLAB

Design of Slab

Grade of concrete	=	30	KN/m^2
Grade of steel	=	415	N/mm^2
Live Load	=	3	kN/m2
Cover	=	20	mm

L_y 4.45 m

L_x 4 m

Breadth of slab = 1000 mm

L_y/L_x 1.11

Design as a Twoway Slab

Depth of the Slab

Depth	=	125	mm
Effective Depth	=	125	mm
Overall Depth	=	150	mm

Effective Span = 4.23

Loads

Self weight	=	3.75	kN/m2
Live Load	=	3	kN/m2
Floor Finish	=	0.6	kN/m2
Service Load	=	7.35	kN/m2
Design Load	=	11.03	kN/m2

Design moments in the x and y directions

α_x+ 0.066

α_y+ 0.056

α_x-

α_y-

INTERPOLATION

1.2	1.11	1.3
0.072	**0.066**	0.079

M_x	=	13.00	KN-m
M_y	=	11.05	KN-m
Vux	=	23.32	KN

Check for depth

d = 56.03 mm d = 130 mm

Total depth = 76.03 mm

Reinforcement (short and long span)

		Shorter span		Longer span	
a	=	4.99		4.99	
b	=	46936.50		46936.50	
c	=	12995110.03		11047076.46	
b^2-4ac	=	1943417425		1982335434	
2a	=	9.99		9.99	
SQ	=	44084.21		44523.43	
Ast_1	=	285.54	mm^2	241.57	mm^2
Ast_2	=	-9112.04853	mm^2	-9156.018408	

Reinforcement in Shorter Direction

spacing of	10	mm	=	275	mm c/c
spacing of	12	mm	=	396	mm c/c
Provide	12	mm bars at		150	mm c/c

Reinforcement in Longer Direction

spacing of	10	mm	=	325	mm c/c
spacing of	12	mm	=	468	mm c/c
Provide	12	mm bars at		150	mm c/c

Check for shear stress

Considering the short span & unit width of slab

ζv	=	Vu / bd	
	=	0.1794	N/mm^2
Pt	=	0.220	

INTERPOLATION

0.5	0.22	0.75	Table19
0.48	**0.390**	0.56	

ζc = 0.390 N/mm^2

ζc > ζv Shear reinforcement is not reqd

Check for deflection Control

Modification Factor From IS 456

K = 1.2

Design of Slab

Grade of concrete	=	30	KN/m^2
Grade of steel	=	415	N/mm^2
Live Load	=	3	kN/m2
Cover	=	20	mm

L_y 5 m

L_x 2.5 m

Breadth of slab	=	1000	mm

L_y/L_x 2.00

Design as a Oneway Slab

Depth of the Slab

Depth	=	78.125	mm
Effective Depth	=	78.125	mm
Overall Depth	=	103.125	mm

Effective Span	=	2.73

Loads

Self weight	=	2.578125	kN/m2
Live Load	=	3	kN/m2
Floor Finish	=	0.6	kN/m2
Service Load	=	6.178125	kN/m2
Design Load	=	9.27	kN/m2

Design moments in the x and y directions

α_x+ 0.128

α_y+ 0.056

α_x-

α_y-

INTERPOLATION

1.2	2.00	1.3
0.072	**0.128**	0.079

M_x	=	8.84	KN-m				
M_y	=	3.87	KN-m				
Vux	=	12.65	KN				
Check for depth							
d	=	46.21	mm	d	=	100	mm
Total depth	=	66.21	mm				

Reinforcement (short and long span)

		Shorter span		Longer span	
a	=	4.99		4.99	
b	=	36105.00		36105.00	
c	=	8840629.98		3867775.62	
b^2-4ac	=	1126952035		1226300217	
2a	=	9.99		9.99	
SQ	=	33570.11		35018.57	
Ast_1	=	253.77	mm^2	108.76	mm^2
Ast_2	=	-6975.14841	mm^2	-7120.153528	

Reinforcement in Shorter Direction

spacing of	8	mm	=	198	mm c/c
spacing of	12	mm	=	446	mm c/c
Provide	8	mm bars at		150	mm c/c

Reinforcement in Longer Direction

spacing of	8	mm	=	462	mm c/c
spacing of	12	mm	=	1040	mm c/c
Provide	8	mm bars at		150	mm c/c

Check for shear stress

Considering the short span & unit width of slab

ζv = Vu / bd

= 0.1265 N/mm^2

Pt = 0.254

INTERPOLATION

0.5	0.25	0.75	Table19
0.48	**0.401**	0.56	

ζc = 0.401 N/mm^2

ζc > ζv Shear reinforcement is not reqd

Check for deflection Control

Modification Factor From IS 456

K = 1.2

DESIGN OF STAIRCASE

Stair case Design

Span c / c	=	4.00	m
Rise (R)	=	0.15	m
Tread (T)	=	0.275	m
Going (G)	=	0.25	m
Breadth of Stair	=	1.5	m
Finishes	=	0.015	m
Live load	=	3	KN/m^2
Characteristic yield strength of steel , f_y (N/mm^2)	=	Fe415	
Grade of Steel	=	415	N/mm^2
Characteristic compressive strength of concrete , f_{ck} (N/mm^2)	=	M30	
Grade of Concrete	=	30	N/mm^2
Dia of main steel	=	20	mm
Dia of distribution steel	=	8	mm
Cover For Slab	=	15	mm

Solution

1 Thickness of waist slab = 0.1143 m

Total Thickness of waist slab w = 140 mm

d = (140 15 10

= 115 mm

2 Dead Load from Stair case Slab B

$$= \sqrt{G^2 - R^2}$$

= 0.314 m

3 Dead Load from Slab

B = 0.292 m

Dead load = 1/G[(WB+RT/2)25+(FT)23.5]

= 6.532 KN/m^2

4 Design Load

W = 1.5(DL+LL)

14.298 KN/m^2

5 Bending Moment

M = $Wl^2/10$

= 23 KN m

Moment capacity of Slab = 4.14bd2

Mu = 54.7515 KN m

Mu > M Hence Depth Provided is Satisfactory

6 **Area of Main Steel**

1. Determination of steel by Quadratic Equation

= 41520.8 4.9945 54.7515

= 25103

Ast Reqd = **1644** mm^2/m

2. Determination of steel by Lever arm from Lever arm factor

f1= 1.16Mu/fckbd^2

0.16008

z/d=La= 0.5+sqrt(0.25-f1)

0.800

z= La*d 91.98

Ast= M/0.87fyz

Ast Reqd **1649** mm^2/m

3. Determination of steel by Lever arm from neutral axis depth

x/d= 1.2-[1.2^2 - (6.6Mu)/fckbd^2]^0.5

0.473

z d(1 -0.42x/d)

92.18 mm

Ast M/0.87fyz

Ast Reqd **1645.2** mm^2/m

Percent of steel = 1.43

Steel for 1.5m Width = 2473 mm^2

No of bars reqd = 8

Pitch = 127 mm

Area of Steel Provided = = 2513 mm^2

Provide 20 mm bars @ 128 mm c/c

7 **Distribution Steel**

As = 168 mm^2/m

Pitch = 250 mm

Use 8mm dia bars at 250 mm c/c

8 **Check for Shear**

V = Wl/2

= 28.60 KN

v = 0.25 N/mm^2

ζc = 0.76 N/mm^3

ζc > v Shear Steel is not Reqd

BILL OF QUANTITIES

ARCHITECTURAL & STRUCTURAL WORKS						
Sl. No	**SOR Ref No**	**Description of Work**	**Unit**	**Quantity**	**Rate (Rs)**	**Amount (Rs)**
1.01	251a	Excavation in foundation in ordinary soil (loam, clay or sand) including lift upto 1.5m and lead upto 30m and including filling watering and ramming of excavated earth into the trenches or into the space between the building and the sides of the foundation trenches or into the plinth and removal and disposal of surplus earth as directed by engineer in charge upto a distance of 30m from the foundation trenches	cum	2,430.55	38.00	92,360.98
1.01a	254a	Extra for every additional 30m lead or part of 30m or for every additional 1.5m lift or part of 1.50m	cum	1,856.47	43.00	79,828.12
1.01b	254a	Extra for every additional 30m lead or part of 30m or for every additional 1.5m lift or part of 1.50m	cum	-	48.00	-
1.02	255a	Sand filling in plinth including supply of necessary quantity of sand from a distance not exceeding 8 km from the site of work and including watering, dressing etc labour and T&P etc required for the proper completion of the work, saplings of girth upto 30cm measured at a height of 1m above ground level and removal of rubbish upto a distance of 50m outside the periphery of area cleared	cum	11,867.27	220.00	2,610,798.31
1.03	2.27 CPWD	Supplying and filling in plinth with Jamuna sand under floors including, watering, ramming consolidating and dressing complete.	cum	1,180.00	331.65	391,347.00
1.04	4.11 CPWD	Providing and laying damp-proof course 50mm thick with cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone aggregate 20mm nominal size).	sqm	313.00	178.05	55,729.65
1.05	4.12 CPWD	Extra for providing and mixing water proofing material in cement concrete work @ 1 kg per 50kg of cement.	per 50 kg cement	100.00	27.45	2,745.00
1.06	281	Cement concrete with 40mm gauge approved stone ballast, coarse sand& cement in the proportion of 8:4:1 including supply of all materials , labour, tools & plants etc. required for proper completion of the work.	cum	443.00	2,500.00	1,107,500.00
1.07	5.33 CPWD	Providing and laying in position machine batched, machine mixed and machine vibrated design mix cement concrete of specified grade for reinforced cement concrete work including pumping of concrete to site of laying but excluding the cost of centering, shuttering, finishing and reinforcement. including Admixtures in recommended proportions as per IS 9103 to accelerate, retard setting of concrete, improve workability without impairing strength and durability as per direction of Engineer-in-charge. M-25 grade reinforced cement concrete by using 410kg. of cement per cum of concrete. All work up to floor V level.	cum	6,589.48	4,147.40	27,329,195.49
1.08	5.34.1 CPWD	Add or deduct for providing richer or leaner mixes respectively at all floor levels. Providing M-30 grade concrete by using 420kg of cement per cum of concrete instead of M-25 grade **B.M.C/ R.M.C..**	cum	6,589.48	54.55	359,455.95
		Total Carried Forward				**32,028,960.50**

BILL NO.1 - ARCHITECTURAL & STRUCTURAL WORKS (Contd..)						
Sl. No	**SOR Ref No**	**Description of Work**	**Unit**	**Quantity**	**Rate (Rs)**	**Amount (Rs)**
		Total Brought Forward				**32,028,960.50**
1.09	5.9.1 CPWD	Centering and shuttering including strutting, propping etc. and removal of form for : Foundations, footings, bases of columns, etc. for mass concrete.	sqm	709.25	119.25	84,578.54
1.10	5.9.6 CPWD	Centering and shuttering including strutting, propping etc. And removal of form for : Columns, Pillars, Piers, Abutments, Posts and Struts.	sqm	1,643.41	238.40	391,787.81
1.11	5.9.3 CPWD	Centering and shuttering including strutting, propping etc. and removal of form for : Suspended floors, roofs, landings, balconies and access platform.	sqm	33,010.00	187.35	6,184,423.50
1.12	5.9.5 CPWD	Centering and shuttering including strutting, propping etc. and removal of form for : Lintels, beams, plinth beams, girders, bressumers and cantilevers.	sqm	19,596.34	162.65	3,187,344.91
1.13	5.9.7 CPWD	Centering and shuttering including strutting, propping etc. and removal of form for : Stairs, (excluding landings) except spiral-staircases.	sqm	800.00	204.00	163,200.00
		Total Carried Forward				**42,040,295.26**

BILL NO.1 - ARCHITECTURAL & STRUCTURAL WORKS (Contd..)						
Sl. No	**SOR Ref No**	**Description of Work**	**Unit**	**Quantity**	**Rate (Rs)**	**Amount (Rs)**
		Total Brought Forward				**42,040,295.26**
1.14	504	M.S (Tor steel or Plain) in plain work such as RCC or R.B work including bending for proper shape and including supply of steel and its wastage, bends hooks and authorised overlapping shall be measured and including cost of binding wire.	MT	2,159.58	49,000.00	105,819,340.51
1.15		M-150 Brick work in 1:6 one cement and six fine sand mortar including necessary cutting and moulding of brick as required of one brick thick including supply of all materials labour tools and plant etc required for proper completion of the work.		.		
1.15a	303	In Foundation	cum	863.42	1,900.00	1,640,504.12
1.15b	310	Extra for Superstructure	cum	863.42	185.00	159,733.30
1.15c	310A	M-150 Brick work in 1:6 one cement and six fine sand mortar including necessary cutting and moulding of brick as required of half brick thick including supply of all materials labour tools and plant etc required for proper completion of the work for super structure	cum	19.00	2,125.00	40,375.00
1.16	13.7.2 CPWD	12 mm cement plaster finished with a floating coat of neat cement of mix :1:4 (1 cement: 4 fine sand)	sqm	3,754.00	97.90	367,516.60
1.17	13.8.2 CPWD	15 mm cement plaster on rough side of single or half brick wall finished with a floating coat of neat cement of mix : 1:4 (1 cement: 4 fine sand)	sqm	4,086.00	110.70	452,320.20
1.18	13.16 CPWD	Plastering with CM 1:3 mix (one cement and three sand) 6mm thick including cost, conveyance, labour charges etc. complete as per standard specification- for ceiling	sqm	13,418.47	62.15	833,957.94
1.19	13.48.1 CPWD	Finishing walls with Deluxe Multi surface paint system for interiors and exteriors using Primer as per manufacturers specifications :Two or more coats applied @ 1.25 ltr/10 sqm. over and including one coat of Special primer applied @ 0.75 ltr / 10 sqm.	sqm	7,839.83	62.25	488,029.29
1.20	13.37.1 CPWD	White washing with whiting to give an even shade - new work (three or more coats).. for ceiling including cost of materials and labour charges etc. complete as per standard specification	sqm	13,418.00	6.75	90,571.50
1.21	9.1.2 CPWD	Providing wood work in frames of doors, windows, clerestory windows and other frames, wrought framed and fixed in position : Sal wood	cum	2.54	30,511.95	77,347.79
		Total Carried Forward				**152,009,991.51**

BILL NO.1 - ARCHITECTURAL & STRUCTURAL WORKS (Contd..)						
Sl. No		**Description of Work**	**Unit**	**Quantity**	**Rate (Rs)**	**Amount (Rs)**
		Total Brought Forward				**152,009,991.51**
1.22	13.48.2 CPWD	Painting wood work with Deluxe Multi Surface Paint of required shade. Two or more coat applied @0.90 ltr/10 sqm over an under coat of primer applied @0.75 ltr/ 10 sqm of approved brand or manufacture	sqm	137.00	51.55	7,062.35
1.23	21.3.1 CPWD	Providing and fixing glazing in aluminium door, window, ventilator shutters and partitions etc. with PVC/ neoprene gasket etc. complete as per the architectural drawings and the directions of engineer-in-charge . (Cost of aluminium snap beading shall be paid in basic item): With float glass panes of 4.0 mm thickness	sqm	117.00	554.95	64,929.15
1.24	21.1.1.1 CPWD	Providing and fixing aluminium work for doors, windows, ventilators and partitions with extruded built up standard tubular sections/ appropriate Z sections and other sections of approved make conforming to IS: 733 and IS : 1285, fixed with rawl plugs and screws or with fixing clips, or with expansion hold fasteners including necessary filling up of gaps at junctions, at top, bottom and sides with required PVC/neoprene felt etc. Aluminium sections shall be smooth, rust free, straight, mitred and jointed mechanically wherever required including cleat angle, Aluminium snap beading for glazing / paneling, C.P. brass / stainless steel screws, all complete as per architectural drawings and the directions of Engineer-in-charge. (Glazing and paneling to be paid for separately) : For fixed portion Anodised aluminium (anodised transparent or dyed to required shade according to IS: 1868, Minimum anodic coating of grade AC 15)	Kg	594.00	290.45	172,527.30
1.25	9.48.2 CPWD	Providing and fixing M.S. grills of required pattern in frames of windows etc. with M.S. flats, square or round bars etc. all complete.Fixed to openings /wooden frames with rawl plugs screws etc.	Kg	3,500.00	64.40	225,400.00
1.26	13.48.3 CPWD	Painting Steel work with Deluxe Multi Surface Paint to give an even shade. Two or more coat applied @0.90 ltr/10 sqm over an under coat of primer applied @ 0.80 ltr/ 10 sqm of approved brand or manufacture	Sqm	60.00	53.35	3,201.00
		Total Carried Forward				**152,483,111.31**

BILL NO.1 - ARCHITECTURAL & STRUCTURAL WORKS (Contd..)						
Sl. No	SOR Ref No	Description of Work	Unit	Quantity	Rate (Rs)	Amount (Rs)
		Total Brought Forward				**152,483,111.31**
1.27	11.9.5 CPWD	40 mm thick marble chips flooring rubbed and polished to granolithic finish, under layer 34 mm thick cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone aggregate 12.5mm nominal size) and top layer 6mm thick with white, black, chocolate, grey, yellow or green marble chips of sizes from 1mm to 4mm nominal size laid in cement marble powder mix 3:1 (3 cement : 1 marble powder) by weight in proportion of 4:7 (4 cement marble powder mix : 7 marble chips) by volume including cement slurry etc. complete : Light shade pigment with ordinary cement.	sqm	13,435.00	313.35	4,209,857.25
1.28	16.64 CPWD	Providing and laying 75mm thick compacted bed of dry brick aggregate of 40mm thick nominal size including spreading, well ramming, consolidating and grouting with jamuna sand including finishing smooth etc. complete as per direction of Engineer-in-charge.	sqm	11,789.00	63.15	744,475.35
1.29	7.1 CPWD	Random rubble masonry with hard stone in foundation and plinth including levelling up with cement concrete 1:6:12 (1 cement : 6 coarse sand : 12 graded stone aggregate 20mm nominal size) at plinth level with : Cement mortar 1:6 (1 cement : 6 coarse sand)	cum	629.55	1,838.90	1,157,686.12
1.30	9.6.1 CPWD	Providing and fixing 35 mm thick factory made laminated veneer lumber door shutter conforming to IS : 14616 and TADS 15:2001 (Part B) including ISI marked black enameled M.S. butt hinges with necessary screws as per directions of Engineer-in-charge and panelling with panels of: 12mm thick plain grade - 1, medium density flat pressed three layer particle board FPT - I or graded wood particle board FPT - I IS : 3087 marked bonded with BWP type synthetic resin adhesive as per IS : 848 :	sqm	136.50	1,877.20	256,237.80
1.31	12.15 CPWD	Painting top of roofs with bitumen of approved quality at 17kg per 10 sqm impregnated with a coat of coarse sand at 60 cudm per 10sqm including cleaning the slab surface with brushes and finally with a piece of cloth lightly soaked in kerosene oil complete : With residual type petroleum bitumen of penetration 80/100	sqm	9,622.00	63.00	606,186.00
1.32	5.9.13 CPWD	Centering and shuttering including strutting, propping etc. and removal of form for :Vertical and horizontal fins individually or forming box louvers band, facias and eaves boards.	sqm	956.00	285.55	272,985.80
1.33	5.8 CPWD	Reinforced cement concrete work in vertical and horizontal fins individually or forming box louvers, facias and eaves boards up to floor five level excluding the cost of centering, shuttering, finishing and reinforcement with 1:1½:3 (1 cement : 1½ coarse sand : 3 graded stone aggregate 20mm nominal size).	cum	143.40	3,928.75	563,382.75
1.34	10.6.1 CPWD	Rolling Shutters	sqm	153.60	1,208.45	185,617.92
		Total Carried to Page Collection				**160,479,540.00**

BILL NO.2 - PAVEMENT WORKS						
Sl.No	**SOR Ref No**	**Description of Item**	**Unit**	**Quantity**	**Rate (Rs)**	**Amount (Rs)**
2.01	3.3	Excavation for roadway in soil by mechanical means including cutting and pushing the earth to site of embankment upto a distance of 100 metres (average lead 50 metres) including trimming bottom and side slopes in accordance with requirements of lines, grades and cross sections.	cum			-
2.02	15.2.1	Demolishing cement concerte including disposal of material within 50 metres lead.-1:3:6 or richer mix.	cum			-
2.03	3.16	Construction of embankment with approved - r including all leads and lifts all complete as per drawings and Technical Specifications.	cum			-
2.04	3.18	Construction of sub grade and earthen shoulder satisfying the requirements of minimum soaked CBR value as indicated in the Specifications with approved material with all leads & lifts all complete as per Technical Specifications Clause 305.	cum	16,375.00	249.00	4,077,375.00
		Total Carried Forward				**4,077,375.00**

BILL NO.2 - PAVEMENT WORKS (Contd..)						
Sl.No		Description of Item	Unit	Quantity	Rate (Rs)	Amount (Rs)
		Total Brought Forward				**4,077,375.00**
2.05	6.1	Construction of dry lean cement concrete Sub-base over a prepared granular sub base with coarse and fine aggregate conforming to IS:383, the size of coarse aggregate not exceeding 25 mm, aggregate cement ratio not exceed 15:1, aggregate gradation after blending to be as per Table600-1, cement content not to be less than 150 kg/cum, optimum moisture content to be determined during trial length construction, concrete strength not to be less than 10 Mpa at 7 days, mixed in concrete mixer ,compacting with plate vibrator, finishing and curing.	cum	3,275.00	3,340.25	10,939,318.75
2.06	6.2	Construction of un-reinforced, dowel jointed, plain cement concrete pavement over a prepared sub-base with M 40 grade cement concrete, coarse and fine aggregate conforming to IS:383, maximum size of coarse aggregate not exceeding 25 mm, mixed in a concrete mixer as per approved mix design, laid with manually , compacted and finished in a continuous operation including provision of contraction, expansion, construction and longitudinal joints, joint filler, separation membrane, sealant primer, joint sealant, , dowel bar, tie rod, admixtures as approved, curing as per MoRT&H specifications Clause 601. finishing to lines and grades as per drawing.	cum	9,497.50	3,692.40	35,068,569.00
		Total Carried to Page Collection				**50,085,263.00**
		ABSTRACT ESTIMATE				
		Architectural and structural works				160,479,540.00
		Pavement Works				50,085,263.00
		Electrical Lighting and Related Works	LS			16,845,184.00
		Plumbing Works	LS			18,950,832.00
		Seating and Waiting arrangement				12,633,888.00
		Land Scaping				12,633,888.00
		Quality Control Charge @ 1%				2,105,648.00
		Advertisement Charges				500,000.00
		Contingencies @ 0.5%				1,052,824.00
		VAT added @ 2.8%				5,895,814.00
		Service Tax @ 2.08%				4,379,748.00
		Total Rs				**285,562,629.00**
		Total in Crores				**28.56**

DETAILED QUANTITY ESTIMATE

ARCHITECTURAL & STRUCTURAL WORKS

Item No	Code No.	Description	Dimensions					Unit	Total	Remarks	
			Nos	Length	Width	Depth	Area				
1.01	251a	Excavation						cum	**2,430.55**		
		Column Raft									
			4.00	1.70	1.70	1.50			17.34	F1	C1
			8.00	1.70	1.70	1.50			34.68	F1	C7
			26.00	1.70	1.70	1.50			112.71	F1	C9
			28.00	2.40	2.40	1.50			241.92	F2	C2
			34.00	3.10	3.10	1.50			490.11	F3	C3
			50.00	3.10	3.10	1.50			720.75	F3	C4
			22.00	2.40	2.40	1.50			190.08	F2	C6
			12.00	2.00	2.00	1.50			72.00	F4	C5
			6.00	2.70	2.50	1.50			60.75	F5	C6
			38.00	2.10	2.10	1.50			251.37	F7	C10
			2.00	5.30	2.30	1.50			36.57	CF1	C4,C4
			20.00	2.80	2.30	1.50			193.20	CF2	C8,C8
		Stair case footing	4.00	2.52	1.20	0.75			9.07		
		Total							**2,430.55**		
1.01a	254a	Extra for every additional lift of 1.5m or part thereof in - all kinds of soil							**1,856.47**		
			4.00	1.70	1.70	1.15			13.29	F1	C1
			8.00	1.70	1.70	1.15			26.59	F1	C7
			26.00	1.70	1.70	1.15			86.41	F1	C9
			28.00	2.40	2.40	1.15			185.47	F2	C2
			34.00	3.10	3.10	1.15			375.75	F3	C3
			50.00	3.10	3.10	1.15			552.58	F3	C4
			22.00	2.40	2.40	1.15			145.73	F2	C6
			12.00	2.00	2.00	1.15			55.20	F4	C5
			6.00	2.70	2.50	1.15			46.58	F5	C6
			38.00	2.10	2.10	1.15			192.72	F7	C10
			2.00	5.30	2.30	1.15			28.04	CF1	C4,C4
			20.00	2.80	2.30	1.15			148.12	CF2	C8,C8
		Total							**1,856.47**		
1.01b	254a	Extra for every additional lift of 1.5m or part thereof in - all kinds of soil							**-**		
		Total							**-**		
1.02	255a	Filling with good earth in plinth							**11,867.27**		
		For Admin block	1	32.50	35.20	0.75			858.00		
			1	30.55	7.50	0.75			171.84		
			1	30.40	29.90	0.75			681.72		
			1	14.95	38.21	0.75			428.43		
			1	60.00	34.20	0.75			1,539.00		
			1	14.85	38.23	0.75			425.82		
			1	30.40	29.90	0.75			681.61		
			1	30.55	7.50	0.75			171.84		
			1	32.50	35.20	0.75			858.00		
		Platform	1			1.50	4,034.00		6,051.00		
									11,867.27		
1.03	2.27 CPWD	River sand Filling						cum	**1,180.00**		
		For Admin block	1	32.50	35.20	0.10			114.40		
			1	30.55	7.50	0.10			22.91		
			1	30.40	29.90	0.10			90.90		
			1	14.95	38.21	0.10			57.12		
			1	60.00	34.20	0.10			205.20		

ARCHITECTURAL & STRUCTURAL WORKS

Item No	Code No.	Description	Dimensions					Unit	Total	Remarks	
			Nos	Length	Width	Depth	Area				
			1	14.85	38.23	0.10			56.78		
			1	30.40	29.90	0.10			90.88		
			1	30.55	7.50	0.10			22.91		
			1	32.50	35.20	0.10			114.40		
		Platform	1			0.10	4,034.00		403.40		
		Total							**1,178.90**		
1.04	4.11	Damp proof Course						sqm	**313.00**		
			2	96.65	0.45				86.99		
			2	74.75	0.45				67.28		
			2	55.30	0.45				49.77		
			1	37.74	0.45				16.98		
			2	30.55	1.50				91.65		
		Total							**313.00**		
1.05	4.12 CPWD	Water proofing material						per 50 kg cement	**100.00**		
			1				100.16		100.16		
		Total							**100.00**		
1.06	281	M15 Concrete for Building						cum	**443.00**		
		Column Raft	4.00	1.70	1.70	0.15			1.73	F1	C1
			8.00	1.70	1.70	0.15			3.47	F1	C7
			26.00	1.70	1.70	0.15			11.27	F1	C9
			28.00	2.40	2.40	0.15			24.19	F2	C2
			34.00	3.10	3.10	0.15			49.01	F3	C3
			50.00	3.10	3.10	0.15			72.08	F3	C4
			22.00	2.40	2.40	0.15			19.01	F2	C6
			12.00	2.00	2.00	0.15			7.20	F4	C5
			6.00	2.70	2.50	0.15			6.08	F5	C6
			38.00	2.10	2.10	0.15			25.14	F7	C10
			2.00	5.30	2.30	0.15			3.66	CF1	C4,C4
			20.00	2.80	2.30	0.15			19.32	CF2	C8,C8
		Below plinth beam									
		PB1	1.00	2,059.30	0.45	0.15			139.00		
		PB2	1.00	470.33	0.45	0.15			31.75		
		PB1A	1.00	317.33	0.45	0.15			21.42		
		PB1B	1.00	70.41	0.45	0.15			4.75		
		PB2A	1.00	32.54	0.45	0.15			2.20		
		Stair case footing	4.00	2.52	1.20	0.15			1.81		
		Total							**443.00**		
1.07	5.33 CPWD	M30 Concrete Building							**6,589.48**		
		RAFT	4.00	1.40	1.40	0.30			2.35	F1	C1
			8.00	1.40	1.40	0.30			4.70	F1	C7
			26.00	1.40	1.40	0.30			15.29	F1	C9
			28.00	2.10	2.10	0.20			24.70	F2	C2
			28.00			0.30	3.21		26.92		
			34.00	2.80	2.80	0.50			133.28	F3	C3
			34.00			0.50	4.92		83.64		
			50.00	2.80	2.80	0.50			196.00	F3	C4
			50.00			0.50	4.92		123.00		
			22.00	2.10	2.10	0.20			19.40	F2	C6
			22.00			0.30	3.06		20.16		
			12.00	1.70	1.70	0.35			12.14	F4	C5
			12.00			0.35			-		
			6.00	2.40	2.20	0.20			6.34	F5	C6

ARCHITECTURAL & STRUCTURAL WORKS

Item No	Code No.	Description	Dimensions					Unit	Total	Remarks	
			Nos	Length	Width	Depth	Area				
			6.00			0.35	3.64		7.64		
			38.00	1.80	1.80	0.35			43.09	F7	C10
			38.00			0.35			-		
			2.00	5.00	2.00	0.50			10.00	CF1	C4,C4
			20.00	2.50	2.00	0.20			20.00	CF2	C8,C8
			20.00			0.40	3.48		27.80		
		Stair case footing	4.00	2.52	1.05	0.28			2.91		
		Columns pedestal	4.00	1.00	1.00	0.75			3.00	F1	C1
			8.00	0.65	0.65	0.75			2.54	F1	C7
			26.00	0.70	0.55	0.75			7.51	F1	C9
			28.00	1.00	1.00	0.75			21.00	F2	C2
			34.00	1.00	1.00	0.75			25.50	F3	C3
			50.00	1.00	1.00	0.75			37.50	F3	C4
			22.00	0.85	0.85	0.75			11.92	F2	C6
			12.00	1.00	1.00	0.75			9.00	F4	C5
			6.00	1.00	1.00	0.75			4.50	F5	C6
			38.00	0.75	0.60	0.75			12.83	F7	C10
			4.00	1.00	1.00	0.75			3.00	CF1	C4,C4
			40.00	0.40	0.55	0.75			6.60	CF2	C8,C8
		Columns upto Plinth Level	4.00			2.95	0.385		4.54	F1	C1
			8.00	0.35	0.35	2.95	0.123		2.89	F1	C7
			26.00	0.40	0.25	2.95	0.100		7.67	F1	C9
			28.00			2.75	0.385		29.63	F2	C2
			34.00			1.50	0.385		19.63	F3	C3
			50.00			1.50	0.385		28.86	F3	C4
			22.00	0.55	0.65	2.00	0.358		15.73	F2	C6
			12.00			2.15	0.385		9.93	F4	C5
			6.00			1.90	0.385		4.39	F5	C6
			38.00	0.45	0.30	2.15	0.135		11.03	F7	C10
			4.00			2.00	0.358		2.87	CF1	C4,C4
			40.00	0.40	0.55	1.90	0.220		16.72	CF2	C8,C8
		Plinth Beam							-		
		PB1	1.00	2,059.30	0.25	0.65			334.64		
		PB2	1.00	470.33	0.25	0.45			52.91		
		PB1A	1.00	317.33	0.25	0.65			51.57		
		PB1B	1.00	70.41	0.25	0.65			11.44		
		PB2A	1.00	32.54	0.25	0.45			3.66		
									-		
		Columns upto Platform	4.00			5.00	0.385		7.70	F1	C1
			8.00	0.35	0.35	6.00	0.123		5.88	F1	C7
			26.00	0.40	0.25	6.00	0.100		15.60	F1	C9
			28.00			5.00	0.385		53.88	F2	C2
									-		
		Columns upto Atrium slab level									
			34.00			7.00	0.385		91.59	F3	C3
			50.00			6.00	0.385		115.45	F3	C4
			22.00			6.00	0.358		47.19	F2	C6
			12.00			4.00	0.385		18.47	F4	C5
			6.00			6.00	0.385		13.85	F5	C6
			38.00	0.45	0.30	6.00	0.135		30.78	F7	C10
			4.00			6.00	0.358		8.60	CF1	C4,C4
			40.00	0.40	0.55	6.00	0.220		52.80	CF2	C8,C8
		Ground Floor beam									
		B1 (Grid 1-22& I-F) @ 6.75	8.00	27.50	0.23	0.38			18.98		C1

ARCHITECTURAL & STRUCTURAL WORKS

Item No	Code No.	Description	Dimensions					Unit	Total	Remarks
			Nos	Length	Width	Depth	Area			
		Grid 4-10'& E-F @ 3.75 Lvl & Grid 13-19& E-F @ 3.75 Lv								
		GRB-1	1.00	120.00	0.23	0.33			18.22	
		GRB-2	1.00	105.00	0.23	0.38			18.35	
		GRB-3	1.00	149.67	0.23	0.38			26.16	
		GRB-3A	1.00	36.67	0.23	0.38			6.41	
		GRB-4	1.00	145.00	0.23	0.33			22.01	
		Grid 2-3 & P-Q @ 5.75 Lvl								
		FB1	1	10.00	0.30	0.65			3.90	
		FB2	1	10.00	0.30	0.65			3.90	
		FB2A	2.00	2.50	0.30	0.53			1.58	
		FB3	4.00	4.40	0.25	0.30			2.64	
		FB3A	2.00	1.90	0.25	0.25			0.48	
		First Floor								
		Grid 4-10'& E-F @ 6.75 Lvl & Grid 13-19& E-F @ 6.75 Lv								
		FRB-1	1.00	120.00	0.23	0.28			15.46	
		FRB-2	1.00	105.00	0.23	0.33			15.94	
		FRB-3	1.00	149.67	0.23	0.33			22.72	
		FRB-3A	1.00	36.67	0.23	0.33			5.57	
		FRB-4	1.00	145.00	0.23	0.28			18.68	
		Ground Floor Lintel beam								
		V (L1)	12.00	3.16	0.23	0.23			2.01	
		V (L2)	1.00	40.92	0.23	0.35			3.29	
		V1 (L3)	2.00	1.66	0.23	0.25			0.19	
		D1 (L4)	10.00	1.66	0.23	0.15			0.57	
		D2 (L5)	4.00	15.00	0.12	0.15			1.04	
		D (L2)	5.00	2.56	0.23	0.35			1.03	
		D3 (L4)	1.00	2.26	0.23	0.15			0.08	
		W (L6)	1.00	103.79	0.23	0.30			7.16	
		W1 (L7)	1.00	64.46	0.23	0.30			4.45	
		RS (L8)	1.00	85.00	0.23	0.40			7.82	
		First Floor Lintel beam								
		V (L1)	2.00	3.16	0.23	0.23			0.33	
		V (L2)	1.00	40.00	0.23	0.35			3.22	
		D (L3)	4.00	1.51	0.23	0.35			0.49	
		W (L4)	1.00	103.33	0.23	0.30			7.13	
		W1 (L5)	1.00	60.00	0.23	0.30			4.14	
		RS (L6)	1.00	30.00	0.23	0.15			1.04	
		Roof Slabs								
		B1 (Grid 1-22& I-F) @ 6.75 Lvl							-	
			1.00	215.00	27.50	0.35			2,069.38	
			1.00	20.00	2.50	0.35			17.50	
			44.00	3.50	3.50	0.40			53.90	
			44.00	3.50	1.75	0.40			26.95	
		Grid 4-10'& E-F @ 3.75 Lvl								
			1.00	60.00	10.00	0.12			144.00	
			1.00	30.00	4.33	0.12			31.20	
			1.00	15.00	4.00	0.12			14.40	
		Grid 4-10'& E-F @ 6.75 Lvl								
			1.00	60.00	10.00	0.12			144.00	
			1.00	30.00	4.33	0.12			31.20	
			1.00	15.00	4.00	0.12			14.40	
		Grid 10-13'& D-F @ 7.75								

ARCHITECTURAL & STRUCTURAL WORKS

Item No	Code No.	Description	Dimensions					Unit	Total	Remarks	
			Nos	Length	Width	Depth	Area				
			1.00	30.00	14.33	0.350			150.50		
			2	3.50	3.50	0.40			2.45		
			8	3.50	1.75	0.40			4.90		
		Grid 1-4& C'-F @ 7.75 Lvl									
			1.00	32.50	10.00	0.35			227.50		
			1.00	30.00	7.40	0.35			155.40		
			2.00	3.50	3.50	0.40			4.90		
			8.00	3.50	1.75	0.40			9.80		
		Grid 10b-12a & A-D @ 4.0m									
			1.00	21.61	15.50	0.35			117.21		
			2.00	3.50	3.50	0.40			2.45		
			8.00	3.50	1.75	0.40			4.90		
		Grid 19-22 & B-C' @ 4.0m									
			1.00	30.00	5.00	0.35			105.00		
			3.00	3.50	3.50	0.40			7.35		
		Grid 2-3 & I-Q @ 5.75m Lvl									
			1.00			0.40	88.36		17.67		
			1.00	15.00	70.00	0.35			735.00		
			14.00	3.50	3.50	0.40			34.30		
									-		
		Stair							30.00		
									-		
		Landing							-		
		Slab Ground floor							-		
		First Floor Slabs							-		
1.08	5.34.1 CPWD	Add or deduct for providing richer or leaner mixes							**6,589.48**		
		Shuttering Works									
1.09	5.14.1	For Foundation							**709.25**		
		RAFT FOUNDATION	4.00	5.60		0.30			6.72	F1	C1
			8.00	5.60		0.30			13.44	F1	C7
			26.00	5.60		0.30			43.68	F1	C9
			28.00	8.40		0.20			47.04	F2	C2
			34.00	11.20		0.50			190.40	F3	C3
			50.00	11.20		0.50			280.00	F3	C4
			22.00	8.40		0.20			36.96	F2	C6
			12.00	6.80		-			-	F4	C5
			6.00	9.20		0.60			33.12	F5	C6
			38.00	7.20		-			-	F7	C10
			2.00	14.04		0.50			14.04	CF1	C4,C4
			20.00	9.00		0.20			36.00	CF2	C8,C8
		Stair case footing	4.00	7.14		0.28			7.85		
1.10	5.14.6	For Columns & struts							**1,643.41**		
		Columns pedestal	4.00	4.00		0.75			12.00		

ARCHITECTURAL & STRUCTURAL WORKS

Item No	Code No.	Description	Dimensions					Unit	Total	Remarks	
			Nos	Length	Width	Depth	Area				
			8.00	2.60		0.75			15.60		
			26.00	2.50		0.75			48.75		
			28.00	4.00		0.75			84.00		
			34.00	4.00		0.75			102.00		
			50.00	4.00		0.75			150.00		
			22.00	3.40		0.75			56.10		
			12.00	4.00		0.75			36.00		
			6.00	4.00		0.75			18.00		
			38.00	2.70		0.75			76.95		
			4.00	4.00		0.75			12.00		
			40.00	1.90		0.75			57.00		
		Columns upto Plinth Level	4.00	2.20		2.95			25.95		
			8.00	1.40		2.95			33.04		
			26.00	1.30		2.95			99.71		
			28.00	2.20		2.75			169.33		
			34.00	2.20		1.50			112.15		
			50.00	2.20		1.50			164.93		
			22.00	1.73		2.00			76.03		
			12.00	2.20		2.15			56.74		
			6.00	2.20		1.90			25.07		
			38.00	1.50		2.15			122.55		
			4.00	2.20		2.00			17.59		
			40.00	1.90		1.90			144.40		
		Columns upto Platform	4.00	2.20		5.00			43.98		
			8.00	1.40		6.00			67.20		
			26.00	1.30		6.00			202.80		
			28.00	2.20		5.00			307.88		
		Columns upto Atrium slab level									
			34.00	2.20		7.00			523.39		
			50.00	2.20		6.00			659.73		
			22.00	1.73		6.00			228.08		
			12.00	2.20		4.00			105.56		
			6.00	2.20		6.00			79.17		
			38.00	1.50		6.00			342.00		
			4.00	2.20		6.00			52.78		
			40.00	1.90		6.00			456.00		
1.11	5.14.3	For Slabs							**33,010.00**		
									33,009.96		
1.12	5.14.5	For Lintels and Beams							**19,596.34**		
									19,596.34		
1.13	5.14.7	For Stairs and Ramps							**800.00**		
									800.00		
1.14	NPSR	HYSD Steel upto 16mm dia						MT	**2,159.58**		
		Foundation	50	Kg/cum					35.46		
		Columns	240	Kg/cum					71.71		

ARCHITECTURAL & STRUCTURAL WORKS

Item No	Code No.	Description	Dimensions					Unit	Total	Remarks	
			Nos	Length	Width	Depth	Area				
		Beams	230	Kg/cum					56.34		
		Slabs	480	Kg/cum					1,980.60		
		Stair	200	Kg/cum					4.00		
		Verttical Fins	80	Kg/cum					11.47		
1.15		Brick work in CM 1:5 mix							.		
1.15a	303	All Works Upto Plinth Level						cum	**863.42**		
		Ground Floor									
			2.00	117.18	3.00	0.23			161.70		
			1.00	149.98	3.00	0.23			103.49		
			2.00	234.61	3.00	0.23			323.75		
		Deduction for Doors							-		
		First Floor							-		
			2.00	163.62	3.00	0.23			225.79		
									-		
		Head Room	4.00	25.20	2.10	0.23			48.69		
		Deduction for Doors							-		
		Deduction for ventilators							-		
		Centre wall							-		
		Parapet G.F							-		
		Parapet F.F							-		
		Steps					0.02		-		
1.15b	310	Extra for brick work for							**863.42**		
		Qty as the BW of all works							863.42		
		Total							**863.42**		
1.15c	310A	Half Brick wall						Cum	**19.00**		
		Ground Floor									
			22.00	1.35	3.00	0.12			10.25		
			2.00	12.80	3.00	0.12			8.83		
									-		
									-		
									-		
		Total							**19.00**		
1.16	13.7.2	Plastering with CM 1:4 mix						Sqm	**3,754.00**		
		Ground Floor	2.00	117.18	3.00				703.05		
			1.00	149.98	3.00				449.94		
			2.00	234.61	3.00				1,407.63		
		First Floor	2.00	163.62	3.00				981.71		
			4.00	25.20	2.10				211.68		
									-		
									-		
		Deduction for Doors							-		
		Deduction for ventilators							-		
		Centre wall							-		

ARCHITECTURAL & STRUCTURAL WORKS

Item No	Code No.	Description	Dimensions					Unit	Total	Remarks	
			Nos	Length	Width	Depth	Area				
		Total							**3,754.00**		
1.17	13.8.2	Plastering with CM 1:4 mix						Sqm	**4,086.00**		
		Ground Floor	2.00	117.18	3.00				703.05		
			1.00	149.98	3.00				449.94		
			2.00	234.61	3.00				1,407.63		
		First Floor	2.00	163.62	3.00				981.71		
			4.00	25.20	2.10				211.68		
		For Half Brick Wall	44.00	1.35	3.00				178.20		
			4.00	12.80	3.00				153.60		
										long	wall
										short	wall
											wall
											wall
		Total							**4,086.00**		
1.18	13.16	1:3 Plastering for Ceiling							**13,418.47**		
		Ground Floor	1.00	32.50	35.20				1,144.00		
			1.00	30.55	7.50				229.13		
			1.00	30.40	29.90				908.96		
			1.00	14.95	38.21				571.24		
			1.00	60.00	34.20				2,052.00		
			1.00	14.85	38.23				567.76		
			1.00	30.40	29.90				908.81		
			1.00	30.55	7.50				229.13		
			1.00	32.50	35.20				1,144.00		
		Platform	1.00				4,034.00		4,034.00		
		First Floor									
			2.00	62.32	10.00				1,246.38		
			2.00	15.14	8.33				252.28		
			2.00	15.57	4.20				130.79		
		Total							**13,418.47**		
1.19		Two coats of acrylic emulision paint(Beige colour) interior							**7,839.83**		
		Ground Floor							5121.24		
									-		
		First Floor							2,718.59		
									-		
									-		
									-		
		Deduction for Doors							-		
		Deduction for ventilators							-		
		Centre wall							-		
		Total							**7,839.83**		

ARCHITECTURAL & STRUCTURAL WORKS

Item No	Code No.	Description	Dimensions					Unit	Total	Remarks
			Nos	Length	Width	Depth	Area			
1.20	13.37.1	Two coats of cement						Sqm	**13,418.00**	
									-	
		Same as plastering							13,418.47	
									-	
									-	
		Total							**13,419.00**	
1.21	9.1.2 CPWD	Supply and fixing of country wood frames						cum	**2.54**	
									-	
		Door	65.00	5.20	0.075	0.10			2.54	
									-	
									-	
									-	
		Ventilators							-	
1.22	13.48.2 CPWD	Painting on wodden works with 2 coats enamel Paint (Frames)						Sqm	**137.00**	
									-	
									-	
		Door	65.00	2.10	1.00				136.50	
									-	
									-	
		Total							**137.00**	
1.23	21.3.1 CPWD	Ventilators glazing						Sqm	**117.00**	
			36.00						116.64	
									-	
		Total							**117.00**	
1.24	21.1.1 CPWD	Aluminium Ventilators						Kg	**594.00**	
			36.00	1.00	1.00		16.50		594.00	
									-	
		Total							**594.00**	
1.25	9.48.2 CPWD	M.S Grills						Kg	**3,500.00**	
			1.00	100.00		1.00	35.0000		3,500.00	
									-	
		Total							**3500.00**	
1.26	13.48.3 CPWD	Painting steel work						Sqm	**60.00**	
			1.00	100.00	1.00	0.60			60.00	
									-	
		Total							**60.00**	
1.27	11.9.5	Granolithic flooring 50mm						sqm	**13,435.00**	
		Ground Floor	1.00	32.50	35.20				1,144.00	
			1.00	30.55	7.50				229.13	
			1.00	30.40	29.90				908.96	
			1.00	14.95	38.21				571.24	
			1.00	60.00	34.20				2,052.00	
			1.00	14.85	38.23				567.76	
			1.00	30.40	29.90				908.81	
			1.00	30.55	7.50				229.13	
			1.00	32.50	35.20				1,144.00	
		Platform	1.00				4,034.00		4,034.00	
		First floor	2.00				823.00		1,646.00	
		Total							**13,435.00**	
1.28	16.64 CPWD	40 mm brick Aggregates below 1:2:4 pcc Flooring						sqm	**11789.00**	

ARCHITECTURAL & STRUCTURAL WORKS

Item No	Code No.	Description	Dimensions					Unit	Total	Remarks	
			Nos	Length	Width	Depth	Area				
									11789.00		
		Total							11789.00		
1.29	7.1 CPWD	Random Rubble Masonry						cum	**629.55**		
									-		
									-		
			2.00	96.65			1.14		220.36		
			2.00	74.75			1.14		170.43		
			2.00	55.30			1.14		126.08		
			1.00	37.74			1.14		43.02		
			2.00	30.55			1.14		69.65		
									-		
									-		
		Total							**629.55**		
1.30	9.6.1 CPWD	Factory made panelled door shutters						Sqm	**136.50**		
									-		
									-		
		Door							136.50		
		Total							**136.50**		
1.31	12.15 CPWD	Painting top of roofs						Sqm	**9,622.00**		
									1,671.00		
									7,951.00		
		Total							**9,622.00**		
1.32	5.9.13 CPWD	Verical Fins						Sqm	**956.00**		
		For Handrail of ramps	4.00	100.00	1.00				400.00		
			1.00	556.00	1.00				556.00		
		Parapet wall at Ground floor							-		
									-		
									-		
		Parapet wall at first floor							-		
									-		
		Total							956.00		
1.33	5.8 CPWD	RCC work for Verical Fins						Cum	**143.40**		
			4.00	100.00	1.00	0.15			60.00		
			1.00	556.00	1.00	0.15			83.40		
									143.40		

Appendix 16: Outline specifications for development of Bus Terminal

1.1 Street furniture

Appropriate street furniture shall be provided wherever necessary within the site. The street furniture shall be designed so as to compliment the overall design concept of the Town Center. Materials used for the street furniture shall be durable, low on maintenance, corrosion resistant, resistant to aggressive environmental influences. The components of street furniture shall comprise, but not be limited to the following:

- Signage- direction, information, safety and facility signs (as per in compliance with IRC 67. IRC 30 & 31 standards)
- Benches
- Litterbins
- Railings and Guards
- Street Lights/Poles

1.2 Road Marking

Appropriate road marking shall be provided in the Project Site as per IRC: 67-1997.

1.3 Exterior Lighting

Appropriate exterior lighting, not only for aesthetics but also for functional requirements shall be provided and shall include illumination of car parks, walkways, access roads, both for visitors and for service, delivery and maintenance requirements. Street lighting shall be such that there are no shadow areas anywhere along the road/ walkways.

1.4 Landscaping

All open areas in the Project Site shall be landscaped appropriately. Landscaping shall be judiciously done so as to reduce surrounding noise, reduce vehicular pollution and enhance the overall aesthetics of the Project Site
.

1.5 External Cladding

Cladding shall be of such material that is low on maintenance, corrosion resistant, resistant to aggressive environmental influences, dimensionally stable, ecological (fully recyclable).

1.6 Safety Requirements

Shall be as per codes and standards. Exit facilities shall be designed so as to enable evacuation from the facility in not more than 2.5 minutes. Fire escape routes shall be enclosed by fire resistant construction.

1.7 Support facilities:

Facilities such as business centre, administration offices, public conveniences, fine dining etc shall be provided. Other facilities shall include:
First aid centre comprising a reception area, a treatment room, a small staff office and a disabled person's toilet.
Travel bureau and other shops: this could be a permanent unit in the public concourse, together with a bank / ATM and retail outlets.

1.8 Site Development related specifications

- All development to be carried out within the ambit of the relevant bye-laws and development control norms.
- The Developer shall provide landscaping, internal roads and parking area within the site based on the Design Requirements stipulated in plan.
- Internal paving to be a combination of black top road, concrete-paving bocks, interlocking paving blocks, landscaped garden and green areas.
- Rain/storm water shall be drained with a network of RCC drains.
- Provisions of plumbing and sanitary facilities will be done in accordance with the best trade practices and applicable codes and byelaws. (National Building Code & Hand Book of Water Supply & Drainage SP: 35 (S&T) – 1987).

1.9 Parking Space

- All Project Facilities shall have adequate parking space for vehicles and minimum should be provided in accordance with the building bye laws and layout plans.
- The parking space would be designed factoring the current capacity of the Project Facility and adequately providing for future increase in capacity.
- Parking space shall be in compliance with Applicable bye Law.

1.10 Water Supply, Drainage, Sewer and sanitation aspects

- The main **water supply system** for the Project site shall be part of the project development activity.
- Water quality should be as per Indian Standards for drinking Water (IS: 10500)
- The following systems shall be provided for, in accordance with the prevalent Good Industry Practices:
  Rainwater management System
  Storm Water Drainage Systems
  Sewage Disposal System
  Solid Waste Disposal System

1.11 Environment Management Plan (EMP)

- Measures to mitigate impacts during the Construction phase.
- Measures to mitigate impacts during the Operation Phase.

Securing Environment Clearances to conform with the laws pertaining to environment, health and safety aspects is essential requirement for the Developer.

1.12 Fire Safety System

- The Developer shall design, supply, erect, test, and commission the entire Fire Protection System (FPS) as per the requirements of National Building Code of India (NBC).
- It is the responsibility of the Developer to get the building and installed Fire Protection System inspected **and approved by the local Fire Service Officer**, or other Government and /or Local Authorities.
- Areas of public concentration including parks, open spaces, parking areas shall have an access to fire protection facilities and equipments.
- Fire Alarm System - The system shall be complete with detectors, manual call points, fire alarm panels, battery, etc and shall be in accordance with the National Building Code.
- Fire exit staircases as per best practice.
- Adequate information shall be displayed for fire safety within the Demised Plot.

1.13 Security Systems

- Provide **Emergency Evacuation Measures**: Provide self-luminescent markings where the backup power for the emergency lighting and exit signs is not of the self-contained battery pack type integral with the lighting and sign fitting.
- Provision of self luminescent markings along a staircase: The fire code requires emergency lighting and exit signs to be provided with standby power supply so that in the event of a break in the normal power supply, the standby power supply will kick in to make the escape facilities visible.
- All Security Measures should be in line with international standards and as per the applicable local law

1.14 Emergency Management Plan:

- In the light of the high density prospect of the proposed project configuration and the attendant high risk of fire and accidents, the Developer is to develop an Emergency Management Plan to the satisfaction of DOT
- The Emergency Response Protocol ("ERP") shall be developed by the Developer in consultation with the local police, hospital/ambulance services, fire departments and other authorities/support personnel and the **Project Engineer**
- Special emphasis has to be laid on the evacuation of a large number of people from terminal building
- Safety – The developer shall implement a Safety Management Programme in line with relevant guidelines (NBC & any other).

1.15 Building facilities requirements

a. Power Backup

- The Developer shall provide power back up to ensure operation of all Project Facilities. The developer will also make arrangements for 24-hour backup power for all facilities.

b. Minimum Amenities Requirements

- Public convenience facilities (the number of such utilities) within the project facilities to be provided as per norms.
- Minimum toilet block with all the facilities shall be provided on each floor as per the National Building Code. IS: 1172, IS: 2064 and IS: 2065 shall be followed for working out the basic requirements for water supply, drainage and sanitation.
- Separate Toilet & other facilities shall be designed physically handicapped persons and women.
- The sanitation requirements are to be worked out in accordance with the applicable Byelaws and are to be provided for each building based on the type of building

1.16 General specifications for Civil works

- RCC framed structure – RCC of grade M30 for footings, columns, retaining walls, roof beams & slabs
- External/ Internal walls with 200mm/ 150mm/ 100mm thick solid concrete block masonry in CM
- Internal surfaces plastered in CM 1:6 (lime rendered) and painted with oil bound distemper paint
- External surfaces plastered in CM 1:6 (sponge finished) and painted with water proof cement paint, textured paint where required as per elevation.
- Vitrified tiles for flooring/ skirting for common areas
- Vitrified tiles for flooring/ skirting/ dadoing for staircase/ lift lobby areas and common passages.
- Ceramic tiles for flooring/ skirting/ dadoing
- Kota stone slabs for flooring/ skirting to staircase steps
- Vacuum dewatered concrete flooring in basement with necessary shrinkage reinforcement.
- Aluminum powder coated sliding windows, glazed with 5mm clear float glass, necessary hardware fittings and MS grills/ guard bars enamel painted.
- Aluminum powder coated louvered ventilators and MS grills/ guard bars enamel painted.
- Weather proofing course by Crystallization method to Terraces, Toilets, Balconies etc.
- Parapet with granite coping on top, Lift/ Staircase, Headroom above, Elevation features (if any, as per drawing).
- Underground sump tank and RCC overhead water tank of sufficient capacity
- Landscaping works, Rainwater harvesting,
- All round compound wall with 150mm thick concrete hollow block masonry, plastered & painted
- Electrical works with good quality materials (necessary & minimum reqd. points inside), Transformer yard with fencing.
- Water supply and sanitary works with good quality materials

www.WilburSmith.com

WilburSmith
ASSOCIATES
#8, Second Floor, 80 Feet Road,
RT Nagar Bangalore Karnataka - 560 032. India
w +91.80. 3918.7500 f +91.80. 2363.4097