"Design and Analysis of Multilevel Car Parking In JUIT"

A PROJECT

Submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

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By

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT SOLAN – 173 234

HIMACHAL PRADESH, INDIA

June, 2016

Certificate

This is to certify that the work which is being presented in the project title **"Design and Analysis of Multilevel Car Parking"** in partial fulfilment of the requirements for the award of the degree of Bachelor of technology and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Siddharth Saxena (121661), Sulakshya Gaur (121684)** during a period from July 2015 to June 2016 under the supervision of Mr. Abhilash Shukla **(**Assistant Professor), Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

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Acknowledgement

We would like to express our gratitude and appreciation to all those who gave us the possibility to complete this report. A special thanks to our final year project Guide, Mr. Abhilash Shukla, whose help, stimulating suggestions and encouragement, helped us to coordinate my project especially in writing this report.

We also thank the Head of Department of Civil Engineering, Dr. Ashok Kumar Gupta for providing me opportunity to embark on this project.

We would like to appreciate the guidance given by our Laboratory Assistant, Mr. Itesh Kumar Singh, other supervisors, family members and friends.

At last we would like to acknowledge our panel members especially in our project presentation that has improved our presentation skills by their comment and tips.

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Abstract

This project is regarding the design of multilevel car parking facility. The facility designed is a G+3 reinforced concrete structure and appropriate foundation design is done of the structure. All the designs have been done according to Indian codes i.e. taking into account of IS 456:2000 for RCC design, IS 875:1987 (Part 1&2) for Dead and Live loads and their combination, IS 1893:2002 for taking into account earthquake load, and using BS:8007 for the design of slabs. Moreover, ramp is provided for assessing the upper storeys of the parking.

The foundation provided in the parking is of raft foundation as the soil has a low bearing capacity and the area to be covered is large. All the designs have been done in Staad pro and Staad foundation software and necessary checks are provided for determining the safety of the structure.

The required dimensions of beams, columns and slabs are also provided and necessary reinforcement is provided with proper detailing.

The parking facility is designed for approximately 200 four wheelers (cars). The necessary estimation of the vehicles was done in the college area during entire week and considering the further increase of the vehicles the capacity of parking was estimate.

Chapter 1

Introduction

1.1 Background

India’s urban population is currently around 30% of its total population. In context to urban transport system, the Central Business District’s are majorly facing the space issues in terms of open spaces, green spaces, and clear headways on roads, which lead to major inconvenience as well as delays in existing systems. Population of India’s six major metropolises increased by about 1.9 times during 1981 to 2001, the number of motor vehicles went up by over 7.75 times during the same period. Parking is one of the major concerns in terms of space occupation in these places. It can be broadly classified into two categories: On street , Off- street.

Present population of India has crossed the figure of 110 crore mark. It is said that India will overtake china in population chart in the year 2020.People of India nowadays are in every part of the world. As a result nowadays there is problem of parking, be it a two wheeler bike or a four wheeler car. On-street parking system has also failed to accommodate the vehicles of the city. This is where an effective system is needed for solving the problems of parking. One of such system which can be effectively used in solving the problem of parking is Multi Level Car Parking System.

India is a democratic country. People of different caste, creed, community etc. reside in all over the country. As a result present population of India has crossed the figure of 110 crore mark. It is said that India will overtake china in population chart in the year 2020. People of India nowadays are in every part of the world. The cities in India like Delhi, Bangalore, Ahmedabad etc have become population hubs. The reasons for attraction towards the city may be either of the following reasons i.e. searches for jobs, education, business etc. Industrial and commercial areas are the main areas where the cities heart lies. People working therein are in constant need of vehicles like bikes, cars etc. As a result nowadays there is problem of parking, be it a two wheeler bike or a four wheeler car. On-street parking system has also failed to accommodate the vehicles of the city. This is where an effective system is needed for solving the problems of parking. One of such system which can be effectively used in solving the problem of parking is Multi Level Car Parking System. Parking is one of the major problems that is created by the increasing road track. It is an impact of transport development. The availability of less space in urban areas has increased the demand for parking space especially in areas like Central Business District.

Multiple Level Car Parking- It is a building (or part there hereof) which is designed specifically to be for Automobile Parking and where there are a number of floors or levels on which parking takes place.

Is essentially a Stacked Car Park “Multilevel Car Park” – Term Originated in UK, in US it is called a “Parking Structure” Types

1. Manually operated (non mechanized-with ramps) 2. Mechanized (Classified in different type based on technology) • Mini • Puzzle • Tower In order to accommodate the large volume of vehicles, small cities and towns must develop their infrastructure. One solution may be a multi-level car parking system to maximize car parking capacity by utilizing vertical space, rather than expand horizontally. With land in metros and ‘a’ grade cities becoming scarce and dearer, and plots getting smaller, conventional parking is proving infeasible.

The Equivalent Car Space (ECS) that can be accommodated at the parking site would vary with the technology used. There are two basic technologies used for Multilevel Parking:

• Conventional type

• Automated type

Conventional multilevel -parking system can be underground, above found or both under and above ground structure, the above ground structures are usually Open-deck parking structures, which typically have at least two sides that are minimum 50 percent, open to the outside. The open parking structure is preferable to close parking structures for above ground, as it do not require mechanical ventilation and specialized fire protection system. The design of conventional multi-level parking includes:

• Entry and exit ramps and/or car lifts

• Aisle/circulation space between the vehicles.

• Car parking area.

System has been thought through to the last detail and is permanently being developed according to market and regulatory requirements. The system evolves to meet the requirements of modern car park construction. The standard, basic module is 16.00 m wide comprising two 5.00 m deep parking bays and a 6.00 m wide traffic lane. The parking bay width is 2.50 m, giving a bay size of 2.5m × 5m.

Chapter 2

Literature Review

1.Vertical Car Parking – A Prototype[1]

Sawankumar G. Narone, Swapnil S. Chabukswar, Shriharh A. Valyal, Ravikant B. Hirapure, Prof. V. R. Solapure

Summary

This project deals with manufacture of a Prototype of Vertical Car Parking System. This system has been implemented to reduce the excess use of land space which is already very scarce in metro cities. Different types of vehicle parking are applied worldwide namely Multi-level Automated Car Parking, Automated Car Parking System, and Rotary Parking System. The present project work is aimed to develop a scale down working model of a car parking system for parking cars within a large parking area. The chain and sprocket mechanism is used for driving the parking platform. This total prototype is powered by a D.C motor. When the car comes on the ramp the switch will be activated and the bucket comes to carry the vehicle. When the switch will be operated by the operator, sprockets starts to rotate and the new space will be adjusted for new vehicle. Planners, developers, architects are finding out solutions to tackle this problem of parking, so we took this opportunity to bring the technology of automated parking to where it is needed.

I. Vertical Car Parking model has been designed; all the parts in it were manufactured and assembled and tested successfully.
II. Analysis of the model has been done and developed with the scaling of 1:9 for life size model Such as SUV's like Fortuner.
III. As the life cycle model involves proper design and advanced methods are to be used to meet the requirements of the customers.

2. Introduction of a parking design and simulation model[2]

Wen Long YUE ,Lecturer Transport Systems, Centre University of South Australia Adelaide William YOUNG, Professor, Department of Civil Engineering ,Monash University Clayton.

Summary-This paper is to introduce the procedures involved in the development and validation of a parking design and simulation model, PARKSIM 2, which could be used to evaluate the design of a parking lot layout. The performance measurement on a design will provide quantitative information to parking lot designers enabling them to choose the best output. PARKSIM 2 is a PCbased microscopic, discrete computer simulation model. It can duplicate the vehicle and pedestrian movements as well as the interactions between them in a parking lot.

3.Modelling and Parametric Study of Typical Multi Level Car Parking System[3]

Dr. D. R. Panchal Applied Mechanics Department, Faculty of Tech. and Engg., The M. S. University of Baroda, Vadodara, Gujarat

Summary-Multi level car parking systems has become quite popular in recent times in cities which have become population hubs due to growth of industrial areas, commercial activities etc. as compared to conventional type of parking. Multi level car parking system is just the extension of the conventional surface parking lots in the vertical direction in the particular area. Hence some suitable structural system should be enveloped in order to store large number of vehicles in the particular space. This structural system may be made either of concrete, steel concrete composite or the precast concrete. Conventional concrete has become quite common whereas the precast option if employed then it can be erected fast and thus can be completed faster saving valuable time and money. Another most effective way of constructing multi-level car parks is by utilizing the steel concrete composite frame option which can give savings in steel weight of about 30% to 50% over non-composite construction thus reducing the overall cost of structure. For the present work, a typical G+5 storey multi-level self-car parking system with capacity to store 448 cars has been considered in earthquake zone III with medium class soil. Various models has been modelled and then analysed and designed. The building geometry has been modelled, analysed and designed using software STAAD.Pro. Analysis has been done by the approximate method of earthquake analysis i.e. Equivalent Static Method of Analysis along with the dead loads & live loads and designing for the same. For the purpose of result comparison, best efficient and economical section sizes have been selected through optimization process.

I. This kind of car parking system is suitable for the Indian environment as the number of cars is increasing day by day. Hence it is adoptable as this system provides maximum density by storing large number of cars in the particular area.
II. Modelling, analysis & design of the structure with staad.pro V8i is found to be user friendly as it deals with powerful GUI, easy syntax, advance analysis and multi material design.
III. Displacements percentage reduction of about 65.48 & 40.13 are noticed in the respective +ve X & Z direction when ductile code is used for analysis & design compared to

conventional code. Similarly 65.8 & 40.24 percentage reduction in displacements are noticed in the respective –ve X & Z direction.

IV. The cost of the substructure is found to be more since the reaction & moments governing the foundation design seem to be higher when ductile code is used for analysis & design.

V. When IS 456-2000 code is utilized, concrete & steel quantity are about 733.7 & 102.35 tonnes. This concrete & steel quantity increases to 1079 & 107.26 tonnes for IS 13920-1993 code when used for analysis & design. A difference of about 10,25,120 rupees is seen between both the concrete codes when they are utilized for analysis & design purpose.

VI. Galvanized steel is maintenance- free for 50–80 years. Life-cycle costs of galvanized steel frames are two to five times less than painted structural steel frames. So if used we can have structural system which is maintenance free and long term durability is achieved.

VII. Percentage displacement reduction of about 22.96 & 42.93 is noticed in the +ve X & Z direction when steel framed structure is analysed & design with AISC ASD code having solid slab as floor element Compared to LFRD design. Similarly 22.91 & 42.8 percentage displacement reduction is noticed in respective –ve X & Z direction. This is because of the difference of the codes how it deals with the steel structure. Specification is to provide a uniform reliability for all steel structures under various loading conditions. This uniformity cannot be obtained with the allowable stress design (ASD) format.

VIII. The cost of the substructure is found to be more since the reaction & moments governing the foundation design seem to be higher when AISC ASD code is used for analysing & designing the framed structure having fixity at the joints with solid slab & composite slab acting as floor elements.

IX. AISC LFRD code when used for analysis & design having fixity at joints with solid slabs as floor element consumes about 573.07 tonnes of steel. This steel consumption increases to value of 956.93 tonnes when AISC ASD code is used. Hence it is desirable to follow the AISC LRFD code since it provides uniform reliability for steel framed structure together with economy. This both codes differ drastically from each other as the ASD results are based on actual stress values compared to the AISC allowable stress values whereas LRFD results are based on the actual forces and moments compared to the AISC limiting forces and moments Capacity.

X. In composite construction different types of slab system are adopted i.e. solid slab, precast slab units and prolife sheet decking with concrete. Total period of construction is less when precast slab system/profile decking is used when compared to solid slab system. Hence economy is achieved while using precast slab system/profile deck floor system.

4. Optimum Solution of Multi-Level Car Park for Different Structural System Considering Composite Slab in Steel Construction[4]

Dhaval M Patel, Hardik Solanki

Summary-The Multilevel car park is a unique type of building. In India, the metropolitan cities have started to build this type of structure to solve a parking problem in congested traffic area. In nearer future, the multilevel car parks become a need of the day. Present study is carried out with an objective to understand the various forms and the structural aspect of the multilevel car parks in India. Accordance with various structural systems, type of decking system also has been studied. In present study it is proposed to analysis and design the multi-level car park by adopting different structural system like 'moment resisting frame' and 'braced frame'. For this dissertation G+3 and G+6 -story car parking structure is considered. In braced frame 'x'-type and 'v'type bracing is selected. The car park is considered of steel structure with composite deck slab. Selected structure has self-park operational system with split-level functional type (staggered floor system). The analysis and design is carried out in accordance with the IS 800:2007 and IS 1893:2002(Part-1). Design of deck slab has been carried out using BS-5950 (Part-4) and Eurocode-4. Analysis has been done using STAAD.Pro v8i. Different parameters like displacement, bending moment, weight of member, base shear etc. are observed and comparison is made between moment resisting frame and braced frame. We have also considered mass asymmetric structure and analyzed.

I. In Braced Frame, considerable reduction in storey displacement is observed compare to Moment Resisting Frame.

II. The overall bending moment is reduced in structural component (i.e column, beam & foundation) when bracings are provided. It leads to decrease the size of component.

III. Also the profile deck floor system is lighter than the solid concrete slab system and this reduction in weight will affect the total cost.

IV. Mass asymmetric structure should be design considering design eccentricity. For structure like car parking where distribution of live load is unfavorable; though the structure is symmetric in geometry, it is necessary to consider accidental eccentricity in design.

V. Displacement is also reduced in braced frame than moment resisting frame.

VI. Base shear is also reduced in braced frame structure compare to moment resisting frame.

VII. The 3.73% weight reduces while considering braced frame over the moment resisting frame.

5. Wilbur Smith Associates, India DPR for Multi-level Parking Facility at Ghaziabad[5]

The main evaluation has indicated that the proposed transport sub project (construction of a Multi storied Parking) for Ghaziabad city was found to be economically viable, with the calculated EIRR values exceeding the economic opportunity cost of capital. The sensitivity analysis has demonstrated the robustness of this result, with the subproject component economically viable even when the combination of changed assumptions was tested.

Furthermore, for the proposed drainage subproject, the calculated EIRR value is considered minimum estimates of economic return, as there are a number of economic benefits of reduced pollution, a cleaner city and improved transport environment that have not been quantified.

As a general practice, an IEE should evaluate impacts due to the location, design, construction and operation of the project. Construction and operation are the two activities in which the project interacts physically with the environment, so they are the two activities during which the environmental impacts occur. In assessing the effects of these processes therefore, all potential impacts of the project should be identified, and mitigation is devised for any negative impacts.

6. Planning For Multi-Level Car Parking Facilities In Metropolitan City Of Delhi[6]

Meghna Shrivastava,Prof. Dr. Sanjay Gupta

Summary- As the land in metropolitan cities and other higher order cities becoming scarce and dearer and plots getting smaller conventional parking is proving infeasible.

Attitudinal survey of parkers at Nehru Place revealed that about 52% users prefer driving up to six levels of parking in case of a multi levels of parking facility. The most popular choice in terms of technology preferred is automated (lift based) selected by nearly 70% of the users.

The financial analysis revealed that :

I. Manual technology was most appropriate option for smaller plots between 3000- 6000sq.m upto 5 levels .

II. For medium sized plots ranging between 6000 -9000 sq.m the technology options could be either manual upto 7 levels or fully automated structures with 12-14 floors.

III. In case of large plots ranging between 9000 -12000 sq.m fully automated structures with 12 to 14 floors are most appropriate options.

Objectives:

- To determine Bearing Capacity of the Soil of the site selected.

  In geotechnical engineering, **bearing capacity** is the capacity of soil to support the loads applied to the ground. The bearing capacity of soil is the maximum average contact pressure between the foundation and the soil which should not produce shear failure in the soil. Ultimate bearing capacity is the theoretical maximum pressure which can be supported without failure; allowable bearing capacity is the ultimate bearing capacity divided by a factor of safety. Sometimes, on soft soil sites, large settlements may occur under loaded foundations without actual shear failure occurring; in such cases, the allowable bearing capacity is based on the maximum allowable settlement.

- To Calculate Capacity of vehicles in the given Area

  In mathematics and civil engineering, **traffic flow** is the study of interactions between vehicles, drivers, pedestrians, cyclists, other travellers and infrastructure (including highways, signage, and traffic control devices), with the aim of understanding and developing an optimal road network with efficient movement of traffic and minimal traffic congestion problems.

- To Design Multilevel Parking System.

  The basic multi-level car parking system with three floors is considered to show the use of control systems in parking systems. The control system will play a major role in organizing the entry to and exit from the parking lots. It also presents the design of multi-level parking lots which occupies less need on the ground and contains the large number of cars.

Chapter 3

Work Details

3.1 Traffic Inflow

Data collection methodology

The most common parking surveys conducted are in-out survey, fixed period sampling and license plate method of survey.

In-out survey

In this survey, the occupancy count in the selected parking lot is taken at the beginning. Then the number of vehicles that enter the parking lot for a particular time interval is counted. The number of vehicles that leave the parking lot is also taken. The final occupancy in the parking lot is also taken. Here the labour required is very less. Only one person may be enough. But we wont get any data regarding the time duration for which a particular vehicle used that parking lot. Parking duration and turn over is not obtained. Hence we cannot estimate the parking fare from this survey.

Fixed Period Sampling

This is almost similar to in-out survey. All vehicles are counted at the beginning of the survey. Then after a fixed time interval that may vary between 15 minutes to 1 hour, the count is again taken. Here there are chances of missing the number of vehicles that were parked for a short duration.

License Plate Method Of Survey

This results in the most accurate and realistic data. In this case of survey, every parking stall is monitored at a continuous interval of 15 minutes or so and the license plate number is noted down. This will give the data regarding the duration for which a particular vehicle was using the parking bay. This will help in calculating the fare because fare is estimated based on the duration for which the vehicle was parked. If the time interval is shorter, then there are less chances of missing short-term parkers. But this method is very labour intensive.

Traffic data

Trucks	**4(college trucks)+1(Private)**	**Near Civil Labs**
4 Wheeler	2	Near Civil Labs
Pickups	2	Near Civil Labs
2-Wheelers	4	faculty near malviya bhavan
4-wheelers	18	faculty near malviya bhavan
4-wheelers	8	Near Temple + Workers mess
3-wheelers	1	Near Temple +Workers mess
4-wheelers	20	Near Vasant Bhawan
Buses	2	Near Vasant Bhawan
4-wheelers	12	Near H-8(Shastri Bhawan)
2-wheelers	5	Near H-8(Shastri Bhawan)
4-wheelers	13	Near Dhayan Kaksh
4-wheelers	10	Gita Bhawan
2-wheelers	2	Gita Bhawan
4-wheelers	10	Azad Bhawan
Ambulance	1	Dispensary
4-wheelers	34	Vivekananda statue
2-wheelers	4	Vivekananda statue
Total 4 wheelers	128	
Total 2 wheelers	11	
Total buses+trucks	7	
Total 3 wheelers	1	

Table 1 :No. of cars at various places in college building

Vehicle Class	Multiplying Factor	No. of Units	Equivalent PCU’s
Buses	3	2	6
Trucks	3	5	15
Four Wheeler	1	128	128
Two wheeler	.5	11	5.5
Three Wheeler	1	1	1

Table 2: No. of equivalents passenger car unit (PCU’s)

TOTAL UNITS =155.5 =160 Units (approx.)

3.2 Engineering Properties Of Soil

Determination of water content in the soil -

Weight of crucible of box 1=20.1grms

Weight of crucible +soil=30.4grms

Weight of crucible box 1 +dry soil=29.4grms

Weight of crucible of box2=19.5grms

Weight of crucible +soil=29.6grms

Weight of crucible box 2 +dry soil=28.5grms

Water content of soil =3.70%

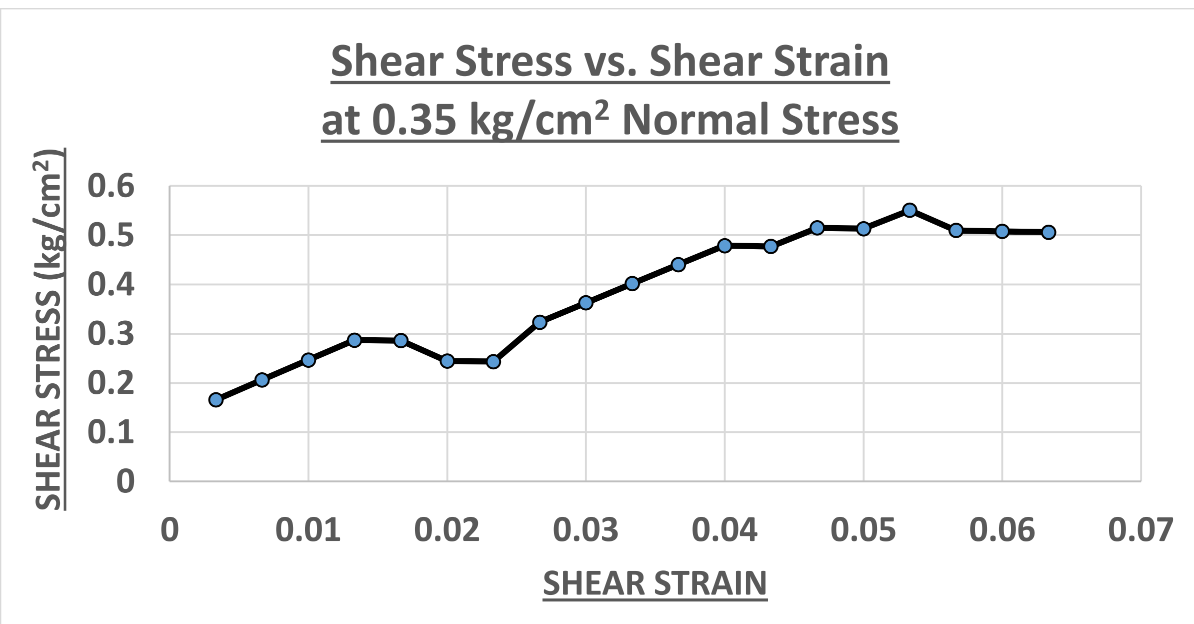


Fig. 1: Graph of shear stress vs shear strain at 0.35kg/cm^2 normal stress

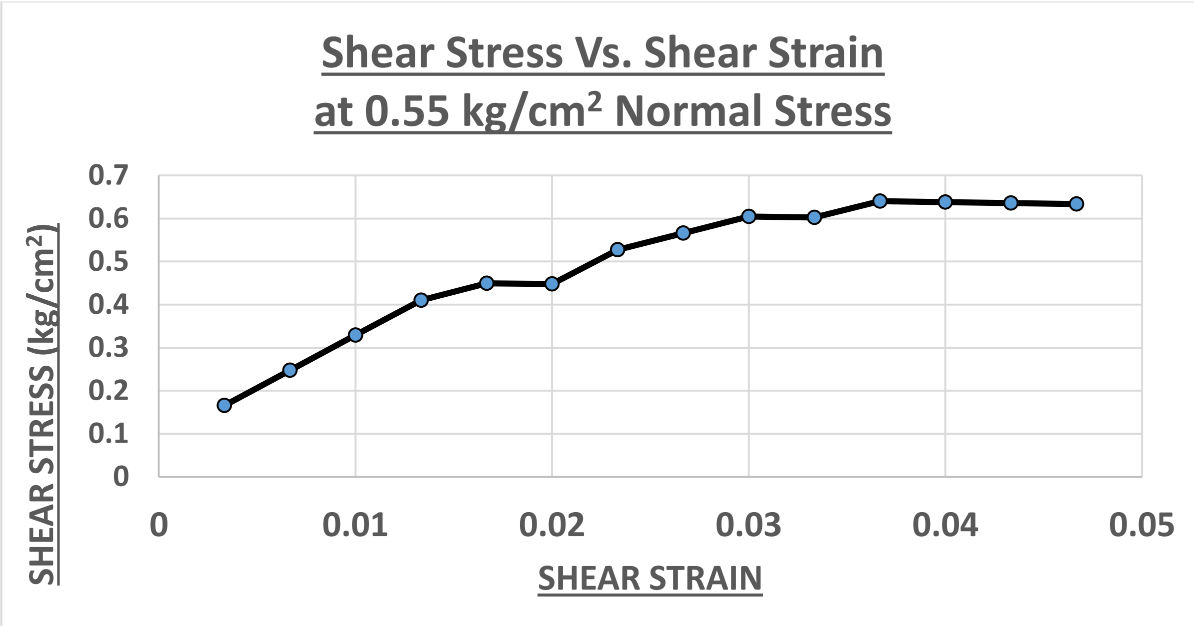


Fig. 2: Graph of shear stress vs shear strain at 0.55kg/cm^2 normal stress

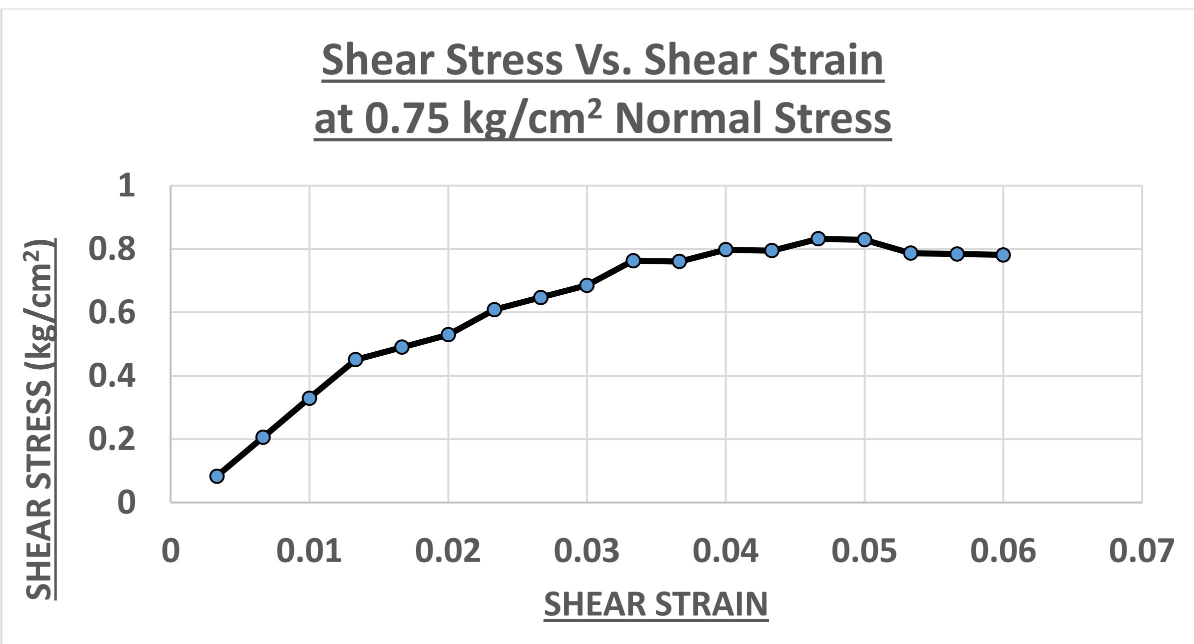


Fig. 3: Graph of shear stress vs shear strain at 0.75kg/cm^2 normal stress

NORMAL STRESS (kg/cm^2)	SHEAR STRESS (kg/cm^2)	SHEAR STRENGTH OF SOIL (kN/m^2)
0.35	0.509	48.788
0.55	0.633	64.597
0.75	0.831	80.407

Table 3: Shear strength of soil

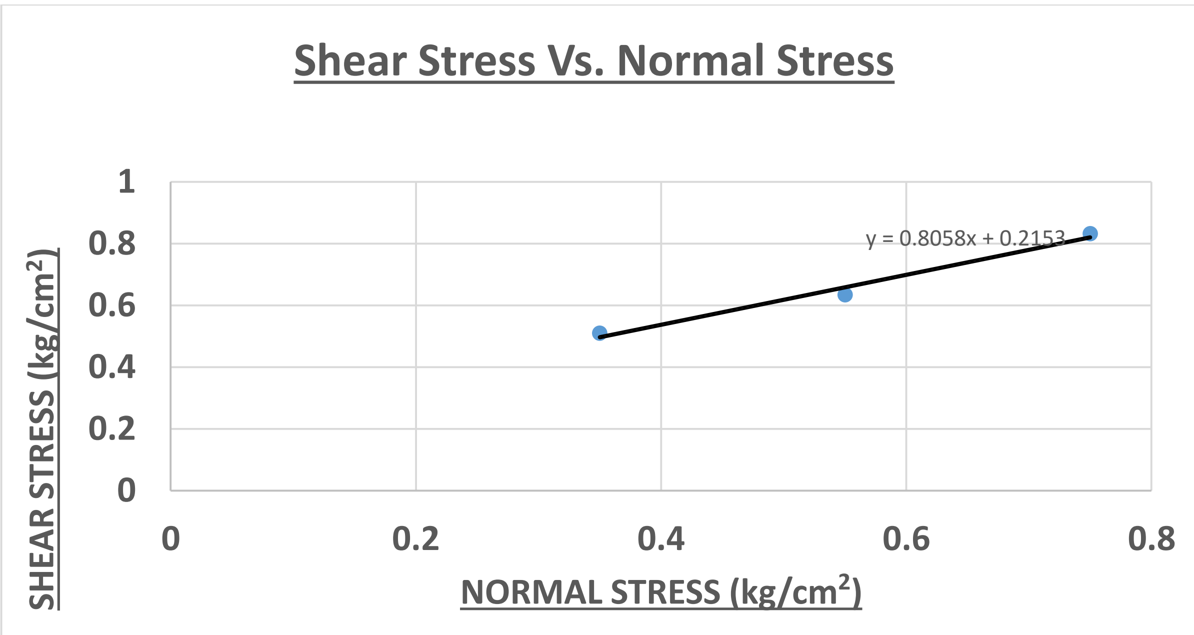


Fig. 4: Graph of shear stress vs normal stress

Formula for Calculation Of Shear Strength Of soil -:

$$\tau_f = c + \sigma_f \tan ø$$

Where

τ_f = shearing resistance of soil at failure

c = apparent cohesion of soil

σ_f = total normal stress on failure plane

ø = angle of shearing resistance of soil (angle of internal friction)

3.3 Map & Images Of Locations

Fig.5: Map of the parking location

Fig.6: Image of the parking location

3.4 Structural Modelling Details

For the present work, typical 3D model of multi-level car parking structure has been taken, situated in Jaypee University Waknaghat. In this slabs, beams and columns are built up of concrete. Concrete wall of 2.1 m height & 150 mm thickness is used as outer periphery throughout the building acting as a barrier. No internal walls are considered as the building deals with the storage of vehicles. The building has been analysed and designed for medium class soil, for earthquake zone IV using Equivalent Static Method of Analysis. The same building has also been analysed and designed with concrete members with minimal changes in the geometry. Designs are based as per the present Indian standard codal provisions. Limit state method in IS 800:2007 is referred for the design. American codes are followed where Indian code lacks in design. The building is modelled, analysed and designed with the help of software STAAD.Pro V8i. Here, for the comparison of the results, best possible economical and efficient section sizes have been selected from optimization process and trial-error methods using advantages of post processor mode of STAAD.Pro, for both concrete as well as composite structure.

Salient features of the building are:

− Length: 42m

− Breadth: 24m

− Column spacing (along the length): 10.5m.

− Column spacing (along the breadth):4m

− Plinth area: 3*1140 sq.m.

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/m^2

− Depth of foundation – 2.5m below

Chapter 4

Indian standards Provisions for Design

This chapter has been included as the following codes are used in the further design of the parking facility.

IS: 875 (Part 1) – 1987 for Dead Loads, Indian Standard Code Of Practice For Design Loads (Other Than Earthquake) For Buildings and Structures, All permanent constructions of the structure form the dead loads. The dead load comprises of the weights of walls, partitions floor finishes, false ceilings, false floors and the other permanent constructions in the buildings. The dead load loads may be calculated from the dimensions of various members and their unit weights. The unit weights of plain concrete and reinforced concrete made with sand and gravel or crushed natural stone aggregate may be taken as 24 kN/m^3 and 24 kN/m^3 respectively.

IS: 875 (Part 2) – 1987 for Imposed Loads, Indian Standard Code Of Practice For Design Loads (Other Than Earthquake), For Buildings And Structures, Imposed load is produced by the intended use or occupancy of a building including the weight of movable partitions, distributed and concentrated loads, load due to impact and vibration and dust loads. Imposed loads do not include loads due to wind, seismic activity, snow, and loads imposed due to temperature changes to which the structure will be subjected to, creep and shrinkage of the structure, the differential settlements to which the structure may undergo.

IS: 875 (Part 3) – 1987 for Wind Loads, Indian Standard Code Of Practice For Design Loads (Other Than Earthquake) For Buildings And Structures, This standard gives wind forces and their effects (static and dynamic) that should that taken into account when designing buildings, structures and components thereof. Wind is air in motion relative to the surface of the earth. The primary cause of wind is traced to earth’s rotation and differences in terrestrial radiation. The radiation effects are primarily responsible for convection either upwards or downwards. The wind generally blows horizontal to the ground at high wind speeds. Since vertical components of atmospheric motion are relatively small, the term ‘wind’ denotes almost exclusively the horizontal wind, vertical winds are always identified as such. The wind speeds are assessed with the aid of anemometers or anemographs which are installed at meteorological observatories at heights generally varying from 10 to 30 meters above ground.

IS: 1893 (Part 1) - 2002, Indian Standard Criteria for Earthquake Resistant Design of Structures, (Part 1-General Provisions and Buildings)**,** It deals with assessment of seismic loads on various structures and earthquake resistant design of buildings. Its basic provisions are applicable to buildings; elevated structures; industrial and stack like structures; bridges; concrete masonry and earth dams; embankments and retaining walls and other structures. Temporary elements such as scaffolding, temporary excavations need not be designed for earthquake forces.

IS: 875 (Part 5) – 1987 for Load Combinations, Indian Standard Code Of Practice For Design Loads (Other Than Earthquake) For Buildings And Structures, The various loads should be combined in accordance with the stipulations in the relevant design codes. In the absence of such recommendations, the following loading combinations, whichever combination produces the most unfavorable effect in the building, foundation or structural member concerned may be adopted (as a general guidance). It should also be recognized in load combinations that the simultaneous occurrence of maximum values of wind, earthquake, imposed and snow loads is not likely.

Load combinations		**Remarks**
1.5(DL+LL)		
1.5(DL±EQ$_X$)	**1.5(DL±WL$_X$)**	**DL – Dead load of the structure**
1.5(DL±EQ$_Z$)	**1.5(DL±WL$_Z$)**	**LL - Live load of the structure**
0.9(DL±1.5EQ$_X$)	**0.9(DL±1.5WL$_X$)**	**EQ$_X$ – Earthquake load along X direction**
0.9(DL±1.5EQ$_Z$)	**0.9(DL±1.5WL$_Z$)**	**EQ$_Z$ - Earthquake load along Z direction**
1.2(DL+LL±EQ$_X$)	**1.2(DL+LL±WL$_X$)**	**WL$_X$ – Wind load along X direction**
1.2(DL+LL±EQ$_Z$)	**1.2(DL+LL±WL$_Z$)**	**WL$_Z$ – wind load along Z direction**

Table 4: Load combinations

IS 456 - 2000, Indian standard code of practice for plain and reinforced concrete (fourth revision), Bureau of Indian Standards. This standard deals with the general structural use of plain and reinforced concrete. For the purpose of this standard, plain concrete structures are those where reinforcement, if provided is ignored for the determination of strength of the structures.

IS 800 - 2007, Indian Standard General Construction in Steel — Code Of Practice (Third Revision) This standard gives only general guidance as regards the various loads to be considered in design. For the actual loads and load combinations to be used, reference may be made to IS 875 for dead, live, snow and wind loads and to IS 1893 (Part 1) for earthquake loads. For seismic design, recommendations pertaining to steel frames only are covered in this standard.

SP: 16 - 1980,Design Aids for Reinforced Concrete to IS: 456-1978 (third revision), Bureau of Indian Standard. This is the explanatory handbook which covers the basis/source of each clause. The objective of these design aids is to reduce design time in the use of certain clauses in the Code for the design of beams, slabs and columns in general building structures. The charts and tables included in the design aids were used in calculation of footings and slabs.

SP: 34 (S&T) – 1987, Hand Book of Concrete Reinforcement and Detailing, Bureau of Indian Standards. This Handbook provides information on properties of reinforcing steel & detailing requirements, including storage, fabrication, assembly, welding and placing of reinforcement in accordance with IS: 456-2000. As a result of the introduction of limit state method of design for reinforced concrete structures and the concept of development length, detailing has become extremely important as many of the design requirements are to be met through detailing. This Handbook will be useful to concrete design engineers, field engineers and students of civil engineering.

4.1 Working With Staad.Pro

Material Constants:

The material constants are: modulus of elasticity (E); weight density (γ); Poisson's ratio (μ); co-efficient of thermal expansion (α), Composite Damping Ratio, and beta angle (β) or coordinates for any reference point. E value for members must be provided or the analysis will not be performed. Weight density (γ) is used only when self weight of the structure is to be taken into account. Poisson's ratio (μ) is used to calculate the shear modulus (commonly known as G) by the formula,

$$\mathbf{G = 0.5 \times E/ (1 + \mu)}$$

If Poisson's ratio is not provided, STAAD will assume a value for this quantity based on the value of E. Coefficient of thermal expansion (α) is used to calculate the expansion of the members if temperature loads are applied. The temperature unit for temperature load and α has to be the same.

Supports:

Supports are specified as PINNED, FIXED or FIXED with different releases (known as FIXED BUT). A pinned support has restraints against all translational movement and none against rotational movement. In other words, a pinned support will have reactions for all forces but will resist no moments. A fixed support has restraints against all directions of movement. Translational and rotational springs can also be specified. The springs are represented in terms of their spring constants.

Loads:

Loads in a structure can be specified as joint load, member load, temperature load and fixed end member load. Staad can also generate the self-weight of the structure and use it as uniformly distributed member loads in analysis. Any fraction of this self-weight can also be applied in any desired direction

Joint Loads:

Joint loads, both forces and moments, may be applied to any free joint of a structure. These loads act in the global coordinate system of the structure. Positive forces act in the positive coordinate directions. Any number of loads may be applied on a single joint, in which case the loads will be additive on that joint.

Member Load:

Three types of member loads may be applied directly to a member of a structure. These loads are uniformly distributed loads, concentrated loads, and linearly varying loads (including trapezoidal). Uniform loads act on the full or partial length of a member. Concentrated loads act at any intermediate, specified point. Linearly varying loads act over the full length of a member.

Area/floor load:

Many times a floor (bound by X-Z plane) is subjected to a uniformly distributed load. It could require a lot of work to calculate the member load for individual members in that floor. However, with the AREA or FLOOR LOAD command, the user can specify the area loads (unit load per unit square area) for members. The program will calculate the tributary area for these members and provide the proper member loads. The Area Load is used for one way distributions and the Floor Load is used for two way distributions.

Fixed End Member Load:

Load effects on a member may also be specified in terms of its fixed end loads. These loads are given in terms of the member coordinate system and the directions are opposite to the actual load on the member. Each end of a member can have six forces: axial; shear y; shear z; torsion; moment y, and moment z.

Load Generator - Moving Load, Wind & Seismic:

Load generation is the process of taking a load causing unit such as wind pressure, ground movement or a truck on a bridge, and converting it to a form such as member load or a joint load which can be then be used in the analysis.

Moving Load Generator:

This feature enables the user to generate moving loads on members of a structure. Moving load system(s) consisting of concentrated loads at fixed specified distances in both directions on a plane can be defined by the user. A user specified number of primary load cases will be subsequently generated by the program and taken into consideration in analysis.

Seismic Load Generator:

The STAAD seismic load generator follows the procedure of equivalent lateral load analysis. It is assumed that the lateral loads will be exerted in X and Z directions and Y will be the direction of the gravity loads. Thus, for a building model, Y axis will be perpendicular to the floors and point upward (all Y joint coordinates positive). For load generation per the codes, the user is required to provide seismic zone coefficients, importance factors, and soil characteristic parameters.

Wind Load Generator:

The STAAD Wind Load generator is capable of calculating wind loads on joints of a structure from user specified wind intensities and exposure factors. Different wind intensities may be specified for different height zones of the structure. Openings in the structure may be modeled using exposure factors. An exposure factor is associated with each joint of the structure and is defined as the fraction of the influence area on which the wind load acts. Built-in algorithms automatically calculate the exposed area based on the areas bounded by members (plates and solids are not considered), then calculates the wind loads from the intensity and exposure input and distributes the loads as lateral joint loads.

Design Parameters:

The program contains a number of parameters that are needed to perform design as per IS: 13920. It accepts all parameters that are needed to perform design as per IS: 456:2000. Over and above it has some other parameters that are required only when designed is performed as per IS: 13920. Default parameter values have been selected such that they are frequently used numbers for conventional design requirements.

Beam Design:

Beams are designed for flexure, shear and torsion. If required the effect of the axial force may be taken into consideration. For all these forces, all active beam loadings are pre- scanned to identify the critical load cases at different sections of the beams. For design to be performed as per IS: 13920 the width of the member shall not be less than 200mm. Also the member shall preferably have a width-to depth ratio of more than 0.3.

Design for Flexure:

Design procedure is same as that for IS: 456:2000. However while designing following criteria are satisfied as per IS: 13920

1. The minimum grade of concrete shall preferablybe M25.
2. Steel reinforcements of grade Fe415 or less only shall be used.
3. The minimum tension steel ratio on any face, at any section, is given by:

$$\rho_{min} = 0.24\sqrt{fck}/f_y$$

The maximum steel ratio on any face, at any section, is given by $\rho_{max} = 0.025$.

4. The positive steel ratio at a joint face must be at least equal to half the negative steel at that face.
5. The steel provided at each of the top and bottom face, at any section, shall at least be equal to one-fourth of the maximum negative moment steel provided at the face of either joint.

Column Design:

Columns are designed for axial forces and biaxial moments per IS 456:2000. Columns are also designed for shear forces. All major criteria for selecting longitudinal and transverse reinforcement as stipulated by IS: 456:2000 have been taken care of in the column design of STAAD.

Allowable Stresses:

The member design and code checking in STAAD are based upon the allowable stress design method as per IS: 800 (1984). It is a method for proportioning structural members using design loads and forces, allowable stresses, and design limitations for the appropriate material under service conditions. It would not be possible to describe every aspect of IS: 800(1984) in this manual. This section, however, will discuss the salient features of the allowable stresses specified by IS: 800:1984 and implemented in STAAD. Appropriate sections of IS 800:1984 will be referenced during the discussion of various types of allowable stresses.

Stability Requirements:

Slenderness ratios are calculated for all members and checked against the appropriate maximum values. IS 800:1984 summarize the maximum slenderness ratios for different types of members? In STAAD implementation of IS 800:1984, appropriate maximum slenderness ratio can be provided for each member. If no maximum slenderness ratio is provided, compression members will be checked against a maximum value of 180 and tension members will be checked against a maximum value of 400.

Deflection Check:

This facility allows the user to consider deflection as criteria in the CODE CHECK and MEMBER SELECTION processes. The deflection check may be controlled using three parameters. Deflection is used in addition to other strength and stability related criteria. The local deflection calculation is based on the latest analysis results.

Earthquake Collapse Check:

This checks at each column / beam interface, the program checks that the capacity of the column exceeds the total capacity of all beams that connect to it. The earthquake check only uses the results from Design Groups that have Design Briefs from the selected Design Code.

Code Checking:

The purpose of code checking is to verify whether the specified section is capable of satisfying applicable design code requirements. The code checking is based on the IS: 800 (1984) requirements. Forces and moments at specified sections of the members are utilized for the code checking calculations. Sections may be specified using the BEAM parameter or the SECTION command. If no sections are specified, the code checking is based on forces and moments at the member ends.

Chapter 5

Analysis & Design Of G + 3 RCC Framed Building Using Staad.Pro

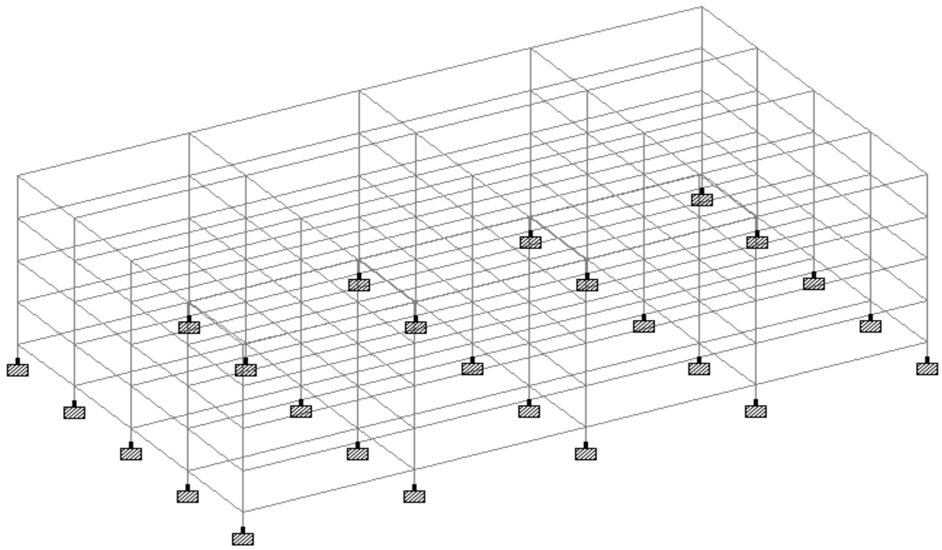


Fig. 7: Modelling of the structure in staad

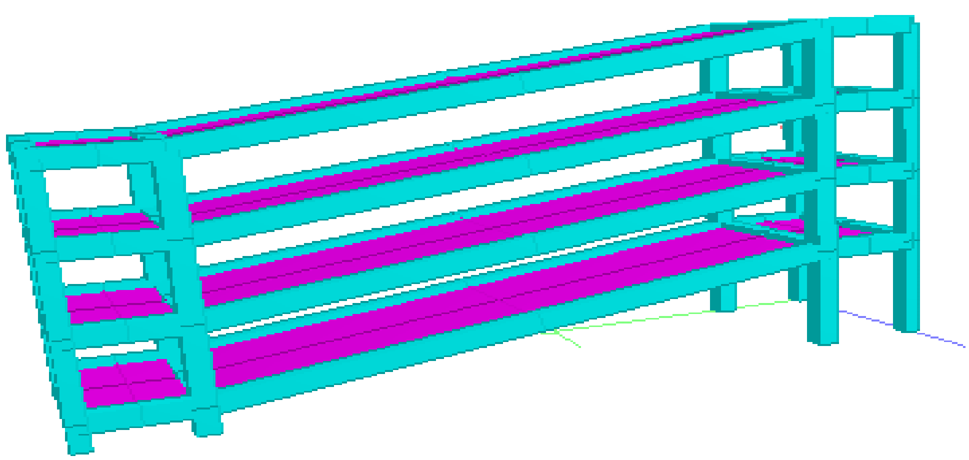
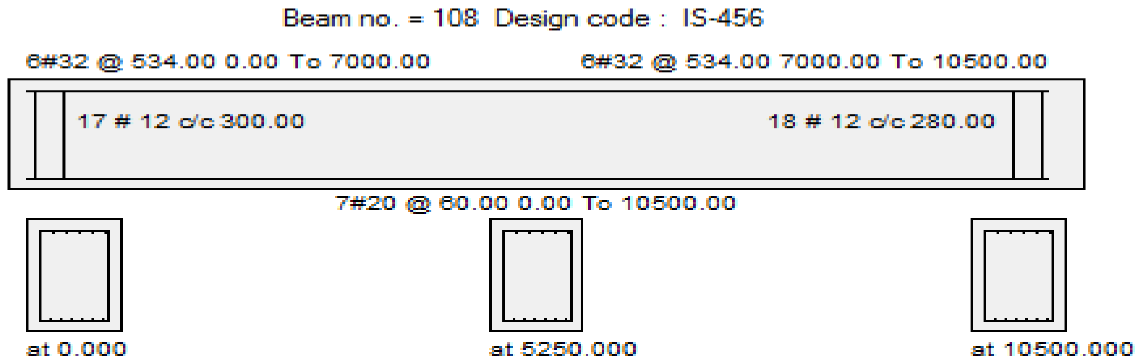


Fig.8: Model of Ramp



Design Load

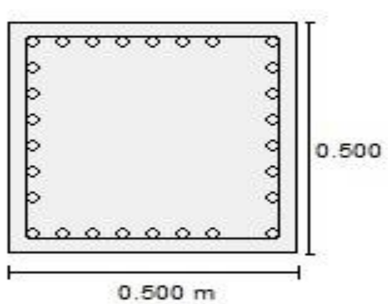
Mz Kn Met	Dist. Met	Load
323.53	5.3	5
-731.76	0	9
-732.09	10.5	12

Design Parameter

Fy(Mpa)	415
Fc(Mpa)	25
Depth(m)	0.600000023
Width(m)	0.400000005
Length(m)	10.5

Fig.9: Reinforcement details in the structural beam

Beam no. = 79 Design code : IS-456



Design Load

Load	12
Location	End 1
Pu(Kns)	2480.21
Mz(Kns-Mt)	410.42
My(Kns-Mt)	1.32

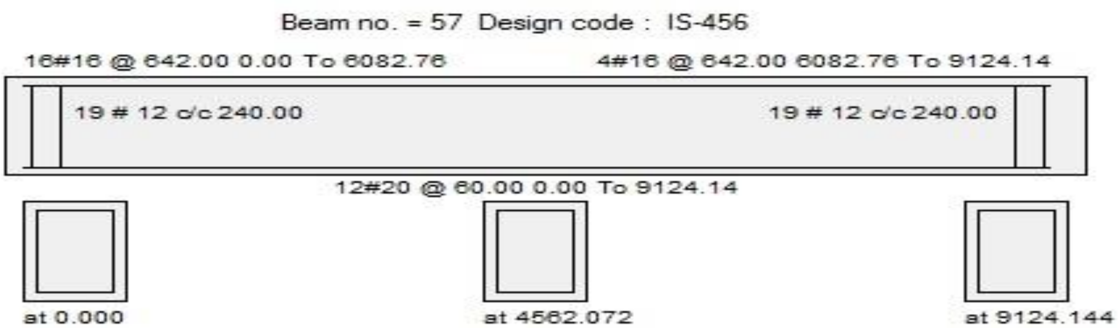
Design Parameter

Fy(Mpa)	415
Fc(Mpa)	25
As Reqd(mm²)	8008
As (%)	3.51
Bar Size	20
Bar No	28

Fig.10: Reinforcement details in structural column

```
| ELEMENT  DESIGN  TO  BS8007  AND  BS8110           ELEMENT NO.    86 |
|----------------------------------------------------------------------|
|         A >                        e          f            g         |
|    l--------|--------k   Top_________________________________        |
|    |                 |     | o_______o_______o_______o_______o |     |
|    |        ! y      |     |       outer bars // to  x       | My   |
|    |        |        |     | o-------o-------o-------o-------o |     |
|    |        z+ --> x |   Bot---------------------------------        |
|    |                 |              Section A-A                      |
|    |                 |                                               |
|    i--------|--------j   Depth=300 mm  Width=1000 mm  Cover=50 mm    |
|         A >                                                          |
|----------------------------------------------------------------------|
| Ultimate Limit State |  12 mm Bars     |  16 mm Bars     |  20 mm Bars  |
| Max.Momnt. kNm/m  Lo |C/C  AS R. AS P.|C/C  AS R.  AS P.|C/C  AS R. AS P.|
|----------------------|---|------|-----|---|------|------|---|------|-----|
| Mx Top =   8.4     5 |150|  719 | 754 |200|  719 | 1065 |200|  719 |1572 |
| Mx Bot =   0.0     0 |150|  719 | 754 |200|  719 | 1065 |200|  719 |1572 |
| My Top =   0.0     0 |150|  719 | 754 |200|  719 | 1065 |200|  719 |1572 |
| My Bot = -47.5     5 |150|  719 | 754 |200|  719 | 1065 |200|  719 |1572 |
 ----------------------------------------------------------------------
```

```
|  SERVICEABILITY    LIMIT    STATE                          ELEMENT NO.    86  |
|---------------------------------------------------------------------------|
| Longitudinal  Moments  Mx   kNm/m  | Transverse    Moments   My   kNm/m  |
| Flexural      Crack    Width   mm  | Flexural      Crack     Width   mm  |
|------------------------------------|--------------------------------------|
| Top=  8.4  L.   5 Bot=   0.0 L.   0| Top=  0.0  L.   0 Bot= -47.5 L.   5 |
|------------------------------------|--------------------------------------|
| 12 | 16 | 20 |  @  | 12 | 16 |  20 | 12  | 16 | 20 |  @  | 12 | 16 | 20  |
|----|----|----|-----|----|----|-----|-----|----|----|-----|----|----|-----|
|-.04|-.03|-.02|  e  |0.00|0.00|0.00 | 0.00|0.00|0.00|  e  |0.35|0.29|0.26 |
|-.06|-.04|-.02|  f  |0.00|0.00|0.00 | 0.00|0.00|0.00|  f  |0.39|0.33|0.28 |
|-.05|-.03|-.02|  g  |0.00|0.00|0.00 | 0.00|0.00|0.00|  g  |0.30|0.24|0.21 |
|---------------------------------------------------------------------------|
|  Thermal   Crack   Width   Calculations  Based  On   Wmax=Smax*R*T1*Alfa |
|---------------------------------------------------------------------------|
| Surface Type : Ground Slab   Constuction type : 1    Temp. Range = 30 C |
|---------------------------------------------------------------------------|
| Surface  Zones & AScrit  | 8 mm bars |10 mm Bars |12 mm Bars |16 mm Bars |
| Top  : 150  mm  525  mm2 |-----------|-----------|-----------|-----------|
| Bot. : 100  mm  175  mm2 | Top | Bot.| Top | Bot.| Top | Bot.| Top | Bot.|
|--------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Smax                  mm | 765 | 765 | 957 | 957 |1148 |1148 |1531 |1531 |
| Wmax                  mm |0.14 |0.14 |0.17 |0.17 |0.21 |0.21 |0.28 |0.28 |
| Sp. For  Wmax = 0.20  mm | 138 | 208 | 173 | 260 | 208 | 312 | 277 | 416 |
 ---------------------------------------------------------------------------
```



Design Load

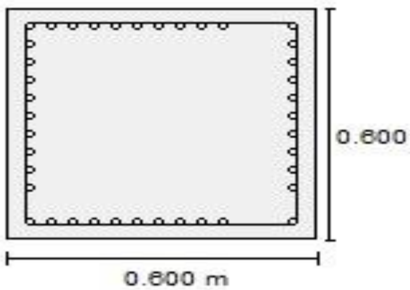
Mz Kn Met	Dist. Met	Load
648.15	9.1	5
-585.05	0	5
-1.47	3.8	10

Design Parameter

Fy(Mpa)	415
Fc(Mpa)	25
Depth(m)	0.699999988
Width(m)	0.5
Length(m)	9.124143795

Fig.11: Reinforcement details in the ramp structure beam

Beam no. = 47 Design code : IS-456



Design Load

Load	9
Location	End 2
Pu(Kns)	1889.26
Mz(Kns-Mt)	469.5
My(Kns-Mt)	534.45

Design Parameter

Fy(Mpa)	415
Fc(Mpa)	25
As Reqd(mm^2)	1179
As (%)	3.49
Bar Size	20
Bar No	40

Fig .12: Reinforcement details in the ramp structure column

Chapter 6
Foundation Design

6.1 Sand Replacement Method

Determination of field density of cohesion less soil is not possible by core cutter method , because it is not possible to obtain a core sample. In such situation, the sand replacement method is employed to determine the unit weight. In sand replacement method, a small cylindrical pit is excavated and the weight of the soil excavated from the pit is measured. Sand whose density is known is filled into the pit. By measuring the weight of sand required to fill the pit and knowing its density the volume of pit is calculated. Knowing the weight of soil excavated from the pit and the volume of pit, the density of soil is calculated. Therefore, in this experiment there are two stages, namely

1. Calibration of sand density.
2. Measurement of soil density.

The apparatus that is required for the test are Sand pouring cylinder, Calibrating can, Metal tray with, a central hole, Dry sand (passing through 1.18 mm sieve),Balance, Moisture content bins, Glass plate, Metal tray and Scraper tool.

STAGE-1 (CALIBRATION OF SAND DENSITY)

Measure the internal dimensions (diameter, d and height, h) of the calibrating can and compute its internal volume, $\mathbf{V_c} = \pi d^2 h/4$.Fill the sand pouring cylinder (SPC) with sand with 1 cm top clearance (to avoid any spill over during operation) and find its weight ($\mathbf{W_1}$).

Place the SPC on a glass plate, open the slit above the cone by operating the valve and allow the sand to run down. The sand will freely run down till it fills the conical portion. When there is no further downward movement of sand in the SPC, close the slit. Measure the weight of the sand required to fill the cone. Let it be $\mathbf{W_2}$.Place back this $\mathbf{W_2}$ amount of sand into the SPC, so that its weight becomes equal to $\mathbf{W_1}$ (As mentioned in point-2). Place the SPC concentrically on top of the calibrating can. Open the slit to allow the sand to run down until the sand flow stops by itself. This operation will fill the calibrating can and the conical portion of the SPC. Now close the slit and find the weight of the SPC with the remaining sand ($\mathbf{W_3}$).

STAGE-2 (MEASUREMENT OF SOIL DENSITY)

Clean and level the ground surface where the field density is to be determined and then place the tray with a central hole over the portion of the soil to be tested. Excavate a pit into the ground, through the hole in the plate, approximately 12 cm deep (same as the height of the calibrating can). The hole in the tray will guide the diameter of the pit to be made in the ground. Collect the excavated soil into the tray and weigh the soil (**W**) and, Determine the moisture content of the excavated soil. Place the SPC, with sand having the latest weight of $\mathbf{W_1}$, over the pit so that the base of the cylinder covers the pit concentrically. Open the slit of the SPC and allow the sand to run into the pit freely, till there is no downward movement of sand level in the SPC and then close the slit . Find the weight of the SPC with the remaining sand (**W4**)

Fig.13: Sand Replacement test

The following observations and calculations have been made

Observation Table

Sample Weight(grams)	
1 Wt. of pouring cylinder + sand w1	6228.50 gm
2 Wt. of pouring cylinder + sand w2	4594.50 gm
3 Wt. of pouring cylinder + sand after making cone on flat surface w3	3938.40 gm
4. Wt. of sand used in hole w4 = w1-w3	2290.01 gm
5 .Wt of sand in cone only w5 = w2-w3	656.01gm
6 .Wt of sand in hole only w6 = w4-w5	1634 gm
7 Volume of sand	1021.25 cm^3
8 Wt of tray + excavated soil w7	2984.60 gm
9 Wt of tray only	1295.60 gm
10 Mass of excavated soil w7-w8	1689 gm

Table 5: Values to calculate soil density

Determination of Modulus of Subgrade

S. No.	Description	Values	Units
1.	Modulus of Subgrade(K_s)	$K_s = 40(SF)q_u$	kN/m^3
2.	Q_u	$q_u = cN_c + \gamma DN_q + 0.5\gamma BN_\gamma$	kN/m^3
	Ψ	18.5	kN/m^3
	ϕ	30	Degree
3.	For sand	C = 0	
		$N_q = 22.46^0$	
		$N_c = 37.16^0$	
		$N_\gamma = 19.7^0$	
		Depth(d)=1m	
		Width(b)=3m	
4.	Q_u	858.16	N/mm^3
5.	K_s	$10.29*10^3$	kN/m^3

Table 6: Values to calculate modulus of subgrade

6.2 Foundation

Foundation is the base of any structure. Without a solid foundation, the structure would not hold for long. We have to be very cautious with the design of foundations because our entire structure rests on the foundation. The job of a foundation is to transfer the loads of the building safely to the ground.

Fig.14: Isolated Footing Reinforcement

The strength of the foundation determines the life of the structure. As we discussed in the earlier article, design of foundation depends on the type of soil, type of structure and its load. Higher the load bearing capacity of the soil, the larger the load it could safely carry. Foundations are basically divided into Shallow Foundations and Deep Foundations. In this article, we are going discuss the step by step guide to Column Footing Design for a shallow foundation.

6.3 Raft Foundation

Raft foundation is a thick concrete slab reinforced with steel which covers the entire contact area of the structure like a thick floor. Sometimes area covered by raft may be greater than the contact area depending on the bearing capacity of the soil underneath. The reinforcing bars runs normal to each other in both top and bottom layers of steel reinforcement. Sometimes inverted main beams and secondary beams are used to carry column loads that require thicker foundation slab considering economy of the structure. Both beams cast monolithically with raft slab. Raft foundation is required where soils have low bearing capacity and have to support heavy structural loads. Raft foundations are preferred in the soil that are suspected to subsidence. Subsidence may occur from different sources like change in ground water level due to climatic change specially in case expansive soil or foundation in mining area.

In one words, where deep foundation like pile foundation are not economical and feasible and isolated column footing is impracticable due to large footing size or over-lapping of neighbour footing , raft foundation is the economical solution. Different types of raft foundations are used to meet different geotechnical, structural requirements and to mitigate uncertainties. It is classified based on

Support condition

Structural system

6.4 Design Of Mat Foundation

Properties

Region	Thickness(m)	Material
boundary	1	Concrete

Soil Details

Boundary	Subgrade Modulus	Soil Height Above Mat	Soil Density	Soil Pressure
Boundary	10291.91kN/m^3	0.000 m	18.500 kN/m^3	0.000 kN/m^2

Mat Dimension

Node No	X Coor(m)	Y Coor(m)	Z Coor(m)
1	0	0	0
2	42	0	0
3	42	0	24
4	0	0	24

Base pressure summary

-	Node	X (m)	Y (m)	Z (m)	Load Case	Base Pressure(kN/m^2)
Maximum Base Pressure	1	0	0	0	3	63.99663
Minimum Base Pressure	8	42	0	12	4	12.19203

Design Parameters

Panel Name	Fy (kN/m^2)	Fc (kN/m^2)	Top Cover (m)	Bottom Cover (m)	Min Bar Size (mm)	Max Bar Size (mm)	Min Spacing (mm)	Max Spacing (mm)
boundary	415000	25000	0.06	0.06	8	32	50	500

Contact Area

Load Case	Area in Contact(m^2)	% of Total Area	Area out of Contact(m^2)	% of Total Area
3	1008	100	0	0
4	1008	100	0	0

Mat Dimensions Under the ramp

Node No	X (m)	Y (m)	Z (m)
1	0	0	0
2	5.5	0	0
3	5.5	0	24
4	0	0	24

Base Pressure summary under ramp

-	Node	X- (m)	Y- (m)	Z- (m)	Load Case	Base Pressure(kN/m^2)
Maximum Base Pressure	3	5.5	0	24	3	169.162
Minimum Base Pressure	2	5.5	0	0	3	0

Contact Area under ramp

Load Case	Area in Contact(m^2)	% of Total Area	Area out of Contact(m^2)	% of Total Area
3	123.75001	93.75	8.25	6.25
4	123.75001	93.75	8.25	6.25

Design Parameters under ramp

Panel Name	Fy (kN/m^2)	Fc (kN/m^2)	Top Cover (m)	Bottom Cover (m)	Min Bar Size (mm)	Max Bar Size (mm)	Min Spacing (mm)	Max Spacing (mm)
Boundary	414999.998	25000	0.06	0.06	8	32	50	500

Design Output of foundation under superstructure

Top of Raft Longitudinal Direction

Zone:- 1

Governing Moment (M_{GOV}) = 249.498(kN-m/m)

For F_C <4.0 $\beta = 0.85$

Effective Depth = $D - (cc + 0.5 \times d_b)$ = 0.736 (m)

Limit Moment of Resistance (M_{umax}) = $R_{umax} \times B \times d_e^2$ = 1865.724 (kNm)

$M_{GOV} <= M_{umax}$ hence OK

Steel Required

Calculated Area of Steel = 960.000 (mm2)

Minimum Area of Steel = 960.000 (mm2)

Provided Area of Steel = 960.000 (mm2)

Reinforcement Details

Bar No= 8

Maximum Spacing(S_{max})(User Specified) = 500.000(mm)

Minimum Spacing(S_{min})(User Specified) = 50.000(mm)

Actual Spacing (S) = 50(mm)

$S_{min} <= S <= S_{max}$

Zone:- 2

Governing Moment (M_{GOV}) = 622.499(kN-m/m)

For F_C <4.0 $\beta = 0.85$

Effective Depth = $D - (cc + 0.5 \times d_b)$ = 0.736 (m)

Limit Moment of Resistance (M_{umax}) = $R_{umax} \times B \times d_e^2$ = 1865.724 (kNm)

$M_{GOV} <= M_{umax}$ hence OK

Steel Required

Calculated Area of Steel = 2481.458 (mm2)

Minimum Area of Steel = 960.000 (mm2)

Provided Area of Steel = 2481.458 (mm2)

Reinforcement Details

Bar No= 20

Maximum Spacing(S_{max})(User Specified) = 500.000(mm)

Minimum Spacing(S_{min})(User Specified) = 50.000(mm)

Actual Spacing (S) = 120(mm)

$S_{min} <= S <= S_{max}$

Zone:- 3

Governing Moment (M_{GOV}) = 972.144(kN-m/m)

For F_C <4.0 $\beta = 0.85$

Effective Depth = $D - (cc + 0.5 \times d_b)$ = 0.736 (m)

Limit Moment of Resistance (M_{umax}) = $R_{umax} \times B \times d_e^2$ = 1865.724 (kNm)

$M_{GOV} <= M_{umax}$ hence OK

Steel Required

Calculated Area of Steel = 4023.466 (mm2)

Minimum Area of Steel = 960.000 (mm2)

Provided Area of Steel = 4023.466 (mm2)

Reinforcement Details

Bar No= 25

Maximum Spacing(S_{max})(User Specified) = 500.000(mm)

Minimum Spacing(S_{min})(User Specified) = 50.000(mm)

Actual Spacing (S) = 120(mm)

$S_{min} <= S <= S_{max}$

Top of Raft Transverse Direction

Zone:- 1

Governing Moment(M_{GOV})= 246.740(kN-m/m)

For F_C <4.0 $\beta = 0.85$

Effective Depth = $D - (cc + 0.5 \times d_b) =$ 0.728 (m)

Limit Moment of Resistance (M_{umax}) =

$R_{umax} \times B \times d_e^2 =$ 1825.386 (kNm)

M_{GOV}<= M_{umax} hence OK

Steel Required

Calculated Area of Steel = 960.000 (mm2)

Minimum Area of Steel = 960.000 (mm2)

Provided Area of Steel = 960.000 (mm2)

Reinforcement Details

Bar No= 8

Maximum Spacing(S_{max})(User Specified) = 500.000(mm)

Minimum Spacing(S_{min})(User Specified) = 50.000(mm)

Actual Spacing (S) = 50(mm)

S_{min}<= S <= S_{max}

Zone:- 2

Governing Moment(M_{GOV})= 387.691(kN-m/m)

For F_C <4.0 $\beta = 0.85$

Effective Depth = $D - (cc + 0.5 \times d_b) =$ 0.728 (m)

Limit Moment of Resistance (M_{umax}) =

$R_{umax} \times B \times d_e^2 =$ 1825.386 (kNm)

M_{GOV}<= M_{umax} hence OK

Steel Required

Calculated Area of Steel = 1528.236 (mm2)

Minimum Area of Steel = 960.000 (mm2)

Provided Area of Steel = 1528.236 (mm2)

Reinforcement Details

Bar No= 10

Maximum Spacing(S_{max})(User Specified) = 500.000(mm)

Minimum Spacing(S_{min})(User Specified) = 50.000(mm)

Actual Spacing (S) = 50(mm)

$S_{min} <= S <= S_{max}$

Zone:- 3

Governing Moment(M_{GOV})= 532.598(kN-m/m)

For F_C <4.0 $\beta = 0.85$

Effective Depth = $D - (cc + 0.5 \times d_b)$ = 0.728 (m)

Limit Moment of Resistance (M_{umax}) =

$R_{umax} \times B \times d_e^2$ = 1825.386 (kNm)

$M_{GOV} <= M_{umax}$ hence OK

Steel Required

Calculated Area of Steel = 2129.711 (mm2)

Minimum Area of Steel = 960.000 (mm2)

Provided Area of Steel = 2129.711 (mm2)

Reinforcement Details

Bar No= 16

Maximum Spacing(S_{max})(User Specified) = 500.000(mm)

Minimum Spacing(S_{min})(User Specified) = 50.000(mm)

Actual Spacing (S) = 90(mm)

$S_{min} <= S <= S_{max}$

Bottom of Raft Longitudinal Direction

Zone:- 1

Governing Moment(M_{GOV})= -241.721(kN-m/m)

For F_C <4.0 $\beta = 0.85$

Effective Depth = $D - (cc + 0.5 \times d_b)$ = 0.736 (m)

Limit Moment of Resistance (M_{umax}) = $R_{umax} \times B \times d_e^{2}$ = 1865.724 (kNm)

$M_{GOV} <= M_{umax}$ hence OK

Steel Required

Calculated Area of Steel = 960.000 (mm2)

Minimum Area of Steel = 960.000 (mm2)

Provided Area of Steel = 960.000 (mm2)

Reinforcement Details

Bar No= 8

Maximum Spacing(S_{max})(User Specified) = 500.000(mm)

Minimum Spacing(S_{min})(User Specified) = 50.000(mm)

Actual Spacing (S) = 50(mm)

$S_{min} <= S <= S_{max}$

Zone:- 3

Governing Moment(M_{GOV})= -250.636(kN-m/m)

For F_C <4.0 $\beta = 0.85$

Effective Depth = $D - \left(cc + 0.5 \times d_b\right)$ = 0.736 (m)

Limit Moment of Resistance (M_{umax}) = $R_{umax} \times B \times d_e^{2}$ = 1865.724 (kNm)

$M_{GOV} <= M_{umax}$ hence OK

Steel Required

Calculated Area of Steel = 964.155 (mm2)

Minimum Area of Steel = 960.000 (mm2)

Provided Area of Steel = 964.155 (mm2)

Reinforcement Details

Bar No= 8

Maximum Spacing(S_{max})(User Specified) = 500.000(mm)

Minimum Spacing(S_{min})(User Specified) = 50.000(mm)

Actual Spacing (S) = 50(mm)

$S_{min} <= S <= S_{max}$

Bottom of Raft Transverse Direction

Zone:- 1

Governing Moment(M_{GOV})= -150.636(kN-m/m)

For F_C <4.0 $\beta = 0.85$

Effective Depth = $D - (cc + 0.5 \times d_b)$ = 0.728 (m)

Limit Moment of Resistance (M_{umax}) = $R_{umax} \times B \times d_e^2$ = 1825.386 (kNm)

$M_{GOV} <= M_{umax}$ hence OK

Steel Required

Calculated Area of Steel = 960.000 (mm2)

Minimum Area of Steel = 960.000 (mm2)

Provided Area of Steel = 960.000 (mm2)

Reinforcement Details

Bar No= 8

Maximum Spacing(S_{max})(User Specified) = 500.000(mm)

Minimum Spacing(S_{min})(User Specified) = 50.000(mm)

Actual Spacing (S) = 50(mm)

$S_{min} <= S <= S_{max}$

Conclusion

The above structure designed is a G+3 multilevel car parking facility in JUIT. Structure is designed on a soil that has a low bearing capacity. The structure is designed for the total number of cars presently in college and considering a further increase in years.

- A G+3 multilevel parking facility is designed for approximately 200 cars. The complete structure is of concrete, with a slab thickness of 200 mm. for the main parking and slab thickness of 300 mm. for the ramp portion.
- The designs have been done according to the IS codes for the load consideration and the concrete design. However, British Standards have been used for the design of slabs.
- The whole structure is checked according to the set parameters in the codes for deflection, bending and storey drifts and the structure passed in all the mentioned limits. Thus, a safe structure is designed that is capable of bearing such loads.
- Further, the foundation used is Raft as the area too be covered was large and the soil had low bearing capacity and the isolated footing designed overlapped each other
- All the designs have been done in STAAD PRO and STAAD FOUNDATION.

Scope

The main scope of this project is to apply class room knowledge in the real world by designing a RCC building. These building require large and clear areas unobstructed by the columns. The large floor area provides sufficient flexibility and facility for later change in the production layout without major building alterations..
The building is designed in the earthquake zone IV and all the necessary safeguards are taken i.e. the building is designed accordingly.

However, further changes can be made such as introducing automated parking system in spite of a conventional parking system and further changes can also be incorporated in order to make the whole structure more cost effective and safe.

The above designed structure is a whole concrete structure and with change in construction practices steel frame structure can also be used that would be more cost effective and durable and overall time of construction would be reduced.

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ANNEXURE 1: Design Results Of Superstructure Node Displacement

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	Load Combination	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	128	12 GENERATED INDIAN CODE GENRAL_STRUCTURES 8	53.246	-2.72	0	53.316	0	0	-0.004
Min X	148	14 GENERATED INDIAN CODE GENRAL_STRUCTURES 10	-53.486	-1.852	0	53.518	0	0	0.004
Max Y	136	2 LOAD CASE 2 +Z	-0.24	0.387	28.869	28.872	0.001	0	0
Min Y	134	5 GENERATED INDIAN CODE GENRAL_STRUCTURES 1	0.275	-5.57	-0.065	5.577	0	0	0
Max Z	136	13 GENERATED INDIAN CODE GENRAL_STRUCTURES 9	-0.476	-3.225	43.386	43.508	0.002	0	0
Min Z	140	15 GENERATED INDIAN CODE GENRAL_STRUCTURES 11	-0.476	-3.225	-43.386	43.508	-0.002	0	0
Max rX	61	13 GENERATED INDIAN CODE GENRAL_STRUCTURES 9	-0.128	-1.534	12.449	12.543	0.003	0	0
Min rX	65	15 GENERATED INDIAN CODE GENRAL_STRUCTURES 11	-0.128	-1.534	-12.449	12.543	-0.003	0	0
Max rY	146	13 GENERATED INDIAN CODE GENRAL_STRUCTURES 9	-1.213	-1.629	26.917	26.993	0.001	0.001	0.002
Min rY	150	15 GENERATED INDIAN CODE GENRAL_STRUCTURES 11	-1.213	-1.629	-26.917	26.993	-0.001	-0.001	0.002
Max rZ	73	14 GENERATED INDIAN CODE	-14.45	-0.892	0	14.478	0	0	0.005
Min rZ	53	12 GENERATED INDIAN CODE GENRAL_STRUCTURES 8	14.426	-1.313	0	14.486	0	0	-0.005
Max Rst	148	14 GENERATED INDIAN CODE GENRAL_STRUCTURES 10	-53.486	-1.852	0	53.518	0	0	0.004

ANNEXURE 2: Support Reactions Summary Of Superstructure

			Horizontal	Vertical	Horizontal	Moment		
	Node	L/C	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	1	14 GENERATED INDIAN CODE GENRAL_STRUCTURES 10	350.755	2112.019	61.247	4.178	1.35	-294.005
Min Fx	21	12 GENERATED INDIAN CODE GENRAL_STRUCTURES 8	-350.701	1783.507	30.273	2.036	-1.377	293.382
Max Fy	7	5 GENERATED INDIAN CODE GENRAL_STRUCTURES 1	-57.208	4316.635	-14.474	-6.474	-0.017	27.776
Min Fy	11	2 LOAD CASE 2 +Z	1.312	-328.991	-115.31	-183.467	-0.081	-1.733
Max Fz	14	15 GENERATED INDIAN CODE GENRAL_STRUCTURES 11	0.644	3132.877	292.37	300.117	0.117	-0.99
Min Fz	12	13 GENERATED INDIAN CODE GENRAL_STRUCTURES 9	0.644	3132.877	-292.37	300.117	-0.117	-0.99
Max Mx	14	15 GENERATED INDIAN CODE GENRAL_STRUCTURES 11	0.644	3132.877	292.37	300.117	0.117	-0.99
Min Mx	12	13 GENERATED INDIAN CODE GENRAL_STRUCTURES 9	0.644	3132.877	-292.37	-300.117	-0.117	-0.99
Max My	25	15 GENERATED INDIAN CODE GENRAL_STRUCTURES 11	-201.358	1252.052	76.818	170.532	2.543	-1.454
Min My	21	13 GENERATED INDIAN CODE GENRAL_STRUCTURES 9	-201.358	1252.052	-76.818	-170.532	-2.543	-1.454
Max Mz	8	12 GENERATED INDIAN CODE GENRAL_STRUCTURES 8	-283.992	3117.397	0	0	0	350.883
Min Mz	18	14 GENERATED INDIAN CODE GENRAL_STRUCTURES 10	283.815	3113.398	0	0	0	-351.257

ANNEXURE 3: Node Displacement Of Ramp

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	42	12 GENERATED INDIAN CODE GENRAL_STRUCTURES 8	31.699	-1.276	3.552	31.923	0.001	-0.001	0
Min X	41	18 GENERATED INDIAN CODE GENRAL_STRUCTURES 14	-29.321	-0.896	2.79	29.467	0.001	0.001	0
Max Y	41	17 GENERATED INDIAN CODE GENRAL_STRUCTURES 13	1.492	0.732	18.071	18.147	0.001	0	0
Min Y	53	5 GENERATED INDIAN CODE GENRAL_STRUCTURES 1	1.16	-63.845	-7.183	64.258	0	0.001	-0.004
Max Z	38	13 GENERATED INDIAN CODE GENRAL_STRUCTURES 9	0.627	-4.92	19.201	19.831	-0.003	0	0.001
Min Z	53	15 GENERATED INDIAN CODE GENRAL_STRUCTURES 11	1.066	-58.691	-24.013	63.422	0	0.001	-0.004
Max rX	49	5 GENERATED INDIAN CODE GENRAL_STRUCTURES 1	1.478	-10.488	1.877	10.757	0.007	0	0
Min rX	52	5 GENERATED INDIAN CODE GENRAL_STRUCTURES 1	0.863	-8.701	1.787	8.925	-0.006	0	0
Max rY	53	14 GENERATED INDIAN CODE GENRAL_STRUCTURES 10	-21.228	-57.002	-8.318	61.393	0	0.001	-0.004
Min rY	38	12 GENERATED INDIAN CODE GENRAL_STRUCTURES 8	16.829	-5.971	3.74	18.244	-0.004	-0.001	0.001
Max rZ	20	14 GENERATED INDIAN CODE GENRAL_STRUCTURES 10	-8.339	-3.132	-2.22	9.18	0.003	0	0.002
Min rZ	53	12 GENERATED INDIAN CODE GENRAL_STRUCTURES 8	23.542	-58.571	-4.758	63.304	0	0	-0.004
Max Rst	53	5 GENERATED INDIAN CODE GENRAL_STRUCTURES 1	1.16	-63.845	-7.183	64.258	0	0.001	-0.004

ANNEXURE 4: Support Reactions Of Ramp

			Horizontal	Vertical	Horizontal	Moment		
	Node	L/C	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	5	14 GENERATED INDIAN CODE GENRAL_STRUCTURES 10	764.464	4903.599	-872.117	-266.571	-26.045	-363.053
Min Fx	6	12 GENERATED INDIAN CODE GENRAL_STRUCTURES 8	-752.173	5941.715	-1010.04	-291.039	24.151	368.934
Max Fy	6	15 GENERATED INDIAN CODE GENRAL_STRUCTURES 11	-323.345	6116.12	-141.328	228.078	5.421	80.394
Min Fy	7	19 GENERATED INDIAN CODE GENRAL_STRUCTURES 15	-33.728	-783.51	502.368	316.49	-6.364	23.477
Max Fz	8	14 GENERATED INDIAN CODE GENRAL_STRUCTURES 10	-11.03	-306.739	688.685	360.952	-7.527	-55.135
Min Fz	6	12 GENERATED INDIAN CODE GENRAL_STRUCTURES 8	-752.173	5941.715	-1010.04	-291.039	24.151	368.934
Max Mx	8	15 GENERATED INDIAN CODE GENRAL_STRUCTURES 11	-2.103	-670.327	658.531	390.555	8.047	-1.853
Min Mx	6	13 GENERATED INDIAN CODE GENRAL_STRUCTURES 9	-321.328	4677.29	-931.728	-295.242	5.919	79.958
Max My	6	12 GENERATED INDIAN CODE GENRAL_STRUCTURES 8	-752.173	5941.715	-1010.04	-291.039	24.151	368.934
Min My	5	14 GENERATED INDIAN CODE GENRAL_STRUCTURES 10	764.464	4903.599	-872.117	-266.571	-26.045	-363.053
Max Mz	6	12 GENERATED INDIAN CODE GENRAL_STRUCTURES 8	-752.173	5941.715	-1010.04	-291.039	24.151	368.934
Min Mz	5	14 GENERATED INDIAN CODE GENRAL_STRUCTURES 10	764.464	4903.599	-872.117	-266.571	-26.045	-363.053

ANNEXURE 5: Plate stress summary of foundation of Superstructure

-	Plate	Load Case	SQx (kN/m2)	SQy (kN/m2)	Sx (kN/m2)	Sy (kN/m2)	Sxy (kN/m2)	Mx (kN-m/m)	My (kN-m/m)	Mxy (kN-m/m)
Max SQX	4	3	2.98889	5.32532	0	0	0	-19.517	-28.008	-2.4914
Max SQY	4	3	2.98889	5.32532	0	0	0	-19.517	-28.008	-2.4914
Max SX	1	3	-3.59482	-4.26531	0	0	0	-19.132	-27.427	-3.6834
Max SY	1	3	-3.59482	-4.26531	0	0	0	-19.132	-27.427	-3.6834
Max SXY	1	3	-3.59482	-4.26531	0	0	0	-19.132	-27.427	-3.6834
Max MX	1	4	0.0892	0.03254	0	0	0	0.38717	-0.0466	0.11919
Max MY	3	4	-0.27806	-0.01721	0	0	0	0.32584	0.03612	-0.1809
Max MXY	2	3	-3.59482	4.26531	0	0	0	-19.132	-27.427	3.68335
Min SQX	1	3	-3.59482	-4.26531	0	0	0	-19.132	-27.427	-3.6834
Min SQY	3	3	2.98889	-5.32532	0	0	0	-19.517	-28.008	2.49139
Min SX	1	3	-3.59482	-4.26531	0	0	0	-19.132	-27.427	-3.6834
Min SY	1	3	-3.59482	-4.26531	0	0	0	-19.132	-27.427	-3.6834
Min SXY	1	3	-3.59482	-4.26531	0	0	0	-19.132	-27.427	-3.6834
Min MX	3	3	2.98889	-5.32532	0	0	0	-19.517	-28.008	2.49139
Min MY	3	3	2.98889	-5.32532	0	0	0	-19.517	-28.008	2.49139
Min MXY	1	3	-3.59482	-4.26531	0	0	0	-19.132	-27.427	-3.6834

ANNEXURE 6: Plate Stress Summary Of Foundation Of Ramp

-	Plate	Load Case	SQx (kN/m2)	SQy (kN/m2)	Sx (kN/m2)	Sy (kN/m2)	Sxy (kN/m2)	Mx (kN-m/m)	My (kN-m/m)	Mxy (kN-m/m)
Max SQX	4	3	99.0585	100.866	0	0	0	-199.38	-154.42	-242.52
Max SQY	4	3	99.0585	100.866	0	0	0	-199.38	-154.42	-242.52
Max SX	1	3	-88.046	-143.2	0	0	0	-94.301	-192.86	-304.68
Max SY	1	3	-88.046	-143.2	0	0	0	-94.301	-192.86	-304.68
Max SXY	1	3	-88.046	-143.2	0	0	0	-94.301	-192.86	-304.68
Max MX	3	4	8.41196	15.7164	0	0	0	-4.0465	-14.013	-11.843
Max MY	4	4	10.2293	8.12883	0	0	0	-22.133	-12.691	-22.612
Max MXY	2	3	-94.942	-39.79	0	0	0	-164.57	-150.02	29.974
Min SQX	2	3	-94.942	-39.79	0	0	0	-164.57	-150.02	29.974
Min SQY	1	3	-88.046	-143.2	0	0	0	-94.301	-192.86	-304.68
Min SX	1	3	-88.046	-143.2	0	0	0	-94.301	-192.86	-304.68
Min SY	1	3	-88.046	-143.2	0	0	0	-94.301	-192.86	-304.68
Min SXY	1	3	-88.046	-143.2	0	0	0	-94.301	-192.86	-304.68
Min MX	4	3	99.0585	100.866	0	0	0	-199.38	-154.42	-242.52
Min MY	1	3	-88.046	-143.2	0	0	0	-94.301	-192.86	-304.68
Min MXY	1	3	-88.046	-143.2	0	0	0	-94.301	-192.86	-304.68