"Analysis and Design of an RCC Building Intended for Dairy Research and Extension Centre"

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

Mr. Anil Kumar

(Assistant Professor)

By

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173234

HIMACHAL PRADESH, INDIA

June, 2016

CERTIFICATE

This is to certify that the work which is being presented in the project titled **"Analysis and Design of an RCC Building Intended for Dairy Research and Extension Centre"** in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of the work carried out by **Rajat Bhardwaj (121696) and Puneet Goyal (121699)** during the period from July 2015 to June 2016 under the supervision of **Mr. Anil Kumar,** Assistant Professor, Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

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

Date: ………………………

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ACKNOWLEDGEMENT

The success of any project depends largely on the encouragement and guidelines of many others. Therefore we take this opportunity to express our sincere gratitude to the people who have been instrumental in the successful completion of the project. We would like to express our sincere appreciation and gratitude to our guide **Mr. Anil Kumar** without whose able guidance, tremendous support and continuous motivation, the project would not have been carried to perfection. We sincerely thank him for spending all his valuable time and energies during the execution of project.

We take this opportunity to express our sincere gratitude to the Head of Department of Civil Engineering, **Prof. (Dr.) Ashok Kumar Gupta** for all his support and valuable inputs. We thank him for reviving Civil Engineering as the overall mentor by leading with a vision and teaching us with a knowledge imparting attitude.

The successful compilation of final year project depends on the knowledge and attitude inculcated in the total length of the course. So we want to express our sincere gratitude to all the faculties who taught us during the four years of B.Tech.

We would also like to thank my friends, library staff and several authors of various text books which have been referred in this project but have remained unmentioned in the list of references.

RAJAT BHARDWAJ (121696)

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ABSTRACT

The principle objective of this project is to analyze and design a multi-storey building [G+1 (3 dimensional frame)]. The design involves load calculations manually and analyzing the whole structure by structural analysis software Staad.Pro. The design methods used in Staad.Pro analysis are Limit State Design conforming to Indian Standard Code of Practice. Staad.Pro features a state-of-the-art user interface, visualization tools, powerful analysis and design engines with advanced finite element and dynamic analysis capabilities. Initially the analysis of a simple two-dimensional frame was carried out and the results were manually checked for the accuracy. The results proved to be very accurate. A G+1 storey building (2-D Frame) was analysed and designed initially for all possible load combinations of dead, live and seismic loads. Further, the analysis and design of the full G+1 3-D RCC frame under various load combinations was analysed and designed for two regions—one in seismic zone-I and other in seimic zone-V. The cost estimation of the structure was done for both the regions using the rates provided in CSR 2010 (Common Schedule of Rates) of Punjab and Himachal Pradesh provided by CPWD. The results were compared in terms of the cost and safety factor of both the counterparts.

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CHAPTER 1

INTRODUCTION AND OBJECTIVES

1.1 General

A commercial building is a building that is used for commercial use. Types can include office buildings, warehouses, or retail (i.e. convenience stores, 'big box' stores, shopping malls, etc.). In urban locations, a commercial building often combines functions, such as an office on levels 2-10, with retail on floor 1. Local authorities commonly maintain strict regulations on commercial zoning, and have the authority to designate any zoned area as such. A business must be located in a commercial area or area zoned at least partially for commerce.

The design of these modern reinforced concrete structures may appear to be highly complex. However, most of these structures are the assembly of several basic structural elements such as beams, columns, slabs, walls and foundations. Accordingly, the designer has to learn the design of these basic reinforced concrete elements. The joints and connections are then carefully developed. Design of reinforced concrete structures started in the beginning of last century following purely empirical approach. Thereafter came the so called rigorous elastic theory where the levels of stresses in concrete and steel are limited so that stress-deformations are taken to be linear. However, the limit state method, though semi-empirical approach, has been found to be the best for the design of reinforced concrete structures.

The main objective of the project is to analyse and design the RCC Structure using STAAD.Pro. The major components of this buildings are Beams, Columns, Staircase, Slab, Footings in which beams, columns and footings are designed using STAAD.Pro software and design of slab and staircase can be done manually using I.S Codes.

Various loads are acting on this building like dead load, live load, earthquake load. These loads can be calculated using I.S Codes. Various factors are responsible for the acting of these loads.

1.2 Response Spectrum Method for Earthquake analysis

The basic mode superposition method, which is restricted to linearly elastic analysis, produces the complete time history response of joint displacements and member forces. In the past there have been two major disadvantages in the use of this approach. First, the method produces a large amount of output information that can require a significant amount of computational effort to conduct all possible design checks as a function of time. Second, the analysis must be repeated for several different earthquake motions in order to assure that all frequencies are excited, since a response spectrum for one earthquake in a specified direction is not a smooth function.

There are computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and member forces in structural systems. The method involves the calculation of only the maximum values of the displacements and member forces in each mode using smooth design spectra that are the average of several earthquake motions.

1.3 OBJECTIVES

- To analyze and design of a 2 storey RCC framed structure using STAAD.Pro.
- The designed structure should sustain all loads and deform within limits for construction and use.
- To design staircase and slab manually.
- To design the building subjected to earthquake loading.
- To prepare cost and estimation of the building.
- To prepare drawings with reinforcement detailing.

1.4 Work Plan

Description

- Analysis of building -(September ,October)
- Superstructure design in STAAD.Pro. software -(November,December)
- Design Of Foundation in STAAD.foundation and costing of building -(February,March)
- Analyse and design of building subjected to earthquake loading and varying the soil profile -(March ,April)

CHAPTER 2

PROBLEM DEFINITION

2.1 General

Analyze and design a RCC building intended for dairy research and training centre for the usage in business purpose like training to people in dairy farming, milk processing etc., using STAAD.Pro and manual calculations.

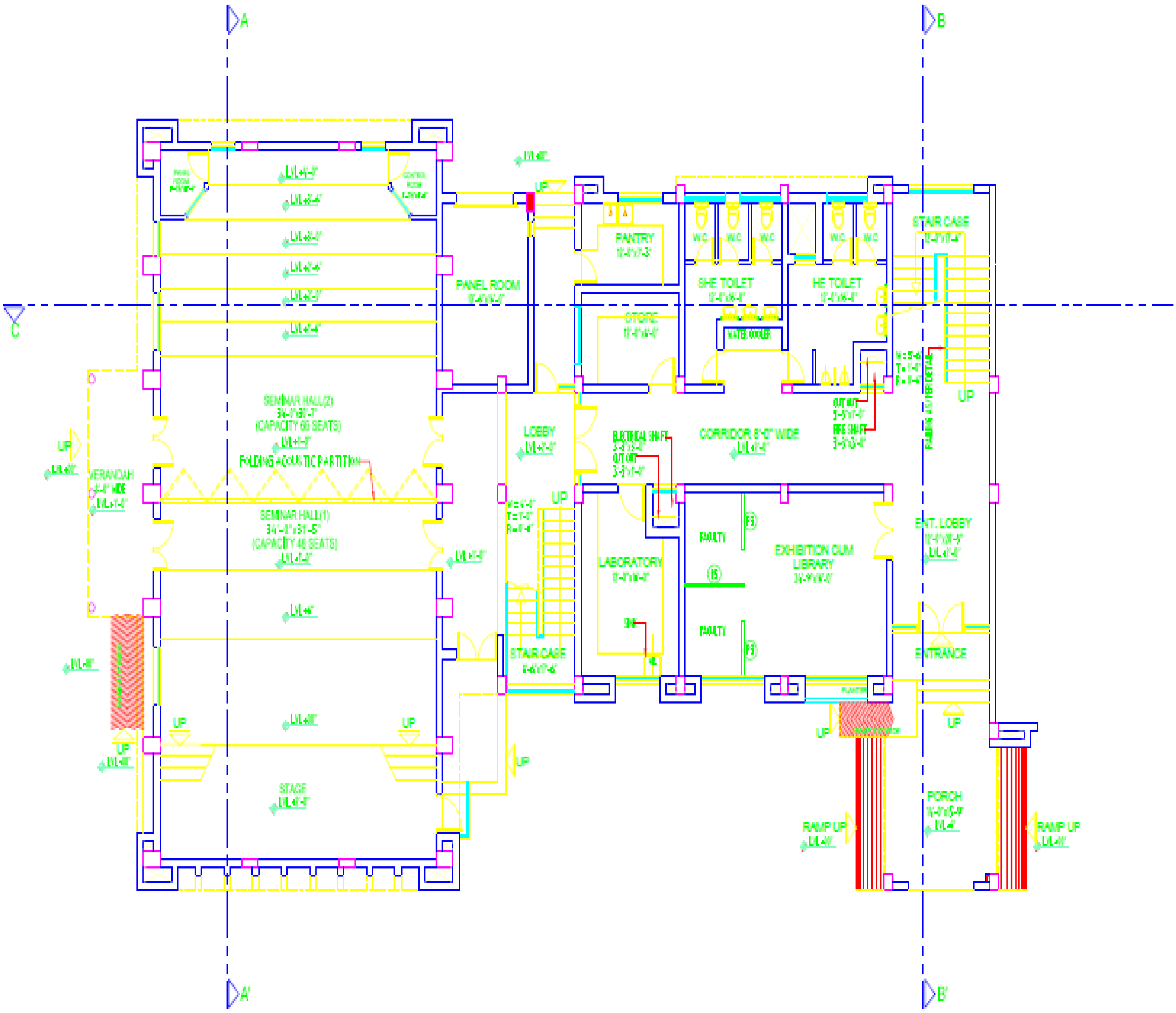


Fig.1 Plan Layout

2.2 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..

This Major Qualifying Project investigated the design of a two storey business building with a large seminar hall for participants to get training.

The project team's goal is to design an structural system that is cost effective, safe, and accommodating to the proposed use. The project team establish an architectural layout and floor plan based on the building's projected business use. The team then model a structural framing system. All principle structural members will be designed, including beams, girders, columns, connections and foundation elements. Frame designs investigating both steel and concrete construction. Both materials then compared and analyzed resulting in one final, cost effective structural frame using one of the materials. The team compared several different structural strategies and materials to review their implications on the economics, performance, and constructability of the structure.

2.3 Background

This background section discusses the research base that contributed to the development of this Major Qualifying Project. The below sections present the information collected regarding the various elements of the building and the structural design and analysis processes of those elements.

2.3.1 Building Purpose and Location

In order to begin the building design process the group had to determine the general purpose of the building and its location. The sections below discuss the background research to define the purpose and location.

2.3.2 Purpose

As stated in the introduction the group will design a general business building. The specific purpose was not identified; however, the building is capable of accommodating several different purposes. The design plan includes an seminar hall which serves as space for participants to get training. The building also provides laboratory to regular check the quality of milk. Architectural consultants such as, **AVINASH KHOSLA AND ASSOC.** provides general floor dimensions and layouts of various aspects of buildings which were used in the building design process.

2.3.3 Structural Design

The structural design of the building was a major focus of the project. When analysing the elements of building like beam, column and slab the group followed the provisions of IS CODE 456-2000,IS 875 PART-1,2,3. The building code provides design values for floor loadings based on room functionality. It also defines other design loads including wind and earthquake. To establish the most effective design it was necessary to compare different framing schemes and corresponding costs. Costs were calculated using estimated unit costs per ton of steel and volume of concrete. Individual members were designed to use as little material as possible while handling design loads and meeting code restrictions. Member sizes throughout the building were also designed to be as repetitive as possible while using standard dimensions.

CHAPTER 3

METHODOLOGY AND LOADS ON BUILDING

3.1 General

The preceding chapter has given background information into the areas of study of the project and has provided a base for defining the various tasks needed to complete each major area of study. The following methodology discusses the approach to complete each task.

This section discusses how the group determined the building layout, geometry, and structural framing. Creating the basic floor plans of the building was essential for defining the structural framework and proportioning the structural elements. To perform an accurate analysis a structural engineer must determine such information as structural loads, geometry, support conditions, and materials properties. The results of such an analysis typically include support reactions, stresses and displacements. This information is then compared to criteria that indicate the conditions of failure. Advanced structural analysis may examine dynamic response, stability and non-linear behaviour. The aim of design is the achievement of an acceptable probability that structures being designed will perform satisfactorily during their intended life. With an appropriate degree of safety, they should sustain all the loads and deformations of normal construction and use and have adequate durability and adequate resistance to the effects of seismic and wind. Structure and structural elements shall normally be designed by Limit State Method. Account should be taken of accepted theories, experiment and experience and the need to design for durability. Design, including design for durability, construction and use in service should be considered as a whole. The realization of design objectives requires compliance with clearly defined standards for materials, production, workmanship and also maintenance and use of structure in service. The design of the building is dependent upon the minimum requirements as prescribed in the Indian Standard Codes. The minimum requirements pertaining to the structural safety of buildings are being covered by way of laying down minimum design loads which have to be assumed for dead loads, imposed loads, and other external loads, the structure would be required to bear. Strict conformity to loading standards recommended in this code, it is hoped, will not only ensure the structural safety of the buildings which are being designed.

3.2 Loads Considered

3.2.1 Dead Loads

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^2 and 25 kN/m^2 respectively.

3.2.2 Imposed Loads

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.

3.2.3 Seismic Loads

Design Lateral Force

The design lateral force shall first be computed for the building as a whole. This design lateral force shall then be distributed to the various floor levels. The overall design seismic force thus obtained at each floor level shall then be distributed to individual lateral load resisting elements depending on the floor diaphragm action.

Design Seismic Base Shear

The total design lateral force or design seismic base shear (V_b) along any principal direction shall be determined by the following expression:

$V_b = A_h W$

Where,

A_h = horizontal acceleration spectrum

W = seismic weight of all the floors

Fundamental Natural Period

The approximate fundamental natural period of vibration (T,), in seconds, of a moment-resisting frame building without brick in the panels may be estimated by the empirical expression:

$T_a = 0.075\ h^{0.75}$ for RC frame building

$T_a = 0.085\ h^{0.75}$ for steel frame building

Where,

h = Height of building, in m. This excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted between the building columns. But it includes the basement storeys, when they are not so connected. The approximate fundamental natural period of vibration (T,), in seconds, of all other buildings, including moment-resisting frame buildings with brick lintel panels, may be estimated by the empirical expression:

$$T = \frac{.09H}{\sqrt{D}}$$

Where,

h= Height of building

d= Base dimension of the building at the plinth level, in m, along the considered direction of the lateral force.

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.

Table 1. Load Combinations

Load combinations		**Remarks**
1.5(DL+LL)		**DL – Dead load of the structure** **LL - Live load of thestructure** **EQX – Earthquake load along X direction EQZ - Earthquake load along Z direction WLX – Wind load along X**
1.5(DL±EQX)	**1.5(DL±WLX)**	
1.5(DL±EQZ)	**1.5(DL±WLZ)**	
0.9(DL±1.5EQX)	**0.9(DL±1.5WLX)**	
0.9(DL±1.5EQZ)	**0.9(DL±1.5WLZ)**	
1.2(DL+LL±EQX)	**1.2(DL+LL±WLX)**	
1.2(DL+LL±EQZ)	**1.2(DL+LL±WLZ)**	

CHAPTER 4
MODELING IN STAAD PRO

4.1 General

The GUI (or Graphical User Interface) communicates with the STAAD.pro analysis engine through the STD input file. That input file is a text file consisting of a series of commands which are executed sequentially. The commands contain either instructions or data pertaining to analysis and/or design. The STAAD input file can be created through a text editor or the GUI Modeling facility. In general, any text editor may be utilized to edit/create the STD input file. The GUI Modeling facility creates the input file through an interactive menu-driven graphics oriented.

4.2 Types of Structures

A structure can be defined as an assemblage of elements. STAAD.Pro is capable of analyzing and designing structures consisting of frame, plate/shell and solid elements. Almost any type of structure can be analyzed by STAAD.Pro software. A space structure, which is a three dimensional framed structure with loads applied in any plane, is the most general. A plane structure is bound by a global X-Y coordinate system with loads in the same plane. A TRUSS structure consists of truss members which can have only axial member forces and no bending in the members.

A floor structure is a two or three dimensional structure having no horizontal (global X or Z) movement of the structure [FX, FZ &MY are restrained at every joint]. The floor framing (in global X-Z plane) of a building is an ideal example of a floor structure. Columns can also be modeled with the floor in a floor structure as long as the structure has no horizontal loading. If there is any horizontal load, it must be analyzed as a space structure.

4.3 Generation of the structure

The structure may be generated from the input file or mentioning the co-ordinates in the GUI. The figure below shows the GUI generation method.

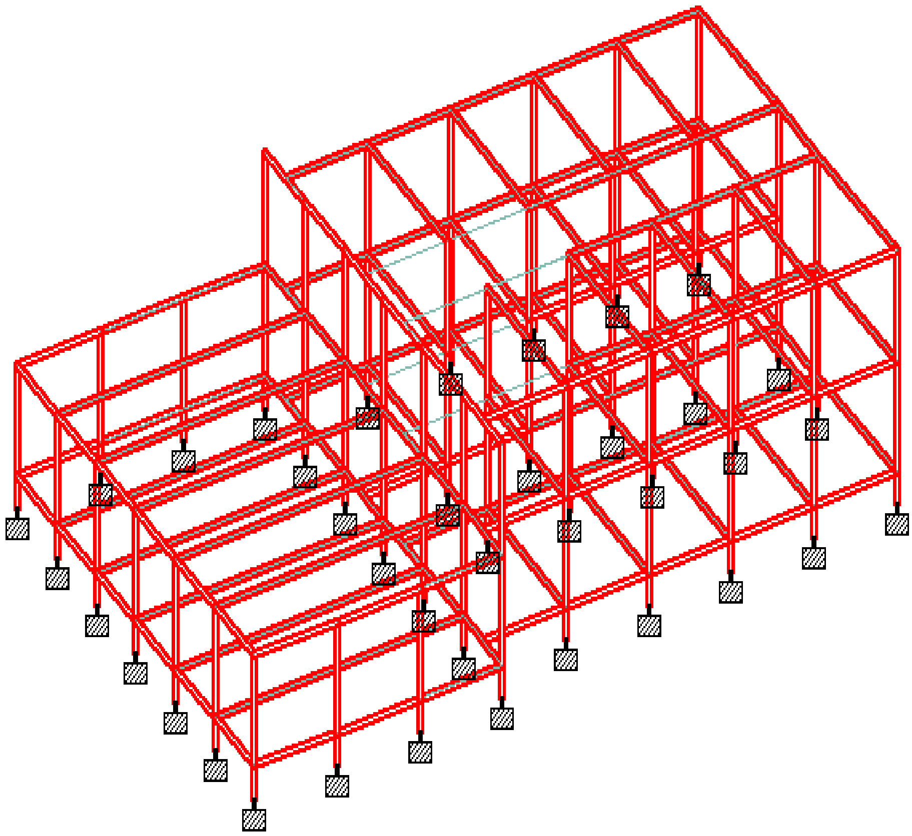


Fig.2 Modeled Structure

4.4 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. A translational spring constant is defined as the force to displace a support joint one length unit in the specified global direction. Similarly, a rotational spring constant is defined as the force to rotate the support joint one degree around the specified global direction.

4.5 Loads

Loads in a structure can be specified as joint load, member load, temperature load and fixed end member load. STAAD.Pro 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.

4.5.1 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.

4.5.2 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. Trapezoidal linearly varying loads act over the full or partial length of a member. Trapezoidal loads are converted into a uniform load and several concentrated loads. Any number of loads may be specified to act upon a member in any independent loading condition. Member loads can be specified in the member coordinate system or the global coordinate system. Uniformly distributed member loads provided in the global coordinate system may be specified to act along the full or projected member length.

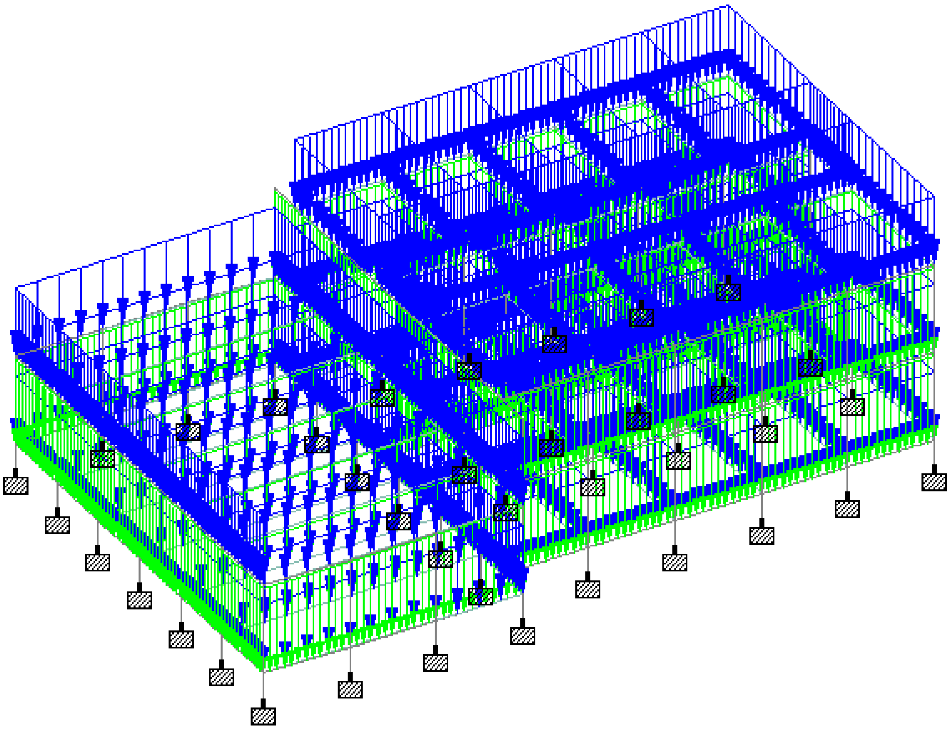


Fig.3 Member loads

4.5.3 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.

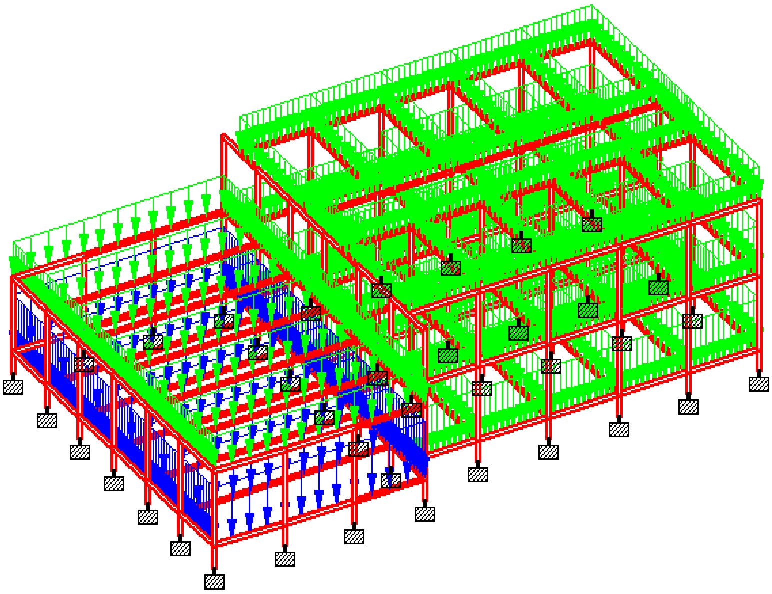


Fig.4 Due to Live Loads

4.5.4 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. Instead of using the approximate code based formulas to estimate the building period in a certain direction, the program calculates the period using Raleigh quotient technique. This period is then utilized to calculate seismic coefficient C. After the base shear is calculated from the appropriate equation, it is distributed among the various levels and roof per the specifications. The distributed base shears are subsequently applied as lateral loads on the structure. These loads may then be utilized as normal load cases for analysis and design.

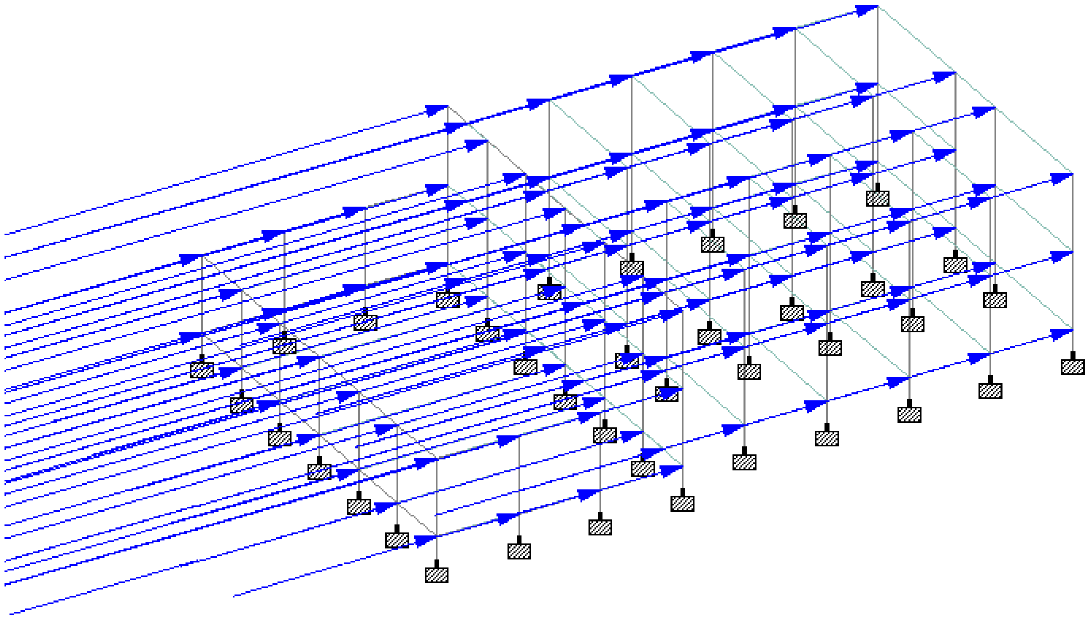


Fig.5 Seismic load Diagram

4.6 Section Types for Concrete Design

The following types of cross sections for concrete members can be designed.

For Beams Prismatic (Rectangular)

For Columns Prismatic (Rectangular)

4.7 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. 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. These values may be changed to suit the particular design being performed by this manual contains a complete list of the available parameters and their default values. It is necessary to declare length and force units as Millimetre and Newton before performing the concrete design.

4.7.1 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.

4.7.2 Design for Flexure

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

1. The minimum grade of concrete shall preferably be M20.
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:
4. $P_{min} = 0.24 \frac{\sqrt{fck}}{\sqrt{fy}}$
5. The maximum steel ratio on any face, at any section, is given by $P_{max} = 0.025$
6. The positive steel ratio at a joint face must be at least equal to half the negative steel at that face.
7. 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.

4.7.3 Design for Shear

The shear force to be resisted by vertical hoops is guided by the IS 13920:1993 revision. Elastic sagging and hogging moments of resistance of the beam section at ends are considered while calculating shear force. Plastic sagging and hogging moments of resistance can also be considered for shear design if PLASTIC parameter is mentioned in the input file. Shear reinforcement is calculated to resist both shear forces and torsional moments.

4.7.4 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 have been taken care of in the column design of STAAD.Pro. However following clauses have been satisfied to incorporate provisions of IS 13920.

1. The minimum grade of concrete shall preferably be M20
2. Steel reinforcements of grade Fe415 or less only shall be used.
3. The minimum dimension of column member shall not be less than 200 mm. For columns having unsupported length exceeding 4m, the shortest dimension of column shall not be less than 300 mm.

4. The ratio of the shortest cross-sectional dimension to the perpendicular dimension shall preferably be not less than 0.

5. The spacing of hoops shall not exceed half the least lateral dimension of the column, except where special confining reinforcement is provided.

6. Special confining reinforcement shall be provided over a length lo from each joint face, towards mid span, and on either side of any section, where flexural yielding may occur. The length lo shall not be less than a) larger lateral dimension of the member at the section where yielding occurs, b) 1/6 of clear span of the member, and c) 450 mm.

7. The spacing of hoops used as special confining reinforcement shall not exceed ¼ of minimum member dimension but need not be less than 75 mm nor more than 100 mm.

4.8 Design Operations

STAAD.Pro contains a broad set of facilities for designing structural members as individual components of an analyzed structure. The member design facilities provide the user with the ability to carry out a number of different design operations. These facilities may design problem. The operations to perform a design are:

1. Specify the members and the load cases to be considered in the design.
2. Specify whether to perform code checking or member selection.
3. Specify design parameter values, if different from the default values.
4. Specify whether to perform member selection by optimization.

These operations may be repeated by the user any number of times depending upon the design requirements.

Earthquake motion often induces force large enough to cause inelastic deformations in the structure. If the structure is brittle, sudden failure could occur. But if the structure is made to behave ductile, it will be able to sustain the earthquake effects better with some deflection larger than the yield deflection by absorption of energy. Therefore ductility is also required as an essential element for safety from sudden collapse during severe shocks. STAAD.Pro has the capabilities of performing concrete design as per IS 13920. While designing it satisfies all provisions of IS 456 – 2000 and IS 13920 for beams and columns.

4.9 General Comments

This section presents some general statements regarding the implementation of Indian Standard code of practice (IS: 800-1984) for structural steel design in STAAD.Pro. The design philosophy and procedural logistics for member selection and code checking are based upon the principles of allowable stress design. Two major failure modes are recognized failure by overstressing, and failure by stability considerations. The flowing sections describe the salient features of the allowable stresses being calculated and the stability criteria being used. Members are proportioned to resist the design loads without exceeding the allowable stresses and the most economic section is selected on the basis of least weight criteria. The code checking part of the program checks stability and strength requirements and reports the critical loading condition and the governing code criteria. It is generally assumed that the user will take care of the detailing requirements like provision of stiffeners and check the local effects such as flange buckling and web crippling.

4.10 Allowable Stresses

The member design and code checking in STAAD.Pro 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 in this manual. This section, however, will discuss the salient features of the allowable stresses specified by IS: 800 and implemented in STAAD.Pro Appropriate sections of IS: 800 will be referenced during the discussion of various types of allowable stresses.

4.11 Multiple Analyses

Structural analysis/design may require multiple analyses in the same run. STAAD.Pro allows the user to change input such as member properties, support conditions etc. in an input file to facilitate multiple analyses in the same run. Results from different analyses may be combined for design purposes. For structures with bracing, it may be necessary to make certain members inactive for a particular load case and subsequently activate them for another. STAAD provides an INACTIVE facility for this type of analysis.

4.12 Post Processing Facilities

All output from the STAAD run may be utilized for further processing by the STAAD.Pro GUI.

4.13 Stability Requirements

Slenderness ratios are calculated for all members and checked against the appropriate maximum values. IS: 800 summarize the maximum slenderness ratios for different types of members. In STAAD implementation of IS: 800, 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.

4.13.1 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.

4.13.2 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.

CHAPTER 5

DESIGN OF THE BUILDING

5.1 Design of Slabs

Typically we divided the slabs into two types:

1. Roof Slab
2. Floor Slab

In case of roof slab the live load obtained is less compared to the floor slab. Therefore we first design the roof slab and then floor slabs.

We have two types of supports. They are

1. Ultimate support
2. Penultimate support

Ultimate support is the end support and the penultimate supports are the intermediate supports.

Ultimate support tends to have a bending moment of $\frac{\mathrm{Wu} \times \mathrm{L}^2}{10}$ and the penultimate supports have $\frac{\mathrm{Wu} \times \mathrm{L}^2}{12}$

Design of roof slab

It is a continuous slab on the top of the building which is also known as terrace. Generally terrace has less live load and it is empty in most of the time except some occasions in case of any residential building.

The plan layout of roof slab is shown in below figure.

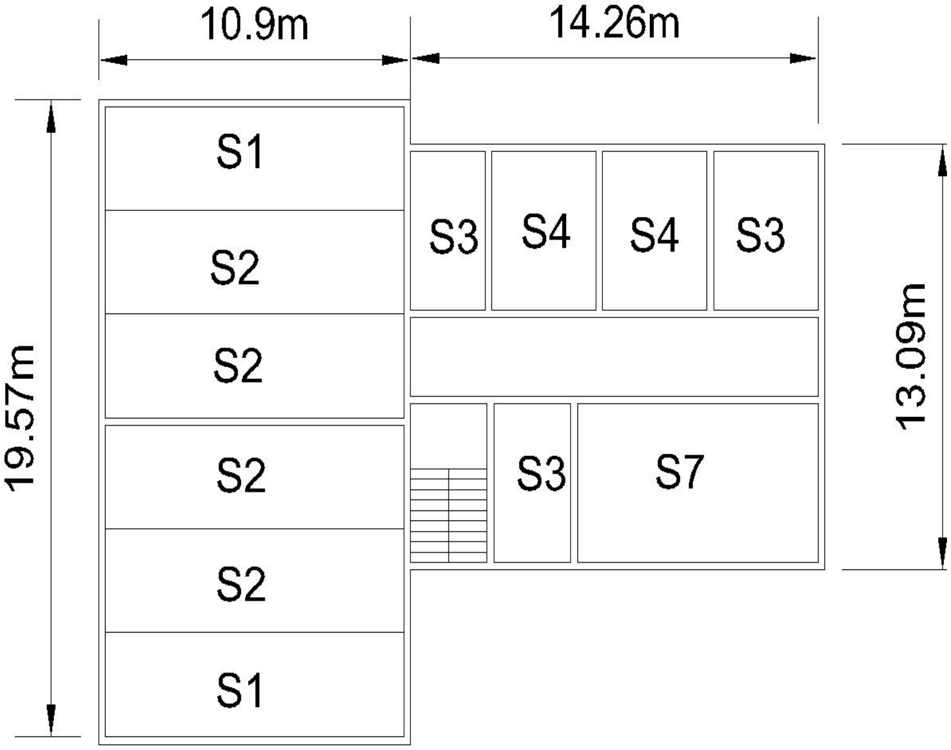


Fig.6 Plan of Roof Slab

Design of Roof Slab (S1)

Calculation of Depth (D) by using modification factor

Assume the percentage of the tension reinforcement (Pt) provided is 0.4%

From IS456-2000, P38 Fig4, we get the modification factor (α) = 1.4

Required Depth (D) = $D = \frac{L}{R} + d^1$

$$\frac{L}{R} = \frac{\text{Span}}{\text{allowable} \frac{L}{d} \text{ratio}}$$

d^1 = Centre of the reinforcement to the end fibre (= 20 mm for slab)

From IS456-2000, P39, Clause 24 & Clause 23.2 for continuous span we have

$$\frac{\text{Span}}{\text{Effective depth}} = \frac{L}{d} = 26$$

r_a = 26 x 1.4 = 36.4

Therefore, $D = \frac{10.9 \times 1000}{36.4} + 20 = 320$ mm

Effective depth (d) = D – d^1 = 320-20

=300 mm

Loads

Dead loads (From IS875 – Part 1)

Terrace water proofing = 2.5 kN/m^2

Self-weight of the slab = 1 x 1 x D x 25 = 0.3× 25

=7.5 kN/m^2

Live loads (From IS875 – Part 2)

Roof = 1.5 kN/m^2

Total load (W) = 2.5+7.5+1.5 = 11.5 kN/m^2

Ultimate load or limit state load or design load (Wu) = 1.5 x W = 1.5 x11.5

= 17.25 kN/m^2

Design moment (for end panel)

$$\boldsymbol{Mu} = \frac{\mathbf{Wu \times L^2}}{\mathbf{10}} = \frac{17.25 \times 10.9^2}{10} = 207.9 \text{ kN}$$

Calculation of area of steel

From IS456-2000, P96, Clause G-1.1 (b) we have

$$\mathbf{M_u = 0.87 \times fy \times Ast \times d \times \left(1 - \frac{fy \times Ast}{fck \times b \times d}\right)}$$

$$207.9 \times 10^6 = 0.87 \times 415 \times \text{Ast} \times 300 \left(1 - \frac{415\text{Ast}}{20 \times 1000 \times 300}\right)$$

Ast = 2264 mm^2

Spacing of 8mm φ bars = $\frac{\mathbf{ast \times 1000}}{\mathbf{Ast}} = \frac{\frac{\pi}{4} \times 144 \times 1000}{2264} = 50$ mm

Therefore, Provide 12 mm φ @ 50mm c/c.

Distribution steel

A_{st} = 0.12% of Ag

$$\frac{0.12}{1000} \times 320 \times 1000 = 384 mm^2$$

Spacing of 8mm φ bars =130 mm

Design of Roof slab (S2)

Depth (D) = 320 mm

Total load (W) = 11.25 kN/m^2

Limit state load (Wu) = 1.5 x 11.25 = 17.25 kN/m^2

Design moment (for intermediate panel)

$$\mathbf{Mu} = \frac{\mathbf{Wu \times L^2}}{\mathbf{12}} = \frac{17.25 \times 10.9^2}{12} = 170.78 \text{ kN} - \text{m}$$

Calculation of area of steel

$$\mathbf{M_u = 0.87 \times \mathit{fy} \times \mathit{Ast} \times \mathit{d} \times \left(1 - \frac{\mathit{fy} \times \mathit{Ast}}{\mathit{fck} \times \mathit{b} \times \mathit{d}}\right)}$$

$$170.78 \times 10^6 = 0.87 \times 415 \times \text{Ast} \times 300 \left(1 - \frac{415\text{Ast}}{20 \times 1000 \times 300}\right)$$

A_{st} = 1800 mm^2

Spacing of 12mm φ bars = $\frac{\boldsymbol{ast \times 1000}}{\boldsymbol{Ast}} = \frac{\frac{\pi}{4} \times 144 \times 1000}{1800} = 62.83\ mm$

Therefore, Provide 12mm φ @ 62.83mm c/c.

Distribution steel

A_{st} = 0.12% of Ag

$$\frac{0.12}{1000} \times 320 \times 1000 = 384\ mm^2$$

Spacing of 8mm φ bars = 130 mm

Design of Slab (S3)

Depth (D) = 92 mm

Total load (W) = 5.8 kN/m^2

Limit state load (Wu) = 1.5 x 5.8 = 8.7 kN/m^2

Design moment

$$\mathbf{Mu} = \frac{\mathbf{Wu \times L^2}}{\mathbf{10}} = \frac{8.7 \times 2.62^2}{10} = 5.97\ kN - m$$

Calculation of area of steel

$$\mathbf{M_u = 0.87 \times \mathit{fy} \times \mathit{Ast} \times \mathit{d} \times \left(1 - \frac{\mathit{fy}\times\mathit{Ast}}{\mathit{fck}\times\mathit{b}\times\mathit{d}}\right)}$$

$$5.97 \times 10^6 = 0.87 \times 415 \times \mathrm{Ast} \times 72 \left(1 - \frac{415\mathrm{Ast}}{20 \times 1000 \times 72}\right)$$

A_{st} = 247mm^2

Spacing of 8mm φ bars $= \frac{\boldsymbol{ast\times1000}}{\boldsymbol{Ast}} = \frac{\frac{\pi}{4}\times64\times1000}{247} = 203mm$

Therefore, Provide 8mm φ @ 200mm c/c.

Distribution steel

A_{st} = 0.12% of Ag

$$\frac{0.12}{100} \times 72 \times 1000 = 90\mathrm{mm}^2$$

Spacing of 8mm φ bars = 500mm

Design of Slab (S4)

Depth D = 120 mm

Total load (W) = 6.5 kN/m^2

Limit state load (Wu) = 1.5 x 6.5 = 9.75 kN/m^2

Design moment

$$\mathbf{Mu} = \frac{\mathbf{Wu \times L^2}}{\mathbf{12}} = \frac{9.75 \times 3.65^2}{12} = 10.8\ \mathrm{kN} - \mathrm{m}$$

Calculation of area of steel

$$\mathbf{M_u = 0.87 \times \mathit{fy} \times \mathit{Ast} \times \mathit{d} \times \left(1 - \frac{\mathit{fy}\times\mathit{Ast}}{\mathit{fck}\times\mathit{b}\times\mathit{d}}\right)}$$

$$10.8 \times 10^6 = 0.87 \times 415 \times \mathrm{Ast} \times 100 \left(1 - \frac{415\mathrm{Ast}}{20 \times 1000 \times 100}\right)$$

A_{st} = 320 mm^2

Spacing of 8mm φ bars = $\frac{\textbf{ast}\times\textbf{1000}}{\textbf{Ast}} = \frac{\frac{\pi}{4}\times 64\times 1000}{320} = 157$ mm

Therefore, Provide 8mm φ @ 160mm c/c.

Distribution steel

A_{st} = 0.12% of Ag

$$\frac{0.12}{100} \times 100 \times 1000 = 120mm^2$$

Spacing of 8mm φ bars = 400 mm

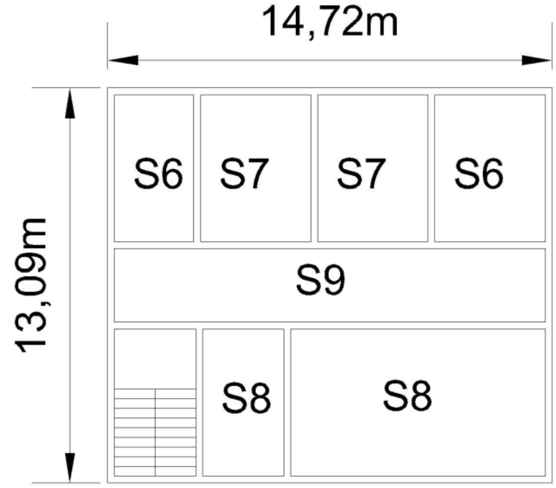


Fig.7 Ground Floor Slab

Design of Slab: S6 (Two way slab)

Size of slab = 3.65 m × 4.87 m

Edge conditions = two adjacent edges discontinuous

Materials used = M-20 grade of concrete and Fe-415 HYSD bars

Depth of slab: 5.5 inch = 139 mm

Adopt the effective depth (d) = 120 mm

Loads

Self weight of slab = (25 × 0.12) = 3 kN/m^2

Imposed load = 3 kN/m^2

Weight of flooring 50 mm thick = (0.05 × 24) = 1.2 kN/m^2

Total working load = W = 7.2 kN/m^2

Therefore design ultimate load = W_u = (1.5 × 7.2) = 10.8 kN/m

Ultimate design moments

The moment coefficients for $\frac{Ly}{Lx} = \frac{4.98}{3.73} = 1.33$

Short span moment coefficients

a) –ve moment coefficient = α_x = 0.057

b) +ve moment coefficient = α_x = 0.043

Long span moment coefficients

a) –ve moment coefficient = α_y = 0.077

b) +ve moment coefficient= α_y = 0.058

M_{ux} (-ve) = ($\alpha_x w_u L_x^2$) = (0.057 × 10.8 ×3.73^2) = 8.56 kN-m

M_{ux} (+ve)= ($\alpha_x w_u L_x^2$) = (0.043 × 10.8 × 3.73^2) = 6.46 kN-m

M_{uy} (-ve) = ($\alpha_y w_u L_x^2$)= (0.077 × 10.8 × 3.73^2) = 11.56 kN-m

M_{uy} (+ve) = ($\alpha_y w_u L_x^2$)= (0.058 × 10.8 × 3.73^2) = 8.71 kN-m

V_u = 0.5 w_u L_x= 0.5 ×10.8 × 3.73 = 20.1 kN

Check for depth

$M_{u,lim}$ = 0.138 f_{ck} bd^2

$d = \sqrt{\frac{11.56\times10^6}{0.138\times20\times1000}}$= 64.71mm < 120mm

Hence the effective depth selected is sufficient to resist the design ultimate moment.

$A_{st,min}$ = (0.12% bd) = 0.0012 x 1000 x 120 = 144 mm^2

Reinforcements along short and long span directions

The area of reinforcement is calculated using the relation,

$$\mathbf{M_u = 0.87 \times fy \times Ast \times d \times \left(1 - \frac{fy\times Ast}{fck\times b\times d}\right)}$$

Spacing of the selected bars are computed using the relation,

Spacing = S = (Area of 1 bar/ total area) x1000 such that A_{st} (provided) ≥ A_{st} (min)

In addition, the spacing should be the least Of three times the effective depth or 300 mm using 10 mm diameter bars for long span, d = 135 mm & for short span, d = 125 mm.

The detail of reinforcements provided in the two-way slab is compiled in the table below:

Table 2. Details of Reinforcement in Slab S6

Location	A_{st} (required)	Spacing of 10 mm bars
1. Short Span		
a) –ve B.M. (top of supports)	204 mm^2	380 mm
b) +ve B.M. (centre of span)	153 mm^2	500 mm
2. Long Span		
a) –ve B.M (top of supports)	280 mm^2	280 mm
b) +ve B.M (centre of span)	208 mm^2	375 mm

Torsion Reinforcement at corners

Area of torsional steel in each 4 layers = (0.75 x 204) = 153 mm^2

Distance over which the torsion reinforcement is provided = (1/5 short span) = (0.2 x 3730) = 746 mm.

Provide 6 mm diameter bars at 150 mm c/c for a length of 746 mm at all 4 corners in 4 layers.

Design of slab: S8 (Two-way slab)

Size of slab = 7.62 m × 4.87 m

Edge conditions = two adjacent edges discontinuous

Materials used = M-20 grade of concrete and Fe-415 HYSD bars

Depth of slab: 5.5 inch = 139 mm

Adopt the effective depth (d) = 120 mm

Loads

Self weight of slab = (25 × 0.12) = 3 kN/m^2

Imposed load = 3 kN/m^2

Weight of flooring 50 mm thick = (0.05 × 24) = 1.2 kN/m^2

Total working load = W = 7.2 kN/m^2

Therefore design ultimate load = W_u = (1.5 × 7.2) = 10.8 kN/m

Ultimate design moments

The moment coefficients for $\frac{Ly}{Lx} = \frac{7.7}{4.98} = 1.54$

Short span moment coefficients

a) –ve moment coefficient = α_x = 0.06

b) +ve moment coefficient = α_x = 0.045

Long span moment coefficients

a) –ve moment coefficient = α_y = 0.093

b) +ve moment coefficient= α_y = 0.069

M_{ux} (-ve) = ($\alpha_x w_u L_x^2$) = (0.06 × 10.8 ×4.98^2) = 16.07 kN-m

M_{ux} (+ve)= ($\alpha_x w_u L_x^2$) = (0.045 × 10.8 × 4.98^2) = 12.05 kN-m

M_{uy} (-ve) = ($\alpha_y w_u L_x^2$) = (0.093 × 10.8 × 4.98^2) = 24.9 kN-m

M_{uy} (+ve) = ($\alpha_y w_u L_x^2$) = (0.069 × 10.8 × 4.98^2) = 18.48 kN-m

V_u = 0.5 $w_u L_x$ = 0.5 ×10.8 × 4.98 = 26.8 kN

Check for depth

$M_{u,lim} = 0.138 f_{ck} bd^2$

$d = \sqrt{\frac{24.9\times10^6}{0.138\times20\times1000}}$= 95mm < 120mm

Hence the effective depth selected is sufficient to resist the design ultimate moment.

$A_{st,min}$ =(0.12% bd) = 0.0012 x 1000 x 120 = 144 mm^2

Reinforcements along short and long span directions

The area of reinforcement is calculated using the relation,

$$\mathbf{M_u} = \mathbf{0.87 \times fy \times Ast \times d \times \left(1 - \frac{fy\times Ast}{fck\times b\times d}\right)}$$

Spacing of the selected bars are computed using the relation,

Spacing = S = (Area of 1 bar/ total area) x1000 such that A_{st} (provided) ≥ A_{st} (min)

In addition, the spacing should be the least Of three times the effective depth or 300 mm using 10 mm diameter bars for long span, d = 135 mm & for short span, d = 125 mm.

The detail of reinforcements provided in the two-way slab is compiled in the table below:

Table 3. Details of Reinforcement in Slab S7

Location	A_{st} (required)	Spacing of 10mm bars
1. Short Span		
a) –ve B.M (top of supports)	398 mm^2	200 mm
b) +ve B.M (centre of span)	292 mm^2	268 mm
2. Long Span		
a) –ve B.M (top of supports)	647 mm^2	120 mm
b) +ve B.M (centre of span)	463 mm^2	170 mm

Torsion Reinforcement at corners

Area of torsion steel in each 4 layers = (0.75 x 292) = 219 mm^2

Distance over which the torsion reinforcement is provided = (1/5 short span) = (0.2×4980) = 1000 mm.

Provide 6 mm diameter bars at 130 mm c/c for a length of 1000 mm at all 4 corners in 4 layers.

(Same for Design of other slabs having same area and end conditions)

Design of slab: S9 (One-way slab)

Size of slab = 13.59 m × 2.47 m

Edge conditions = two adjacent edges discontinuous

Materials used = M-20 grade of concrete and Fe-415 HYSD bars

Depth of slab: 5.5 inch = 139 mm

Adopt the effective depth (d) = 120 mm

Loads

Self weight of slab = (25 × 0.12) = 3 kN/m^2

Imposed load = 3 kN/m^2

Weight of flooring 50 mm thick = (0.05 × 24) = 1.2 kN/m^2

Total working load = W = 7.2 kN/m^2

Therefore design ultimate load = W_u = (1.5 × 7.2) = 10.8 kN/m

Ultimate moments and shear forces,

$\mathbf{M_u}$ **= $\mathbf{(0.125 w_u L^2)}$** = $(0.125\times10.8\times2.6^2)$ = 9.126 kN-m

$\mathbf{V_u}$ **= $\mathbf{(0.5 w_u L)}$** = $(0.5 \times 10.8 \times 2.6)$ = 14.04 kN

Limiting moment of resistance

$\mathbf{M_{u,llim} = 0.138\, f_{ck} \times b \times d}$

= $(0.138\times20\times1000\times120^2)$ = 39.7 kN-m

$M_u < M_{u,lim}$. Section is under reinforced.

$$\mathbf{M_u = 0.87 \times \boldsymbol{fy} \times \boldsymbol{Ast} \times \boldsymbol{d} \times \left(1 - \frac{\boldsymbol{fy}\times \boldsymbol{Ast}}{\boldsymbol{fck}\times \boldsymbol{b}\times \boldsymbol{d}}\right)}$$

$$9.126 \times 10^6 = 0.87 \times 415 \times Ast \times 120\left(1 - \frac{415Ast}{20 \times 1000 \times 120}\right)$$

A_{st}= 220 mm^2

Solving A_{st} = 220 mm^2>$A_{st,min}$ = 160 mm^2

Using 10 mm diameter of bars, the spacing of the selected bars are computed using the relation,

Spacing = S = (Area of 1 bar/ total area) ×1000 such that A_{st} (provided) ≥ A_{st} (min)

S = (1000×78.5 / 220) = 350mm

Adopt spacing of 350 mm with alternative bars are bent up at supports.

Distribution bars

$\mathbf{A_{st,min}}$ =(0.12% bd) = 0.0012 × 1000 × 120 = 144 mm^2

Providing 8mm bars at 350 c/c

Check for shear stress

$\mathbf{T_v} = \frac{\boldsymbol{Vu}}{\boldsymbol{bd}} = \frac{14.04\times10^3}{1000\times120}$= 0.12 N/mm^2

$\mathbf{P_t} = \frac{\mathbf{100Ast}}{\mathbf{bd}} = \frac{100\times220\times0.5}{1000\times120}$ = 0.091

Permissible shear stress slab (as IS- 456) is calculated as

Kt_c = 0.36 N/mm^2 >T_v

Hence slab is safe.

Check for deflection control

$\mathbf{(L/d)_{max} = (L/d)_{basic} \times k_t \times k_c \times k_f}$

For P_t = s($\frac{100\times220}{1000\times120}$) = 0.18 percent ,$k_c$ = 1, k_f = 1.

$(L/d)_{max}$ = (26×1.4×1×1) = 36.4

$(L/d)_{provided}$ = 12 Hence deflection criteria are satisfied.

5.2 Design of Staircase

Stairs consist of steps arranged in a series for purpose of giving access to different floors of a building. Since a stair is often the only means of communication between the various floors of a building, the location of the stair requires good and careful consideration. In a residential house, the staircase may be provided near the main entrance. In a public building, the stairs must be from the main entrance itself and located centrally, to provide quick accessibility to the principal apartments. All staircases should be adequately lighted and properly ventilated.

Various types of Staircases

1. Straight stairs
2. Dog-legged stairs
3. Open newel stair
4. Geometrical stair

RCC design of a Dog-legged staircase

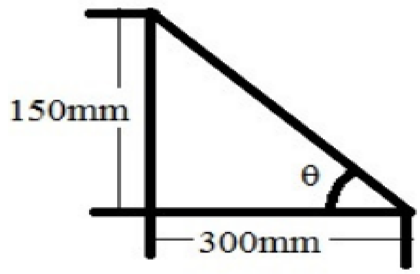
In this type of staircase, the succeeding flights rise in opposite directions. The two flights in plan are not separated by a well. A landing is provided corresponding to the level atwhich the direction of the flight changes.

Dimensions

B x L x H = 2820mm x 6000mm x 3350mm

Assume, Rise = 150mm

Tread = 300mm



$$\text{Sec}\theta = \frac{\sqrt{150^2 + 300^2}}{300} = 1.12$$

No. of risers = $\frac{3350}{150}$

= 22.33 say 22

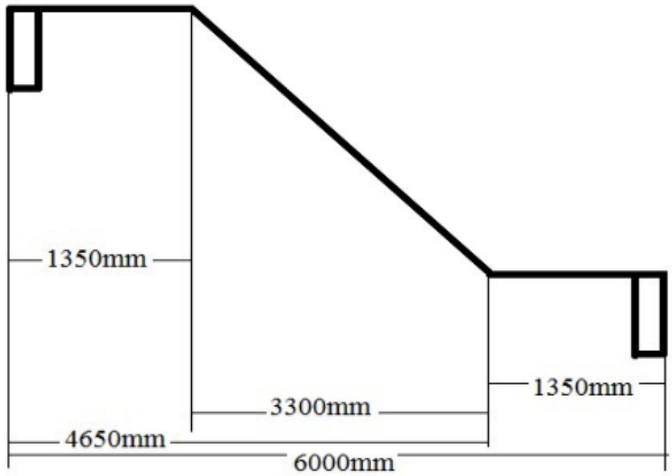
Provide 11 + 11.

For flight-1: 11 and for Flight-2: 11

Going = 11 x treads = 11 x 300 = 3300 mm

Total width of landings = 6000 – 3300 = 2700 mm

Therefore, width of landing at each end = 1350 mm



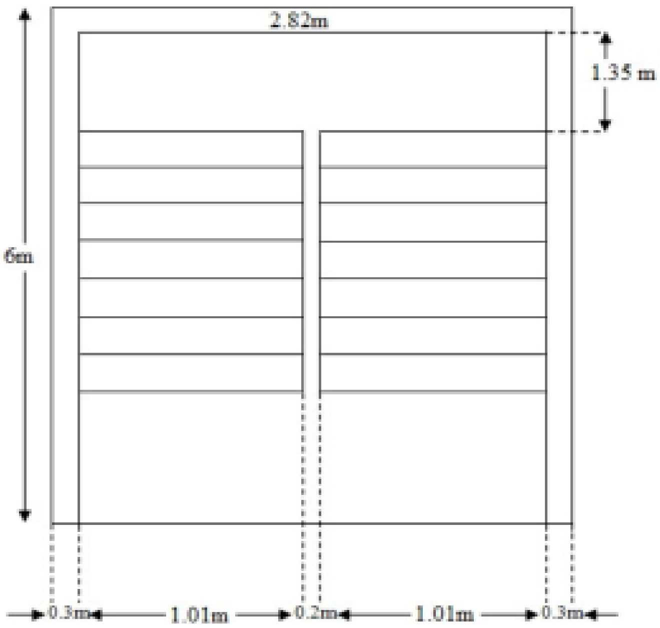


Fig.8 Plan Layout of Stairs

Design of Flight -1

Type: One way single span simply supported inclined slab

Span (L): 3300 + 1350 = 4650mm

Trail Depth

From IS456-2000, P39, Clause 24 & Clause 23.2 for Simply supported span we have

$$\frac{\text{Span}}{\text{Effective depth}} = \frac{\text{L}}{\text{d}} = 20$$

ra = 20 x 1.4 = 28

Therefore, D = $= \frac{4750}{28} + 20$ = 189.65mm say 200 mm

Effective depth (d) = D – d^1 = 200 – 20 = 180mm

Loads

Self weight of slab (inclined) = 25 x D x secθ

= 25 x 0.2 x 1.12

= 5.6 kN/m^2

Weight of steps = $\frac{25 \times rise \times \sec\theta}{2} = \frac{25 \times 0.15 \times 1.1}{2}$

= 2.09 kN/m^2

Live load = 5 kN/m^2

Floor Finish = 1 kN/m^2

Total Load (W) = 13.69 kN/m^2

Ultimate load (W_u) = 1.5 x 13.69 = 20.54 kN/m^2

Design moment (M_u) = $\frac{Wu \times L^2}{10} = \frac{20.54 \times 4.65^2}{10} = 44.4\ kN - m$

$M_{u,lim}$ = 0.138 x f_{ck} x b x d^2 = 0.138 x 20 x 1000 x 180^2

= 89.42 x 10^6 N-mm = 89.42 kN-m

$M_u < M_{ulim}$

Main steel

From IS456-2000, P96, Clause G-1.1 (b) we have

$$\mathbf{Mu = 0.87 \times fy \times Ast \times d \times \left(1 - \frac{fy \times Ast}{fck \times b \times d}\right)}$$

$$44.7 \times 10^6 = 0.87 \times 415 \times \text{Ast} \times 180 \times \left(1 - \frac{415 \times \text{Ast}}{20 \times 1000 \times 180}\right)$$

Ast = 753.21 mm^2

Spacing of 12mm φ bars =$\frac{\boldsymbol{ast \times 1000}}{\boldsymbol{Ast}} = \frac{\frac{\pi}{4} \times 144 \times 1000}{753.2} = 150.15\ mm$

Therefore, Provide 12mm φ @ 150mm c/c.

Distribution steel

A_{st}= 0.12% of A_g

$=\frac{0.12\times200\times1000}{1000} = 240 \text{ mm}^2$

Spacing of 8mm φ bars $=\frac{\frac{\pi}{4}\times64\times1000}{240} = 209 \text{ mm}$

Therefore, Provide 8mm φ @ 200mm c/c.

Design of flight-2

Same as design of flight-1.

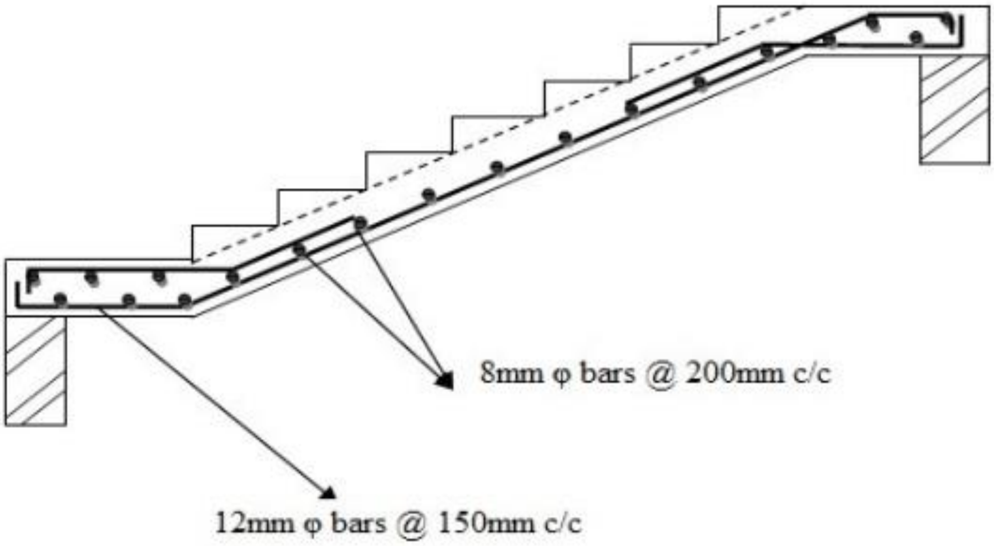


Fig.9 Design of Staircase

5.3 Design of Beams

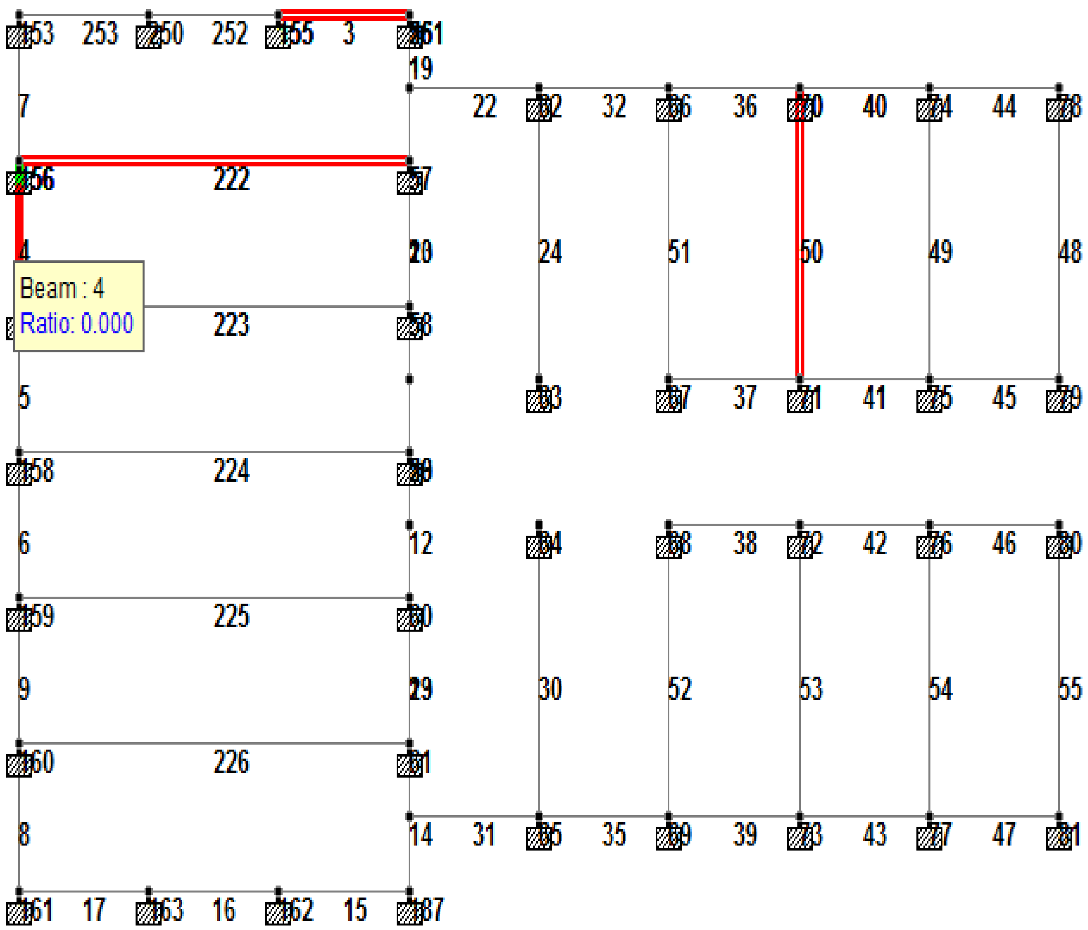


Fig.10 Plan of Beams

Beam No.3 Design Results

M25 Fe420 (Main) Fe415 (Sec.)

LENGTH: 3690.0 mm SIZE: 304.8 mm X 444.5 mm COVER: 40.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

Column1

SECTION 0.0 mm 922.5 mm 1845.0 mm 2767.5 mm 3690.0 mm

TOP 244.58 244.58 244.58 244.58 244.58
REINF. (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm)
BOTTOM 244.58 244.58 244.58 244.58 244.58
REINF. (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm)

SUMMARY OF PROVIDED REINF. AREA

Column1

SECTION 0.0 mm 922.5 mm 1845.0 mm 2767.5 mm 3690.0 mm

TOP 7-16í 7-16í7-16í7-16í7-16í
REINF. 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s)
BOTTOM 7-16í 7-16í7-16í7-16í7-16í
REINF. 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s)

SHEAR 2 legged 8í 2 legged 8í 2 legged 8í 2 legged 8í 2 legged 8í

REINF. @ 140 mm c/c @ 140 mm c/c @ 140 mm c/c @ 140 mm c/c @ 140 mm c/c

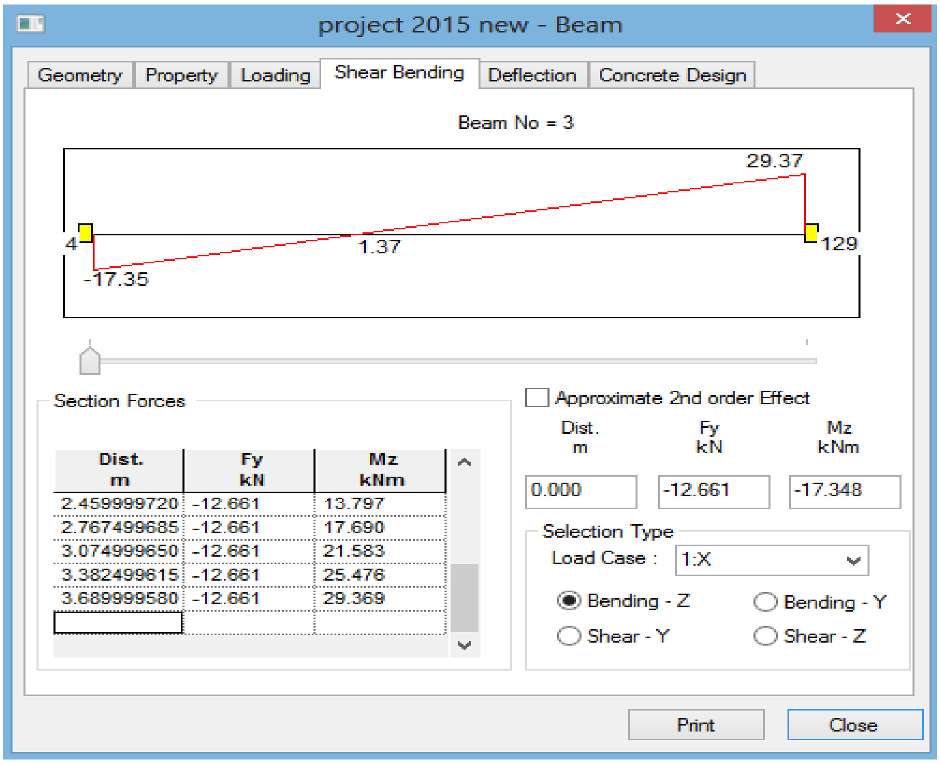


Fig.11 Shear bending of beam no. 3

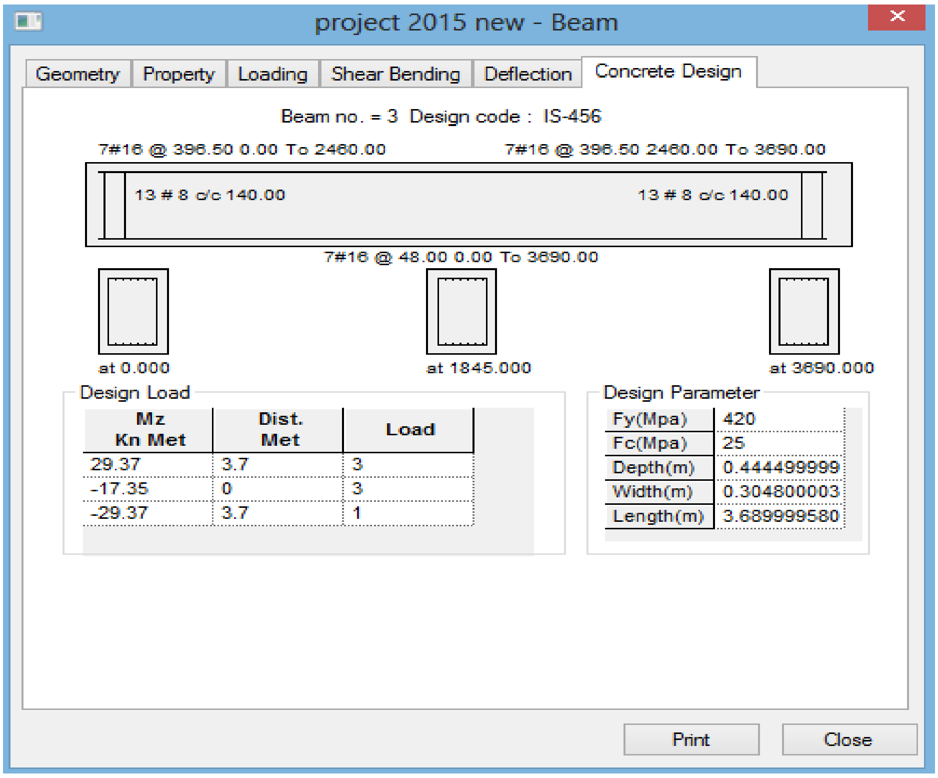


Fig.12 Concrete design of beam no. 3

Beam No.4 Design Results

M25 Fe420 (Main) Fe415 (Sec.)

LENGTH: 3048.0 mm SIZE: 228.6 mm× 444.5 mm COVER: 40.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

Column1

SECTION 0.0 mm 762.0 mm 1524.0 mm 2286.0 mm 3048.0 mm

TOP 183.44 183.44 183.44 183.44 183.44
REINF. (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm)
BOTTOM 183.44 183.44 183.44 183.44 183.44
REINF. (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm)

SUMMARY OF PROVIDED REINF. AREA

Column1

SECTION 0.0 mm 762.0 mm 1524.0 mm 2286.0 mm 3048.0 mm

TOP 5-16í 5-16í5-16í5-16í5-16í
REINF. 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s)
BOTTOM 5-16í 5-16í5-16í5-16í5-16í
REINF. 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s)

SHEAR 2 legged 8í 2 legged 8í 2 legged 8í 2 legged 8í 2 legged 8í
REINF. @ 120 mm c/c @ 120 mm c/c @ 120 mm c/c @ 120 mm c/c @ 120 mm c/c

SHEAR DESIGN RESULTS AT DISTANCE d (EFFECTIVE DEPTH) FROM FACE OF THE SUPPORT

SHEAR DESIGN RESULTS AT 546.9 mm AWAY FROM START SUPPORT

VY = -9.17 MX = -0.45 LD = 2

Provide 2 Legged 8í @ 120 mm c/c

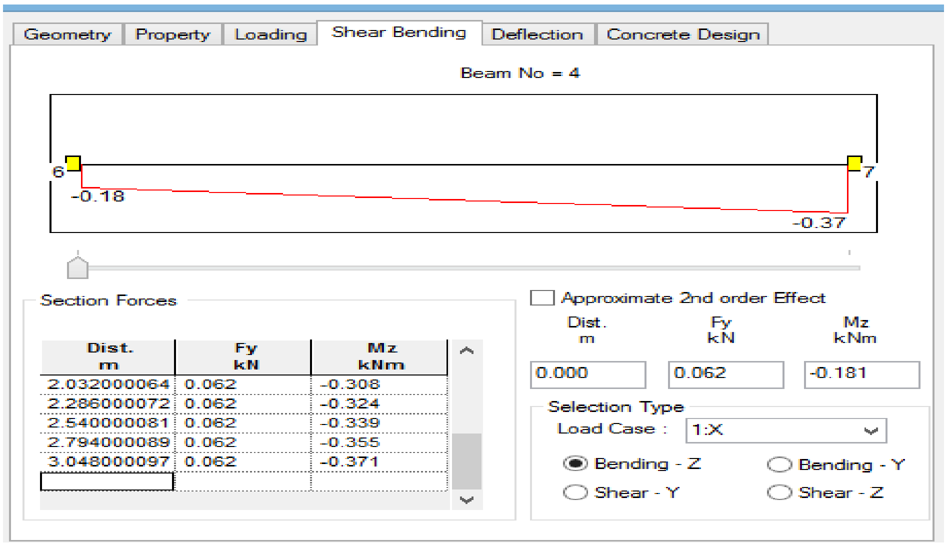


Fig.13 Shear bending of beam no. 4

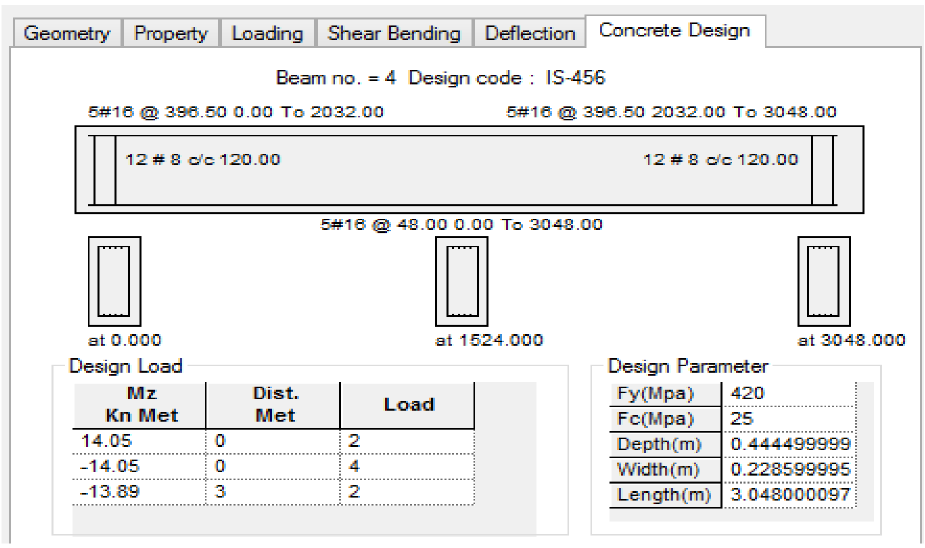


Fig.14 Concrete design of beam no. 4

Beam No.51 Design Results

M25 Fe420 (Main) Fe415 (Sec.)

LENGTH: 6096.0 mm SIZE: 304.8 mm X 609.6 mm COVER: 40.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

Column1

SECTION 0.0 mm 1524.0 mm 3048.0 mm 4572.0 mm 6096.0 mm

TOP 584.54 346.43 346.43 346.43 585.00
REINF. (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm)
BOTTOM 584.54 346.43 346.43 346.43 585.00
REINF. (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm)

SUMMARY OF PROVIDED REINF. AREA

Column1

SECTION 0.0 mm 1524.0 mm 3048.0 mm 4572.0 mm 6096.0 mm

TOP 7-16í 7-16í7-16í7-16í7-16í
REINF. 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s)
BOTTOM 7-16í 7-16í7-16í7-16í7-16í
REINF. 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s)

SHEAR 2 legged 8í 2 legged 8í 2 legged 8í 2 legged 8í 2 legged 8í

REINF. @ 180 mm c/c @ 180 mm c/c @ 180 mm c/c @ 180 mm c/c @ 180 mm c/c

SHEAR DESIGN RESULTS AT DISTANCE d (EFFECTIVE DEPTH) FROM FACE OF THE SUPPORT

SHEAR DESIGN RESULTS AT 712.0 mm AWAY FROM START SUPPORT

VY = -36.94 MX = -0.24 LD = 2

Provide 2 Legged 8í @ 180 mm c/c

SHEAR DESIGN RESULTS AT 712.0 mm AWAY FROM END SUPPORT

VY = -38.24 MX = 0.10 LD = 6

Provide 2 Legged 8í @ 180 mm c/c

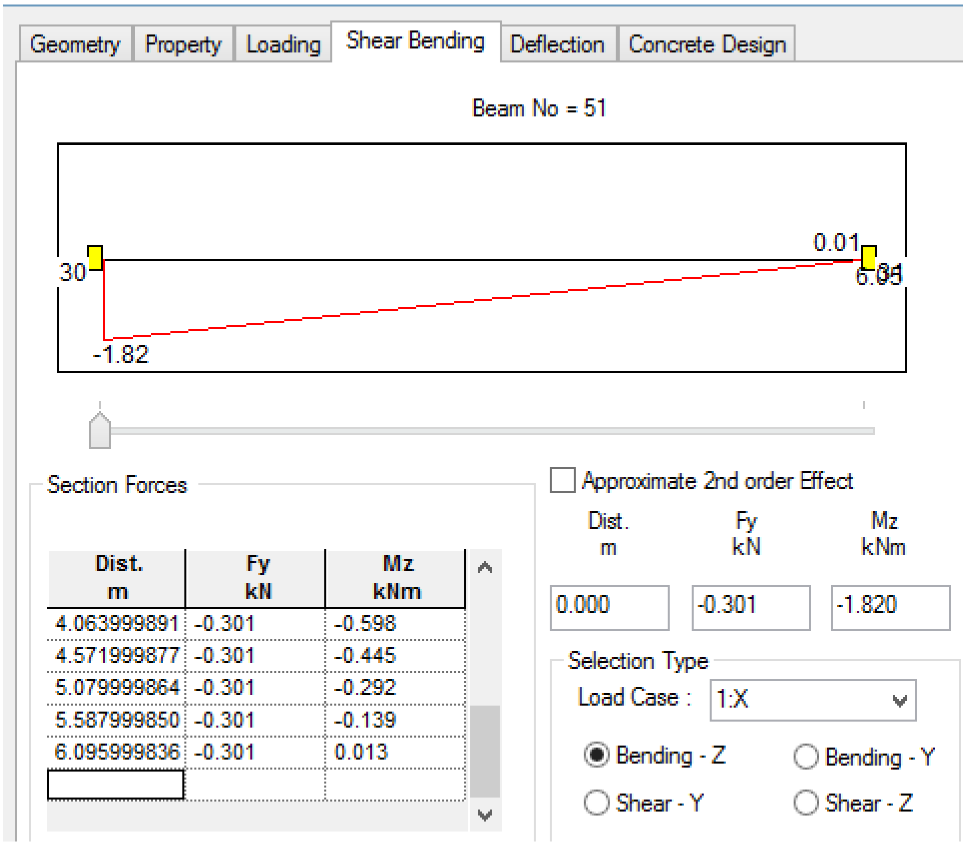


Fig.15 Shear bending of beam no. 51

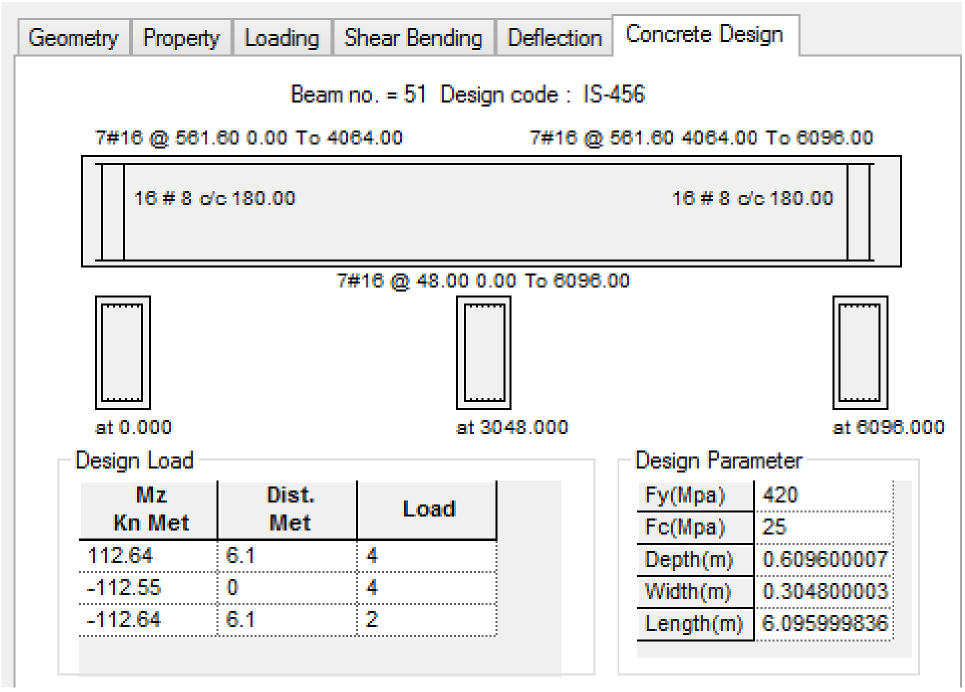


Fig.16 Concrete design of beam no. 51

Beam No.150 Design Results

M25 Fe420 (Main) Fe415 (Sec.)

LENGTH: 6096.0 mm SIZE: 304.8 mm X 596.9 mm COVER: 40.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

Column1					
SECTION	0.0 mm	1524.0 mm	3048.0 mm	4572.0 mm	6096.0 mm
TOP	338.59	338.59	338.59	338.59	338.59
REINF.	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)
BOTTOM	338.59	338.59	338.59	338.59	338.59
REINF.	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)

SUMMARY OF PROVIDED REINF. AREA

Column1

SECTION 0.0 mm 1524.0 mm 3048.0 mm 4572.0 mm 6096.0 mm

TOP 7-16í 7-16í7-16í7-16í7-16í
REINF. 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s)
BOTTOM 7-16í 7-16í7-16í7-16í7-16í
REINF. 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s)

SHEAR 2 legged 8í 2 legged 8í 2 legged 8í 2 legged 8í 2 legged 8í

REINF. @ 180 mm c/c @ 180 mm c/c @ 180 mm c/c @ 180 mm c/c @ 180 mm c/c

----

SHEAR DESIGN RESULTS AT DISTANCE d (EFFECTIVE DEPTH) FROM FACE OF THE SUPPORT

SHEAR DESIGN RESULTS AT 699.3 mm AWAY FROM START SUPPORT

VY = 47.92 MX = -0.02 LD = 6

Provide 2 Legged 8í @ 180 mm c/c

SHEAR DESIGN RESULTS AT 699.3 mm AWAY FROM END SUPPORT

VY = -50.51 MX = -0.02 LD = 6

Provide 2 Legged 8í @ 180 mm c/c

===

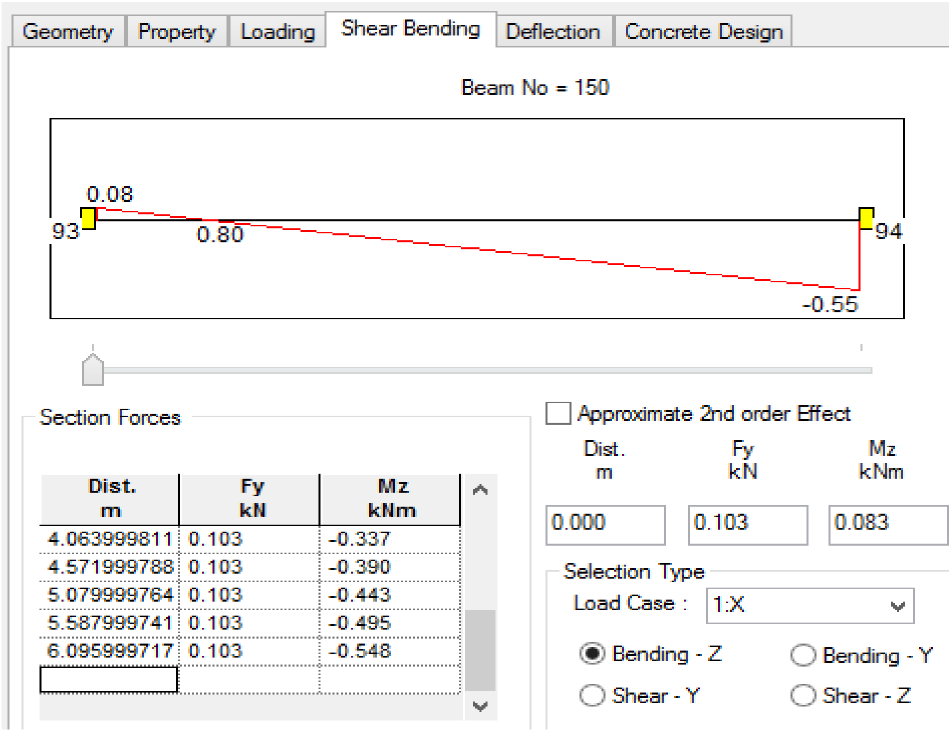


Fig.17 Shear bending of beam no. 150

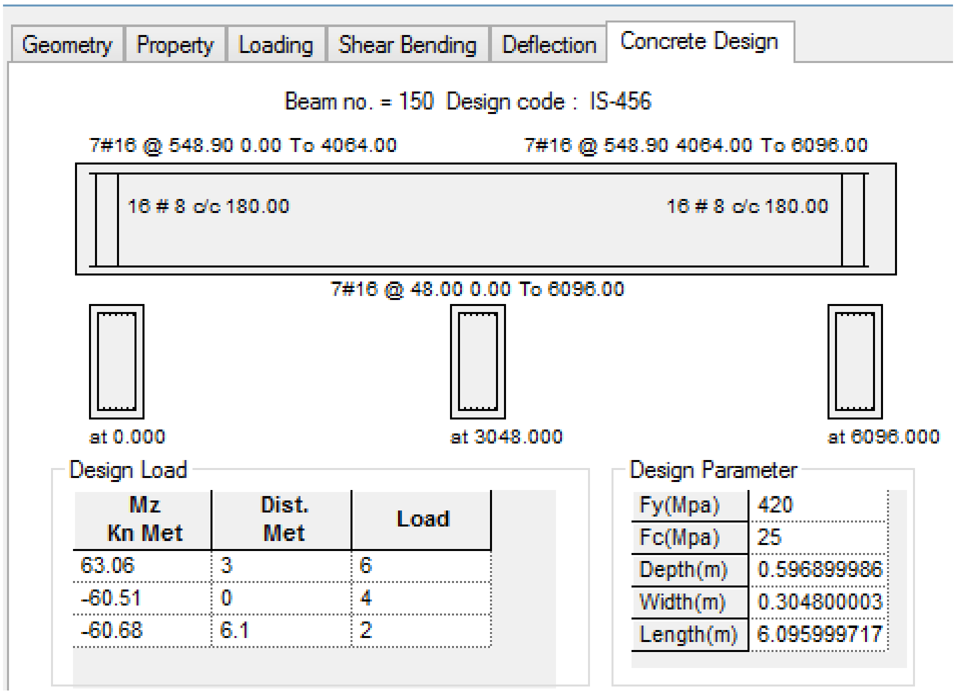


Fig.18 Concrete design of beam no. 150

Beam No.222 Design Results

M25 Fe420 (Main) Fe415 (Sec.)

LENGTH: 11070.0 mm SIZE: 381.0 mm X 749.3 mm COVER: 40.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

Column1

SECTION 0.0 mm 2767.5 mm 5535.0 mm 8302.5 mm 11070.0 mm

TOP 540.75 540.75 540.75 540.75 540.75
REINF. (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm)
BOTTOM 540.75 540.75 540.75 540.75 540.75
REINF. (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm)

SUMMARY OF PROVIDED REINF. AREA

Column1

SECTION 0.0 mm 2767.5 mm 5535.0 mm 8302.5 mm 11070.0 mm

TOP 8-16í 8-16í8-16í8-16í8-16í
REINF. 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s)
BOTTOM 8-16í 8-16í8-16í8-16í8-16í
REINF. 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s)

SHEAR 2 legged 8í 2 legged 8í 2 legged 8í 2 legged 8í 2 legged 8í
REINF. @ 230 mm c/c @ 230 mm c/c @ 230 mm c/c @ 230 mm c/c @ 230 mm c

SHEAR DESIGN RESULTS AT DISTANCE d (EFFECTIVE DEPTH) FROM FACE OF THE SUPPORT

SHEAR DESIGN RESULTS AT 1042.2 mm AWAY FROM START SUPPORT

VY = 61.16 MX = 0.02 LD = 6

Provide 2 Legged 8í @ 230 mm c/c

SHEAR DESIGN RESULTS AT 1042.2 mm AWAY FROM END SUPPORT

VY = -61.54 MX = 0.02 LD = 6

Provide 2 Legged 8í @ 230 mm c/c

===

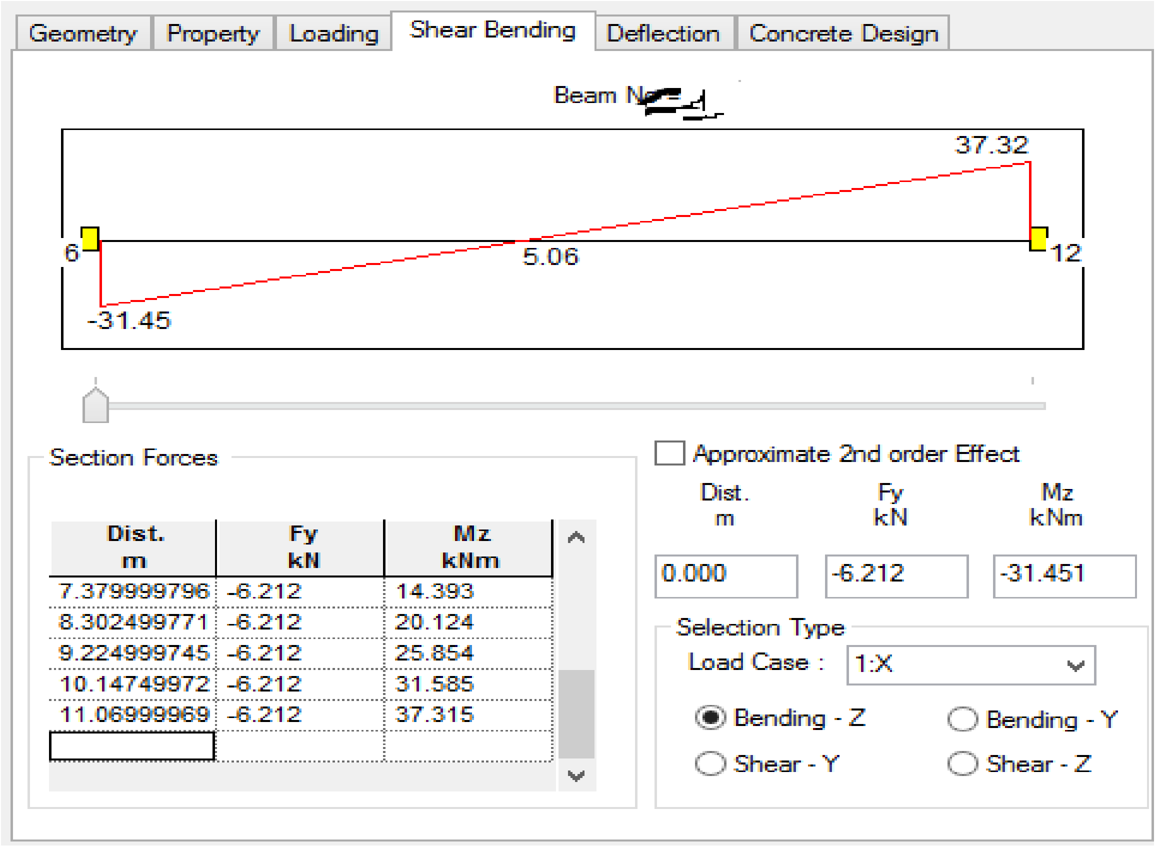


Fig.19 Shear bending of beam no. 222

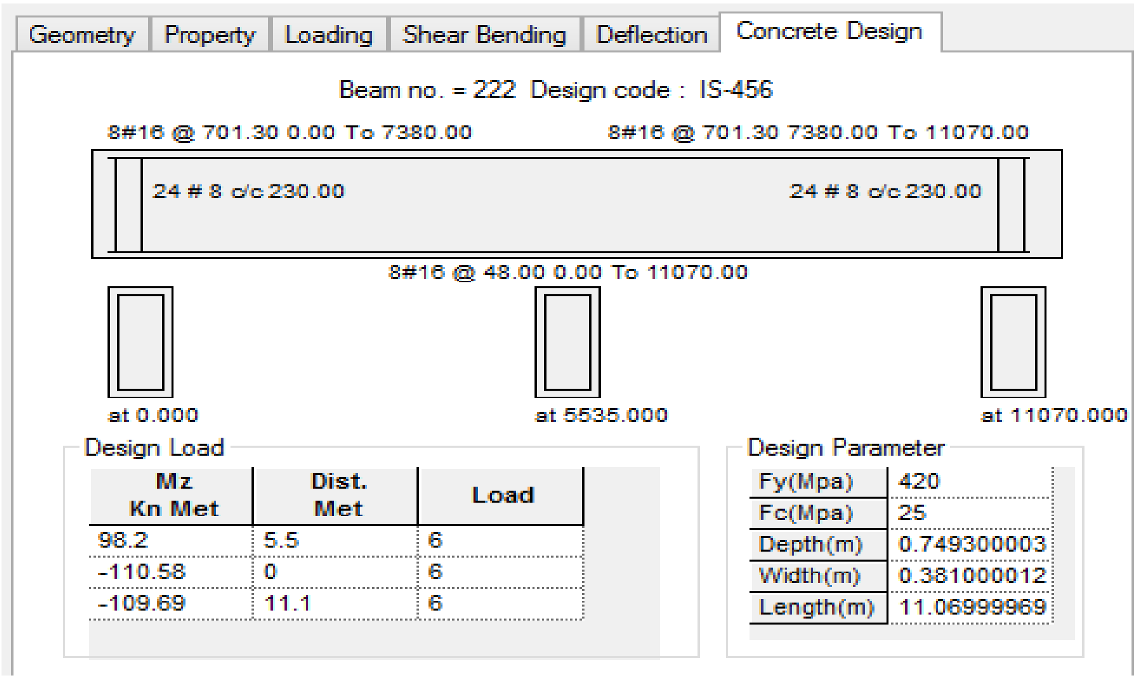


Fig.20 Concrete design of beam no. 222

5.4 Design of Columns

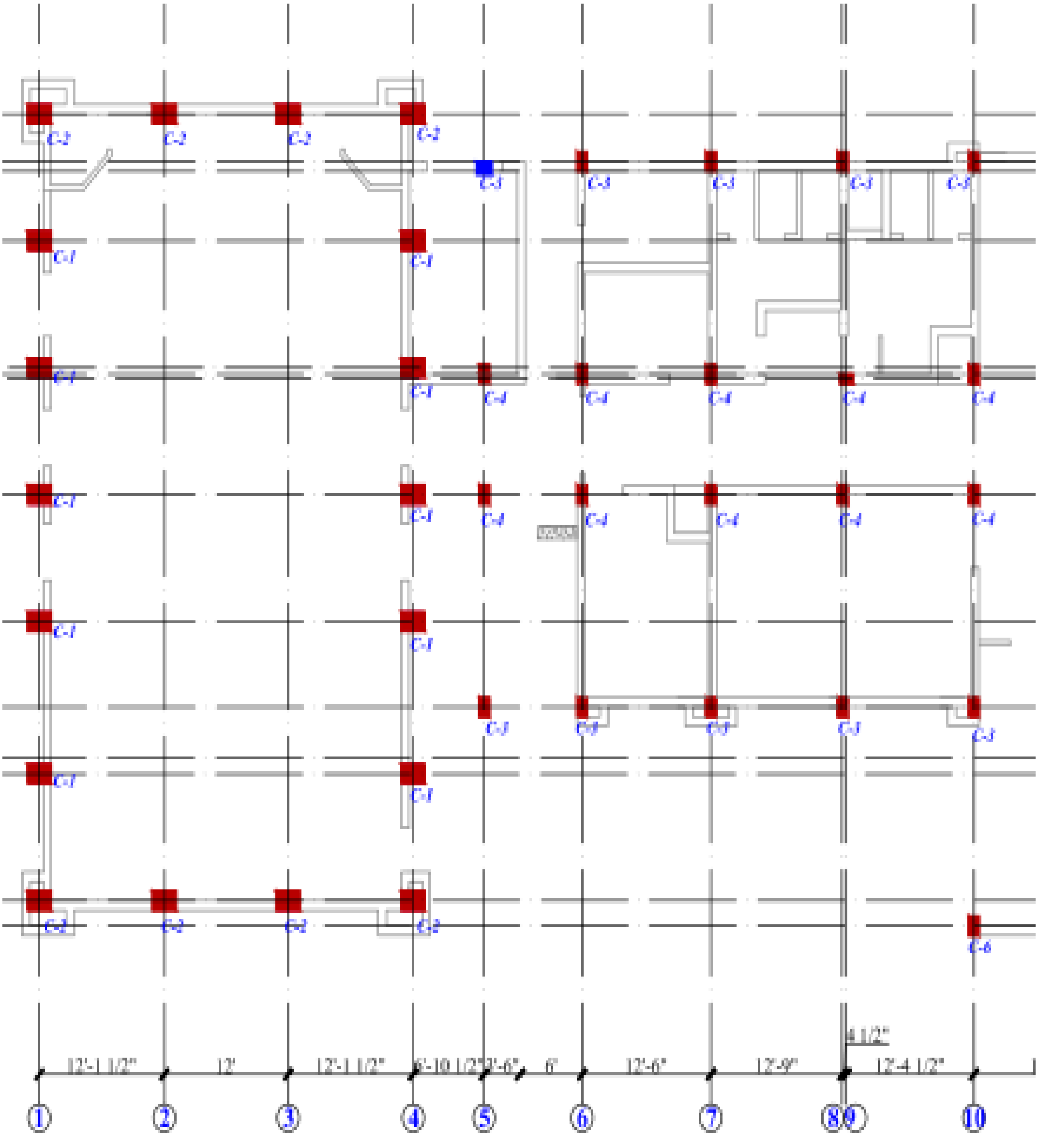


Fig.21 Grid Plan of Columns

Column No.C2 Design Results

M25 Fe420 (Main) Fe415 (Sec.)

LENGTH: 3500.0 mm CROSS SECTION: 304.8 mm X 457.2 mm COVER: 40.0 mm

REQD. STEEL AREA : 1672.25 Sq.mm.

REQD. CONCRETE AREA : 137682.30 Sq.mm.

MAIN REINFORCEMENT : Provide 12 - 16 dia. (1.73%, 2412.74 Sq.mm.)

(Equally distributed)

TIE REINFORCEMENT : Provide 8 mm dia. rectangular ties @ 255 mm c/c

SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED (kNS-MET)

Puz : 2075.69 **Muz1 :** 106.22 **Muy1 :** 65.26

INTERACTION RATIO: 0.99 (as per Cl. 39.6, IS456:2000)

SECTION CAPACITY BASED ON REINFORCEMENT PROVIDED (kNS-MET)

WORST LOAD CASE: 2

END JOINT: 46 **Puz :** 2300.61 **Muz :** 152.36 **Muy :** 90.79 **IR:** 0.71

==

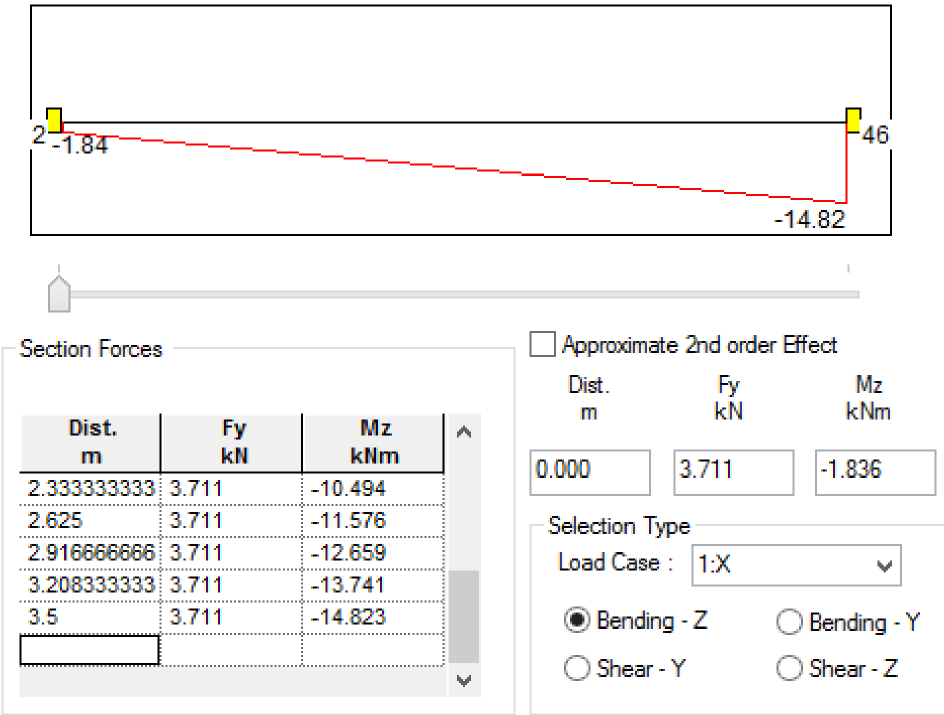


Fig.22 Shear Bending of Column C2

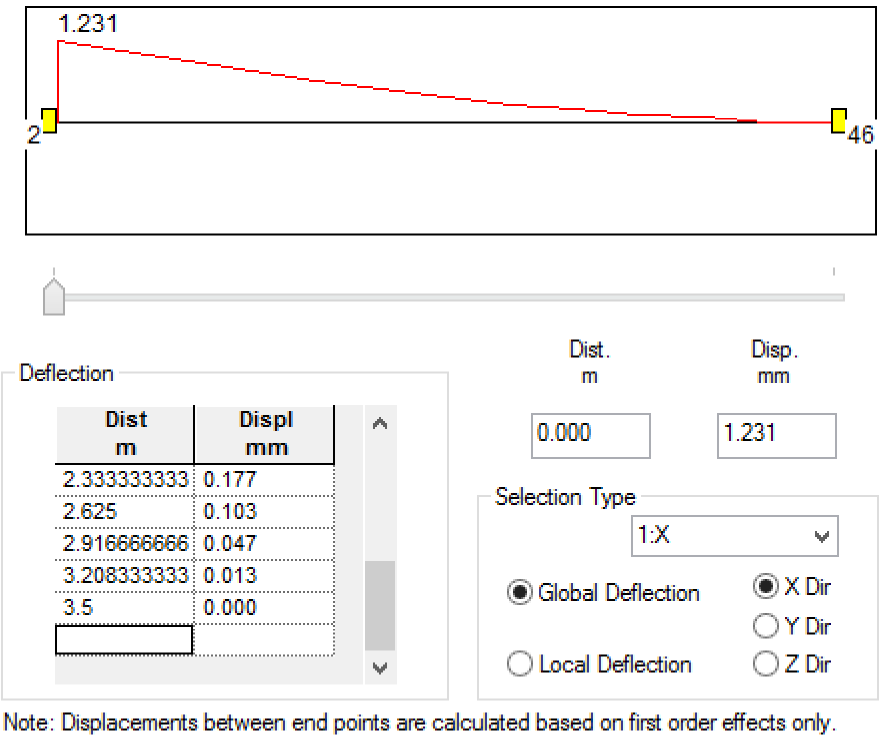
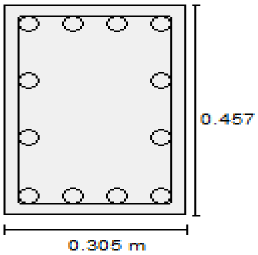


Fig.23 Deflection of Column C2



Design Load

Load	2
Location	End 2
Pu(Kns)	-35.79
Mz(Kns-Mt)	23.73
My(Kns-Mt)	49.93

Design Parameter

Fy(Mpa)	420
Fc(Mpa)	25
As Reqd(mm²)	1672
As (%)	1.73
Bar Size	16
Bar No	12

Fig.24 Concrete Design of Column C2

Column No.C1 Design Results

M25 Fe420 (Main) Fe415 (Sec.)

LENGTH: 3500.0 mm CROSS SECTION: 304.8 mm X 685.8 mm COVER: 40.0mm

REQD. STEEL AREA : 2842.83 Sq.mm.

REQD. CONCRETE AREA: 206189.00 Sq.mm.

MAIN REINFORCEMENT : Provide 16 - 16 dia. (1.54%, 3216.99 Sq.mm.)

(Equally distributed)

TIE REINFORCEMENT : Provide 8 mm dia. rectangular ties @ 255 mm c/c

SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED (KNS-MET)

Puz : 3215.12 **Muz1 :** 291.24 **Muy1 :** 111.82

INTERACTION RATIO: 0.98 **(as per Cl. 39.6, IS456:2000)**

SECTION CAPACITY BASED ON REINFORCEMENT PROVIDED (KNS-MET)

WORST LOAD CASE: 2

END JOINT: 47 **Puz :** 3328.77 **Muz :** 327.30 **Muy :** 123.83 **IR:** 0.89

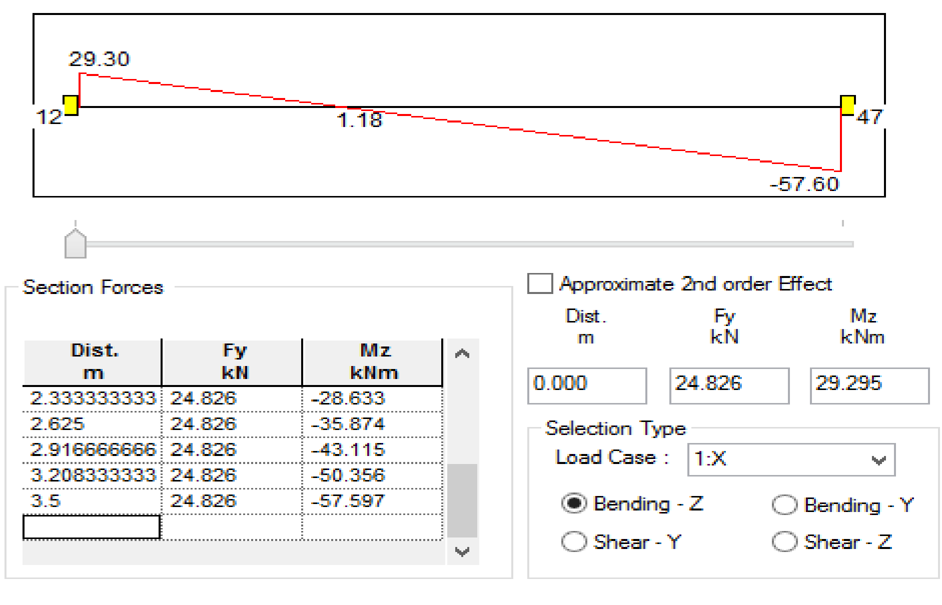


Fig.25 Shear Bending of Column C1

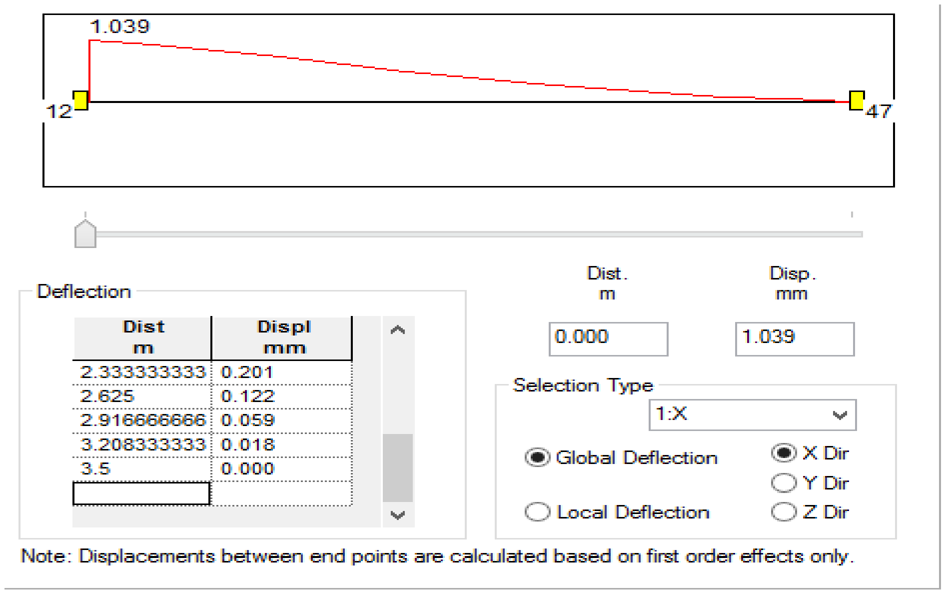


Fig.26 Deflection of Column C1

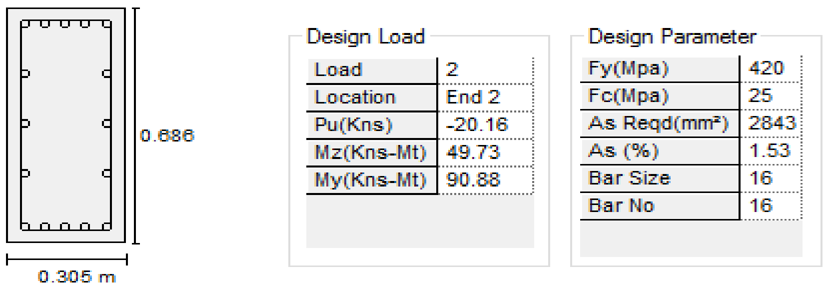


Fig.27 Concrete Design of Column C1

5.5 Footings

5.5.1 General

Footings are structural elements that transmit column or wall loads to the underlying soil below the structure. Footings are designed to transmit these loads to the soil without exceeding its safe bearing capacity, to prevent excessive settlement of the structure to a tolerable limit, to minimize differential settlement, and to prevent sliding and overturning. The settlement depends upon the intensity of the load, type of soil, and foundation level. Where possibility of differential settlement occurs, the different footings should be designed in such away to settle independently of each other.

Foundation design involves a soil study to establish the most appropriate type of foundation and a structural design to determine footing dimensions and required amount of reinforcement. Because compressive strength of the soil is generally much weaker than that of the concrete, the contact area between the soil and the footing is much larger than that of the columns and walls.

5.5.2 Footing Types

The type of footing chosen for a particular structure is affected by the following:

1. The bearing capacity of the underlying soil.
2. The magnitude of the column loads.
3. The position of the water table.
4. The depth of foundations of adjacent buildings.

Footings may be classified as deep or shallow. If depth of the footing is equal to or greater than its width, it is called deep footing, otherwise it is called shallow footing. Shallow footings comprise the following types:

1. Isolated Footings

An isolated footing is used to support the load on a single column. It is usually either square or rectangular in plan. It represents the simplest, most economical type and most widely used footing. Whenever possible, square footings are provided so as to reduce the bending moments and shearing forces at their critical sections. Isolated footings are used in case of light column loads, when columns are not closely spaced, and in case of good homogeneous soil. Under the effect of upward soil pressure, the footing bends in a dish shaped form. An isolated footing must, therefore, be provided by two sets of reinforcement bars placed on top of the other near the bottom of the footing. In case of property line restrictions, footings may be designed for eccentric loading or combined footing is used as an alternative to isolated footing.

2. Combined Column Footing

These are common footings which support the loads from are provided when

• SBC is generally less

• Columns are closely spaced

• Footings are heavily loaded In the above situations, the area required to provide isolated footings overlap.

Hence, it is advantageous to provide single combined footing are located on or close to property line. In such cases footings cannot be extended on one side. Here, the footings of exterior and interior columns are connected by the combined footing. Combined footings essentially consist are generally rectangular in plan. Combined footings can also have a connect inverted T – beam slab.

3. Strap Footing

An alternate way of providing combined footing located close to property line is the strap footing strap footing, independent slabs below columns beam. The strap beam does not remain in contact with the soil the soil. Generally it is used to combine the footing of the outer column to the adjacent one so that the footing does not extend in the adjoining property and section of typical strap footing .Sometimes they can also be trapezoidal in plan have a connecting beam and a slab arrangement, which is An alternate way of providing combined footing located close to property line is the strap footing independent slabs below columns are provided which are then connected not remain in contact with the soil and does not transfer any pressure to used to combine the footing of the outer column to the adjacent one so that footing does not extend in the adjoining property.

4. Bearing Capacity of Soil

The safe bearing capacity of soil is the safe extra load soil can withstand without experiencing shear failure. The Safe Bearing Capacity (SBC) is considered unique at a particular site. But it also depends on the following factors:

• Size of footing

• Shape of footing

• Inclination of footing

• Inclination of ground

• Type of load

• Depth of footing

SBC alone is not sufficient for design. The allowable bearing capacity is taken as the smaller of the following two criteria

• Limit states of shear failure criteria (SBC)

• Limit states of settlement criteria

Based on ultimate capacity, i.e. shear failure criteria, the SBC is calculated as

$$\text{SBC} = \frac{\text{Total load}}{\text{Area of Footing}}$$

Usually the Allowable Bearing Pressure (ABP) varies in the range of 100 kN/m^2 to 400 kN/m^2 . The area of the footing should be so arrived that the pressure distribution below the footing should be less than the allowable bearing pressure of the soil. Even for symmetrical Loading, the pressure distribution below the footing may not be uniform. It depends on the Rigidity of footing, Soil type and Conditions of soil. In case of Cohesive Soil and Cohesion less Soil the pressure distribution varies in a nonlinear way. However, while designing the footings a linear variation of pressure distribution from one edge of the footing to the other edge is assumed. Once the pressure distribution is known, the bending moment and shear force can be determined and the footing can be designed to safely resist these forces.

5.5.3 Design of Isolated Column Footing

The objective of design is to determine

• Area of footing

• Thickness of footing

• Reinforcement details of footing (satisfying moment and shear considerations)

• Check for bearing stresses and development length

This is carried out considering the loads of footing, SBC of soil, Grade of concrete and Grade of steel. The method of design is similar to the design of beams and slabs. Since footings are buried, deflection control is not important. However, crack widths should be less than 0.3 mm.

The steps followed in the design of footings are generally iterative. The important steps in the design of footings are:

- Find the area of footing (due to service loads)
- Assume a suitable thickness of footing
- Identify critical sections for flexure and shear
- Find the bending moment and shear forces at these critical sections (due to factored loads)

- Check the adequacy of the assumed thickness
- Find the reinforcement details
- Check for development length
- Check for bearing stresses

The materials used in RC footings are concrete and steel. The minimum grade of concrete to be used for footings is M20, which can be increased when the footings are placed in aggressive environment, or to resist higher stresses.

Cover

The minimum thickness of cover to main reinforcement shall not be less than 50 mm for surfaces in contact with earth face and not less than 40 mm for external exposed face. However, where the concrete is in direct contact with the soil the cover should be 75 mm. In case of raft foundation the cover for reinforcement shall not be less than 75 mm.

Minimum reinforcement and bar diameter:

The minimum reinforcement according to slab and beam elements as appropriate should be followed, unless otherwise specified. The diameter of main reinforcing bars shall not be less 10 mm. The grade of steel used is either Fe 415 or Fe 500.

Tensile Reinforcement

The total tensile reinforcement at any section shall provide a moment of resistance at least equal to the bending moment on the section calculated.

Total tensile reinforcement shall be distributed across the corresponding resisting section as given below:

a) In one-way reinforced footing, the-reinforcement extending in each direction shall be distributed uniformly across the full width of the footing.

b) In two-way reinforced square footing, the reinforcement extending in each direction shall be distributed uniformly across the full width of the footing.

c) In two-way reinforced rectangular footing, the reinforcement in the long direction shall be distributed uniformly across the full width of the footing. For reinforcement in the short direction, a central band equal to the width of the footing shall be marked along the length of the footing and portion of the reinforcement determined in accordance with the equation given below shall be uniformly distributed across the central band

Transfer of Load at the Base of Column

The compressive stress in concrete at the base of a column or pedestal should be considered as being transferred by bearing to the top of the supporting Pedestal or footing. The bearing pressure on the loaded area shall not exceed the permissible bearing stress in direct compression multiplied by a value equal to

$$\frac{\sqrt{A1}}{\sqrt{A2}}$$

but not greater than 2, where A1 = supporting area for bearing of footing, which in sloped or stepped footing may be taken as the area of the lower base of the largest frustum of a pyramid or cone contained wholly within the footing and having for its upper base, the area actually loaded and having side slope of one vertical to two horizontal; and A2 = loaded area at the column base.

Where the permissible bearing stress on the concrete in the supporting or supported member would be exceeded, reinforcement shall be provided for developing the excess force, either by extending the longitudinal bars into the supporting member, or by dowels.

a) Where transfer of force is accomplished by, reinforcement, the development length of the reinforcement shall be sufficient to transfer the compression or tension to the supporting member.

b) Extended longitudinal reinforcement or dowels of at least 0.5 percent of the cross-sectional area of the supported column or pedestal and a minimum of four bars shall be provided. Where dowels are used, their diameter shall no exceed the diameter of the column bars by more than 3mm

c) Column bars of diameters larger than 36 mm, in compression only can be dowelled at the footings with bars of smaller size of the necessary area. The dowel shall extend into the column, a distance equal to the development length of the column bar and into the footing, a distance equal to the development length of dowel.

5.5.4 Design of Footings

Beam no. 159

1. Vertical load-110 kN
2. Uniaxial moment- 62.28 kN-m
3. Safe bearing capacity- 76.7 kN/m^3

Step 1: Size of the footing

Given Pu = 110 kN and Mu = 62.28 kN-m. The footing should be symmetric with respect to the column as the moment is reversible. Assuming the weights of footing and backfill as 15 per cent of Pu, the eccentricity of load Pu at the base is

$$e = Mu/P \times (1.15) = \frac{62.28 \times 1000000}{1.15 \times 110 \times 1000} = 492 \text{ mm.}$$

This eccentricity may be taken as < L/6 of the footing.

This eccentricity may be taken as < L/3 of the footing.

The factored bearing pressure is

$$76.7 \times (1.5) = 115.05 \text{ kN/m2.}$$

For the footing of length L and width B, we, therefore, have:

$$\text{Pu/BL} + \text{3M/BL2} \leq 115$$

$$110(1.15)/\text{BL} + 3(62.2)/\text{BL2} \leq 115$$

$$\text{B}L^2 - 1.1\text{BL} - 1.62 > 0 \ldots\ldots\ldots.1.$$

For the economic proportion, let us keep equal projection beyond the face of the column in the two directions. This gives

$$(\text{L} - 0.3)/2 = (\text{B} - 0.69)/2$$

$$\text{B} = \text{L} - 0.39 \ldots\ldots.2.$$

Using Eq.(2) in Eq.(1), we get

$$\text{L} = 1.76\text{m} \;\; \text{B} = 1.37\text{m}$$

We get the maximum and minimum pressures as

$$\text{Pu/BL} + 3\text{M/B}L^2 \leq 115$$

$$\text{Pu/BL} - \text{3M/BL2} \leq 115$$

$$\text{We get } 96.43 \frac{\text{kN}}{\text{m}^3} \text{ and } 8.5 \frac{\text{kN}}{\text{m}^3} \text{ resp.}$$

$$\text{Hence both less than 115 ok}$$

Step 2: Thickness of footing slab based on one-way shear

The average soil pressure at section is

$$\{96.43 - (96.43 - 8.5)(1200 - d)/1760\} = 59.95 - 0.049d$$

The one-way shear force at section is

$$= (1.37)(1.2 - 0.001d((59.95 - 0.049d) \text{ kN.}$$

Assuming 0.15 per cent reinforcement in the footing slab,

$$\text{the shear strength of M 25 concrete} = 0.29 \text{ N/mm}^2 .$$

Hence, the shear strength of the section is

$$= 1370 \times d \times 0.29 \times 1000 \text{ kN.}$$

From the condition that shear strength has to be ≥ shear force, we have

$$1370 \times d \times 0.29 \times 1000 = (1.37)(1.2 - 0.001d((59.95 - 0.049d)$$

$$\text{We get d} = 410 \text{ mm.}$$

Step 3: Checking for two-way shear At the critical section

The shear resistance is obtained **Cl.31.6.31 of IS 456**, which gives

$$\tau c = (0.5 + 300/690)(0.25)(5) \text{ but}$$

$$t\text{he multiplying factor } (0.5 + 300/690) \text{ cannot } > 1.0.$$

$$\text{So, we have } \tau c = 0.25(5) = 1.25 \text{ N/mm}^2 .$$

$$\text{Hence, the shear resistance} = (1.25)(2)\{(690 + 410) + (300 + 410)\}(410)$$

$$= 1855.2 \text{ kN.}$$

Actual shear force is determined on the basis of average soil pressure at the centre line of the cross-section which is

$$(96.43 + 8.5)/2 = 104.93 \text{ kN/m}^2 .$$

$$\text{So, the actual shear force is}$$

$$Vu = (104.93)\{(2.7)(2.85) - (0.69 + 0.41)(0.30 + 0.41)\}$$

$$= 72.5 \text{ kN} < s\text{hear resistance} (= 104.9 \text{ kN}).$$

Hence, the depth of the footing is governed by one-way shear.

$$\text{With effective depth} = 410\text{mm,}$$

The total depth of footing

$$= 410 + 50 \times \text{(cover)} + 16 \times \text{(bar dia)} + 8 \times \text{(half bar dia)}$$
$$= 484 \text{ mm}$$

Step 4: Bending moment

In the long direction (along the length = 1760 mm)

Bending moment at the face of column is determined where

$$\text{soil pressure} = 96.4 - (94 - 8.5)(1200)/1760 = 58.6 \text{ kN/m}^2 .$$

So, the bending moment is

$$= 190 \times (2.7) \times (1.2) \times (0.4) + (94 - 58.6) \times 2.7 \times 1.2 \times 2)/2 \times 3$$
$$= 284.4 \text{ kN} - \text{m}.$$
$$\text{M/Bd2} = 284 \times (1000000)/(2700) \times (616) \times (616)$$
$$= 0.415 \text{ N/mm}^2 < 3.45\ N/\text{mm}^2 \text{ for M 25 concrete.}$$
$$T\text{able 3 of SP} - 16 \text{ gives p} = 0.1462$$
$$< 0.15\ per\ cent\ as\ required\ for\ one - way\ shear.$$
$$\text{Thus,}$$
$$A\text{st} = 0.15 \times (1350) \times (616)/100 = 1250 \text{ mm}^2 .$$
$$\text{Provide 7 bars of 16 mm diameter, spacing} = (1350 - 100 - 16)/12 = 102 \text{ mm,}$$
$$\text{say 100 mm c/c.}$$

Development length

Development length of 16 mm diameter bars (M 25 concrete)

$$= 0.87 \times (415) \times (16)/4 \times (1.6) \times (1.4) = 644.73 \text{ mm.}$$
$$\text{Length available} = 700 - 50 - 8 = 648 \text{ mm} > 644.73\ mm.$$
$$\text{Hence, o.k.}$$

Transfer of force at the base of the column

Since the column is having moment along with the axial force, some of the bars are in tension. The transfer of tensile force is not possible through the column-footing interface. So, the longitudinal bars of columns are to be extended to the footing.

$$\text{The required development length of 20 mm bars} = 0.87 \times \frac{415}{4} \times (1.4) \times (1.6)$$
$$= 805.92 \text{ mm. Length available} = 600 \text{ mm} < 805.92\ mm.$$

The bars shall be given 90^o bend and then shall be extended by 200 mm horizontally to give a total length of 410 + 8(20) (bend value) + 200 = 840 mm > 805.92 m

2. Beam no. 176

1. Vertical load-1450 kN
2. Safe bearing capacity- 76.8 kN/m^3

Step 1: Size of the footing

Given P= 1450 kN and q_c = 76.8 kN/m^2 .

Assuming the weight of the footing and backfill as 25 per cent of the load,

the base area required = 1450×(1.25)/76.8 = 23.60 m^2 .

Provide 6 m x 4 m giving 24 m^2 area.

Step 2: Thickness of footing slab based on one-way shear

(i) Along 6 m direction

$$\text{The critical section of one} - \text{way shear is marked.}$$

$$\text{Factored soil pressure} = 1450 \times (1.5)/24 = 90.625\ \text{kN/m2} = 0.096\ \text{N/mm2}$$

Assuming 0.2 per cent reinforcement in the footing slab, Table 19 of IS 456 gives τ c for

$$\text{M20} = 0.32\ \text{N}/mm^2 .$$

$$\text{From the condition that the shear resistance} \geq \text{shear force,}$$

$$\text{we have: } 0.32(4000)\text{d} \geq 0.096(2750 - \text{d})(4000) \text{ or d} \geq 1178.57\ \text{mm}$$

$$\text{Using 16 mm diameter bars with 50 mm cover}$$

$$\text{the total depth} = 1178.57 + 50 + 16 + 8 = 1252.57\ \text{mm.}$$

$$\text{Provide total depth of 1255 mm, so that d} = 1181\ \text{mm.}$$

(ii) Along 4 m direction

The critical section of one-way shear is marked

Resistance shear force = 0.32×6000×1181 = 2267.5 kN

Actual shear force = 0.3×259 ×6000 = 466.2 kN < 2267.5 kN

Step 3: Transfer of force at the base of the column

Factored load = 1450×(1.5) = 2175 kN. From the limiting bearing stress at the column-footing interface 0.45× $f_{ck}\sqrt{\frac{A1}{A2}}$, we have

- At the column face, where A1 = A2; bearing stress = 0.45 fck = 9.0 N/mm^2
- At the footing face, A1 = 24 m^2 and A2 = (0.46) ×(0.3) = 0.138 m^2 .
  But, $(A1/A2)^{1/2}$>/2.

- So, the bearing stress = 2 ×9 = 18 N/mm^2

  The development length required = 0.87×(415) ×(20)/4×(1.6) ×(1.25) ×(1.2) = 752.2 mm

Length available = 1181 – 74 = 1107 mm > 752.2 mm

Step 4: Nominal reinforcement

Clause 34.5.2 stipulates to provide @ 360 mm^2 per metre length in each direction on each force, when the thickness of footing slab is greater than one metre. So, the minimum reinforcement is 16 mm bars @ 130 mm c/c (area = 3125mm2), wherever there is no other reinforcement

5.6	Cost Estimation Of Building Without Subjected To Earthquake Loading						
	(Civil work)						
Sr. No.	**Description of Item**	**Qty.**	**Unit**	**Basic Rate**	**Premium**	**Rate ± Premium**	**Amount**
1	**Earth work in excavation in foundations, trenches etc. in all kinds of soil where pick jumper work is not involved and not exceeding 2.0 metres depth including dressing of bottom and sides of trenches, stacking the excavated soil clear from the edge of excavation**	636.16	Cum	66.28	80%	119.30	75896
2	**Earth filling under floors with surplus ordinary soil or soil containing gravel or kankarupto 40% excavated from foundation and taken only from outside the building plinth in 15 cm layers including ramming, watering and consolidating lead upto 30 metres.**	182.80	Cum	23.72	80%	42.70	7805
3	**Shuttering for faces of concrete foundations and foundation beam & plinth beam (vertical or battering).**	375.00	Sqm	117.27	35%	158.31	59368
4	**Centring and shuttering for columns (Square or rectangular or poly gonal in plain)**						
	Ground Floor	311.36	Sqm	179.27	35%	242.01	75354
	First Floor	123.36	Sqm	181.27	35%	244.71	30188
	Second Floor (Terrace)	63.44	Sqm	183.27	35%	247.41	15696
5	**Centring and shuttering for sides and soffits of beam, beams launchings girders bressumers, lintels.**						
	Ground Floor	194.88	Sqm	139.80	35%	188.73	36780

	First Floor	**246.32**	**Sqm**	**141.80**	**35%**	**191.43**	**47153**
	Second Floor (Terrace)	**15.28**	**Sqm**	**143.80**	**35%**	**194.13**	**2966**
6	**Cement Concrete 1:6:12 with 40mm gauge stone aggregate.**	**3.62**	**Cum**	**1592.96**	**35%**	**2150.50**	**7785**
6 (a)	**Extra for mechanical mixer used by the contractor at his own cost.**	**3.62**	**Cum**	**75.00**	**18%**	**88.50**	**320**
6 (b)	**Extra for vibrator used by the contractor at his own cost.**	**3.62**	**Cum**	**22.75**	**18%**	**26.85**	**97**
7	**Cement concrete 1:4:8 with 40 mm gauge stone ballast.**	**69.30**	**Cum**	**1910.54**	**35%**	**2579.23**	**178741**
7 (a)	**Extra for mechanical mixer used by the contractor at his own cost.**	**69.30**	**Cum**	**75.00**	**18%**	**88.50**	**6133**
7(b)	**Extra for vibrator used by the contractor at his own cost.**	**69.30**	**Cum**	**22.75**	**18%**	**26.85**	**1860**
8	**Reinforced cement concrete M-20 mechanically batch mixed using batch type concrete mixer as per ISL 1791 and vibtated by needle vibrator in foundation & plinth.**	**250.42**	**Cum**	**3274.96**	**28%**	**4191.95**	**1049748**
9	**Reinforced cement concrete M-20 mechanically batch mixed using batch type concrete mixer as per ISL 1791 and vibtated by needle vibrator in superstructure.**						
	Ground Floor	**187.73**	**Cum**	**3591.60**	**28%**	**4597.25**	**863041**
	First Floor	**104.36**	**Cum**	**3615.60**	**28%**	**4627.97**	**482975**
	Second Floor	**9.84**	**Cum**	**3639.60**	**28%**	**4658.69**	**45841**

10	**Reinforced cement concrete M-15 mechanically batch mixed using batch type concrete mixer as per ISL 1791 and vibtated by needle vibrator in foundation and plinth.**	**4.65**	**Cum**	**3217.97**	**28%**	**4119.00**	**19157**
11	**Applying bitumen on roofs/DPC indcluding heating and carriage etc. .**	**0.70**	**Qtls.**	**4196.00**	**54%**	**6461.84**	**4523**
12	**Supplying & Laying dry brick ballast.**	**5.95**	**Cum**	**716.32**	**35%**	**967.03**	**5751**
13	**First class burnt brick work laid in cement sand mortar 1:6 in foundation and plinth.**	**47.32**	**Cum**	**2412.63**	**54%**	**3715.45**	**175815**
14	**First class burnt brick work laid in cement sand mortar 1:6 in first storey upto 4 metres above plinth level.**	**154.89**	**Cum**	**2595.23**	**54%**	**3996.65**	**619042**
	First Floor	**132.85**	**Cum**	**2595.23**	**54%**	**3996.65**	**530951**
14 (a)	**Extra for Brick Work done above 4 meter.**						
	First Floor	**132.85**	**Cum**	**54.86**	**54%**	**84.48**	**11224**
15	**115 mm thick brick wall laid in cement sand mortar 1:4 without reinforcement in super structure.**						
	Ground Floor	**46.00**	**Sqm**	**334.32**	**54%**	**514.85**	**23683**
	First Floor	**73.60**	**Sqm**	**334.32**	**54%**	**514.85**	**37893**
15 (a)	**Extra for Brick Work done above 4 meter.**						
	First Floor	**73.60**	**Sqm**	**4.50**	**35%**	**6.08**	**447**

16	**Cement concrete 1:2:4 gola 10cm x 10cm concave quadrant along junction of roofs with parapet wall finished smooth, where specially specified.**	**206.78**	**Rmt**	**35.77**	**38%**	**49.36**	**10207**
17	**Screed of 50mm thick cement concrete 1:8:16 to be laid below the topping.**						
	Ground Floor	**470.00**	**Sqm**	**90.01**	**30%**	**117.01**	**54996**
	First Floor	**379.43**	**Sqm**	**92.01**	**30%**	**119.61**	**45385**
18	**Kota stone tile flooring 20mm to 30 mm thick over 12.5mm thick base of cement mortar 1:3 (1 cement, 3 Sand) laid and jointed with neat cement slurry, mixed with pigment to match the shade of stone including rubbing and polishing.**						
	Ground Floor	**316.90**	**Sqm**	**954.05**	**35%**	**1287.97**	**408152**
	First Floor	**83.37**	**Sqm**	**956.05**	**35%**	**1290.67**	**107607**
	Second Floor	**6.62**	**Sqm**	**958.05**	**35%**	**1293.37**	**8564**
19	**Kota stone tiles 20mm thick in skirting risers of steps, dado walls and pillars laid in 12.5mm thick cement mortar 1:3 (1 cement 3 coarse sand) and jointed with neat cement slurry mixed with pigment to match the shade of stone, including rubbing and polishing.**						
	Ground Floor	**12.93**	**Sqm**	**977.51**	**35%**	**1319.64**	**17066**
	First Floor	**2.09**	**Sqm**	**979.51**	**35%**	**1322.34**	**2760**
	Second Floor	**0.94**	**Sqm**	**981.51**	**35%**	**1325.04**	**1239**

20	**Black Granite stone tiles 20mm thick in skirting, risers of steps, dado walls and pillars laid in 12.5mm thick cement mortar 1:3 (1 cement 3 coarse sand) and jointed with neat cement slurry mixed with pigment to match the shade of stone, including rubbing and polishing including labour for fixing dowel pins and cramps.**						
	Ground Floor	**101.05**	**Sqm**	**3277.99**	**35%**	**4425.29**	**447176**
	First Floor	**17.99**	**Sqm**	**3279.99**	**35%**	**4427.99**	**79679**
21	**Providing and laying vitrified floor tiles 600x600mm size premium quality, manufactured using Double Charge Technology, with water absorption less than 0.08% and conforming to IS: 15622 of approved make in all colours and shades, laid on 20mm thick cement mortar 1:4 (1 cement :4 fine sand) for new flooring laid with cement based high polymer modified quick set tile adhesive (water based) of approved make IS 15477 marked using 5 Kg adhesive per sqm of tile area in average 3mm thickness over existing base,etc. complete (Design is homogenous throughout the tile body).**						
	Ground Floor	**212.64**	**Sqm**	**1198.11**	**33%**	**1593.49**	**338839**
	First Floor	**233.09**	**Sqm**	**1200.11**	**33%**	**1596.15**	**372041**
22	**Providing and laying Rectified Porcelain floor tiles 450x450mmx8mm or more (thickness to be specified by the manufacturer) of premium quality conforming to IS:15622 of approved make in all colours laid on 20mm thick bed of Cement Mortar 1:4 (1 Cement : 4 Fine sand) for new flooring complete Rectified tiles have finished edges allowing them to be placed closer together for a narrower grout joint as opposed to other tiles and are more expensive.**						
	Ground Floor	**35.69**	**Sqm**	**837.56**	**33%**	**1113.95**	**39755**
	First Floor	**44.16**	**Sqm**	**839.56**	**33%**	**1116.61**	**49306**

23	12.5 mm thick cement plaster 1:5.						
	Ground Floor	1012.00	Sqm	76.18	40%	106.65	107932
	First Floor	1196.00	Sqm	77.38	40%	108.33	129565
	Second Floor	74.26	Sqm	78.58	40%	110.01	8169
24	12.5 mm thick cement plaster 1:4						
	Ground Floor	677.87	Sqm	84.10	40%	117.74	79812
	First Floor	477.52	Sqm	85.30	40%	119.42	57026
	Second Floor	69.00	Sqm	86.50	40%	121.10	8356
25	12.5mm thick cement plaster in damp proof course 1:3 with two coats of bitumen at 1.65Kg. Per sqmlaid hot and sanded.						
	Ground Floor	53.67	Sqm	176.88	40%	247.63	13291
26	Cold twisted deformed (Ribbed/ Tor Steel Bar) Bars Fe 500 grade as per IS 1786-1985, for R.C.C works, where not including in the complete rate of RCC including bending and placing in position complete.	853.93	Qtls.	5166.94	16%	5993.65	5118177
						TOTAL CIVIL COST	11921332

Rs. 119.21 Lakhs

CHAPTER 6

BUILDING DESIGN IN EARTHQUAKE PRONE AREA

6.1 General

A seismic design of high rise buildings has assumed considerable importance in recent times. In traditional methods adopted based on fundamental mode of the structure and distribution of earthquake forces as static forces at various stories may be adequate for structures of small height subjected to earthquake of very low intensity but as the number of stories increases the seismic design demands more rigorous.

During past earthquakes, reinforced concrete (RC) frame buildings that have columns of different heights within one storey, suffered more damage in the shorter columns as compared to taller columns in the same storey.

Poor behaviour of short columns is due to the fact that in an earthquake, a tall column and a short column of same cross section move horizontally by same amount.

However, the short column is stiffer as compared to the tall column, and it attracts larger earthquake force. Stiffness of a column means resistance to deformation- the larger is the stiffness, larger is the force required to deform it. If a short column is not adequately designed for such a large force, it can suffer significant damage during an earthquake. This behaviour is called Short Column Effect. The damage in these short columns is often in the form of X-shaped cracking - this type of damage of columns is due to shear failure .

In this 2 storey building, we analyse and design the building using STAAD.Pro and STAAD.foundation and make it safe to earthquake.

6.2 Analysis of a two storey building

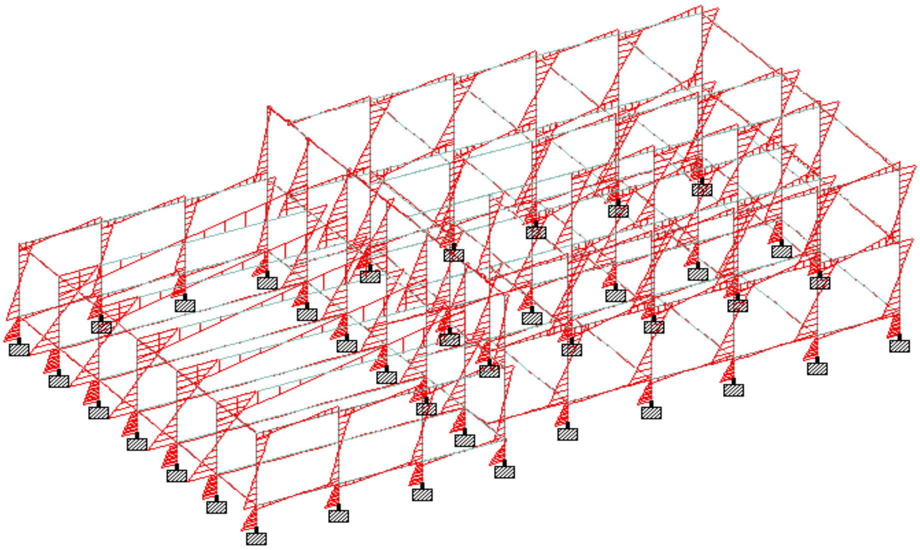


Fig.28 Summary of Beam End Forces

6.3 Design of Beams

Beam No.1 Design Results

M25 Fe415 (Main) Fe250
(Sec.)

LENGTH: 3050.0 mm SIZE: 230.0 mm X 440.0 mm
COVER: 50.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

SECTION 0.0 mm 762.5 mm 1525.0 mm 2287.5 mm
3050.0mm

TOP 286.78 180.90 0.00 180.90
316.67

REINF. (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm)

BOTTOM 180.90 180.90 180.90 180.90 180.90

REINF. (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm) (Sq. mm)

SUMMARY OF PROVIDED REINF. AREA

SECTION 0.0 mm 762.5 mm 1525.0 mm 2287.5 mm 3050.0 mm

TOP 3-12í 2-12í 2-12í2-12í 312í

REINF. 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s) 1layer(s)

BOTTOM 2-12í 2-12í2-12í2-12í2-12í

REINF. 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s)

SHEAR 2 legged 8í 2 legged 8í 2 legged 8í 2 legged 8í 2 legged 8í

REINF. @ 110 mm c/c @ 110 mm c/c @ 110 mm c/c @ 110 mm c/c @ 110 mm c/c

----

SHEAR DESIGN RESULTS AT DISTANCE d (EFFECTIVE DEPTH) FROM FACE OF THE SUPPORT

SHEAR DESIGN RESULTS AT 530.0 mm AWAY FROM START SUPPORT

VY = 33.09 MX = -0.90 LD = 10

Provide 2 Legged 8í @ 110 mmc/c

SHEAR DESIGN RESULTS AT 530.0 mm AWAY FROM END SUPPORT

VY = -37.98 MX = 1.69 LD = 8

Provide 2 Legged 8í @ 110 mm c/c

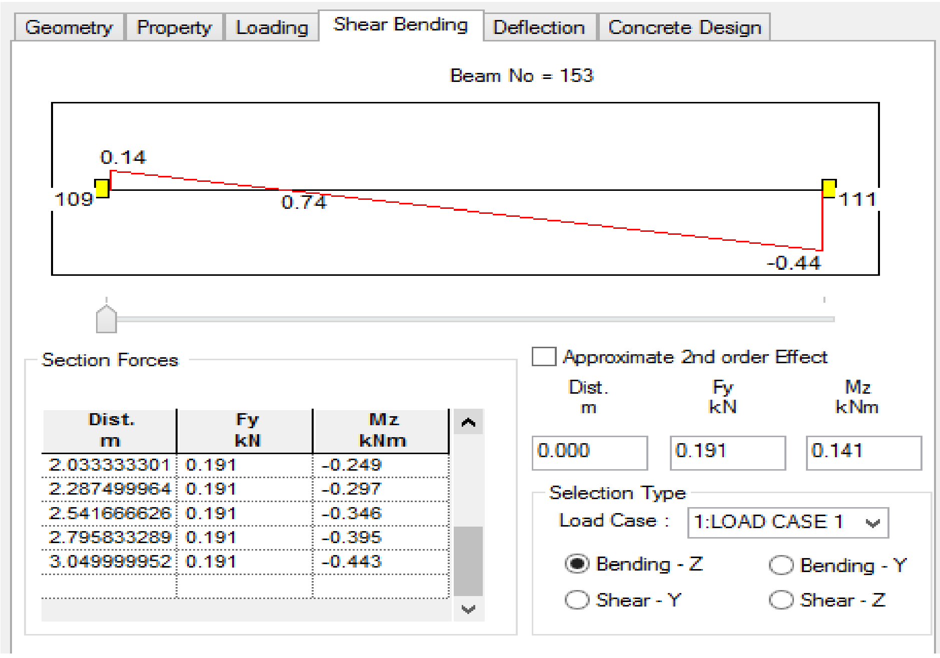


Fig.29 Shear bending diagram of Beam No. 153

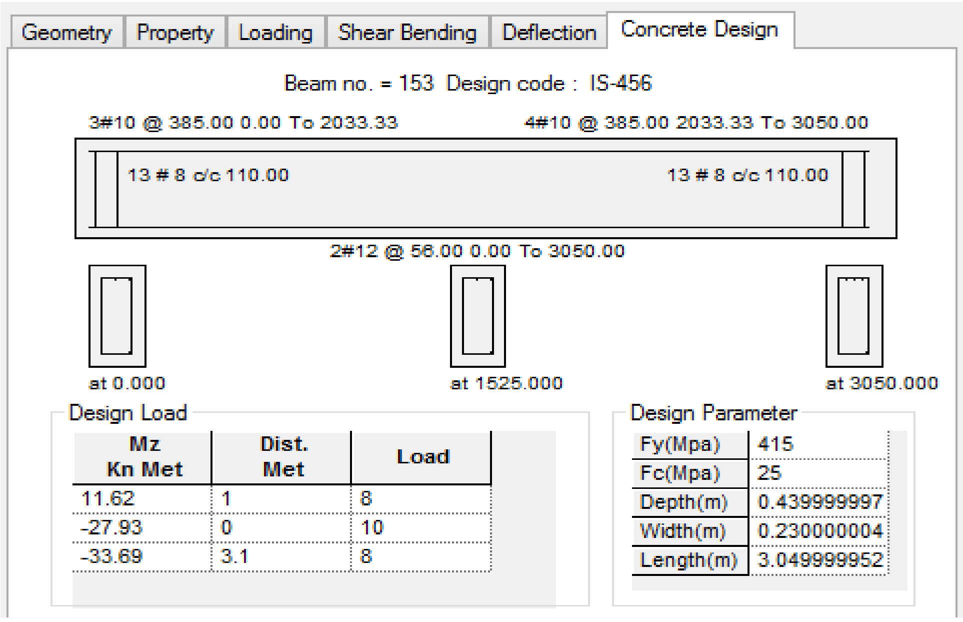


Fig.29 Concrete design of Beam No. 153

Beam No.2 Design Results

M25 Fe415 (Main) Fe250 (Sec.)

LENGTH: 3690.0 mm SIZE: 300.0 mm X 300.0 mm COVER: 50.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

SECTION	0.0 mm	922.5 mm	1845.0 mm	2767.5 mm	3690.0 mm
TOP REINF.	759.58 (Sq. mm)	150.54 (Sq. mm)	0.00 (Sq. mm)	150.54 (Sq. mm)	560.35 (Sq. mm)
BOTTOM REINF.	0.00 (Sq. mm)	167.83 (Sq. mm)	178.43 (Sq. mm)	179.15 (Sq. mm)	0.00 (Sq. mm)

SUMMARY OF PROVIDED REINF. AREA

SECTION 0.0 mm 922.5 mm 1845.0 mm 2767.5 mm 3690.0 mm

TOP 10-10í 2-10í 2-10í2-10í 8-10í

REINF. 2 layer(s) 1 layer(s) 1 layer(s) 1 layer(s) 2 layer(s)

BOTTOM 2-12í 2-12í2-12í2-12í2-12í

REINF. 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s) 1 layer(s)

SHEAR 2 legged 8í 2 legged 8í 2 legged 8í 2 legged 8í 2 legged 8í

REINF. @ 90 mm c/c @ 90 mm c/c @ 90 mm c/c @ 90 mm c/c @ 90 mm c/c

----

SHEAR DESIGN RESULTS AT DISTANCE d (EFFECTIVE DEPTH) FROM FACE OF THE SUPPORT

SHEAR DESIGN RESULTS AT 470.0 mm AWAY FROM START SUPPORT

VY = 47.30 MX = 0.85 LD= 12

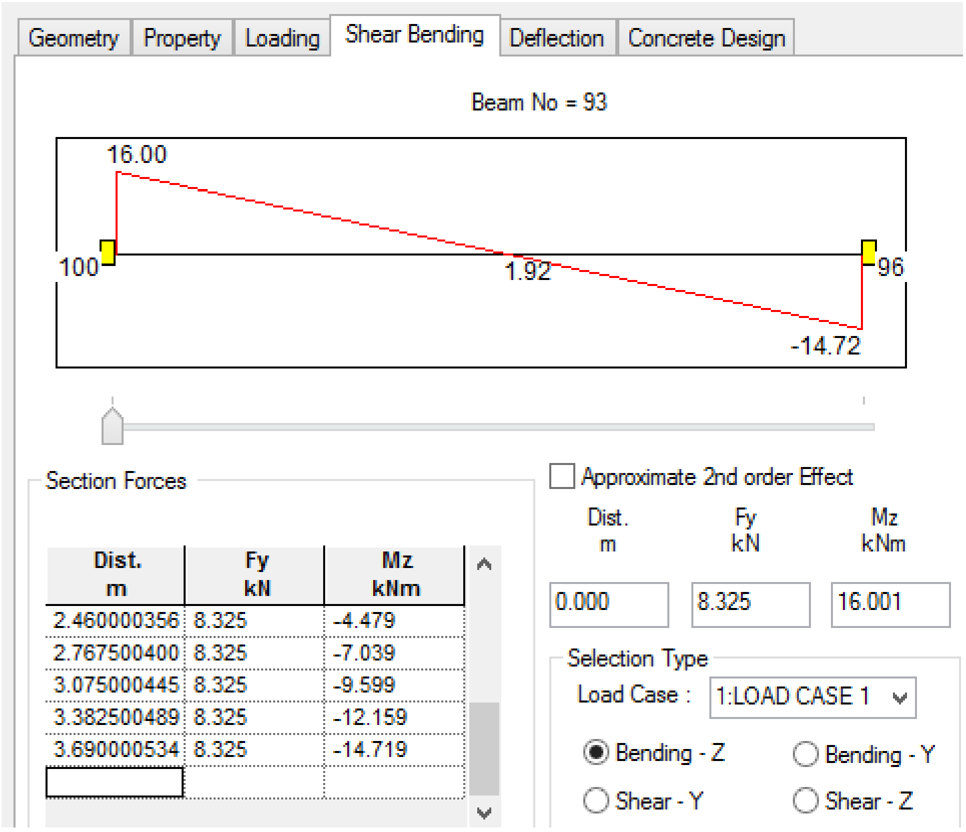
Provide 2 Legged 8í @ 90 mm c/c

SHEAR DESIGN RESULTS AT 470.0 mm AWAY FROM END SUPPORT

VY = -33.81 MX = -1.99 LD= 8

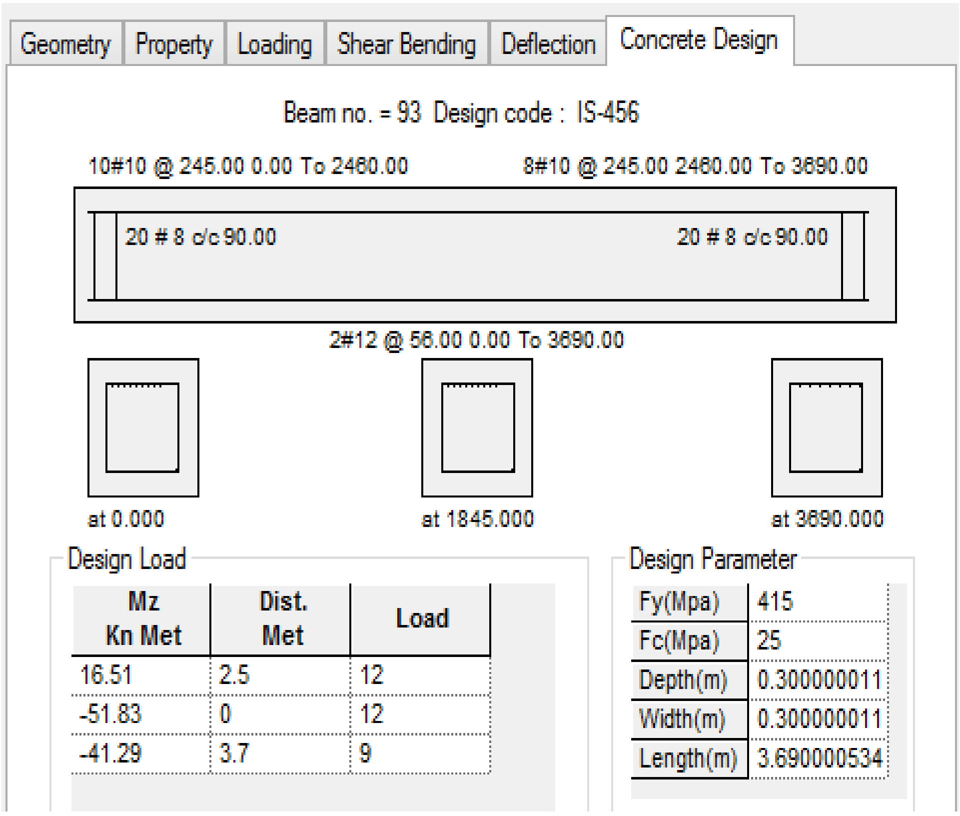
Provide 2 Legged 8í @ 90 mm c/c

==



Dist. m	Fy kN	Mz kNm
2.460000356	8.325	-4.479
2.767500400	8.325	-7.039
3.075000445	8.325	-9.599
3.382500489	8.325	-12.159
3.690000534	8.325	-14.719

Fig.30 Shear Bending Diagram of Beam No. 93



Mz Kn Met	Dist. Met	Load
16.51	2.5	12
-51.83	0	12
-41.29	3.7	9

Fy(Mpa)	415
Fc(Mpa)	25
Depth(m)	0.300000011
Width(m)	0.300000011
Length(m)	3.690000534

Fig.31 Concrete Design of Beam No. 93

6.4 Design of Columns

Column No. 111 Design Results

M25 Fe415 (Main) Fe250
(Sec.)

LENGTH: 3500.0 mm CROSS SECTION: 300.0 mm X 690.0 mm
COVER: 50.0 mm

** GUIDING LOAD CASE: 10 END JOINT: 109
SHORT COLUMN

REQD. STEEL AREA : 4315.50
Sq.mm.
REQD. CONCRETE AREA: 202684.50
Sq.mm.
MAIN REINFORCEMENT : Provide 16 - 20 dia. (2.43%, 5026.55
Sq.mm.)
(Equally distributed)
TIE REINFORCEMENT : Provide 8 mm dia. rectangular ties @ 300 mm
c/c

SECTION CAPACITY BASED ON REINFORCEMENT
REQUIRED (KNS-MET)

Puz : 3623.40 Muz1 : 465.00 Muy1 :
162.31

INTERACTION RATIO: 1.00 (as per Cl. 39.6, IS456:2000)

SECTION CAPACITY BASED ON REINFORCEMENT
PROVIDED (KNS-MET)

WORST LOAD

CASE: 10

END JOINT: 109 Puz : 3836.71 Muz : 519.19 Muy : 177.32

IR: 0.91

===

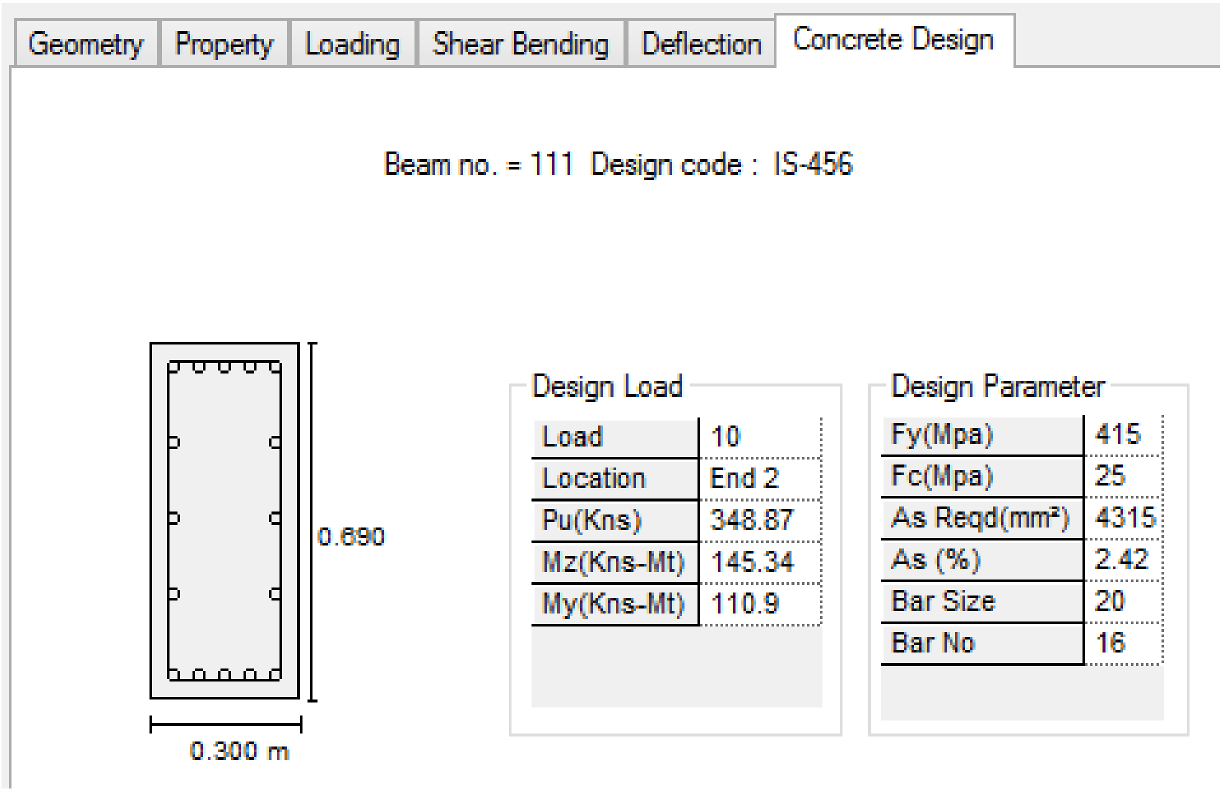


Fig.32 Concrete Design of Column No. 111

6.5 Design of Slabs

```
  ELEMENT  DESIGN  TO  BS8007  AND  BS8110              ELEMENT NO.   279
-------------------------------------------------------------------------
            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=181 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 =   0.9    12 |200|  431 | 565 |200|  431 | 1065 |200|  431 |1572
 Mx Bot =   0.0     0 |200|  431 | 565 |200|  431 | 1065 |200|  431 |1572
 My Top =   1.4     5 |200|  431 | 565 |200|  431 | 1065 |200|  431 |1572
 My Bot =   0.0     0 |200|  431 | 565 |200|  431 | 1065 |200|  431 |1572
-------------------------------------------------------------------------
-------------------------------------------------------------------------
  SERVICEABILITY    LIMIT    STATE                     ELEMENT NO.   279
```

```
  ELEMENT  DESIGN  TO  BS8007  AND  BS8110              ELEMENT NO.   292
-------------------------------------------------------------------------
            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=181 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 =   0.2    12 |200|  431 | 565 |200|  431 | 1065 |200|  431 |1572
 Mx Bot =  -0.3     9 |200|  431 | 565 |200|  431 | 1065 |200|  431 |1572
 My Top =   2.3     5 |200|  431 | 565 |200|  431 | 1065 |200|  431 |1572
 My Bot =   0.0     0 |200|  431 | 565 |200|  431 | 1065 |200|  431 |1572
-------------------------------------------------------------------------
-------------------------------------------------------------------------
  SERVICEABILITY    LIMIT    STATE                     ELEMENT NO.   292
```

6.6 Design of foundations

Table 4. Properties Details

Region	**Thickness (m)**	**Material**
Boundary	**1**	Concrete

Table 5. Soil Details

Boundary	**Subgrade Modulus**	**Soil Height Above Mat**	**Soil Density**	**Soil Pressure**
Boundary	10858.271 $kN/m^2/m$	0.000 m	18.500 kN/m^3	0.000 kN/m^2

Table 6. Mat Dimension

Boundary Name : boundary

Node No	**X Coor(m)**	**Y Coor(m)**	**Z Coor(m)**
1	0	0	0
2	29.52	0	0
3	29.52	0	18.3
4	0	0	18.3

Table 7. Base Pressure Summary

	Node	**X-Coor(m)**	**Y-Coor(m)**	**Z-Coor(m)**	**Load Case**	**Base Pressure(kN/m^2)**
Maximum Base Pressure	6	29.52	0	9.15	3	45.09
Minimum Base Pressure	5	14.76	0	0	4	5.943

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)	Wood and Armer Moment
Boundary	414999.998	25000.000	0.060	0.060	8	32	50.000	500.000	Not Used

Design Parameters

Design Output

Top of Mat Longitudinal Direction

Zone:- 1

Governing Moment (M_{GOV}) = 16.343 kN-m/m

For F_C <4.0 $\beta = 0.85$

Effective Depth = $D - (cc + 0.5 \times d_b)$ = 0.236 m

Limit Moment of Resistance (M_{umax}) = $R_{umax} \times B \times d_e^2$ = 191.830 kN-m

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

Steel Required

Calculated Area of Steel = 360.000 mm^2

Minimum Area of Steel = 360.000 mm^2

Provided Area of Steel = 360.000 mm^2

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) = 210mm

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

Top of Mat Transverse Direction

Zone:-1

Governing Moment(M_{GOV}) = 16.388 kN-m/m

For F_C <4.0 $\beta = 0.85$

Effective Depth= 0.228 m

Limit Moment of Resistance (M_{umax}) = $R_{umax} \times B \times d_e^2$ = 179.045 kN-m

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

Steel Required

Calculated Area of Steel = 360.000 mm^2

Minimum Area of Steel = 360.000 mm^2

Provided Area of Steel = 360.000 mm^2

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) = 210 mm

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

Bottom of Mat Longitudinal Direction

Zone:-1

Governing Moment(M_{GOV}) = -6.899 kN-m/m

For F_C <4.0 $\beta = 0.85$

Effective Depth = D - (cc+0.5 d_b) = 0.236 m

M_{umax}= 191.830 kN-m

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

Steel Required

Calculated Area of Steel = 360.000 mm^2

Minimum Area of Steel = 360.000 mm^2

Provided Area of Steel = 360.000 mm^2

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) = 210 mm

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

Bottom of Mat Transverse Direction

Zone:-1

Governing Moment(M_{GOV}) = -28.760 kN-m/m

For F_C <4.0 $\beta = 0.85$

Effective Depth = D - (cc + 0.5 d_b) = 0.228 m

Limit Moment of Resistance (M_{umax}) = 179.045 kN-m

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

Steel Required

Calculated Area of Steel = 360.000 mm^2

Minimum Area of Steel = 360.000 mm^2

Provided Area of Steel = 360.000 mm^2

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) = 210 mm

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

Zone:-2

Governing Moment(M_{GOV}) = -32.6 kN-m/m

For F_C <4.0

Effective Depth = 0.228 m

Limit Moment of Resistance (M_{umax}) = 179.045 kN-m

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

Steel Required

Calculated Area of Steel = 408.4 mm^2

Minimum Area of Steel = 360 mm^2

Provided Area of Steel = 408.405 mm^2

Reinforcement Details

Bar No. = 10

Maximum Spacing(S_{max})(User Specified) = 500 mm

Minimum Spacing(S_{min})(User Specified) = 50 mm

Actual Spacing (S) =190 mm

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

Zone:-3

Governing Moment(M_{GOV}) = -36.610 kN-m/m

For F_C <4.0

Effective Depth =D – (cc + 0.5d_b) = 0.228 m

Limit Moment of Resistance (M_{umax}) = 179.045 kNm

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

Steel Required

Calculated Area of Steel = 460.146 mm^2

Minimum Area of Steel = 360.000 mm^2

Provided Area of Steel = 460.146 mm^2

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) = 100mm

6.7	Cost Estimation Of Building Subjected To Earthquake Loading						
	(Civil work)						
Sr. No.	**Description of Item**	**Qty.**	**Unit**	**Basic Rate**	**Premium**	**Rate + Premium**	**Amount**
1	**Earth work in excavation in foundations, trenches etc. in all kinds of soil where pick jumper work is not involved and not exceeding 2.0 metres depth including dressing of bottom and sides of trenches, stacking the excavated soil clear from the edge of excavation**	**636.16**	**Cum**	**126.50**	**80%**	**227.70**	**144854**
2	**Earth filling under floors with surplus ordinary soil or soil containing gravel or kankarupto 40% excavated from foundation and taken only from outside the building plinth in 15 cm layers including ramming, watering and consolidating lead upto 30 metres.**	**182.80**	**Cum**	**50.50**	**80%**	**90.90**	**16617**
3	**Shuttering for faces of concrete foundations and foundation beam & plinth beam (vertical or battering).**	**570.00**	**Sqm**	**60.00**	**35%**	**81.00**	**46170**
4	**Centring and shuttering for columns (Square or rectangular or poly gonal in plain)**						
	Ground Floor	**462.50**	**Sqm**	**114.40**	**35%**	**154.44**	**71429**
	First Floor	**170.00**	**Sqm**	**116.40**	**35%**	**157.14**	**26714**
	Second Floor (Terrace)	**80.00**	**Sqm**	**118.40**	**35%**	**159.84**	**12787**
5	**Centring and shuttering for sides and soffits of beam, beams launchings girdersbressumers, lintels.**						
	Ground Floor	**279.50**	**Sqm**	**110.00**	**35%**	**148.50**	**41506**

	First Floor	**338.40**	**Sqm**	**112.00**	**35%**	**151.20**	**51166**
	Second Floor (Terrace)	**80.27**	**Sqm**	**114.00**	**35%**	**153.90**	**12354**
8	**Cement Concrete 1:6:12 with 40mm gauge stone aggregate.**	**4.85**	**Cum**	**1592.96**	**35%**	**2150.50**	**10430**
8 (a)	**Extra for mechanical mixer used by the contractor at his own cost.**	**4.85**	**Cum**	**92.00**	**18%**	**108.56**	**527**
8 (b)	**Extra for vibrator used by the contractor at his own cost.**	**4.85**	**Cum**	**32.75**	**18%**	**38.65**	**187**
9	**Cement concrete 1:4:8 with 40 mm gauge stone ballast.**	**103.70**	**Cum**	**2910.40**	**35%**	**3929.04**	**407441**
9 (a)	**Extra for mechanical mixer used by the contractor at his own cost.**	**103.70**	**Cum**	**95.00**	**18%**	**112.10**	**11625**
9 (b)	**Extra for vibrator used by the contractor at his own cost.**	**103.70**	**Cum**	**32.75**	**18%**	**38.65**	**4007**
10	**Reinforced cement concrete M-20 mechanically batch mixed using batch type concrete mixer as per ISL 1791 and vibtated by needle vibrator in foundation & plinth.**	**290.30**	**Cum**	**3774.40**	**28%**	**4831.23**	**1402507**
11	**Reinforced cement concrete M-20 mechanically batch mixed using batch type concrete mixer as per ISL 1791 and vibtated by needle vibrator in superstructure.**						
	Ground Floor	**327.47**	**Cum**	**3426.50**	**28%**	**4385.92**	**1436257**
	First Floor	**239.74**	**Cum**	**3426.50**	**28%**	**4385.92**	**1051480**
	Second Floor	**67.36**	**Cum**	**3426.50**	**28%**	**4385.92**	**295436**

12	Reinforced cement concrete M-15 mechanically batch mixed using batch type concrete mixer as per ISL 1791 and vibtated by needle vibrator in foundation and plinth.	11.20	Cum	3774.40	28%	4831.23	54110
13	Applying bitumen on roofs/DPC indcluding heating and carriage etc. .	0.70	Qtls.	68.50	54%	105.49	74
14	Supplying & Laying dry brick ballast.	7.25	Cum	716.32	35%	967.03	7011
15	First class burnt brick work laid in cement sand mortar 1:6 in foundation and plinth.	61.30	Cum	1767.30	54%	2721.64	166837
16	First class burnt brick work laid in cement sand mortar 1:6 in first storey upto 4 metres above plinth level.	190.00	Cum	1767.30	54%	2721.64	517112
	First Floor	140.50	Cum	1767.00	54%	2721.18	382326
16 (a)	Extra for Brick Work done above 4 meter.						
	First Floor	140.50	Cum	136.30	54%	209.90	29491
17	115 mm thick brick wall laid in cement sand mortar 1:4 without reinforcement in super structure.						
	Ground Floor	75.00	Sqm	167.50	54%	257.95	19346
	First Floor	89.40	Sqm	167.50	54%	257.95	23061
17 (a)	Extra for Brick Work done above 4 meter.						
	First Floor	80.50	Sqm	22.00	35%	29.70	2391

20	**Cement concrete 1:2:4 gola 10cm x 10cm concave quadrant along junction of roofs with parapet wall finished smooth, where specially specified.**	**245.50**	**Rmt**	**35.77**	**38%**	**49.36**	**12119**
25	**Screed of 50mm thick cement concrete 1:8:16 to be laid below the topping.**						
	Ground Floor	**512.30**	**Sqm**	**660.00**	**30%**	**858.00**	**439553**
	First Floor	**417.00**	**Sqm**	**660.00**	**30%**	**858.00**	**357786**
29	**Kota stone tile flooring 20mm to 30 mm thick over 12.5mm thick base of cement mortar 1:3 (1 cement, 3 Sand) laid and jointed with neat cement slurry, mixed with pigment to match the shade of stone including rubbing and polishing.**						
	Ground Floor	**316.90**	**Sqm**	**954.05**	**35%**	**1287.97**	**408152**
	First Floor	**83.37**	**Sqm**	**956.05**	**35%**	**1290.67**	**107607**
	Second Floor	**6.62**	**Sqm**	**958.05**	**35%**	**1293.37**	**8564**
30	**Kota stone tiles 20mm thick in skirting risers of steps, dado walls and pillars laid in 12.5mm thick cement mortar 1:3 (1 cement 3 coarse sand) and jointed with neat cement slurry mixed with pigment to match the shade of stone, including rubbing and polishing.**						
	Ground Floor	**12.93**	**Sqm**	**977.51**	**35%**	**1319.64**	**17066**
	First Floor	**2.09**	**Sqm**	**979.51**	**35%**	**1322.34**	**2760**
	Second Floor	**0.94**	**Sqm**	**981.51**	**35%**	**1325.04**	**1239**

31	**Black Granite stone tiles 20mm thick in skirting, risers of steps, dado walls and pillars laid in 12.5mm thick cement mortar 1:3 (1 cement 3 coarse sand) and jointed with neat cement slurry mixed with pigment to match the shade of stone, including rubbing and polishing including labour for fixing dowel pins and cramps.**						
	Ground Floor	**101.05**	**Sqm**	**3277.99**	**35%**	**4425.29**	**447176**
	First Floor	**17.99**	**Sqm**	**3279.99**	**35%**	**4427.99**	**79679**
35	**Providing and laying vitrified floor tiles 600x600mm size premium quality, manufactured using Double Charge Technology, with water absorption less than 0.08% and conforming to IS: 15622 of approved make in all colours and shades, laid on 20mm thick cement mortar 1:4 (1 cement :4 fine sand) for new flooring laid with cement based high polymer modified quick set tile adhesive (water based) of approved make IS 15477 marked using 5 Kg adhesive per sqm of tile area in average 3mm thickness over existing base,etc. complete (Design is homogenous throughout the tile body).**						
	Ground Floor	**212.64**	**Sqm**	**1198.11**	**33%**	**1593.49**	**338839**
	First Floor	**233.09**	**Sqm**	**1200.11**	**33%**	**1596.15**	**372041**
36	**Providing and laying Rectified Porcelain floor tiles 450x450mmx8mm or more (thickness to be specified by the manufacturer) of premium quality conforming to IS:15622 of approved make in all colours laid on 20mm thick bed of Cement Mortar 1:4 (1 Cement : 4 Fine sand) for new flooring complete Rectified tiles have finished edges allowing them to be placed closer together for a narrower grout joint as opposed to other tiles and are more expensive..**						
	Ground Floor	**35.69**	**Sqm**	**837.56**	**33%**	**1113.95**	**39755**
	First Floor	**44.16**	**Sqm**	**839.56**	**33%**	**1116.61**	**49306**

39	**12.5 mm thick cement plaster 1:5.**						
	Ground Floor	**1012.00**	**Sqm**	**87.30**	**40%**	**122.22**	**123687**
	First Floor	**1196.00**	**Sqm**	**88.50**	**40%**	**123.90**	**148184**
	Second Floor	**74.26**	**Sqm**	**89.70**	**40%**	**125.58**	**9325**
40	**12.5 mm thick cement plaster 1:4**						
	Ground Floor	**677.87**	**Sqm**	**84.10**	**40%**	**117.74**	**79812**
	First Floor	**477.52**	**Sqm**	**85.30**	**40%**	**119.42**	**57026**
	Second Floor	**69.00**	**Sqm**	**86.50**	**40%**	**121.10**	**8356**
40	**12.5mm thick cement plaster in damp proof course 1:3 with two coats of bitumen at 1.65Kg. Per sqmlaidhot and sanded.**						
	Ground Floor	**53.67**	**Sqm**	**176.88**	**40%**	**247.63**	**13291**
54	**Cold twisted deformed (Ribbed/ Tor Steel Bar) Bars Fe 500 grade as per IS 1786-1985, for R.C.C works, where not including in the complete rate of RCC including bending and placing in position complete.**	**1228.00**	**Qtls.**	**5166.94**	**16%**	**5993.65**	**7360203**

TOTAL CIVIL COST **16726775**

Rs. 167.27 Lakhs

CHAPTER 7

CONCLUSIONS

STAAD.Pro and STAAD.foundation has the capability to calculate the reinforcement needed for any concrete section. The program contains a number of parameters which are designed as per IS: 456(2000). Beams are designed for flexure, shear and torsion.

Maximum sagging (creating tensile stress at the bottom face of the beam) and hogging (creating tensile stress at the top face) moments are calculated for all active load cases at each of the above mentioned sections. Each of these sections are designed to resist both of these critical sagging and hogging moments.

Shear reinforcement is calculated to resist both shear forces and torsional moments. Two-legged stirrups are provided to take care of the balance shear forces acting on these sections.

Columns are designed for axial forces and biaxial moments at the ends. Square columns are designed with reinforcement distributed on each side equally for the sections under biaxial moments and with reinforcement distributed equally in two faces for sections under uni-axial moment.

Design of footing is calculated manually for building without subjected to earthquake loading and with the help of staad foundation software subjected to earthquake loading. Footing design is safe and has very little region of failure as compared to both buildings due to variation of soil properties.

When a 2 storey RCC structure without subjected to earthquake loading was constructed of an area of 5128 Sq.ft, the cost incurred came out to be Rs119.21 lacs. For the final part of the project, the same building was designed with subjected to earthquake loading and the overall cost came out to be Rs 167.27 lacs. As expected the cost increase was a mere 40%.

From the costing results we can see that building designing for earthquake loading is less economical than building without earthquake loading but due to the increasing rate of earthquakes in India, it is safe to presume that the added safety factor outweighs the extra cost incurred. Thus it is advised that no matter how small or casual the structure is, it should be made earthquake resistant, after all nature may not give us a second chance.

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ANNEXURE A

Summary of Beam Displacements

			Horizontal	Vertical	Horizontal	Moment		
	Node	**L/C**	**Fx KN**	**Fy KN**	**Fz KN**	**Mx KNm**	**My KNm**	**Mz KNm**
Max Fx	109	6 LL	56.847	101.062	0.294	0.278	-0.021	-62.287
Min Fx	50	6 LL	-56.247	100.621	0.192	0.172	-0.02	61.503
Max Fy	55	5 DL	-12.69	215.287	-6.063	-7.217	-0.024	12.661
Min Fy	53	4 -Z	0.922	-87.231	37.25	71.613	-1.426	-1.318
Max Fz	70	4 -Z	-2.794	25.017	52.497	98.711	-0.912	5.559
Min Fz	70	2- Z	2.794	-25.017	-52.497	-98.711	0.912	-5.559
Max Mx	70	4 -Z	-2.794	25.017	52.497	98.711	-0.912	5.559
Min Mx	70	2 Z	2.794	-25.017	-52.497	-98.711	0.912	-5.559
Max My	105	2 Z	-15.337	-3.685	-7.351	-23.968	3.605	28.47
Min My	105	4 -Z	15.337	3.685	7.351	23.968	-3.605	-28.47
Max Mz	59	1-X	-44.365	11.327	-0.547	-0.837	-0.427	88.262
Min Mz	59	3 -X	44.365	-11.327	0.547	0.837	0.427	-88.262

ANNEXURE B

Summary of Node Displacements

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	**L/C**	**X mm**	**Y mm**	**Z mm**	**mm**	**RX rad**	**RYrad**	**RZ rad**
Max X	85	1-X	9.068	2.475	0.641	9.422	0	0	-0.001
Min X	85	3-X	-9.068	-2.475	-0.641	9.422	0	0	0.001
Max Y	28	1-X	4.385	3.792	0.438	5.813	0	0	-0.001
Min Y	83	5 DL	-0.748	-19.006	0.369	19.024	0	0	0.004
Max Z	101	2-Z	-0.119	0.016	19.158	19.158	0	0	0
Min Z	101	4-Z	0.119	-0.016	-19.158	19.158	0	0	0
Max RX	72	2-Z	0.866	0.054	18.233	18.254	0.002	0	0
Min RX	72	4-Z	-0.866	-0.054	-18.233	18.254	-0.02	0	0
Max RY	72	1-X	6.625	0.013	0.622	6.654	0	0.001	-0.002
Min RY	72	3 X	-6.625	-0.013	-0.622	6.654	0	-0.001	0.002
Max RZ	85	5 DL	-0.708	-13.341	0.375	13.365	-0.01	0	0.005
Min RZ	72	1-X	6.625	0.013	0.622	6.654	0	0.001	-0.002
Max Rst	101	2-Z	-0.119	0.016	19.158	19.158	0	0	0

ANNEXURE C

Summary of Beam Forces

	Beam	L/C	Node	Fx KN	Fy KN	Fz KN	Mx KNm	My KNm	Mz KNm
Max Fx	19	4 –Z	2	272.73	10.93	-9.645	7.338	6.868	36.54
Min Fx	19	2 Z	2	-272.73	-10.93	9.645	-7.338	-6.868	-36.54
Max Fy	225	6 LL	9	22.752	94.182	-0.011	0.057	0.061	144.846
Min Fy	226	6 LL	16	20.45	-94.415	-0.037	-0.046	-0.24	148.308
Max Fz	19	1 X	2	-10.539	-10.508	62.303	-4.742	-47.833	-16.767
Min Fz	19	3 –X	2	10.539	10.508	-62.303	4.742	47.833	16.767
Max Mx	118	3 –X	72	4.147	8.317	-14.276	11.384	5.518	9.233
Min Mx	118	1 X	72	-4.147	-8.317	14.276	-11.384	-5.518	-9.233
Max My	80	2 Z	70	-25.017	-2.794	52.497	0.912	98.711	5.559
Min My	80	4 –Z	70	25.017	2.794	-52.497	-0.912	-98.711	-5.559
Max Mz	226	6 LL	16	20.45	-94.415	-0.037	-0.046	-0.24	148.308
Min Mz	159	6 LL	9	101.062	-56.847	-0.294	-0.021	0.751	-136.677

ANNEXURE D

Summary of Plate Stress Table

	Plate	Load Case	SQx kN/m^2	SQy kN/m^2	Sx kN/m^2	Sy kN/m^2	Sxy kN/m^2	Mx kn-m	My kN-m	Mxy kN-m
Max SQX	3	3	0.613	1.22817	0	0	0	-3.453	5.42322	-3.1994
Max SQY	3	3	0.613	1.22817	0	0	0	-3.453	5.42322	-3.1994
Max SX	1	3	-0.432	0.16928	0	0	0	-4.526	-2.1162	-0.1939
Max SY	1	3	-0.432	0.16928	0	0	0	-4.526	-2.1162	-0.1939
Max SXY	1	3	-0.432	0.16928	0	0	0	-4.526	-2.1162	-0.1939
Max MX	3	4	0.021	0.66047	0	0	0	-0.576	3.3459	-1.6654
Max MY	4	3	0.608	-1.2308	0	0	0	-3.448	5.42838	3.22918
Max MXY	4	3	0.608	-1.2308	0	0	0	-3.448	5.42838	3.22918
Min SQX	2	3	-0.439	-0.1677	0	0	0	-4.538	-2.1253	0.23282
Min SQY	4	3	0.608	-1.2308	0	0	0	-3.448	5.42838	3.22918
Min SX	1	3	-0.432	0.1692	0	0	0	-4.526	-2.1162	-0.1939
Min SY	1	3	-0.432	0.16928	0	0	0	-4.526	-2.1162	-0.1939
Min SXY	1	3	-0.432	0.16928	0	0	0	-4.526	-2.1162	-0.1939
Min MX	2	3	-0.439	-0.1678	0	0	0	-4.538	-2.1253	0.23282
Min MY	2	3	-0.439	-0.1677	0	0	0	-4.538	-2.1253	0.23282
Min MXY	3	3	0.613	1.22817	0	0	0	-3.453	5.42322	-3.1994

ANNEXURE E

Summary of Beam displacements subjected to Earthquake Loading

		Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	**X mm**	**Y mm**	**Z mm**	**mm**	**rX rad**	**rY rad**	**rZ rad**
Max X	170	19.502	-1.23	-0.032	19.541	0	0	-0.01
Min X	174	-20.311	-3.116	-0.013	20.548	0	0	0
Max Y	103	-0.036	0.257	0.628	0.679	0	0	0
Min Y	103	-0.041	-5.471	-0.008	5.471	0	0	0.001
Max Z	168	5.713	-0.526	43.544	43.92	0.001	-0.001	0
Min Z	171	5.711	-0.526	-43.54	43.916	-0.001	0.001	0
Max rX	107	4.392	-0.185	11.79	12.583	0.004	-0.001	0
Min rX	121	4.394	-0.185	-11.788	12.582	-0.004	0.001	0
Max rY	148	16.247	-1.043	0.038	16.281	0.001	0.002	-0.03
Min rY	150	16.235	-1.039	-0.01	16.268	-0.001	-0.002	-0.03
Max rZ	149	-19.378	-1.62	-0.006	19.446	0	0	0.04
Min rZ	149	18.018	-1.026	0.012	18.047	0	0	-0.04
Max Rst	171	-6.729	-0.869	43.521	44.047	0.001	-0.001	0