"Analysis and Design of a Multi-Storey (G+3) Residential Building "

A PROJECT

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

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

Dr.Ashok Kumar Gupta

(Professor and Head)

(Department of Civil Engineering)

By

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and

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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 a Multi-Storey (G+3) Residential Building"** in partial fulfillment of the requirements for the award of the degree of Bachelor of technology and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Randeep singh (121612) and Shubham Sharma (121676)** during a period from July 2015 to June 2016 under the supervision of **Dr. Ashok kumar Gupta, H.O.D ,**Civil Engineering Department ,Jaypee University of Information Technology , Waknaghat.

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

Date: - ………………………

Dr. Ashok Kumar Gupta External

Professor & Head of Department

Civil Engineering Department

JUIT Waknaghat

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 **Prof. (Dr.). Ashok Kumar Gupta** 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.

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.

RANDEEP SINGH(121612)

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ABSTRACT

The principle objective of this project is to analyse and design amulti-storeyed building [G + 3 (3 dimensional frame)] using Staad Pro. The design involves load calculations manually and analyzing the whole structure by 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. From model generation, analysis and design to visualization and result verification, Staad Pro is the professional’s choice. Initially we started with the analysis of simple 2 dimensional frames and manually checked the accuracy of the software with our results. The results proved to be very accurate. We analysed and designed a G + 3storey building [2-D Frame] initially for all possible load combinations [dead, live and seismic loads].

Staad Pro has a very interactive user interface which allows the users to draw the frame and input the load values and dimensions. Then according to the specified criteria assigned it analyses the structure and designs the members with reinforcement details for RCC frames. We continued with our work with some more multi-storeyed 2-D and 3-D frames under various load combinations. Our final work was the proper analysis and design of a multistorey G + 3 residential building

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CHAPTER 6

CHAPTER 1

INTRODUCTION AND OBJECTIVES

1.1 INTRODUCTION

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 ofreinforced 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 in which beams and columns are designed using Staad 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.

1.1.1 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.

1.2 OBJECTIVES

1. To analyse and design of a 2 storey RCC framed structure using Staad Pro.
2. The designed structure should sustain all loads and deform within limits for construction and use.
3. To design staircase and slab manually.
4. To prepare drawings with reinforcement detailing.

CHAPTER 2

PROBLEM DEFINITION

2.1General

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

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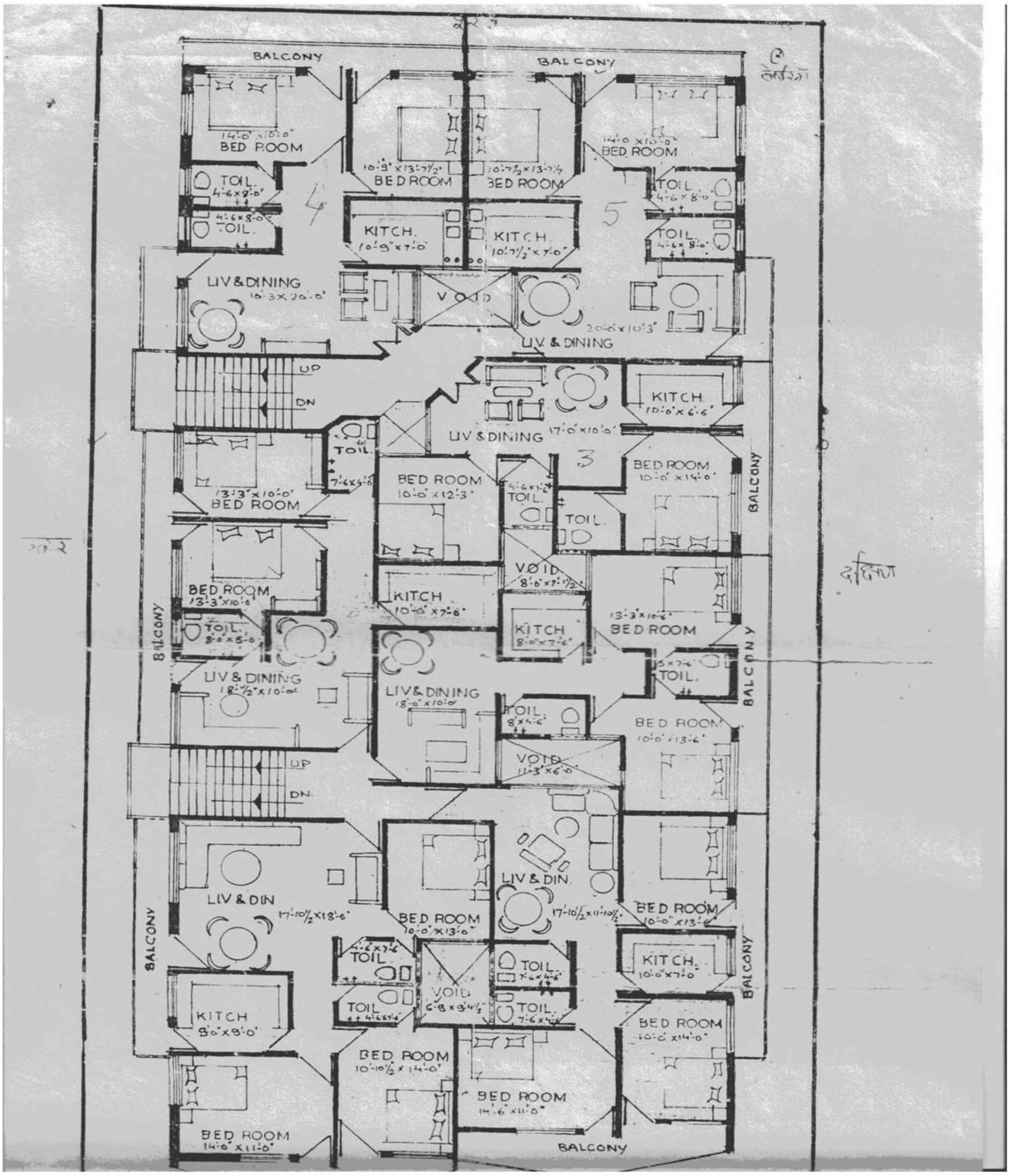


2.2 Scope

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.

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

Dead loads consist of the permanent construction material loads compressing the roof, floor, wall, and foundation systems, including claddings, finishes and fixed equipment. Dead load is the total load of all of the components of the components of the building that generally do not change over time, such as the steel columns, concrete floors, bricks, roofing material etc. In staad pro assignment of dead load is automatically done by giving the property of the member. In load case we have option called self weight which automatically calculates weights using the properties of material i.e., density

3.2.2Imposed 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 No. 1: Load Combinations

<table>
<tr><th colspan="2">Load combinations</th><th>Remarks</th></tr>
<tr><td colspan="2">1.5(DL+LL)</td><td rowspan="7">DL – Dead load of the structure
LL - Live load of the structure
EQX – Earthquake load along X
direction EQZ - Earthquake load along Z
direction WLX – Wind load along X</td></tr>
<tr><td>1.5(DL±EQX)</td><td>1.5(DL±WLX)</td></tr>
<tr><td>1.5(DL±EQZ)</td><td>1.5(DL±WLZ)</td></tr>
<tr><td>0.9(DL±1.5EQX)</td><td>0.9(DL±1.5WLX)</td></tr>
<tr><td>0.9(DL±1.5EQZ)</td><td>0.9(DL±1.5WLZ)</td></tr>
<tr><td>1.2(DL+LL±EQX)</td><td>1.2(DL+LL±WLX)</td></tr>
<tr><td>1.2(DL+LL±EQZ)</td><td>1.2(DL+LL±WLZ)</td></tr>
</table>

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.

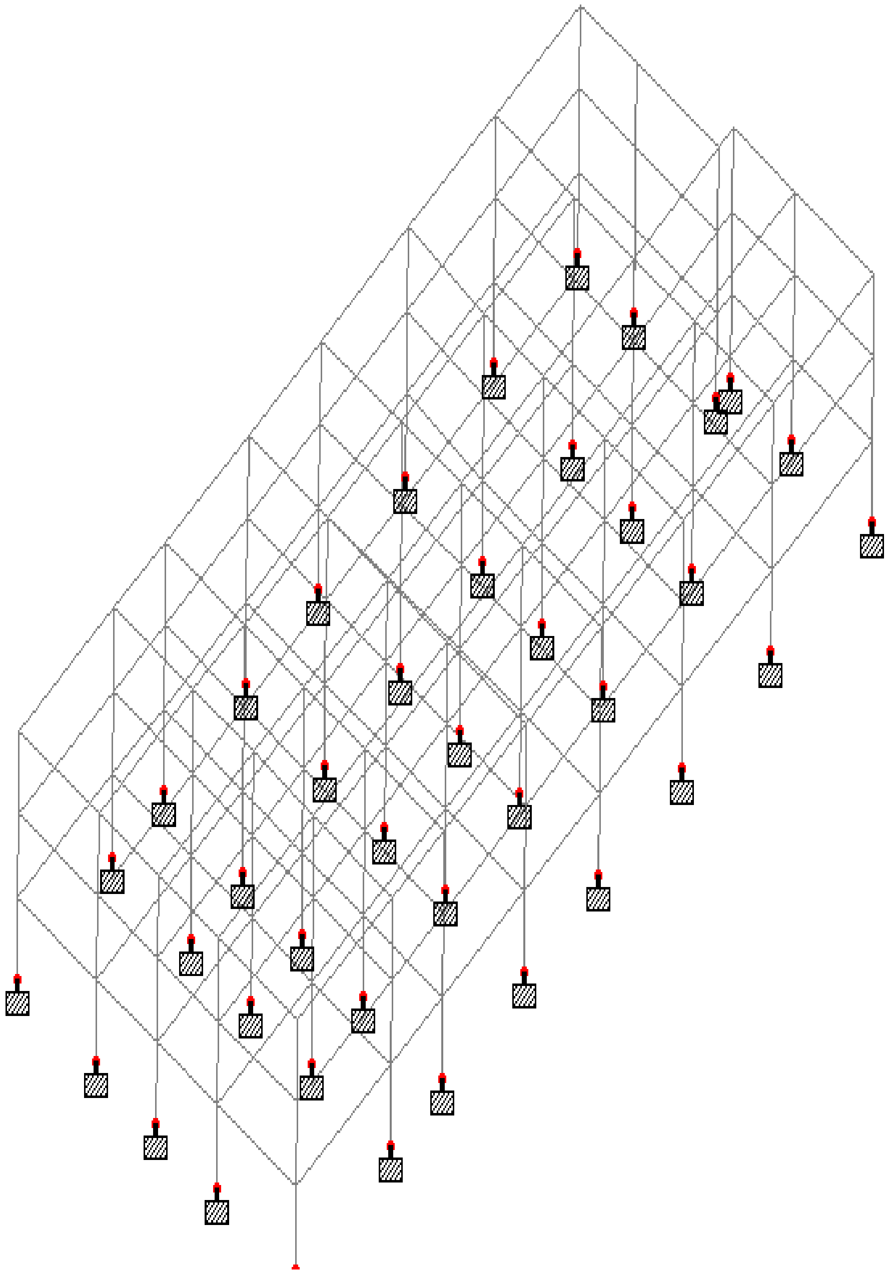
4.2 Types of Structures

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.



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

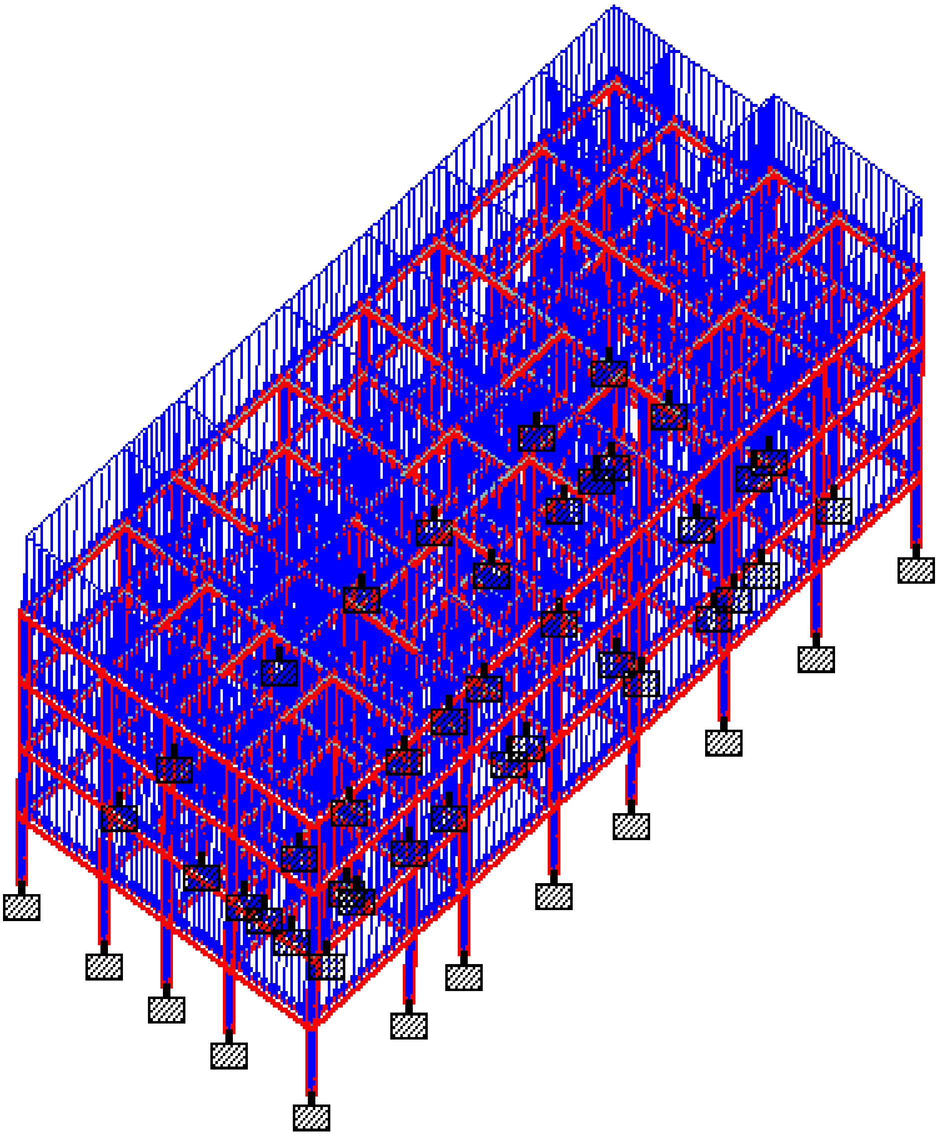
Loads in a structure can be specified as joint load, member load, temperature load and fixed end member load. STAAD.Pro can also generate the self-weight of the structure and use it as uniformly distributed member loads in analysis. Any fraction of this self -weight can also be applied in any desired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

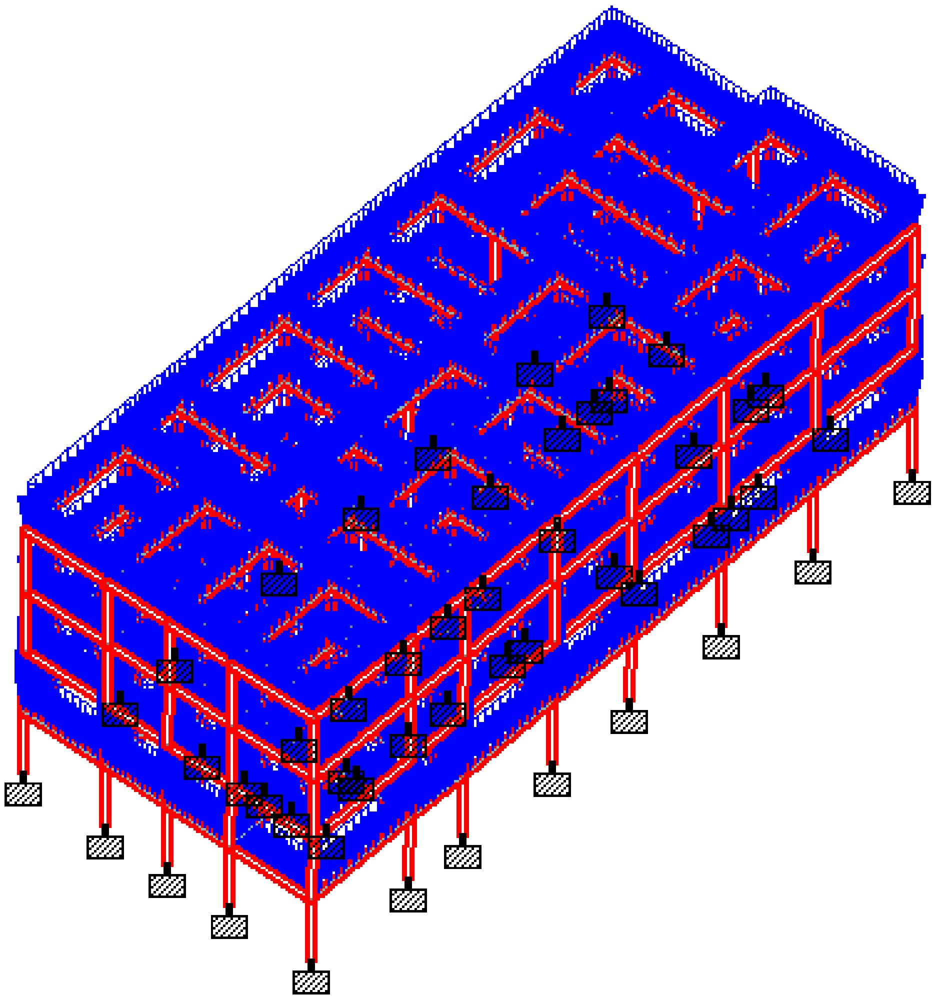
4.5.2 Member load

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.



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.



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. $P_{min} = 0.24 \frac{\sqrt{f_{ck}}}{f_y}$
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

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.

RCC design for dog ledged staircase :

Dimensions for staircase :

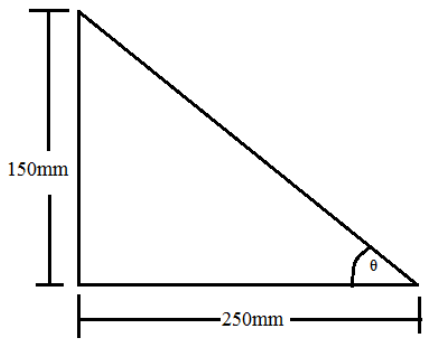
Length (L) = 5040mm

Width (B) = 1980mm

Hight (H) = 3575mm

Let us assume

Rise = 250mm



Tread = 150mm

No. Of staircases = 23.83 or say 24

Provide 12+12 (i.e, provide 12 staircase in each going)

Total width of landings = 5000-(12 * 250) = 2300mm

Width of landing on each end = 1150mm

Design of flight :(simply supported slabs):-

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

D= 216.64 or say 220mm

Span = 2800+1100 mm

Loads in staircase :

As per IS ,

Weight of step = 2.07kn/m^2

Live load = 5kn/m^2

Self load = 0.22 x 1.12 x 25

= 6.16kn/mm^2

Floor load = 1kn/mm^2

Total load = 14.23 kn/mm^2

Ultimate load = 1.5 x 14.23 = 21.345 kn/mm^2

Moment Design :

$M_{u,lim}$ = 0.138 x f_{ck} x b =

0.138 x 0.2 x 1000 x 2.8

= 77.28 kn/mm^2

$M_u = 0.87\ f_y \times A_{st} \times d\ (1- A_{st}\ f_y/bd)$

M_u = 67.442 kn/mm^2

$M_u < M_{u,lim}$

Therefore, provide 16mm φ @ 120mm each.

A_{st} = 0.12% of A_g

Spacing of 8mm φ bars =

Therefore, Provide 8mm φ @ 200mm c/c.

Design of other flights will be similar as flight 1.

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.

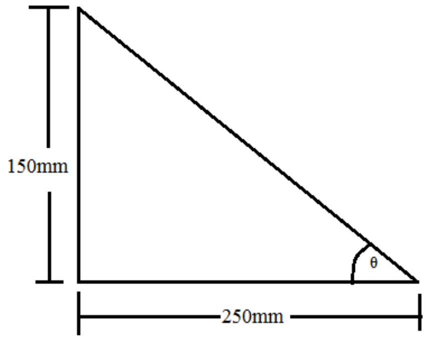
RCC design for dog ledged staircase :

Dimensions for staircase :

Length (L) = 5040mm

Width (B) = 1980mm

Hight (H) = 3575mm



Let us assume

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0.138 x 0.2 x 1000 x 2.8

= 77.28 kn/mm^2

M_u = 0.87 f_y x A_{st} x d (1- A_{st} f_y/bd)

M_u = 67.442 kn/mm^2

$M_u < M_{u,lim}$

Therefore, provide 16mm φ @ 120mm each.

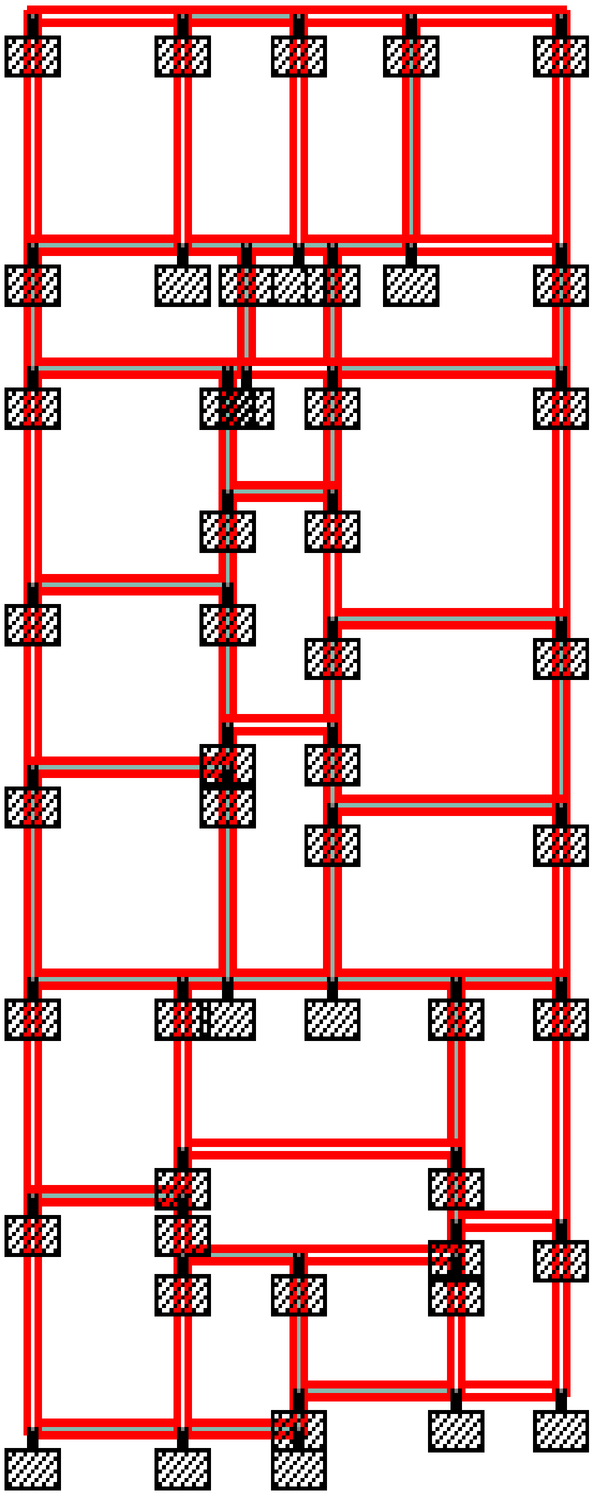
A_{st} = 0.12% of A_g

Spacing of 8mm φ bars =

Therefore, Provide 8mm φ @ 200mm c/c.

Design of other flights will be similar as flight 1.

5.3 Design of Beams



B E A M N O.   943   D E S I G N R E S U L T S

M30   Fe415 (Main)   Fe415 (Sec.)

LENGTH: 4267.0 mm   SIZE: 300.0 mm X 400.0 mm   COVER: 25.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

SECTION	0.0 mm	1066.8 mm	2133.5 mm	3200.3 mm	4267.0 mm
TOP REINF.	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)
BOTTOM REINF.	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)

SUMMARY OF PROVIDED REINF. AREA

SECTION	0.0 mm	1066.8 mm	2133.5 mm	3200.3 mm	4267.0 mm
TOP	3-10í	3-10í	3-10í	3-10í	3-10í
REINF.	1 layer(s)	1 layer(s)	1 layer(s)	1 layer(s)	1 layer(s)
BOTTOM	3-10í	3-10í	3-10í	3-10í	3-10í
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.	@ 150 mm c/c	@ 150 mm c/c	@ 150 mm c/c	@ 150 mm c/c	@ 150 mm c/c

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

SHEAR DESIGN RESULTS AT 570.0 mm AWAY FROM START SUPPORT

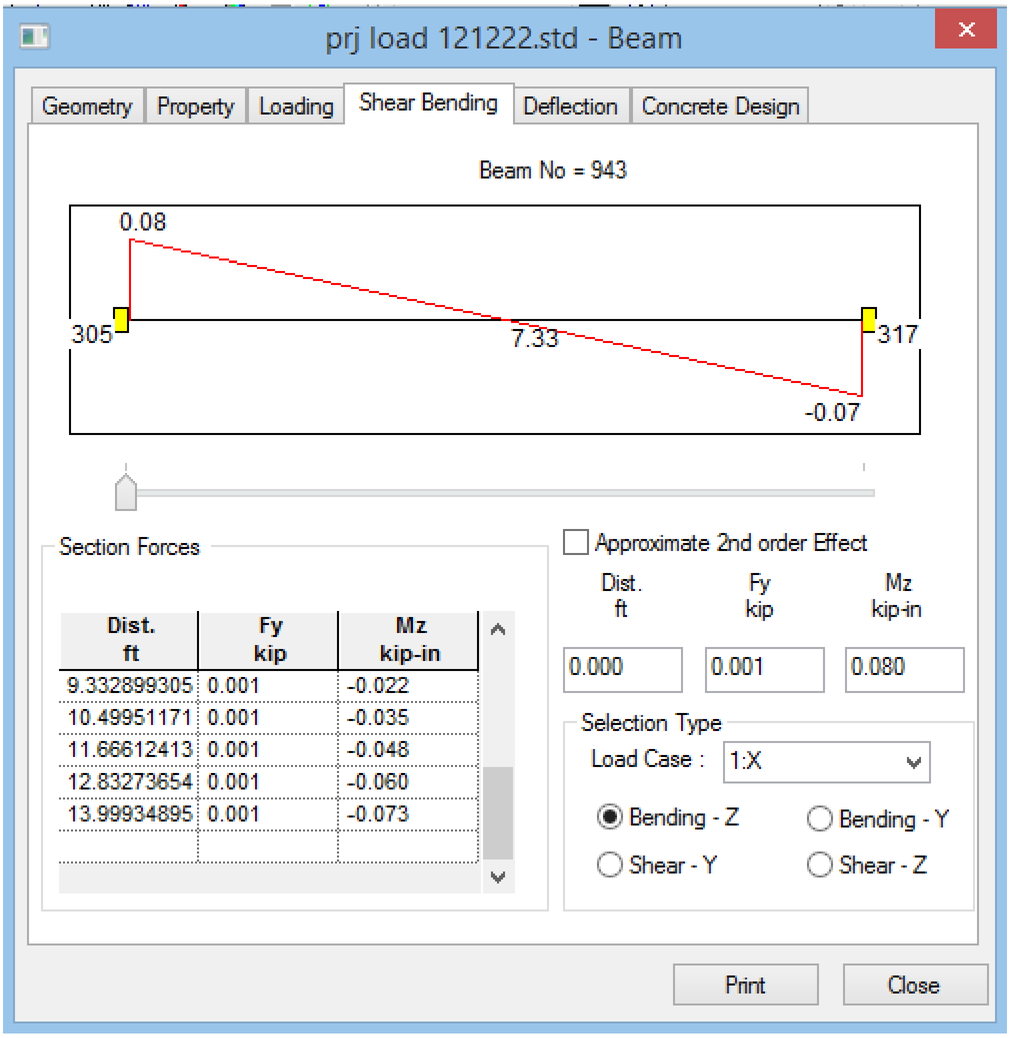
VY = -0.00 MX = -0.04 LD= 5

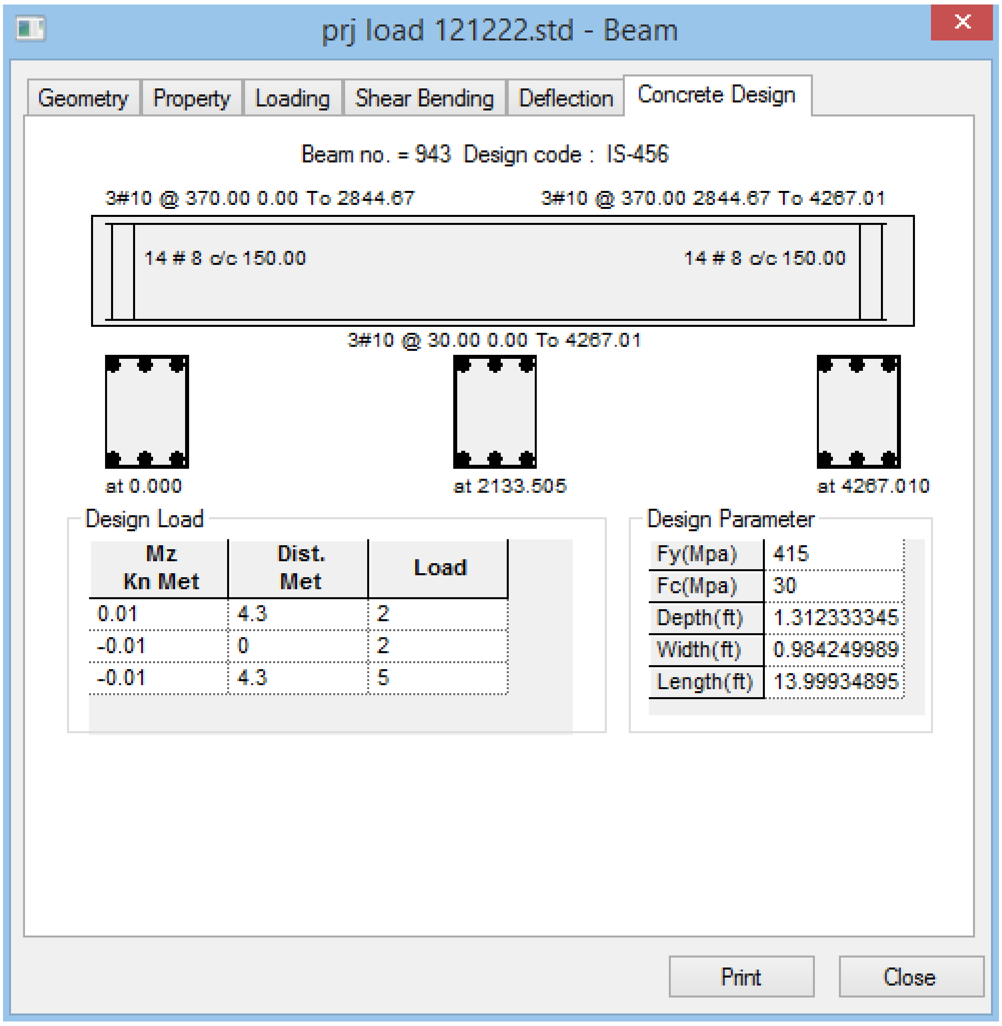
Provide 2 Legged 8í @ 150 mm c/c

SHEAR DESIGN RESULTS AT 570.0 mm AWAY FROM END SUPPORT

VY = -0.00 MX = -0.04 LD= 5

Provide 2 Legged 8í @ 150 mm c/c


prj load 121222.std - Beam
Geometry
Property
Loading
Shear Bending
Deflection
Concrete Design
Beam No = 943
0.08
305
7.33
317
-0.07
Section Forces
Dist. ft
Fy kip
Mz kip-in
9.332899305 0.001 -0.022
10.49951171 0.001 -0.035
11.66612413 0.001 -0.048
12.83273654 0.001 -0.060
13.99934895 0.001 -0.073
Approximate 2nd order Effect
Dist. ft
Fy kip
Mz kip-in
0.000
0.001
0.080
Selection Type
Load Case : 1:X
Bending - Z
Bending - Y
Shear - Y
Shear - Z
Print
Close


prj load 121222.std - Beam
Geometry
Property
Loading
Shear Bending
Deflection
Concrete Design
Beam no. = 943 Design code : IS-456
3#10 @ 370.00 0.00 To 2844.67
3#10 @ 370.00 2844.67 To 4267.01
14 # 8 c/c 150.00
14 # 8 c/c 150.00
3#10 @ 30.00 0.00 To 4267.01
at 0.000
at 2133.505
at 4267.010
Design Load
Mz Kn Met
Dist. Met
Load
0.01 4.3 2
-0.01 0 2
-0.01 4.3 5
Design Parameter
Fy(Mpa) 415
Fc(Mpa) 30
Depth(ft) 1.312333345
Width(ft) 0.984249989
Length(ft) 13.99934895
Print
Close

B E A M N O.   1384   D E S I G N R E S U L T S

M30   Fe415 (Main)   Fe415 (Sec.)

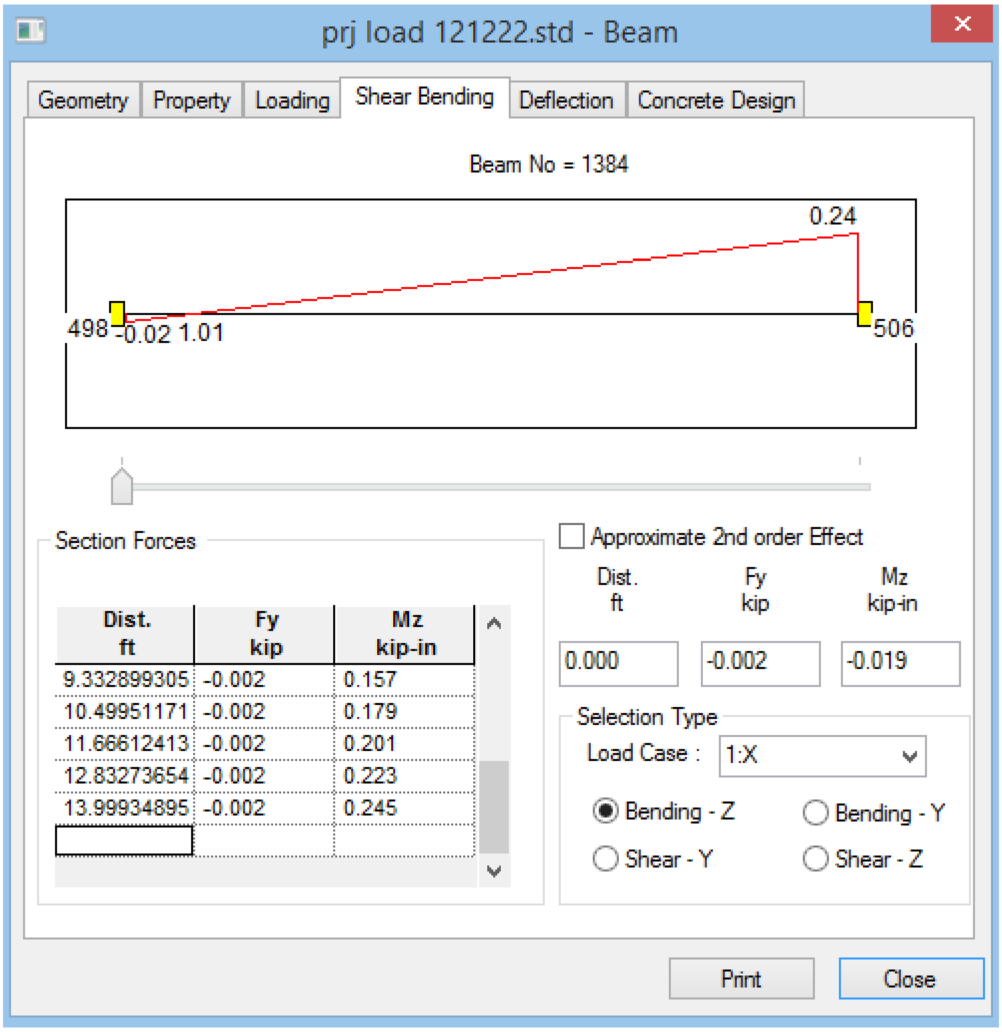
LENGTH: 4267.0 mm   SIZE: 300.0 mm X 400.0 mm   COVER: 25.0 mm

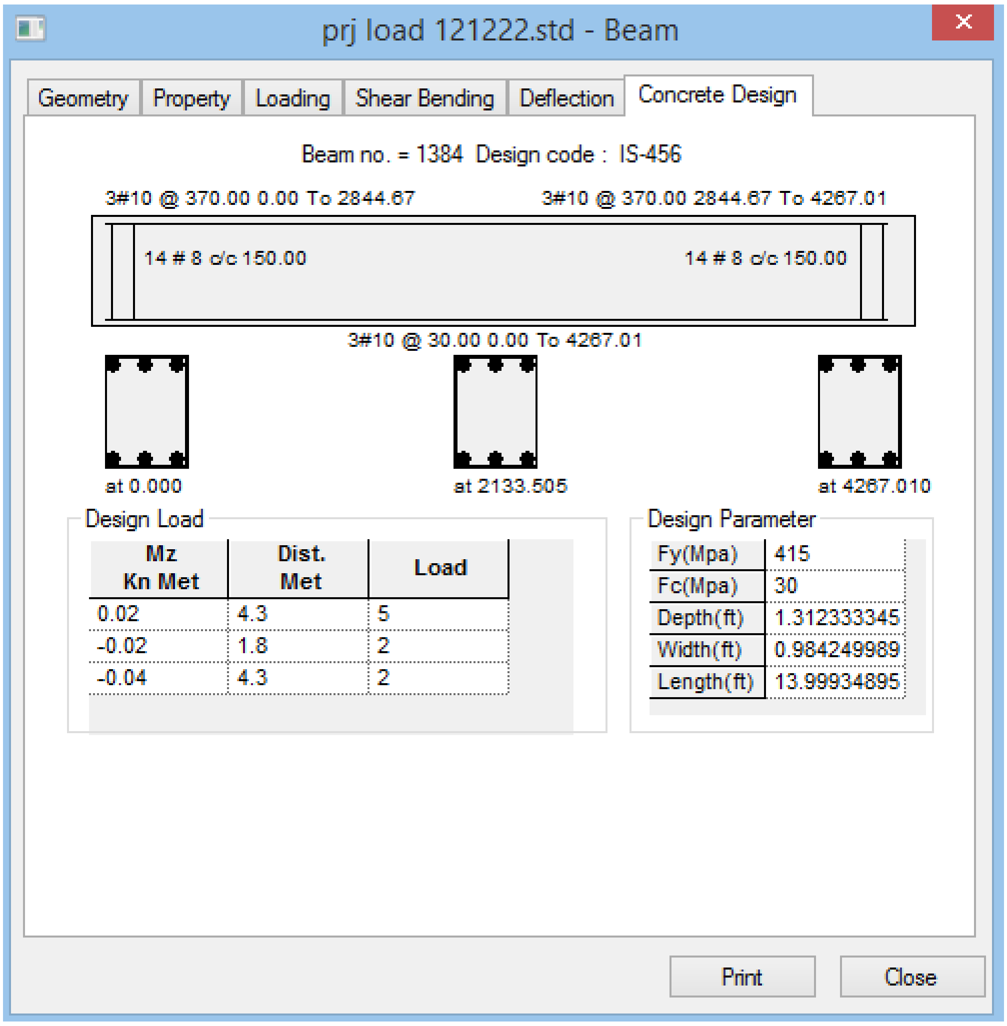
SUMMARY OF REINF. AREA (Sq.mm)

SECTION	0.0 mm	1066.8 mm	2133.5 mm	3200.3 mm	4267.0 mm
TOP REINF.	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)
BOTTOM REINF.	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)

SUMMARY OF PROVIDED REINF. AREA

SECTION	0.0 mm	1066.8 mm	2133.5 mm	3200.3 mm	4267.0 mm
TOP	3-10í	3-10í	3-10í	3-10í	3-10í
REINF.	1 layer(s)	1 layer(s)	1 layer(s)	1 layer(s)	1 layer(s)
BOTTOM	3-10í	3-10í	3-10í	3-10í	3-10í
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.	@ 150 mm c/c	@ 150 mm c/c	@ 150 mm c/c	@ 150 mm c/c	@ 150 mm c/c


prj load 121222.std - Beam
Geometry
Property
Loading
Shear Bending
Deflection
Concrete Design
Beam No = 1384
0.24
498
-0.02 1.01
506
Section Forces
Dist. ft
Fy kip
Mz kip-in
9.332899305 -0.002 0.157
10.49951171 -0.002 0.179
11.66612413 -0.002 0.201
12.83273654 -0.002 0.223
13.99934895 -0.002 0.245
Approximate 2nd order Effect
Dist. ft
Fy kip
Mz kip-in
0.000
-0.002
-0.019
Selection Type
Load Case :
1:X
Bending - Z
Bending - Y
Shear - Y
Shear - Z
Print
Close


prj load 121222.std - Beam
Geometry
Property
Loading
Shear Bending
Deflection
Concrete Design
Beam no. = 1384 Design code : IS-456
3#10 @ 370.00 0.00 To 2844.67
3#10 @ 370.00 2844.67 To 4267.01
14 # 8 c/c 150.00
14 # 8 c/c 150.00
3#10 @ 30.00 0.00 To 4267.01
at 0.000
at 2133.505
at 4267.010
Design Load
Mz Kn Met
Dist. Met
Load
0.02
4.3
5
-0.02
1.8
2
-0.04
4.3
2
Design Parameter
Fy(Mpa) 415
Fc(Mpa) 30
Depth(ft) 1.312333345
Width(ft) 0.984249989
Length(ft) 13.99934895
Print
Close

B E A M N O. 1214 D E S I G N R E S U L T S

M30 Fe415 (Main) Fe415 (Sec.)

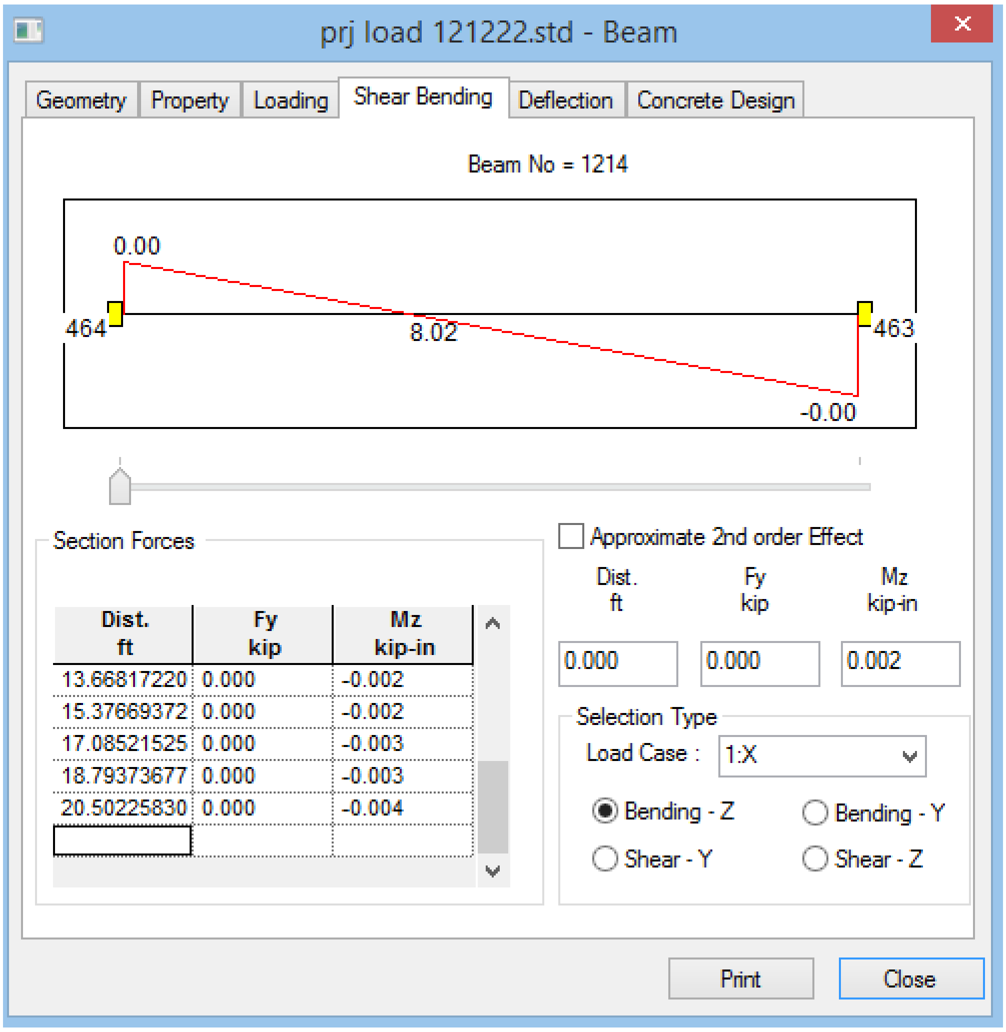
LENGTH: 6249.1 mm SIZE: 300.0 mm X 400.0 mm COVER: 25.0 mm

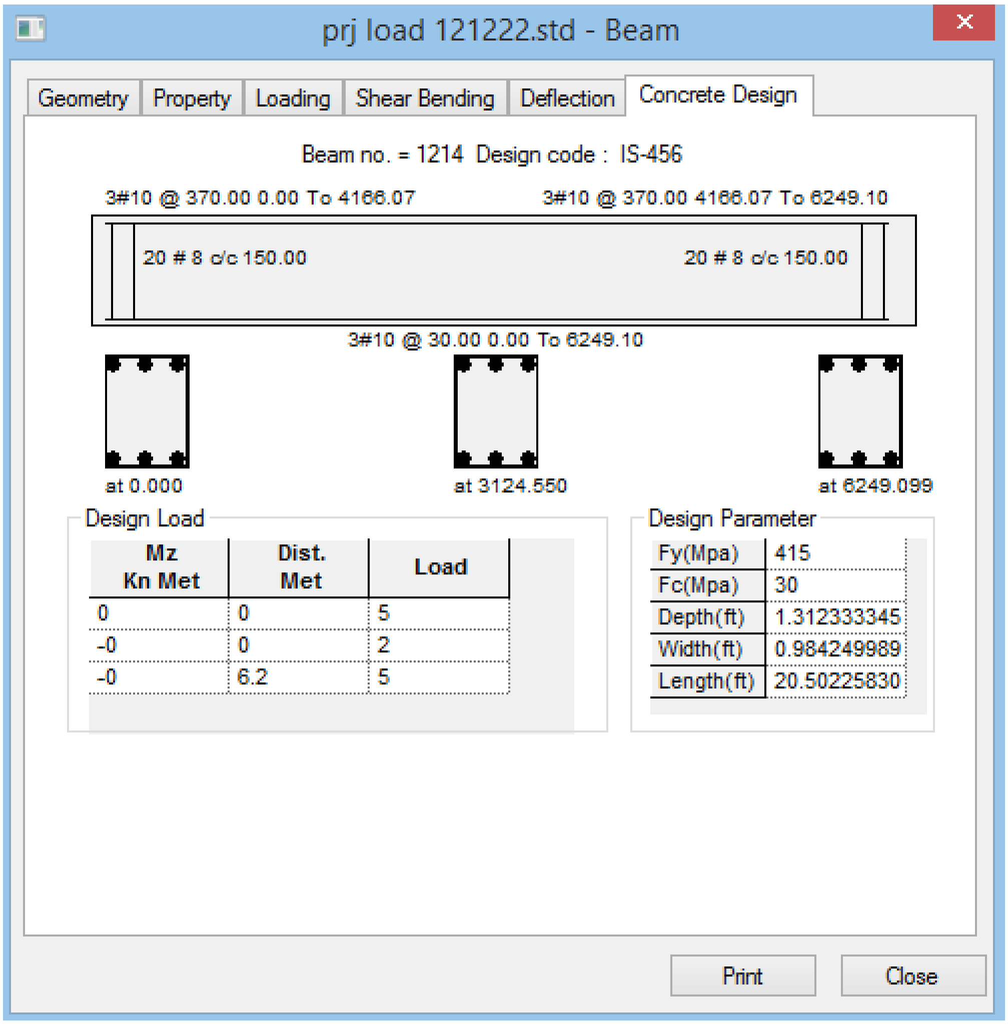
SUMMARY OF REINF. AREA (Sq.mm)

SECTION	0.0 mm	1562.3 mm	3124.5 mm	4686.8 mm	6249.1 mm
TOP REINF.	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)
BOTTOM REINF.	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)	227.35 (Sq. mm)

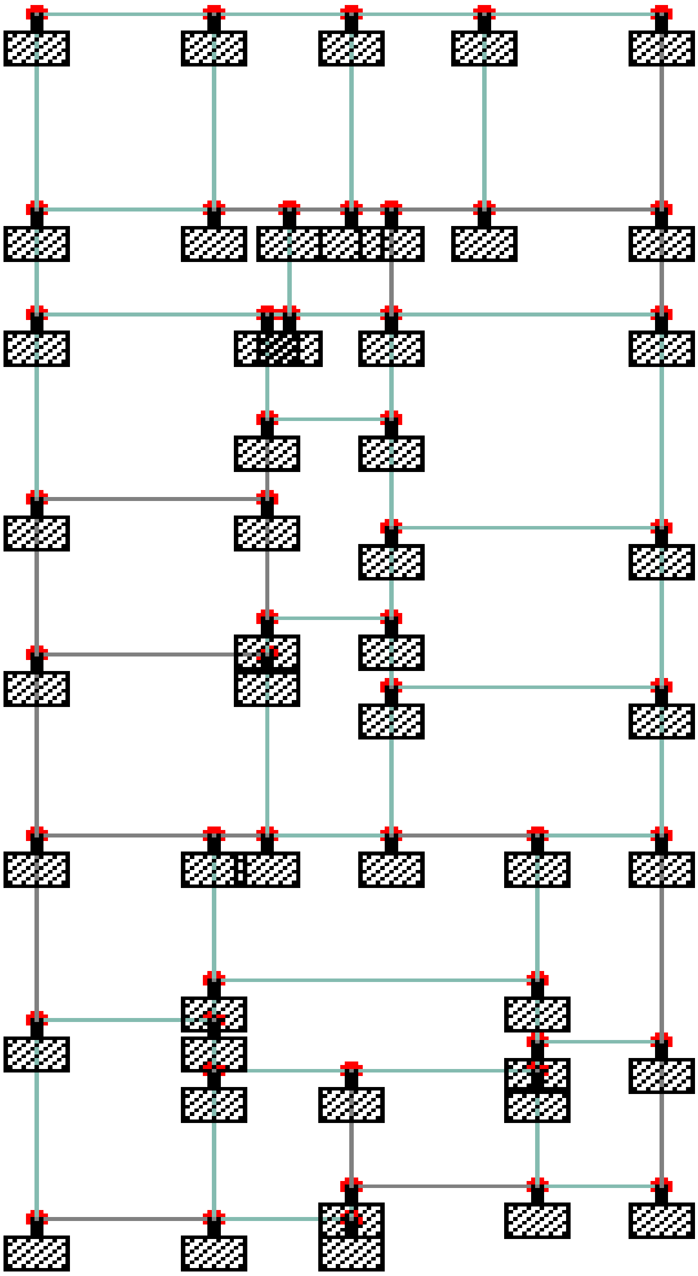
SUMMARY OF PROVIDED REINF. AREA

SECTION	0.0 mm	1562.3 mm	3124.5 mm	4686.8 mm	6249.1 mm
TOP REINF.	3-10í 1 layer(s)	3-10í 1 layer(s)	3-10í 1 layer(s)	3-10í 1 layer(s)	3-10í 1 layer(s)
BOTTOM REINF.	3-10í 1 layer(s)	3-10í 1 layer(s)	3-10í 1 layer(s)	3-10í 1 layer(s)	3-10í 1 layer(s)
SHEAR REINF.	2 legged 8í @ 150 mm c/c	2 legged 8í @ 150 mm c/c	2 legged 8í @ 150 mm c/c	2 legged 8í @ 150 mm c/c	2 legged 8í @ 150 mm c/c


prj load 121222.std - Beam
Geometry
Property
Loading
Shear Bending
Deflection
Concrete Design
Beam No = 1214
0.00
464
8.02
463
-0.00
Section Forces
Dist. ft
Fy kip
Mz kip-in
13.66817220 0.000 -0.002
15.37669372 0.000 -0.002
17.08521525 0.000 -0.003
18.79373677 0.000 -0.003
20.50225830 0.000 -0.004
Approximate 2nd order Effect
Dist. ft
Fy kip
Mz kip-in
0.000
0.000
0.002
Selection Type
Load Case :
1:X
Bending - Z
Bending - Y
Shear - Y
Shear - Z
Print
Close


prj load 121222.std - Beam
Geometry
Property
Loading
Shear Bending
Deflection
Concrete Design
Beam no. = 1214 Design code : IS-456
3#10 @ 370.00 0.00 To 4166.07
3#10 @ 370.00 4166.07 To 6249.10
20 # 8 c/c 150.00
20 # 8 c/c 150.00
3#10 @ 30.00 0.00 To 6249.10
at 0.000
at 3124.550
at 6249.099
Design Load
Mz Kn Met
Dist. Met
Load
0
0
5
-0
0
2
-0
6.2
5
Design Parameter
Fy(Mpa)
415
Fc(Mpa)
30
Depth(ft)
1.312333345
Width(ft)
0.984249989
Length(ft)
20.50225830
Print
Close

5.4 Design of Columns



C O L U M N N O. 977 D E S I G N R E S U L T S

M30 Fe415 (Main) Fe415 (Sec.)

LENGTH: 3658.0 mm CROSS SECTION: 250.0 mm X 350.0 mm COVER: 40.0 mm

** GUIDING LOAD CASE: 2 END JOINT: 353 TENSION COLUMN

REQD. STEEL AREA : 2013.20 Sq.mm.

REQD. CONCRETE AREA: 85486.80 Sq.mm.

MAIN REINFORCEMENT : Provide 12 - 16 dia. (2.76%, 2412.74 Sq.mm.)

(Equally distributed)

TIE REINFORCEMENT : Provide 8 mm dia. rectangular ties @ 250 mm c/c

SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED (KNS-MET)

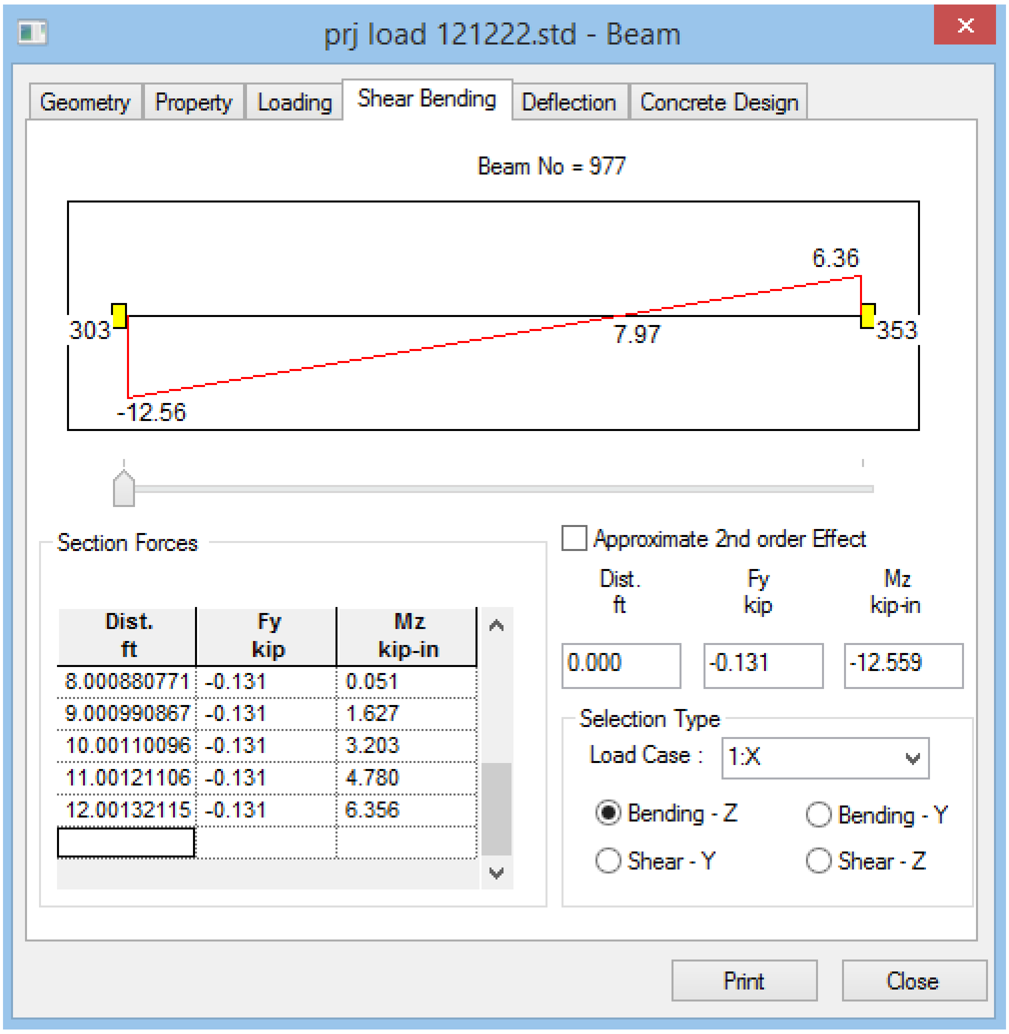
Puz : 1780.68 Muz1 : 29.77 Muy1 : 20.45

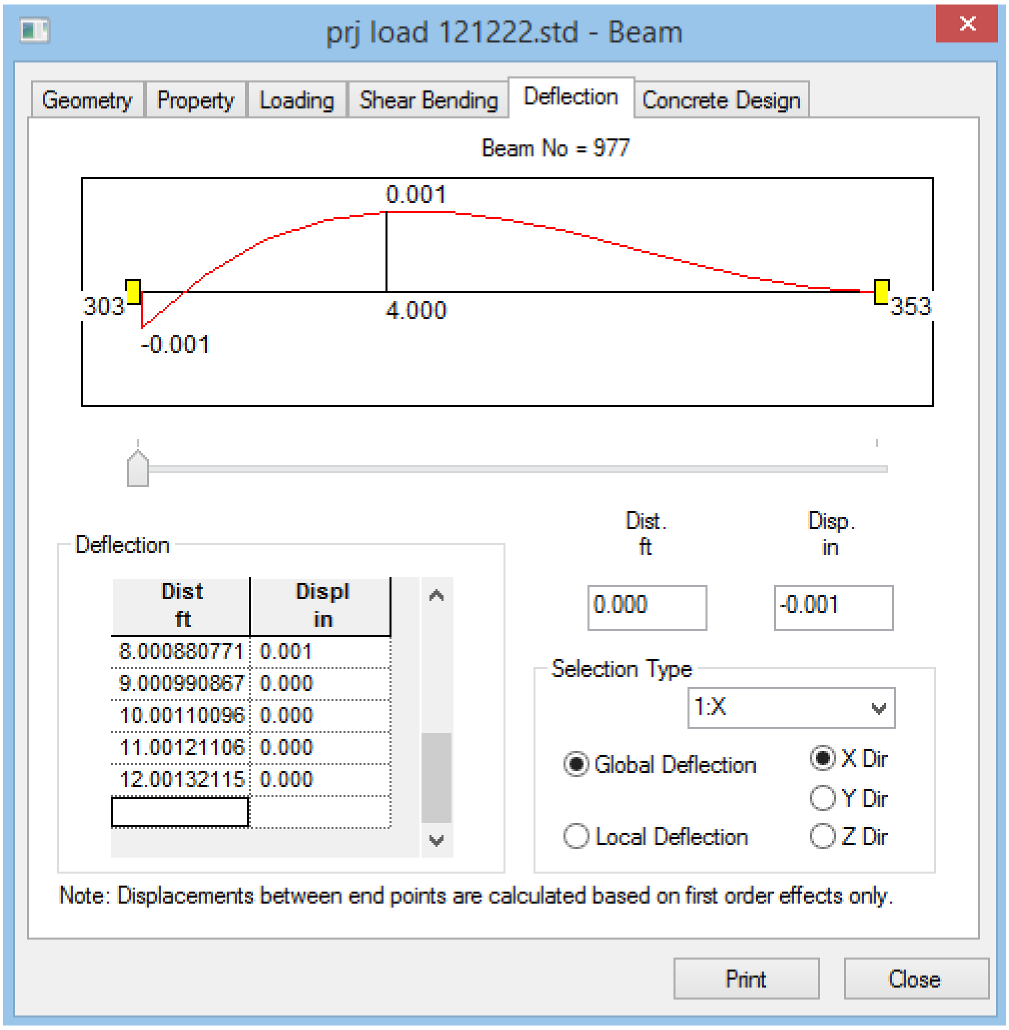
INTERACTION RATIO: 0.86 (as per Cl. 39.6, IS456:2000)

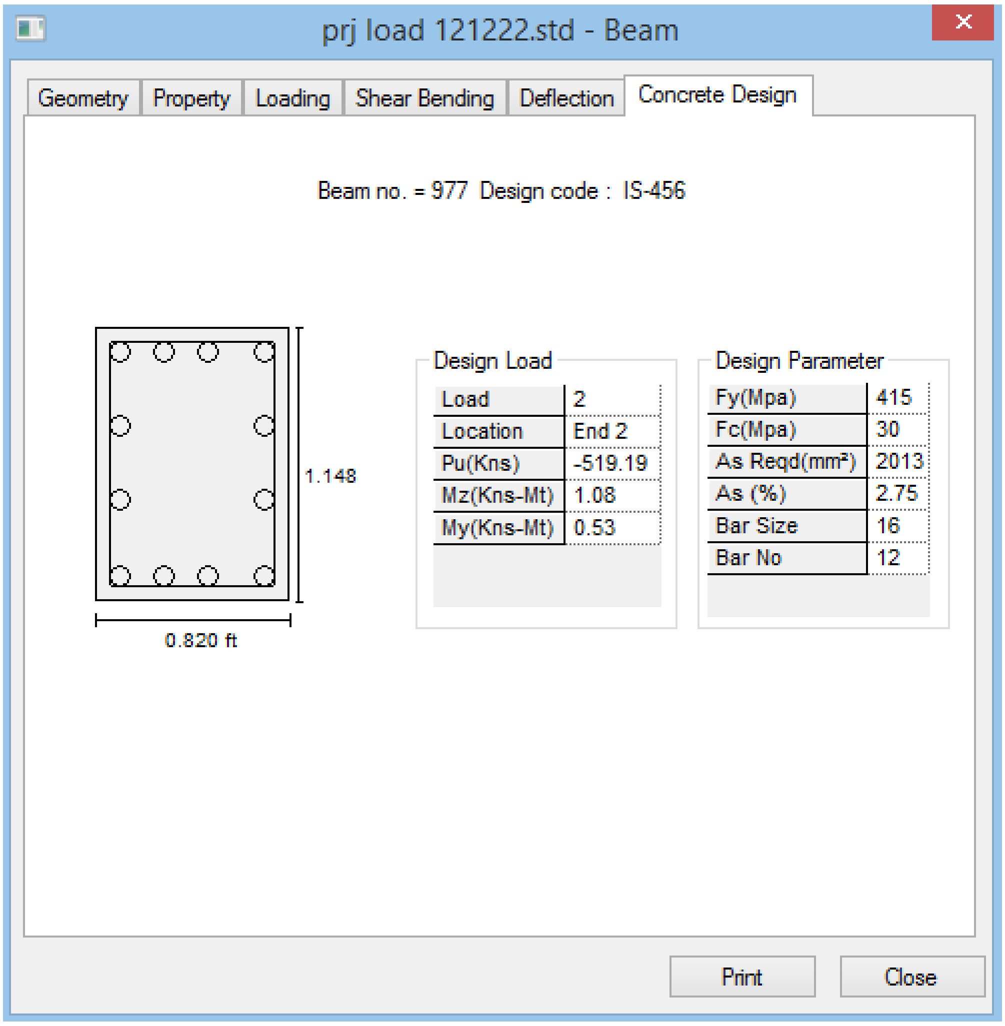
SECTION CAPACITY BASED ON REINFORCEMENT PROVIDED (KNS-MET)

WORST LOAD CASE: 5

END JOINT: 303 Puz : 1899.64 Muz : 122.87 Muy : 77.45 IR: 0.32


prj load 121222.std - Beam
Geometry
Property
Loading
Shear Bending
Deflection
Concrete Design
Beam No = 977
6.36
303
7.97
353
-12.56
Section Forces
Dist. ft
Fy kip
Mz kip-in
8.000880771 -0.131 0.051
9.000990867 -0.131 1.627
10.00110096 -0.131 3.203
11.00121106 -0.131 4.780
12.00132115 -0.131 6.356
Approximate 2nd order Effect
Dist. ft
Fy kip
Mz kip-in
0.000
-0.131
-12.559
Selection Type
Load Case :
1:X
Bending - Z
Bending - Y
Shear - Y
Shear - Z
Print
Close


prj load 121222.std - Beam
Geometry
Property
Loading
Shear Bending
Deflection
Concrete Design
Beam No = 977
0.001
303
4.000
353
-0.001
Deflection
Dist ft
Displ in
8.000880771 0.001
9.000990867 0.000
10.00110096 0.000
11.00121106 0.000
12.00132115 0.000
Dist. ft
Disp. in
0.000
-0.001
Selection Type
1:X
Global Deflection
Local Deflection
X Dir
Y Dir
Z Dir
Note: Displacements between end points are calculated based on first order effects only.
Print
Close


prj load 121222.std - Beam
Geometry
Property
Loading
Shear Bending
Deflection
Concrete Design
Beam no. = 977 Design code : IS-456
1.148
0.820 ft
Design Load
Load 2
Location End 2
Pu(Kns) -519.19
Mz(Kns-Mt) 1.08
My(Kns-Mt) 0.53
Design Parameter
Fy(Mpa) 415
Fc(Mpa) 30
As Reqd(mm²) 2013
As (%) 2.75
Bar Size 16
Bar No 12
Print
Close

C O L U M N N O. 972 D E S I G N R E S U L T S

M30 Fe415 (Main) Fe415 (Sec.)

LENGTH: 3658.0 mm CROSS SECTION: 250.0 mm X 350.0 mm COVER: 40.0 mm

** GUIDING LOAD CASE: 2 END JOINT: 348 TENSION COLUMN

REQD. STEEL AREA : 1306.01 Sq.mm.

REQD. CONCRETE AREA: 86193.99 Sq.mm.

MAIN REINFORCEMENT : Provide 12 - 12 dia. (1.55%, 1357.17 Sq.mm.)

(Equally distributed)

TIE REINFORCEMENT : Provide 8 mm dia. rectangular ties @ 190 mm c/c

SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED (KNS-MET)

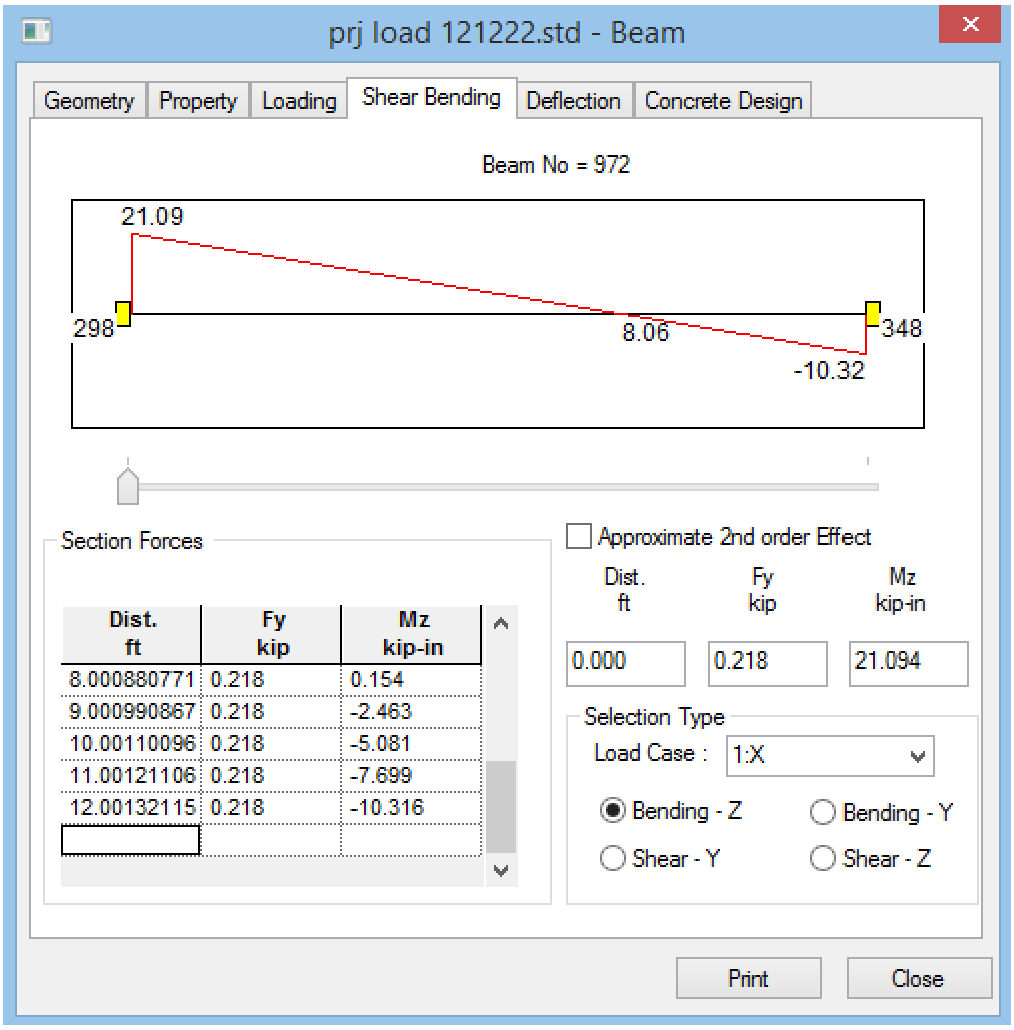
Puz : 1570.11 Muz1 : 20.24 Muy1 : 14.46

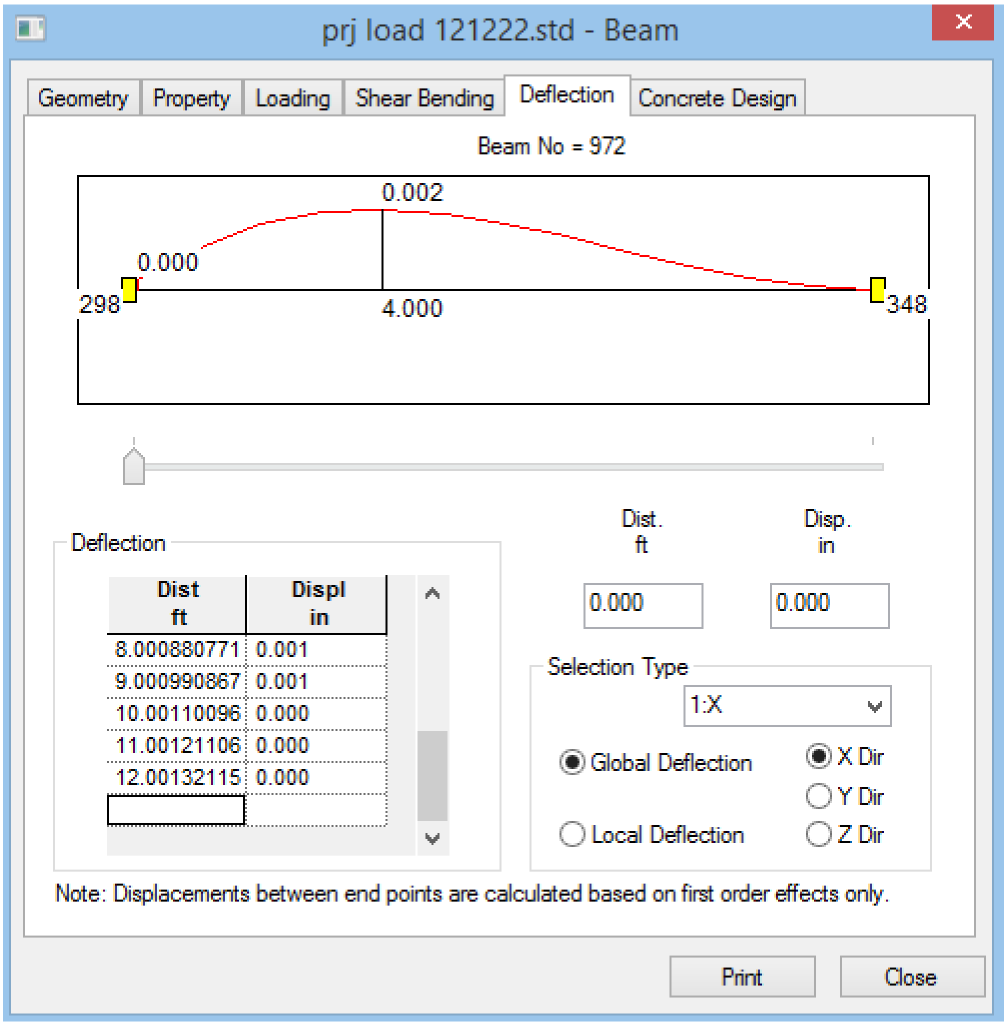
INTERACTION RATIO: 0.80 (as per Cl. 39.6, IS456:2000)

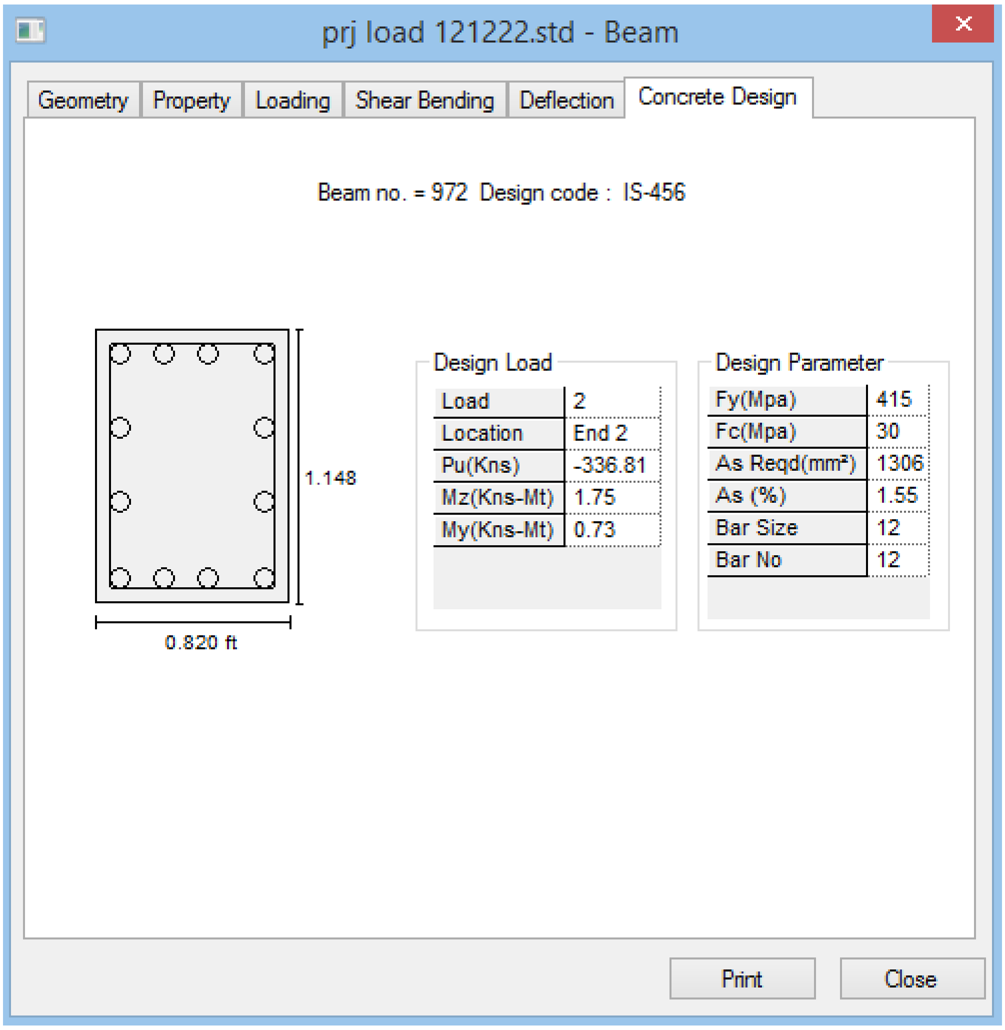
SECTION CAPACITY BASED ON REINFORCEMENT PROVIDED (KNS-MET)

WORST LOAD CASE: 5

END JOINT: 298 Puz : 1585.35 Muz : 88.95 Muy : 58.10 IR: 0.33


prj load 121222.std - Beam
Geometry
Property
Loading
Shear Bending
Deflection
Concrete Design
Beam No = 972
21.09
298
8.06
348
-10.32
Section Forces
Dist. ft
Fy kip
Mz kip-in
8.000880771 0.218 0.154
9.000990867 0.218 -2.463
10.00110096 0.218 -5.081
11.00121106 0.218 -7.699
12.00132115 0.218 -10.316
Approximate 2nd order Effect
Dist. ft
Fy kip
Mz kip-in
0.000
0.218
21.094
Selection Type
Load Case :
1:X
Bending - Z
Bending - Y
Shear - Y
Shear - Z
Print
Close


prj load 121222.std - Beam
Geometry
Property
Loading
Shear Bending
Deflection
Concrete Design
Beam No = 972
0.002
0.000
298
4.000
348
Deflection
Dist ft
Displ in
8.000880771 0.001
9.000990867 0.001
10.00110096 0.000
11.00121106 0.000
12.00132115 0.000
Dist. ft
Disp. in
0.000
0.000
Selection Type
1:X
Global Deflection
Local Deflection
X Dir
Y Dir
Z Dir
Note: Displacements between end points are calculated based on first order effects only.
Print
Close


prj load 121222.std - Beam
Geometry
Property
Loading
Shear Bending
Deflection
Concrete Design
Beam no. = 972 Design code : IS-456
1.148
0.820 ft
Design Load
Load 2
Location End 2
Pu(Kns) -336.81
Mz(Kns-Mt) 1.75
My(Kns-Mt) 0.73
Design Parameter
Fy(Mpa) 415
Fc(Mpa) 30
As Reqd(mm²) 1306
As (%) 1.55
Bar Size 12
Bar No 12
Print
Close

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 Fig. 3 Plan 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

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

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

CHAPTER 6

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. Where ever the rectangular section is inadequate as singly reinforced section, doubly reinforced section is tried.

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. All active load cases are tested to calculate reinforcement. 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. 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

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.

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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