

Analysis of Steel Framed Structure using STAAD Pro and ROBOT Software

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Abstract: As we know that, due to limitations on maximum allowable deflection. The high strength properties of structural steel cannot always be utilized to best advantage. As a result several new methods have been aimed at increasing the stiffness of the steel members without any increase in weight of the steel required. Steel frame is a building technique with a skeleton frame of vertical steel columns and horizontal I-beams, constructed in a rectangular grid to support the floors, roof and walls of a building which are all attached to the frame. The development of this technique made the construction of the skyscraper possible. In this research a steel framed structure is selected and is analyzed for different loading and support condition by using STAAD Pro and Robot Software. The deflection patterns at the Center distance of the members are studied for different loading condition. The principle objective of this project is to analyze and design a steel framed structure by using building design software's. The design involves load calculations and analysis the whole structure by STAAD Pro and Robot Software.

Keywords: STAAD, AISC, SCIA.

I. INTRODUCTION

The rapid growth in population, scarcity and high cost of land has greatly influenced the construction industry. This has led to the construction of buildings upwards. Advances in construction technology, materials, structural systems, analysis and design software facilitated the growth of tall buildings. As the height of buildings increases lateral load resisting system becomes more important than the structural system that resists gravity loads. The lateral load resisting systems that are widely used are: rigid frame, shear wall, wall-frame, braced tube system, outrigger system and tubular system. Building construction has undergone many variations over the years, evolving to meet economic, environmental and social considerations at different times. Floor plans and styles are developed to meet latest trends and fashions, while the choice of construction materials may be guided by reasons ranging from cost to conservation considerations. Builders in the commercial and industrial sector have long recognized the many benefits of steel framing, such as consistent quality, precision measurements, light weight and infinitely variable lengths. As production techniques have been refined and new technologies have arisen, steel framing is securing increasing use in the domestic market. Builders and buyers need to make numerous decisions about the materials and fittings they will use and the designs they will choose when planning every aspect of a new structure. The planning stage is the ideal time to consider aspects such as health and safety as well as cost and appearance. The materials chosen for behind the walls, in the roof space and underfoot are once-only decisions. Steel-framing is becoming increasingly popular, with suggestions in the home building industry that these systems will secure a substantial share of the domestic market sometime after the

turn of the century. As well as suiting traditional choices in layout and exterior finishes, steel framing can widen the options available. The special qualities of steel, such as its strength and light weight, lend themselves to innovative design ideas.

A. Steel as a Structural Material

Structural steel is a material used for steel construction, which is formed with a specific shape following certain standards of chemical composition and strength. They can also be defined as hot rolled products, with a cross section of special form like angles, channels and beams/joints. There has been an increasing demand for structural steel for construction purposes in the India. Measures are been taken by the structural steel authority for ready availability of structural steel on time for the various projects. The people at every level are working hard to realize the purpose of producing steel on time, like, service centers, producers, fabricators and erectors along with the general contractors, engineers and architects are all working hand in hand. Steel has always been more preferred to concrete because steel offers better tension and compression thus resulting in lighter construction. Usually structural steel uses three dimensional trusses hence making it larger than its concrete counterpart. There are different new techniques which enable the production of a wide range of structures and shapes, the procedures being the following:

- High-precision stress analysis
- Computerized stress analysis
- Innovative jointing

B. Types of Structural Steel

Various types of structural steel sections and their technical specifications are as follows:

- Beams
- Channels
- Angles
- Flats

14 Advantages of steel as a structural material

Structural steel sections are usually used for construction of buildings, buildings, and transmission line towers (TLT), industrial sheds and structures etc. They also find in manufacturing of automotive vehicles, ships etc. Steel exhibits desirable physical properties that make it one of the most versatile structural materials in use. Its great strength, uniformity, light weight, easy of use, and many other desirable properties makes it the material of choice for numerous structures such as steel bridges, high rise buildings, towers, and other structure.

Elasticity: steel follows hooks law very accurately.

Ductility: A very desirable of property of steel, in which steel can withstand extensive deformation without failure under high tensile stresses, i.e., it gives warning before failure takes place.

Toughness: Steel has both strength and ductility.

Additions to Existing Structures: Example: new bays or even entire new wings can be added to existing frame buildings, and steel bridges may easily be widened.

15 Disadvantages of steel as a structural material

Maintenance Cost: Steel structures are susceptible to corrosion when exposed to air.

Fire Proofing Cost: steel is an incombustible material; however, its strength is reduced tremendously at high temperature due to common fires.

Fatigue: The strength of structural steel member can be reduced if this member is subjected to cyclic loading.

Brittle Fracture: under certain conditions steel lose its ductility, and brittle fracture may occur at places of stress concentration. Fatigue type loadings and very low temperature trigger the situation

C. STAAD Pro

The full form of STAAD is STRUCTURAL AIDED ANALYSIS AND DESIGN. It was developed by Research Engineers International in Yorba Linda ,CA later it was sold to Bentley systems in late 2005. STAAD. Pro is an analysis & design software package for structural engineering used in performing the analysis & design of wide variety of types of structures. It allows structural engineers to analyze& design

virtually any type of structure through its flexible Modeling environment, advanced features & fluent data collaboration. STAAD.Pro may be utilized for analyzing and designing practically all types of structures – buildings, bridges, towers, transportation, industrial and utility structures. STAAD-PRO was born giant. It is the most popular software used now a days. Basically it is performing design works. There are four steps using STAAD-PRO to reach the goal.

- Prepare the input file.
- Analyze the input file.
- Watch the results and verify them.
- Send the analysis result to steel design or concrete design engines for designing purpose.

Limitations of Hand Computation Methods:

- Applicable for small problem
- Tedious for even medium sized problems
- 3-d analysis almost impossible

Advantages of Computer Analysis:

- Matrix methods of structural analysis
- Development of numerical techniques
- Finite element method
- 3-d analysis can be done

Use of Computers in Structural Design of Buildings:

- STAADPRO is a very powerful software which can be used for 3-Danalysis & is useful for analysis and design of multi-storied buildings.
- Full range of analysis including static, P-delta, response spectrum, time history, cable etc.and
- Steel design,
- Concrete design and
- Timber design is available in STAADPRO
- It provides the user environment for–
- Model development (Graphical as well as input editor)
- Model visualization on screen,
- Analysis & design, and Verification
- Pre and Post Processor
- Isometricandperspectiveviewand3Dshapes

D. Robot

Robot software is the set of coded commands or instructions that tell a mechanical device and electronic system, known together as a robot, what tasks to perform. Robot software is used to perform autonomous tasks. Many software systems and frameworks have been proposed to make programming robots easier .Robot software is the set of coded commands or instructions that tell a mechanical device and electronic system, known together as a robot, what tasks to perform. Robot software is used to perform autonomous tasks. Many software systems and frameworks have been proposed to make programming robots easier. Some robot software aims at developing intelligent mechanical devices. Common tasks include feedback loops, control, path finding, data filtering, and locating. We define “stable” a family of

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systems whose requirements and architecture is well understood and designed so that specific applications of the family may be developed re-using, adapting and specializing knowledge, architecture and existing components. This would be extremely beneficial to the research community since every research group, even the smallest, would have the possibility to concentrate its efforts on a small piece of the robotics puzzle (Kortenkamp, Schultz 1999). For example, experts in automated planning could experiment new path planning algorithms for a mobile robot relying on the obstacle avoidance and self-localization functionalities encapsulated in components off-the-shelf.

Computer assistance in an engineer's work is currently getting more effective and precise. The automation of the design process makes the time of project completion shorter and in-crases competitiveness of a product. Autodesk's Robot Structural Analysis is one of the tools facilitating the work of designers and constructors. Autodesk Robot Structural Analysis is an integrated graphic application used for modeling, analysis and dimensioning of various construction types. The program features construction design, carrying out static calculations of a construction, outcomes verification, standardized calculations of construction elements and gathering documentation for calculated and dimensioned constructions. The most relevant features of the Robot include: A fully graphic definition of construction in the graphic editor (loading a DXF file containing construction geometry prepared with a different program is also possible).A possibility of a graphic representation of the designed construction as well as displaying various calculation outcomes (force, displacement, multiple windows work etc.) calculation of the construction (dimensioning) while designing another construction (multi-threading),carrying out static and dynamic construction analyses, assigning the rod type while creating the construction model, not in standard modules. Composing any type of print (calculation notes, screenshots, print composition, and exporting objects to other programs).

E. Design of Constructional Connection

The main function of the connection is to distribute the internal forces between the elements. In a steel construction basic elements such as columns, beams, bracings and ties are used. Next, the components of the external building partitions-ceilings and partition walls – are attached to the main constructional elements. The most commonly used connection types in multi-storey buildings are articulated nominal connections (beam-to-beam and beam-to-column), moment connections (beam-to-column) in case of continuous frames, bracings connections, column bases.

F. Code AISC 360-10

The design code 2010 AISC Specification for Structural Steel Buildings (ANSI/AISC 360-10) was used. The more recent version of the AISC Specification for Structural Steel Buildings (ANSI/AISC 360-10) has been implemented in SCIA Engineer v2013.1. Furthermore, the available

functionalities in the software enable a rigorous structural analysis according to the Direct Analysis Method, including considerations of 2nd order deformations, initial imperfections, and plasticity. Related to initial imperfections, a number of approaches have been enabled in order to fit the preferences of the designer.

- Related to global imperfections
- Related to member imperfections

Objectives of the Study:

- To determine the instability behavior of steel members using STAAD Pro and ROBOT software.
- To provide appropriate section using software analysis.
- To compare the design proficiency of the software's.

II. MATERIALS AND METHODOLOGY

A. Loads Considered

- Dead Loads
- Imposed Loads
- Wind Load
- Seismic Load

B. Working with STAAD.Pro

Input Generation: The GUI (or user) communicates with the STAAD 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 procedure.

Types of Structures:

- A STRUCTURE can be defined as an assemblage of elements. STAAD 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.
- 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.

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.

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

$$G = 0.5 \times E / (1 + \text{POISS}) \quad (1)$$

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

Section Types for Concrete Design: The following types of cross sections for concrete members can be designed.

- For Beams Prismatic (Rectangular & Square) & T-shape
- For Columns Prismatic (Rectangular, Square and Circular)

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 Millimeter and Newton before performing the concrete design.

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 prescanned to identify the critical load cases at different sections of the beams. For design to be performed as per IS: 13920 the width of the member shall not be less than 200mm. Also the member shall preferably have a width-to depth ratio of more than 0.3.

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

- The minimum grade of concrete shall preferably be M20.
- Steel reinforcements of grade Fe415 or less only shall be used.

- The minimum tension steel ratio on any face, at any section, is given by:

$$\rho_{\min} = 0.24 \sqrt{f_{ck}/f_y} \quad (2)$$

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

- The positive steel ratio at a joint face must be at least equal to half the negative steel at that face.
- 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.

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.

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.

Design Operations: STAAD 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:

- Specify the members and the load cases to be considered in the design.
- Specify whether to perform code checking or member selection.
- Specify design parameter values, if different from the default values.
- 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 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.

C. Overview of Autodesk Robot Structural Analysis Professional API

Autodesk Robot Structural Analysis Professional software inherently offers full access to an open API. Robot Structural Analysis Professional API exposes the standard functionality of Robot, facilitating programmatic control through external software. Access to Robot through this mechanism can enable any routine tasks or processes accessible through the standard user interface to be fully automated and, thus, more rapidly repeatable, extendible, and scalable. With help from Robot Structural Analysis Professional API, users can drive their analysis model for a number of tasks, including creating complex models; generating and modifying geometry/mesh; applying and editing material properties, sectional information, and boundary conditions; and running analyses and extracting results. Programmatic access can enable the execution and control of the analysis tasks so multiple design options can be more quickly evaluated while also testing for design compliance. Therefore, Robot API is a powerful tool for concept design optioneering as well as detailed design.

Automation of Design Processes: A typical design analysis process involves the following steps:

- Geometry generation
- Mesh generation
- Assignment of structural material and sectional properties
- Analysis run and results evaluation
- Iteration through the above four steps until design criteria is met

The Robot Structural Analysis Professional API enables programmatic control of each of the above processes, helping provide rapid reduction in each design iteration time. The example below illustrates automation through links to Microsoft® Excel® software; however, the open API enables real customization of the design processes by integrating Robot with proprietary CAD packages, post-processing software, or bespoke tools developed as a plug-in to the Robot interface. The API uses Microsoft's component object model (COM) technology. This means the user can develop simple Visual Basic® for Applications (VBA) code from within applications such as Excel, Microsoft® Word, AutoCAD® software, or develop sophisticated .Net applications to link Robot analysis software with external software. The benefits of automation are numerous. Automation can help:

- Reduce of design time
- Increase accuracy
- Increase efficiency
- Eliminate arduous, repetitive tasks
- Support rapid design exploration

Optimization Targets, Constraints, and Variables: Typical objectives or targets for optimization may include:

Minimizing:

- Stress
- Deflection
- Weight

- Cost
- Embodied energy

Maximizing:

- Repetition of components

In many cases, these objectives will need to be met within a framework of other conflicting architectural, engineering, fabrication, and client constraints. Typical constraints may be the minimum or maximum section sizes available, maximum deflection due to physical constraints, maximum curvature, total cost not to be exceeded, and so forth. Variables of optimization process are typically the section sizes, but may also be the whole geometric form, numbers of section types used, and so on.

The optimization question then is: Given the constraints, what are the most appropriate values of the design variables to achieve the optimization target? The answer to this question requires use of mathematical techniques that iteratively seek the optimum solutions.

Optimization Techniques: Optimization as a topic is vast and spans a wide range of mathematical and numerical techniques. A sample of which include:

- Simple Newton Raphson techniques
- Dynamic relaxation
- Genetic algorithm
- Simulated annealing
- Hill climbing methods

Each algorithm is a common factor in that it seeks to (progressively) improve a design based on the targets and constraints defined above. When applying these optimization techniques to real design projects, the emphasis must be on practical, constructible solutions. Thus, we go on to look at how novel, but practical, tools can be developed and integrated into established design processes and existing software practices.

Analysis Automation and Design Optimization: As introduced earlier, Robot Structural Analysis Professional API helps to provide control over the following aspects of analysis:

- Geometry generation and manipulations (for example, node coordinates).
- Mesh generation (for example, mesh size).
- Structural size and property assignment (for example, section database, material stiffness).
- Analysis runs (for example, nonlinear) and results evaluation (for example, deflections, member forces).

With a programmable COM interface, the API helps enable automation of the analysis. Using this capability, one can more easily write a program that automatically:

- Re-creates the geometry and mesh parametrically
- Applies the sizing and material properties to the mesh elements

- Runs the analysis
- Interrogates the results
- Reports the results, for example, forces schedules in a table or a drawing.

The integration of Robot Structural Analysis Professional with a powerful BIM application, such as an Autodesk® Revit® product, helps to further benefits including direct linking of the diagram shown in Fig.1.

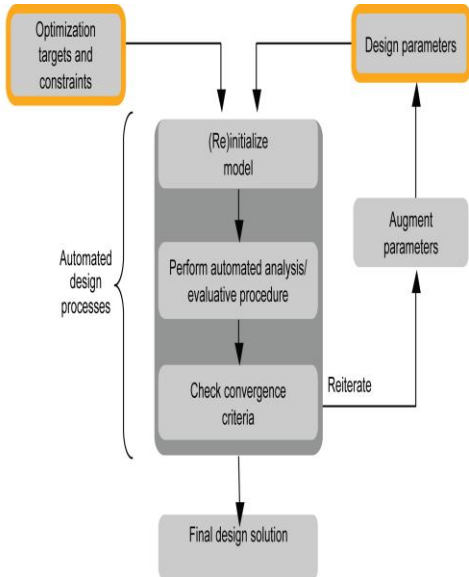


Fig. 1. Procedure setup for automated analysis.

III. RESULTS AND DISCUSSION

Results of this paper is as shown in bellow Figs.2 to 6.

A. Analysis of Steel Framed Building Using STAAD.Pro

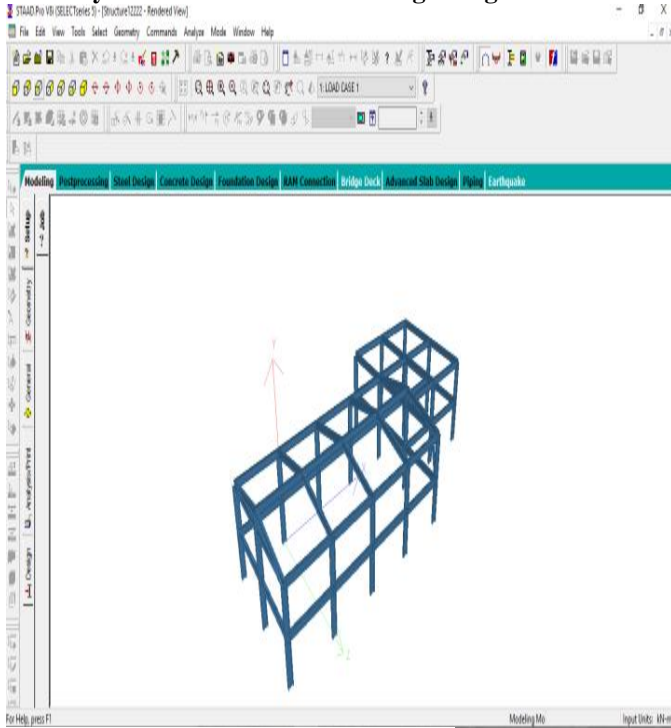


Fig.2. Elevation Steel Framed Building.

Generation of Member Property:

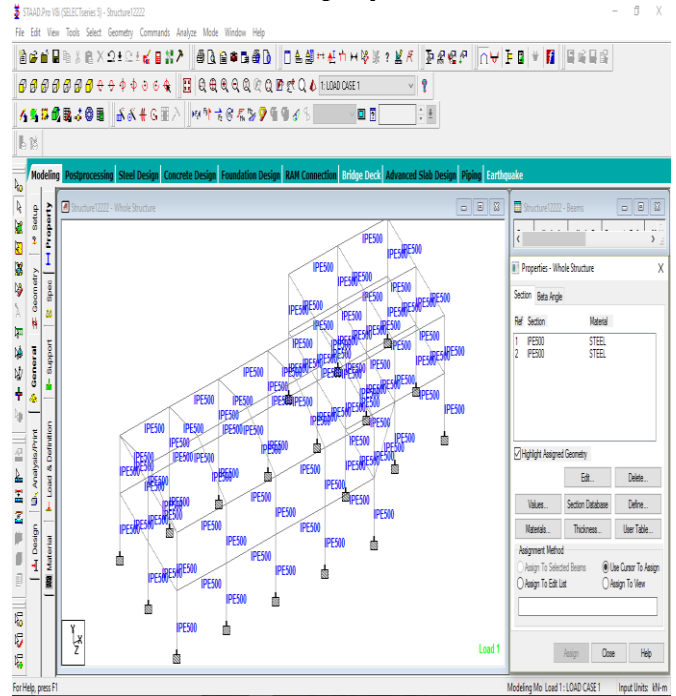


Fig.3. Generation of member property.

Generation of member property can be done in STAAD.Pro by using the window as shown above. The member section is selected and the dimensions have been specified. The beams are having a dimension of 0.5 * 0.3 m and the columns are having a dimension of 0.8 * 0.8 m at the ground floor and at the other top floors they are having a dimension of 0.5 * 0.5 m.

Supports: The base supports of the structure were assigned as fixed. The supports were generated using the STAAD.Pro support generator.

TABLE I: Section Properties

Prop	Section	Area (cm ²)	Iyy (cm ⁴)	Izz (cm ⁴)	J(cm ⁴)	Material
1	IPE 500	101.00	1.94 E +3	42.9 E +3	50.181	STEEL
2	IPE 500	116.00	2.14 E +3	48.2 E +3	71.734	STEEL

Materials for the Structure: The materials for the structure were specified as concrete with their various constants as per standard IS code of practice.

TABLE II: Materials For The Structure

Material	Name	E(kN/mm ²)	v	Density(kg/m ³)	α (°C)
1	Steel	205.000	0.300	7.83 E +3	12 E -6
2	Stainlesssteel	197.930	0.300	7.83 E +3	18 E -6
3	Aluminum	68.948	0.330	2.71 E +3	23 E -6
4	Concret	21.718	0.170	2.4 E +3	10 E -6

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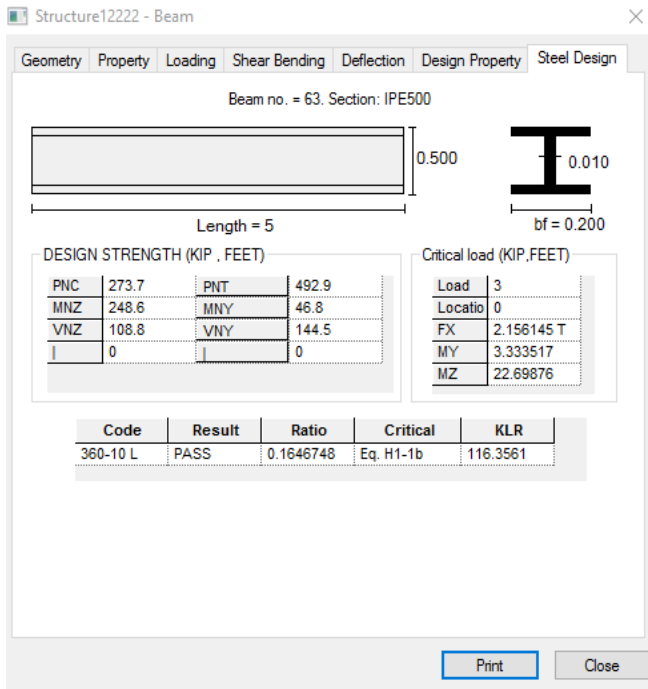


Fig.4. Steel Design of the structure.

B. Analysis of Steel Framed Building Using Robot

Dead load consideration (Robot) Properties:

Nodes X Y Z [m]

55 -5.00 -10.00 3.00

45 0.0 -10.00 3.00

Length=5.00 [m]

Bar type: AllBeams

Section: IPE 500

Material: STEEL

Additional attributes:

Gamma angle=0.0

Section properties:

IPE 500

HY=20.0, HZ=50.0 [cm]

AX=115.52 [cm²]

IX=89.00, IY=48198.50, IZ=2141.69 [cm⁴]

Material properties:

E=199948.02 (MPa) NI=0.30 G=76904.15 (MPa)

Force density (unit weight)=76.97 (kN/m³) Re=248.21 (MPa) LX=0.00 (1/°C)

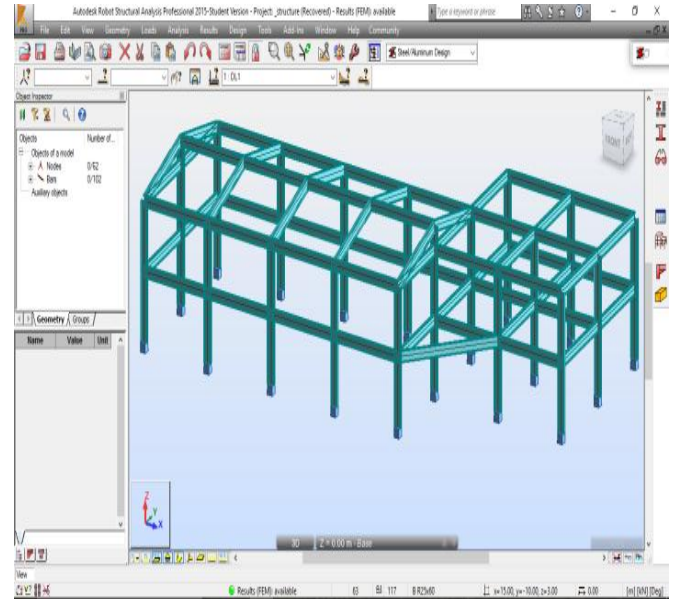


Fig.5. Steel Framed Building3D.

Code verification according to ANSI/AISC 360-10:

Section: IPE 500

Bar type: AllBeams

Material: STEEL Re=248.21 (MPa)

Section OK

Symbol Ax, Iy, Iz ...

UnitDescription Ratio:

RAT 0.14 Efficiency ratios

3 COMB1 1*1.20+2*1.60Governing load case – ULS

x = 0.00 L = 0.00 m Point Other

Lambda y 24.48 Slenderness ratio

Lambda z 116.12 Slenderness ratio

Deflections (LOCAL SYSTEM):

uyt 0.0cm Member deflection along Y axis - Total loads

uyt max 2.1 cm Allowable member deflection along Y axis - Total loads

2 LL1 Governing load case - SLS Verified

Uzt -0.0cm Member deflection along Z axis - Total loads

uzt max 2.1 cm Allowable member deflection along Z axis - Total loads

2 LL1 Governing load case - SLS Verifie

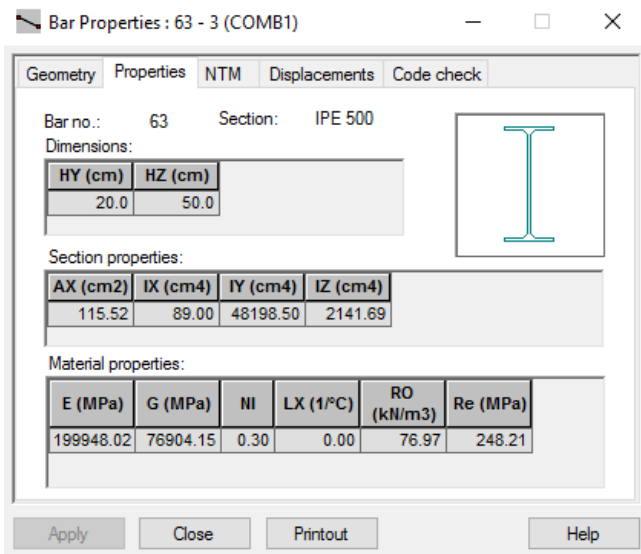


Fig.6. Steel Design of the structure.

C. Analysis of the Structure using ROBOT

Recently, Jardim-Goncalves and Grilo [2010] stated that: Software companies are now developing suites of modeling and construction-related software tools that are interoperable, but they tend only to address interoperability among themselves and not in relation to other vendors' applications. Using Robot Structural Analysis for engineer calculations of beam-to-column connection type allowed us to evaluate bolted connection resistance, calculation of weld stress and verification of column web stability. All the outcomes were verified. They are fully compliant with the design and are resistant enough to the forces and moments. Using computer software, through automation, substantially increased the pace of work both while drawing the project and analyzing the data. Also, information about compliance with the norm and fulfilling the assumed endurance conditions was obtained.

IV. CONCLUSION

In connection with the handling of structures it is noticed that steel is the simplest material to model since it is isotropic. Also it should be noticed that Robot and STAAD Pro originally are developed for steel structures. This might also be the case for the links to the applications. Therefore it is not surprising that the best results are obtained with the simple steel structure. Iterative optimization is inherent to every design process. This is especially important at the concept design stage, where the engineers explore a number of design options in terms of geometric forms, structural schemes, and individual member sizes before arriving at a working solution. The process continues through the detailed design stage, where more precise member sizes and connection specifications are detailed. In the majority of projects, the iterative design process is manual and trial-and-error based. The engineers typically decide on a design target, for example maximum deflection, or a target weight for the structure, and manually adjust the geometry and sizing parameters until the target is achieved. Manual design iterations are often ad-hoc and inefficient; it can take a long time, and engineers can

never be certain of how far the design is from the true optimum solution. Automated design optimization can help to drastically reduce design time, reduce costs, and enhance confidence in the design. In terms of Design STAAD output will be as same as our hand out manual calculations. Whereas Robot is more towards graphical user interface (GUI) side, In STAAD, it is exact error in check of inputs via STAAD EDITOR. That flexibility is missing in robot, but Robot has very strong tendency to generate detailed calculations +3D Render view + Detailed Reinforcement Arrangement.

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