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Comparison of Design of Steel Member Manually and in Staad Pro Software as per IS 800:2007

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ABSTRACT: Structural engineering is a discipline that integrates science and art to design and construct safe, economical, and aesthetically pleasing structures such as buildings, bridges, and frameworks. Structural engineers analyse forces acting on structures, perform strength calculations, and develop detailed drawings to ensure stability and safety. Their expertise extends beyond buildings and bridges to tunnels, retaining walls, storage tanks, mining structures, and specialized fields like shipbuilding and aircraft design.

KEYWORDS: Structural engineering, design, construction, stability, strength calculations, bridges, frameworks, material efficiency, safety.

I. INTRODUCTION

Structural engineering is the science and art of designing and making, with economy and elegance, buildings, bridges, frameworks and other similar structures so that they can safely resist the forces to which they may be subjected. Structural engineers carry out strength calculations and prepare drawings of structures to ensure they are strong enough to avoid collapse when loaded, the most common structures dealt with are buildings and bridges, but tunnels, walls to hold back earth embankments, large tanks and silos as well as mining structures, also form part of a structural engineer's work. Specialist areas include oil drilling platforms and associated infrastructure, shipbuilding and aircraft design. Some structural engineers work in the design of structures (carrying out the strength calculations and supervising drawings), others specialize in the building of structures and some work in research. Structural engineers commonly work with architects, builders, mechanical, electrical and chemical engineers to ensure that all parts of the structure are safe and capable of fulfilling their intended function. They also make sure structures use appropriate materials efficiently.

A building code (also building control or building regulations) is a set of rules that specify the standards for constructed objects such as buildings and non-building structures. Buildings must conform to the code to obtain planning permission, usually from a local council. The main purpose of building codes is to protect public health, safety and general welfare as they relate to the construction and occupancy of buildings and structures. The building code becomes law of a particular jurisdiction when formally enacted by the appropriate governmental or private authority. Building codes are generally intended to be applied by architects, engineers, interior designers, constructors and regulators but are also used for various purposes by safety inspectors, environmental scientists, real estate developers, subcontractors, manufacturers of building products and materials, insurance companies, facility managers, tenants, and others. Codes regulate the design and construction of structures were adopted into law.

II. HISTORY

In earlier periods say in sixties, engineering calculations were done by slide rules. Then in seventies, came the era of calculators, which replaced slide rules completely. The calculators are very much in vogue these days but to aid the structural engineer have come computers which are high-speed calculators and much more. When similar members (say, slabs, beams columns, footings) are to be designed, relevant computer programs can be used to get more accurate methods which were earlier difficult and time-consuming to use manually. For example, frames under horizontal loads

were analysed by portal or cantilever methods manually. These gave only approximate results and we had to be satisfied with them. But now, computer can be used effectively to get accurate results.

Computers have recently been brought in to aid structural designers. These machines are as effective as the available software (i.e., computer programs). Programs are available for design of slabs, simply supported and continuous beams. Columns under biaxial bending, isolated footings, combined footings and rafts. There are also available 2-D plane frame programs, grids, retaining walls, etc. not only all the available programs may be to the liking of a designer. The assumptions made in the development of some programs may not be acceptable to the structural designer and in one case, it was found that the column program purchased was valid only for short columns and not for long columns, although at the time of purchase, it was claimed to be valid for both short and long columns. In practice, continuous beams, frame analysis under horizontal loads are almost always solved by a computer. Sometimes, a building is divided into frames in both the principal directions. All the frames with the vertical and the horizontal loads are put in the computer and the solution is got which includes the complete design of beams at all the floor levels. Column loads are then assembled manually. Column design under biaxial bending at all levels is done by a computer program. A very powerful program STAAD Pro is also available in the market which can be used for 3-D analysis of a building as a whole. It is useful for analysis and design of multi-storied buildings. We may consider the followings methods of approach in order to tap the full capacity of STAAD Pro software.

III. ABOUT CODE AND SOFTWARE

This Indian Standard (Third Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Structural Engineering and Structural Sections Sectional Committee had been approved by the Civil Engineering Division Council.

The steel economy programmer was initiated by erstwhile Indian Standards Institution in the year 1950 with the objective of achieving economy in the use of structural steel by establishing rational, efficient and optimum standards for structural steel products and their use. IS 800: 1956 was the first in the series of Indian Standards brought Out under this programme. The standard was revised in 1962 and subsequently in 1984, incorporating certain very important changes.

Latest revision made in 2007 which is based on Limit State Method (LSM) for more economy. IS 800 is the basic Code for general construction in steel structures and is the prime document for any structural design and has influence on many other codes governing the design of other special steel structures, such as towers, bridges, silos, chimneys, etc. Realizing the necessity to update the standard to the state of the art of the Steel construction technology and economy, the current revision of the standard was undertaken. Consideration has been given to the developments taking place in the country and abroad, and necessary modifications and additions have been incorporated to make this standard more useful.

The revised standard will enhance the confidence of designers, engineers, contractors, technical institutions, professional bodies and the industry and will open a new era in safe and economic construction in steel.

In this revision the following major modifications have been affected:

- a) In view of the development and production of new varieties of medium and high tensile structural steels in the country, the scope of the standard has been modified permitting the use of any variety of structural steel provided the relevant provisions of the standard are satisfied.
- b) The standard has made reference to the Indian Standards now available for rivets, bolts and other fasteners.
- c) The standard is based on limit state method, reflecting the latest developments and the state of the art.

The revision of the standard was based on a review carried out and the proposals framed by Indian institute of Technology Madras (IIT Madras). The project was supported by Institute of Steel Development and Growth (INS DAG) Kolkata. There has been considerable contribution from INS DAG and IIT Madras, with assistance from a number of academic, research, design and contracting institutes/organizations, in the preparation of the revised standard.

IS 800:2007 is based on Limit State Method of design. The design concept is totally changed in comparison to earlier IS 800:1984 which is based on elastic method. The design methodologies for the steel structures namely, working stress design method and limit state design methods are briefly explained. The importance of limit state design method is highlighted. In the present work, the detailed study of structural component as Beam by designing using

Limit State Method and Working Stress Method has been carried out and submitted the comparative study of the same in the form of graphs. Index Terms— IS 800:1984 and IS 800:2007, Limit state method (Plastic method), Working stress method (Elastic method).

CONCEPT OF LIMIT STATES in the method of design based on limit state concepts the structure shall be designed to withstand safely all loads to act on it throughout its life, it shall also satisfy the serviceability requirements such as limitations on deflection and cracking. The acceptable limit for the safety and serviceability requirements before failure occurs is called limit state. The aim of the design is to achieve acceptable probabilities that the structure will not become unfit for the use for which it is intended, i.e., that it will not reach a limit state. All relevant limit state shall be considered in design to ensure an adequate degree of safety and serviceability. In general, the structure shall be designed on the basis of the most critical limit state and shall be checked for other limit states.

IV. SCOPE AND OBJECTIVES

In this study, an attempt is made to compare the results obtained from design of steel member by using manual calculations and STAAD Pro software.

1. Compare the results obtained from manual calculations and Staad Pro.
2. Finding any discrepancy in manual calculation.
3. Compare the parameters, boundary condition affects on final results.

V. METHODOLOGY

Using STAAD Pro for Analysis and design the Structure as a whole Steps in Design

1. A structure is planned first. Preparing data for STAAD Pro program at all levels i.e., generation of model, load intensities, support conditions, material properties etc.
2. The plan of formwork shuttering is modelled in STAAD Pro. The structure is composed by three different part, inner formwork, external formwork & supporting column frames. Formwork is provided with set of panels consist of skin plate, omega, stiffener & Walers (Beams).
3. Support conditions are considered as pin support. After modelling, cross-sectional dimensions are assigned to the columns and beams.
4. The structural framing members & Skin plate design check has been done in limit state method in STAAD and plate has been checked for limit state method. Then self-weight, live load, wind load and concrete pressure are applied on structure.
5. The values of dead load and live load are obtained from IS 875 part 1 and 2, wind load is obtained from IS 875 part 3-2015, 3rd revision and concrete pressure as per CIRIA, Report 108 and IS 14687, with respect to tributary width of span as a point load or UDL.
6. Effective load is applied on structure. Defined all design parameters with respect to all boundary conditions.
7. The structure is then checked for errors and then modelling is completed. Analyze and design of formwork shuttering is done as per the selected design codes. Once analysis is completed for different load combination design will be performed for load envelope case.
8. In manual calculations, I developed spreadsheet as per IS 800:2007 (Limit State Method). There are two types of Actual forces considered and taken from STAAD results and manual calculations.
9. After comparing those forces as per manual calculation and STAAD result, we found additional force as Axial force from STAAD result.
10. Define all boundary conditions same in both manual calculations and in STAAD and also same value of other design parameters like L_y and L_z in both manual calculation and in STAAD.
11. Then checked the structure for different criteria's like for deflection ratio, support reaction, Reactions for load calculations and maximum support reactions.

12. Checked deflection ratio as per IS14687, cl.7.5, for member of length more than 3m is $L/1000$ or 3mm, for column is $L/150$, & local deflection for members, panels are within a limit of 3mm.
13. For comparisons, select any one member from structure and check utilization ratio for it in STAAD. By using same forces check utilization ratio on same member in manual calculations.

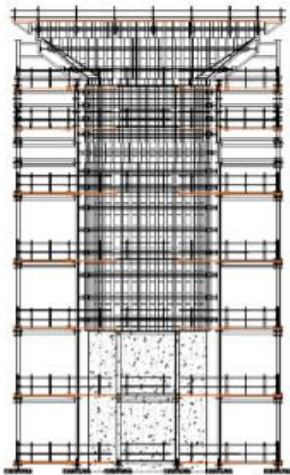
There are some variations observed in results.

VI. SAMPLE CALCULATION

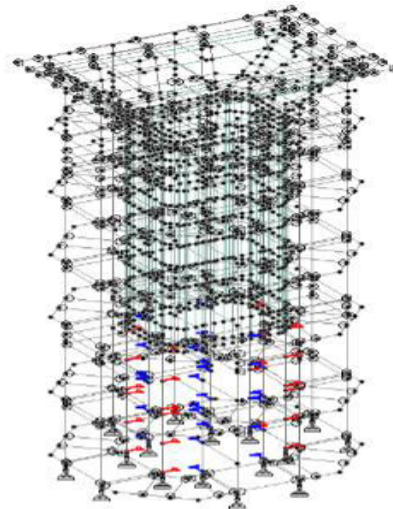
BASIC DATA

Type of Structure – Pier formwork shuttering for MAHSR

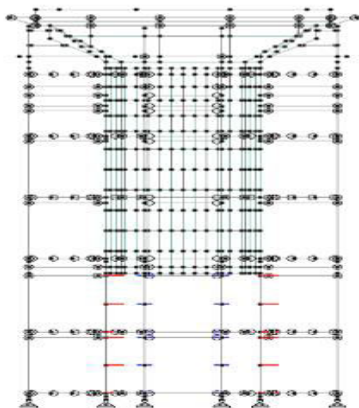
Height – 14m



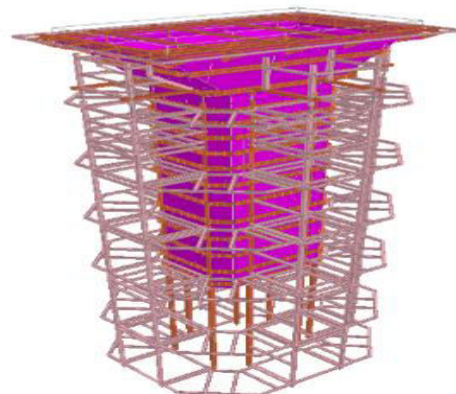
OVERVIEW OF STRUCTURE



3D VIEW OF STRUCTURE



FRONT VIEW OF STRUCTURE



3D RENDER VIEW OF STRUCTURE

Manual Calculations: Beam 1

1. Check utilization ratio for Beam no: 1250, Section: ISMC250 DD

Material

Modulus of Elasticity of steel	=	2E+05	Mpa
Yield stress (fy)	=	240	Mpa
Permissible Bending stress	=	218.18	Mpa
Yield stress/partial safety factor, fbd (fy/ γ_{mo})	=		
Partial safety factor	γ_{mo}	=	1.1
Ultimate Tensile Stress	=	410	Mpa

Geometry

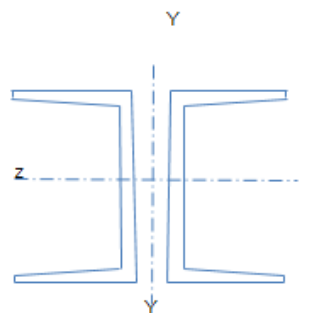
Beam Spacing	=	1 m c/c
Bending length @x axis	=	2.5 m
Lateral Unsupported length @y axis	=	0.26 m

Loading

Max. concrete pressure	=	78.3 kN/m ²	
UDL on beam	w	=	78.3 kN/m
Compressive force =	P	=	67 kN (Staad Out put, Tension force = 223 kN)
moment @minor axis	My	=	0.10 kNm (Staad Out put, BM @ Z = 64 kNm)
moment @major axis	Mz	=	95.0 kNm (Staad Out put)
Max. shear force	Fy	=	198.0 kN (Staad Out put)

Properties -

D	=	250	mm
B	=	80	mm
a	=	7734	mm ²
Tf	=	14	mm
tw	=	7.2	mm
rx	=	99.35	mm
ry	=	55.18	mm
Ixx	=	76336000.35	mm ⁴
Iyy	=	23548463.28	mm ⁴
Zzz	=	610688.00	mm ³
Zyy	=	224271.08	mm ³
Zpz	=	705664.1	mm ³
Zpy	=	369515.72	mm ³



Section classification

Limit $\epsilon=(250/f_y)^{1/2} =$	1.02	
Class 1 (plastic) limit $=9.4\epsilon$	=	9.59
Class 2 (Compact) limit $=10.5\epsilon$	=	10.7
Class 3 (Semi-Compact) limit $=15.7\epsilon$	=	16

IS 800:2007

Ref. C.L 3.7

Table no.2

Section b/tf =	5.7143	Section Category is	plastic
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Calculation for Mdz

Ref.C.L.9.3.1.2

Mz = Factored bending moment about minor axis = 0.1 kNm
Mnd=1.11Mdz (1-n) 148.3 kNm

Where,

Mdz=β_b Z_{pz} f_y/l_{mo}

Ref.C.L.8.2.1.2

β_b= 1

	β _{bz} =
plastic	1
Compact	1
Semi-comp	0.865

Limit of Md

Mdz=1.2Z_{ey}f_y/l_{ym} = 160 kN.m for simply supported

Mdz=1.5Z_{ey}f_y/l_{ym} = 200 kN.m for cantilever beam

This beam is simply supported Therefore Mdz = 159.9 kN.m

Mdz = 153.963 kN.m Then Mdz = 154 kN.m

n = N/Nd = 0.1322

Calculation for Mdy

Ref.C.L.9.3.1.2

M_y = Factored bending moment about minor axis = 0.1 kNm

M_{ndy}=1.56*M_{dy} (1-n)/(n+0.6) 149.08 kNm

M_{dy}=β_b Z_{py} f_y/l_{mo}

β_b= 1

	β _{by} =
plastic	1
Compact	1
Semi-comp	0.6

Limit of Md

M_{dy}=1.2Z_{ey}f_y/l_{ym} = 58.7 kN.m for simply supported

M_{dy}=1.5Z_{ey}f_y/l_{ym} = 73.4 kN.m for cantilever beam

This beam is simply supported Therefore M_{dy} = 58.72 kN.m

M_{dy} = 80.62 kN.m Then M_{dy} = 58.7 kN.m

n = N/Nd = 0.1322

Calculation for Nd

Ref.C.L.9.3.1.1

N=factored applied force = 223 kN

Nd = Design strength = A_g.f_y /l_{mo} = 1687 kN

Combine check

Ref.C.L.9.3.1.1

N/Nd + M_y/M_{dy} + M_z/M_{dz} =

$$\frac{223}{1687} + \frac{0.1}{58.718} + \frac{95.0}{153.96308} = 0.75 < 1 \text{Safe}$$

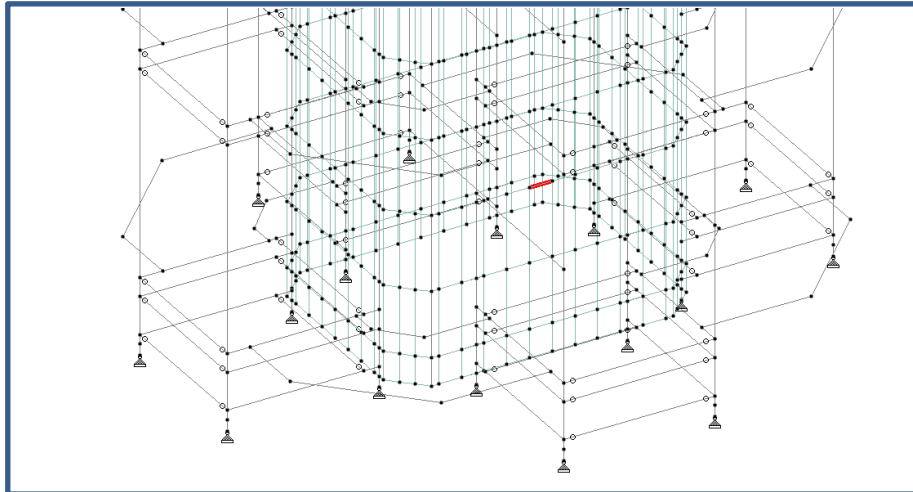
Deflection [(W L⁴) / (145 E I)]

$$\frac{78}{145} \times \frac{2500}{2E+05} \times \frac{76336000.35}{1} = 1.38 \text{ mm}$$

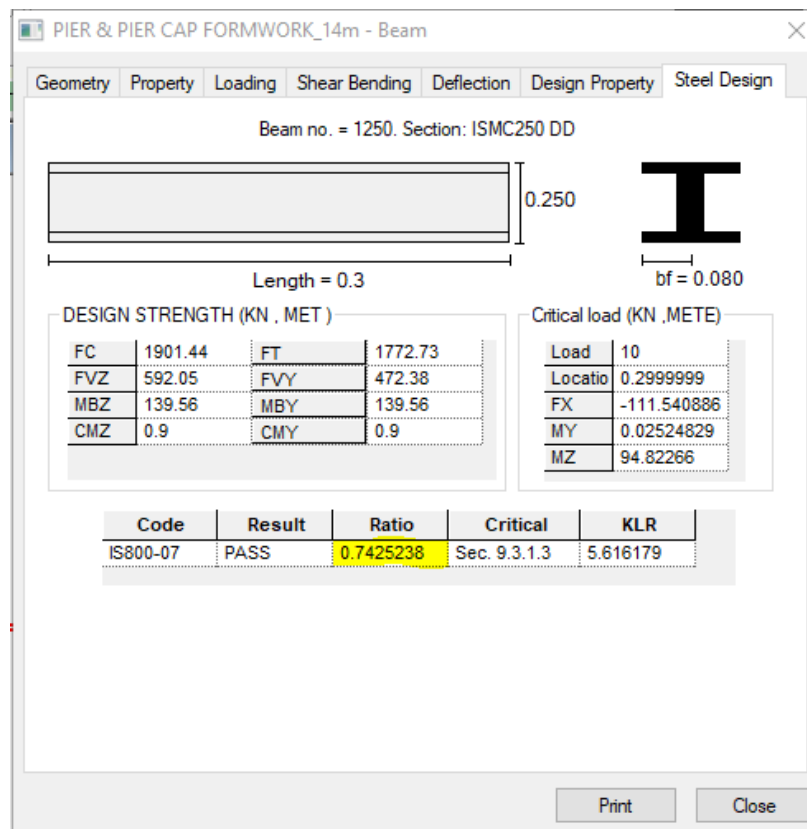
$$\text{Allowable deflection} = \text{Min} (L/1000) = 2.500 \text{ mm or } 3 \text{ mm}$$

$$\text{Therefore allowable} = 2.50 \text{ mm Safe}$$

STAAD Result for Beam no: 1250



VIEW OF MEMBER IN STRUCTURE



VII. CONCLUSION

The above checks can help to a greater extend and it makes sure that the user has modelled the structure with no mistake and further that there is no error in the input. After running the analysis also, a simple check on the result can be made using the available formulae.

- Manual analysis results are compared with the STAAD results and identified that the variation is at Approx. 1% to 3% which is acceptable while considering extra time & error in manual design calculation.
- Manual calculation has not specified bending moment reduction factor for top and bottom unsymmetrical section in horizontal axis.
- Always better to know two or more than a single software so that a counter check can be made especially for a large and mega project to avoid suspicious results and to continue his design with peace of mind.
- Software based calculation save the time.
- Software calculation minimises the manual errors, and gives more accuracy.
- If we applied same parameters, loading and boundary conditions for structure in both cases we got same results with negligible difference.
- If Parameters are changes, variations may be found in both results.
- Hence, we conclude that both results are almost same, so for better efficiency and to save time we recommend STAAD Pro.

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