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STEEL DESIGN USING WORKING STRESS METHOD AND CLAUSES OF SECTION 12 OF IS 800: 2007 – A COMPARISON

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Abstract— ***The 'Code of Practice for General Construction in Steel – IS 800' was revised in the year 2007. The previous version of the code was released in the year 1984. It took 23 years for the revision of the code. During these years, there was a huge leap in the design philosophy of steel structures. The method of design changed from the 'working stress method' to the 'limit state method'. This change was captured in the new revision that became available in the year 2007. It also captured the need for seismic design in a detailed manner that was non-existent in the previous revisions of the code. These requirements are mentioned in the section 12 of IS 800 – 2007; 'Design and Detailing for Earthquake loads'. Some of the requirements are found to have a large impact on the design of structures. The new clauses specify different and stringent requirements for bracing members, connections, etc. As a result, there is an increase in the quantity of steel consumed. The quantity consumed as a part of connections has also increased. The present study intends to look critically at the provisions mentioned in the Section 12 of IS 800 – 2007, analyse the feasibility and practicality of using these clauses in design and understand the impact that it has on the quantities vis-à-vis the working stress method of design which has been prevalent.***

Keywords— Working stress method, Limit state method, analysis, seismic, connection,

I. INTRODUCTION

Steel design as per Indian Codes underwent a paradigm shift when the IS 800 – 2007 came into force. Unlike the earlier version of the code, i.e. IS 800 – 1984 which advocated the working stress method of design, this version introduced the 'Limit State design' of Steel Structures. This change captured the outcomes of many researches that have happened all over the world in the past 20 years. Many countries have advanced in the study of steel structures. Their codes have also developed over the years and this has helped in improving the usage of steel in these countries. The need for a revised steel design code in India was highly felt. In line with other codes, the limit state method of design is introduced; however, the working stress design is retained as an alternative in the current version of the code.

The revised code brought about many changes and new requirements for the design of steel structures. It also captured the need for seismic design in a detailed manner that was non-existent in the previous revisions of the code. These requirements are mentioned in the Section 12 of IS 800 – 2007; 'Design and Detailing for Earthquake loads'. Some of the requirements are found to have a large impact on the design of structures. As a result, the quantity of steel consumed, becomes quite high. Though there are some papers on the theory and comparison of steel design based on many codes [(17)], there are few papers which talk about the quantitative impact that these provisions have on the quantity of steel and pricing of structures.

Objective

A study was conducted to look at the provisions mentioned in the Section 12 of IS 800 – 2007 and compare the effect of these requirements with the working stress design. In doing so, the specific requirements for connections were reviewed in greater detail. A sample commercial building was considered for analysis. Two different heights of the building viz. 46m and 81 m were considered. Each of these buildings were considered to be in three different seismic zones; viz. zone II, zone III and zone V. Loads were applied on the model based on the prevalent IS codes. The structure was analysed. Design of the structure was carried out as per both working stress design and limit state design incorporating section 12 requirements. Important connections of the structure eg. base plates, column splices, beam to column joints and beam to beam joints were identified. These important connections were designed based on the working stress design requirements and as per requirements of Section 12. The total quantity of steel consumed in connections was worked out for all cases. The objective of the study was to compare the results of design as per working stress design requirements and Section 12 requirements. The connection steel quantity for the major connections with respect to the total tonnage of steel in the building was also worked out. The net increase in quantity for different seismic zones for different heights of the building were worked out.

II. ANALYSIS MODEL AND DESIGN

A commercial building was considered for analysis. Two different heights of the building were considered.
First: The structure is 50m long and 30m wide. It is a G+8 storeyed structure with a height of 46m.
Second: The structure is 50m long and 30m wide. It is a G+15 storeyed structure with a height of 81m.
Both these buildings were analysed for three seismic zones: viz. zone II, zone III and zone V.

The building is a steel framed structure with secondary steel beams and composite floor. The frame is moment-connected along the width. There are brace frames provided in the other direction for lateral stability. The structure was modelled above the pedestal level. The base of the structure was considered as pinned.

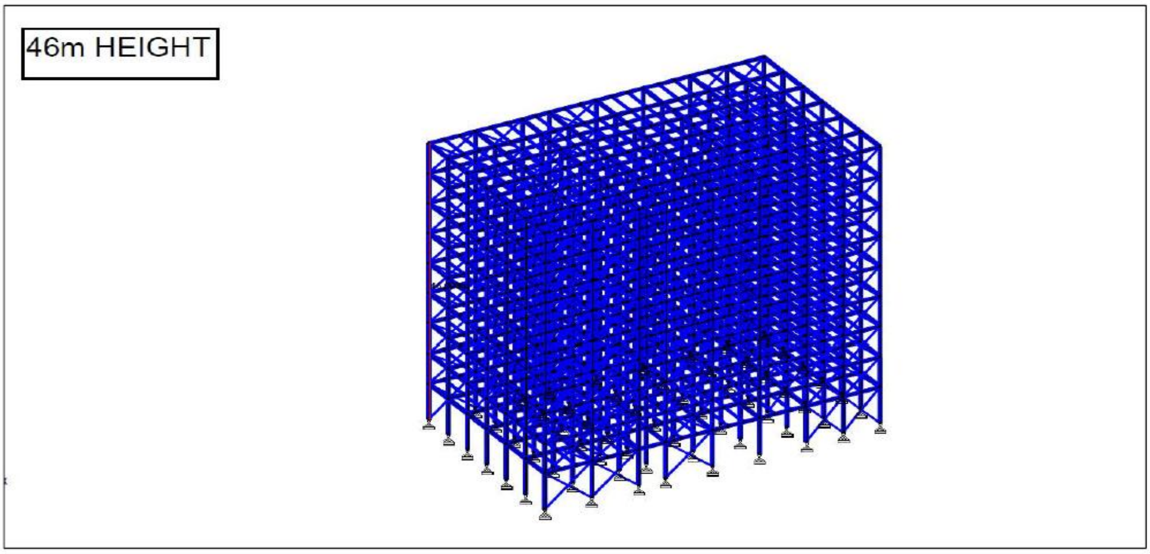

Figure 1 *Snapshot of the analysis model created*

Loading Parameters

Table I Superimposed Dead Loads

Item no.	Description	Loads used	
		UDL (kN/m2)	Concentrated (kN)
1.	Floor finishes	1.25	-
2.	Water proofing for terrace	2.0	-
3.	Sunken area of toilets	6.0	-
4.	HVAC Equipment loads on roof	1.0	-
5.	Service loads on all floors	1.0	-
6.	False ceiling loads	1.0	-
7.	Partition loads	2.0	-
8.	Glazing load	0.375	-

Table II Live loads

Item no.	Description	Loads used	
		UDL (kN/m2)	Concentrated (kN)
1.	Stairs & Corridor	4.0	4.5
2.	Toilets	2.0	-
3.	Office areas	3.0	-
4.	Storage	5.0	4.5
5.	Roof live load (accessible)	1.5	Roof slab: 3.75kN uniformly distributed over any span of 1m width; Beam/truss wall : 9kN uniformly distributed over the span

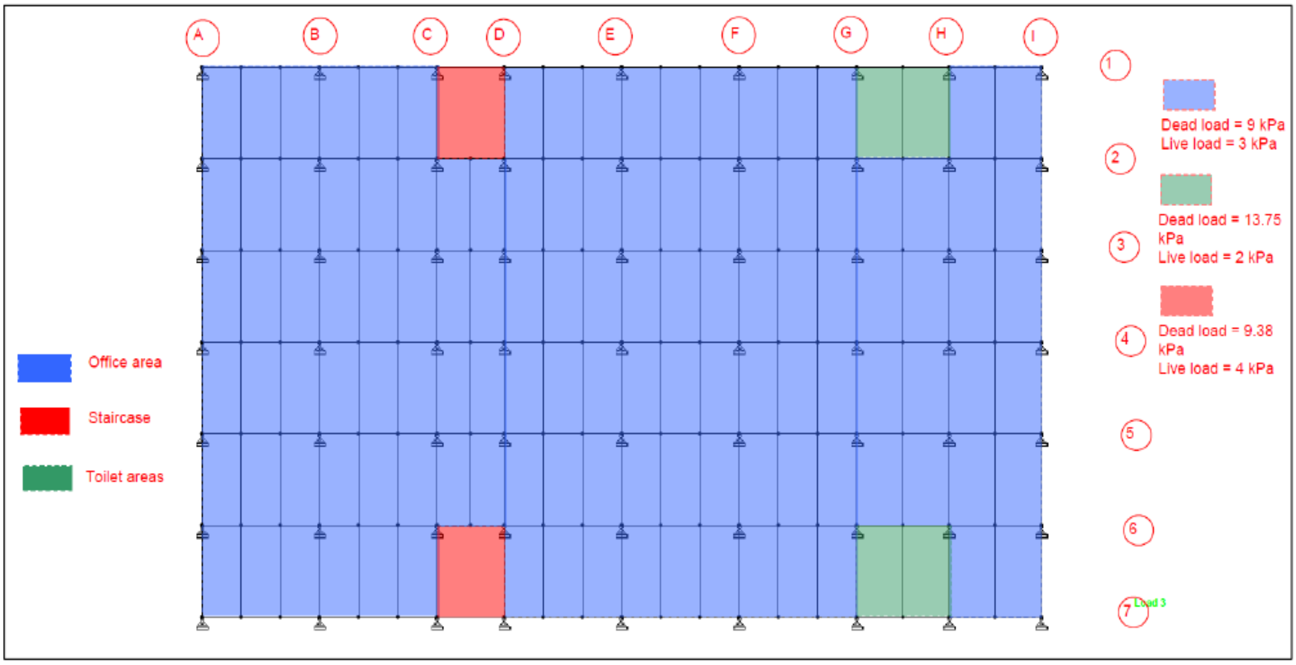

Figure 2 Plan indicating loading diagram

Table III Wind loads

Basic wind speed	39 m/s
Risk coefficient (k1)	1.00 (General buildings)
Terrain category	2
Structure category	Class C for structures and/or their components such as cladding, glazing, roofing, etc. having maximum dimension (greatest horizontal or vertical dimension) greater than 50 m.
Topography factor(k3)	1.0

Table IV Wind load coefficient k_2

Height (m)	10	15	20	30	50	81
K_2	0.93	0.97	1.00	1.04	1.1	1.22

Earthquake Load

The loading due to earthquake is assessed based on the provisions of IS: 1893-2002 (Part1).
Seismic analysis shall be carried out for three different seismic zones:
Seismic Zone = II, III & V
Seismic Zone Factor (Z) = 0.1, 0.16 & 0.36
Importance Factor (I) = 1.0
Response Reduction Factor (R) = 4.0 & 4.5 (FOR ZONE V)
(Response reduction factor, depending on the seismic damage performance of the structure characterized by ductile or brittle deformation.
I/R shall not be greater than 1.0
S_a/g - Average response acceleration coefficient based on appropriate natural periods and damping of the structure. The value of damping is chosen as 2% of the critical.
For Steel structure, $T = 0.085h^{0.75}$ where h = height of the building
Design Horizontal Seismic Coefficient, $A_h = (Z/2) \times (S_a/g) \times (I/R)$

(for any structure with T < 0.1s, $A_h \geq Z/2$, whatever be the value of I/R)
Design Seismic Base shear, $V_b = A_h \times W$
where 'W' is the seismic weight of the building

Cases of analysis

Six cases of analyses were considered for analysis and design
Case 1: Building height – 46m – Zone II
Case 2: Building height – 46m – Zone III
Case 3: Building height – 46m – Zone V
Case 4: Building height – 81m – Zone II
Case 5: Building height – 81m – Zone III
Case 6: Building height – 81m – Zone V

The load combinations as per IS 875 – part V were considered. Additional combinations as per requirements of Section 12 were considered for the LSD cases. The load combinations considered are:
1.5DL+1.5LL
1.2DL+1.2LL+/-1.2WL/EQ
1.5DL+/-1.5WL/EQ
0.9DL+/-1.5WL/EQ
1.2DL+0.5LL+/-2.5EQ
0.9DL+/-2.5EQ

Connection design

Major connections of the building are designed using both the working stress method and Limit state method incorporating section 12 requirements. The connections that have been designed are:
1) Base plate
2) Bracing connection
3) Column splice
4) Beam to beam shear connections – with fin plate
5) Beam to column – moment connection

III. RESULTS AND DISCUSSION

The maximum utilization ratios for members is limited to 0.9. However, as per requirements of section 12, the utilization ratios for columns and bracing members for the Limit state design case is restricted to 0.8.
The connections for WSD were designed for 1.2 times the forces obtained from the analysis results. The connections for LSD were designed based on the requirements of Section 12 of IS 800 – 2007.

Case	Quantity as per WSD				Quantity as per LSD				Variation	Variation %
	From model	Connection	Conn. %	Total	From model	Connection	Conn. %	Total		
	(MT)	(MT)		(MT)	(MT)	(MT)		(MT)		
1	1261.7	80.96	6.42	1342.66	1314.2	127.39	9.69	1441.59	98.93	7.37
2	1261.7	80.96	6.42	1342.66	1314.2	130.02	9.89	1444.22	101.56	7.56
3	1276.7	111.27	8.72	1387.97	1365.1	145.95	10.69	1511.05	123.08	8.87
4	2725.7	283.95	10.42	3009.65	2725.7	338	12.40	3063.7	54.05	1.80
5	2725.7	317.31	11.64	3043.01	2752.2	361.87	13.15	3114.07	71.06	2.34
6	2725.7	381.71	14.00	3107.41	3086.2	414.83	13.44	3501.03	393.62	12.67

Figure 3 Summary of quantities

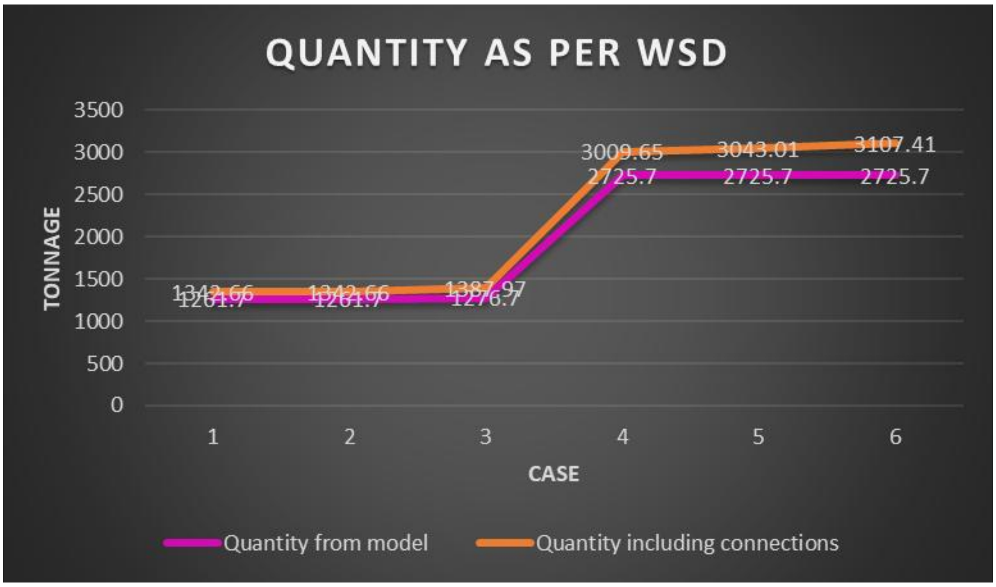

Figure 4 Graph indicating the main steel quantity and quantity including connections for all cases (as per WSD)

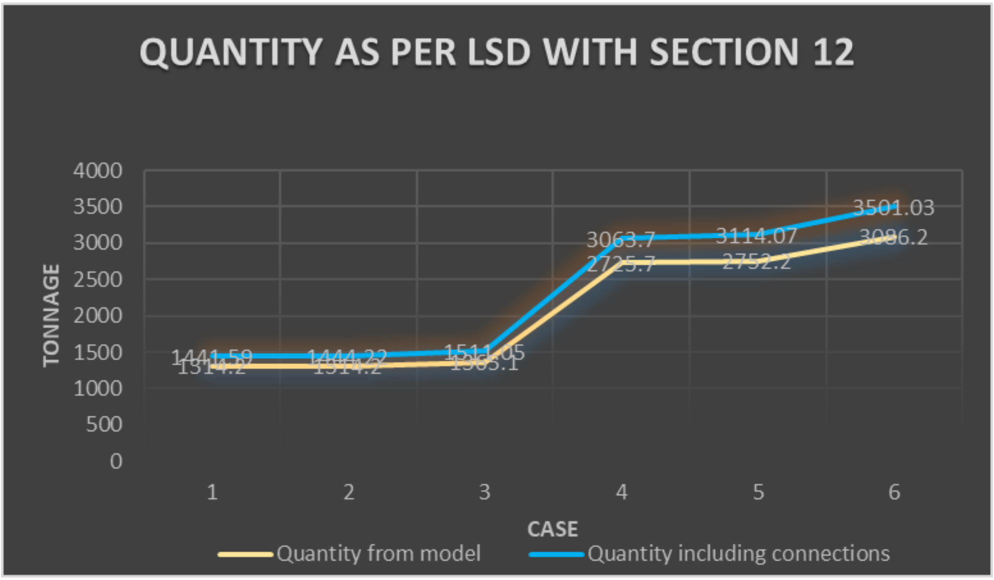

Figure 5 Graph indicating the main steel quantity and quantity including connections for all cases (as per LSD)

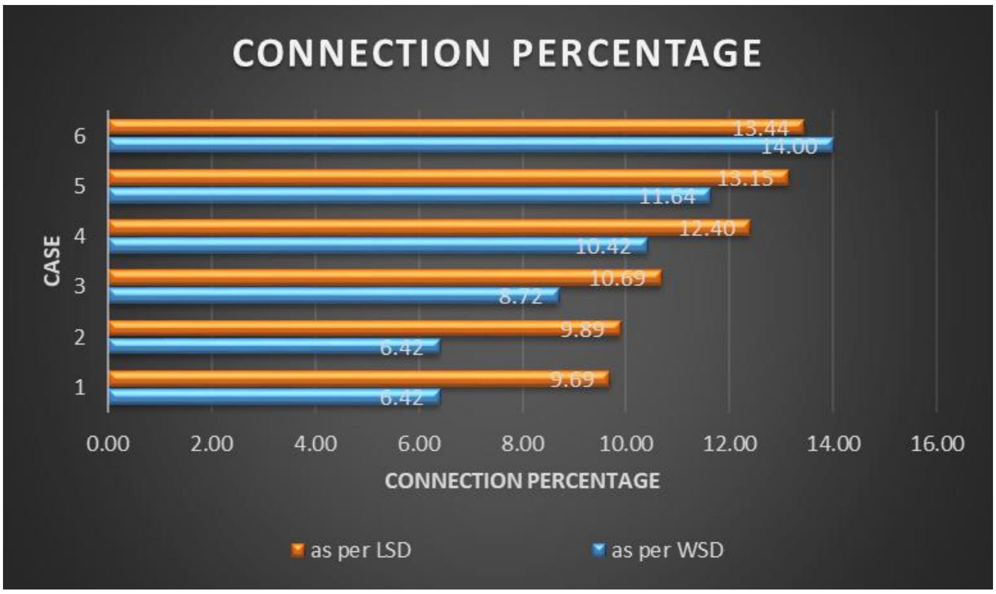

Figure 6 Percentage of connections for each case as per WSD and LSD

The chart indicates the percentage of connections for the working stress design (WSD) and the limit state design (LSD) for all the six cases considered here. The percentage of connections are higher in LSD than WSD except for the zone 5 in the higher building.

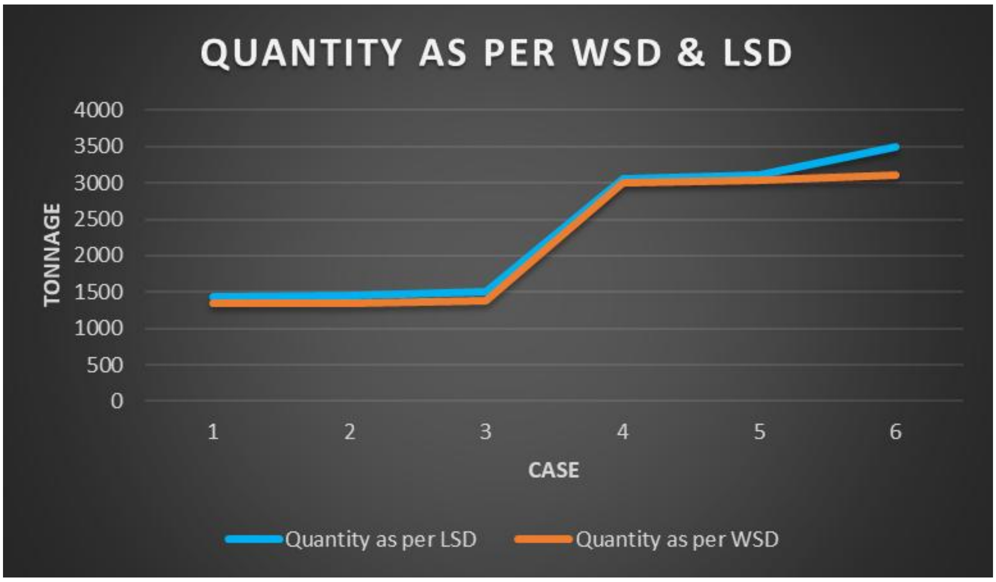

Figure 7 Graph indicating variation in total steel quantity as per WSD and LSD

The graph shows that the increase in steel for the shorter structure has a uniform variation. For the higher structure, though the variation for zones II and III are fairly uniform, there is a steep increase in zone V.

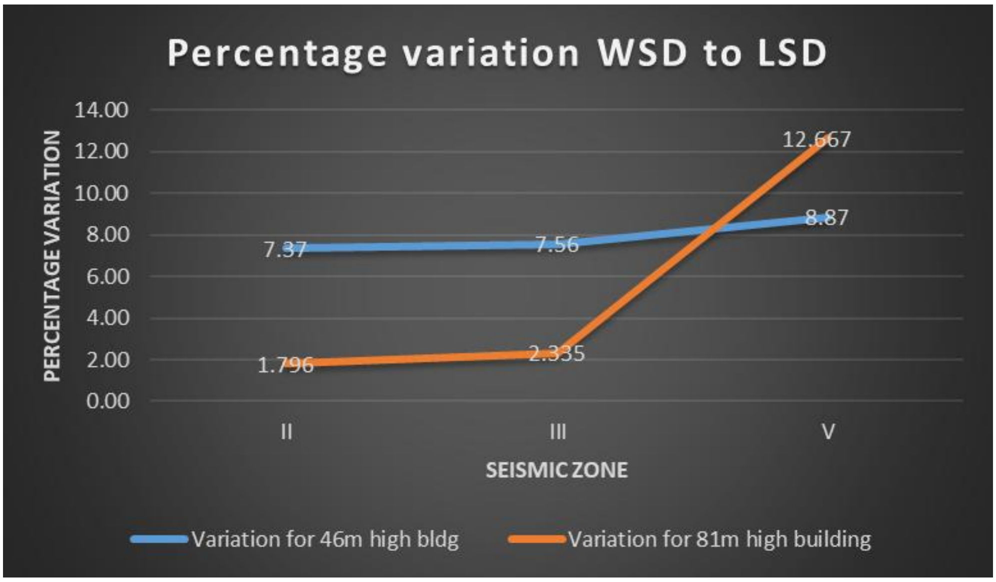

Figure 8 Percentage variation in total tonnage for 46m and 81m high building for Zones II, III & V

The graph indicates the percentage variation in steel quantities for all the three zones for the 46m and 81m high structures. It may be noted that the increase in steel percentage for 46m high building between WSD and LSD varies from 7.37% to 8.87%. The increase in steel percentage for 81m high building between WSD and LSD varies from 1.79% to 12.69%. The percentage increase between zones II and III is marginal. However, for zone V, there is a steep increase in the difference.

IV. CONCLUSION

The incorporation of section 12 of IS 800-2007 results in an overall increase in the quantity of steel consumed. It can be seen that for the shorter structure, there is a variation in steel quantities as per WSD and LSD are in the range of 7-8% for all three zones viz. zones II, III and V. However, for the higher structure, the variation in steel quantities for zones II and III are marginal. The quantity variation drastically increases for zone V.

The maximum variation noted here is 12%. This is a huge increase as compared to the designs carried out as per the earlier codes. Some of the major implications of these are:

1) The budgets for new buildings need to be revised accordingly, considering the new requirements stipulated in the code.
2) Connections for heavier members become bulky and there are practical difficulties in accommodating elements in a connection within the available levels and geometries.
3) Considering the high cost of construction, the preference of steel as a construction material over concrete will further reduce.

Limit state method of design has become the preferred method for design world over. The Euro codes and American codes for steel design now adhere to this method of design. However, the clauses of section 12 are found to be very stringent as compared to the international codes. A more detailed analysis of the requirements may be needed to rationalize the results obtained.

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