Project Part- B Report
On

PARAMETRIC STUDY OF LATERALLY SUPPORTED AND UNSUPPORTED STEEL BEAM

Submitted in partial fulfillment of the requirements

For the degree of

BACHELOR OF ENGINEERING

In

CIVIL ENGINEERING

By

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CERTIFICATE

This is to be certify that **Mr. Khan Mohd Ismail (13CES22), Mr. Khan Kamruddin Saleem (14CES17), Mr. Khan Saeed Jabirullah (14CES23)** has satisfactorily completed and delivered a project a seminar report entitled **"Parametric Study of Laterally Supported and Unsupported Steel Beam"** in partial fulfillment for the completion of the B.E. in civil engineering course conducted by the university of Mumbai in anjuman-I-Islam kalsekar technical campus, New Panvel, Navi-Mumbai, during the academic year 2017-18.

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1 Approval Sheet

This B. E. Project Part-B entitled “PARAMETRIC STDUY OF LATERALLY SUPPORTED AND UNSUPPORTED STEEL BEAM” by Mr. Khan Mohd Ismail (13CES22), Mr. Khan Kamruddin Saleem (14CES17), Mr. Khan Saeed Jabirullah (14CES23) is approved for the ***Bachelor of Engineering in Civil Engineering.***

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2 Declaration

I, Mr./Ms. Khan Mohd Ismail, Khan Kamruddin, Khan Saeed Civil engineering student of Anjuman Islam Kalsekar Technical Campus, hereby declare that I have completed the project titled “Parametric Study of Laterally Supported and Unsupported Beam” during the academic year 2013-2017. I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Abstract

Steel as a building material has been used extensively in various type of structure some of the examples of civil engineering works in steel are high-rise building skeletons, industrial buildings, transmission tower, railway bridges, overhead tanks, chimneys, bunkers and silos.

Since these sections often show that the web resists shear forces, while the flanges resist most of the bending moments experienced by the beam. Mainly while considering the designing of both beams, the design procedure is different and it is observed that the selection of the beams depends upon the intensity of the loads, length of the beam and economy. As per structure requirement, as an engineer we have to select any one of these two that is either laterally supported or laterally unsupported beam. So our aim is narrowed towards the comparative study of the behavior of these two beams on various combination of the loading and accordingly the cost of the beam on stability criterion as per IS code 800:2007. Provision of IS 800:2007 for strength determination of laterally restrained as well as unrestrained beam, which are symmetrical about at least one axis are expressed. We are trying to predict the size of the section on the basis of the amount of loading and for that purpose we will generate an equation which can help designer and engineer to select the suitable beam.

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List Of Parameters

Sr. no.	Designation	Name of Parameter
1.	I	Moment of Interia of a Member
2.	fy	Yield Strenth of Steel
3.	γ_{mo}	Partial Safety factor for material Strength
4.	Zp	Plastic Section Modulus
5.	d	Total depth of section
6.	tw	Thickness of web
7.	b	Overall width of Section
8.	t_f	Thickness of flange
9.	Vd	Design Shear Strength
10.	Vu	Factored Shear Force
11.	h	Height of I-Section
12.	Md	Design bending strength under high shear
13.	δ	Deflection of beam
14.	KL	Young’s Modulus of steel
15.	fcd	Effective Length of a Member
16.	b_1	Design Compressive stress
17.	n_1	Width of stiff bearing on flange
18.	fc	Width of dispersion
19.	fw	Buckling stress
20.	fyw	Resisting Force
21.	L_{LT}	Yield Stress of web
22.	XLT	Effective length of beam
23.	Md	Stress reduction factor bending
24.	fcrb	Bending strength
25.	Φ_{LT}	Extreme fibre bending compressive stress
26.	λ_{LT}	Imperfection parameter
27.	L	Non-dimensional Effective slenderness ratio
		Centre to Centre length of supporting Member

Chapter 1

Introduction

1.1. General

Steel because of its different preferences has been credited as a basic configuration material. High quality/weight proportion makes steel an exceptionally appealing basic material for elevated structures, long-span bridges, structures situated on delicate ground, and structures situated in high seismic zones where strengths following up on the structure because of a tremor are as a rule corresponding to the weight of the structure. Legitimately outlined steel structures can have high ductility, which is an imperative trademark for opposing stun stacking, for example, impacts or earthquake.

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, ease 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.

A **beam** is a structural element that primarily resists loads applied laterally to the beam's axis. Its mode of deflection is primarily by bending. The loads applied to the beam result in reaction forces at the beam's support points. The total effect of all the forces acting on the beam is to produce shear forces and bending moments within the beam, that in turn induce internal stresses, strains and deflections of the beam. Beams are characterized by their manner of support, profile (shape of cross-section), length, and their material.

Beams are traditionally descriptions of building or civil engineering structural elements, but any structures such as automotive automobile frames, aircraft components, machine frames, and other mechanical or structural systems contain beam structures that are designed to carry lateral loads are analyzed in a similar fashion.

1.2 Classification based on supports

In engineering, beams are of several types:

1. Simply supported - a beam supported on the ends which are free to rotate and have no moment resistance.

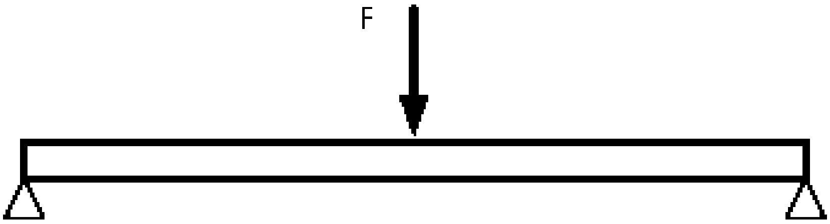

Fig. 1.1 Simply Supported Beam

2. Fixed - a beam supported on both ends and restrained from rotation.

Fig. 1.2 Fixed Beam

3. Over hanging - a simple beam extending beyond its support on one end.

Fig. 1.3 Over Hanging Beam

4. Double overhanging - a simple beam with both ends extending beyond its supports on both ends.

Fig. 1.4 Double Over Hanging Beam

5. Continuous - a beam extending over more than two supports.

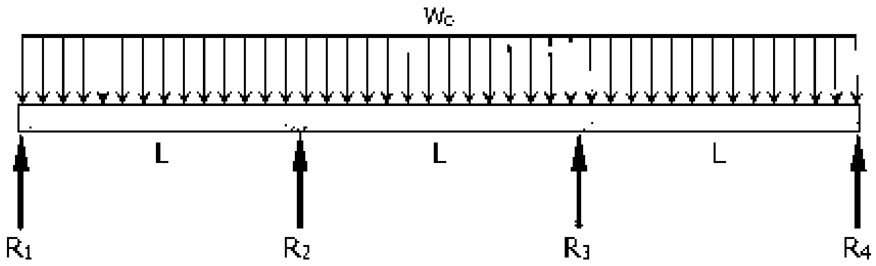

Fig. 1.5 Continuous Beam

6. Cantilever - a projecting beam fixed only at one end.

Fig. 1.6 Cantilever Beam

7. Trussed - a beam strengthened by adding a cable or rod to form a truss.

Fig. 1.7 Trussed Beam

An I-beam is only the most efficient shape in one direction of bending: up and down looking at the profile as an I. If the beam is bent side to side, it functions as an H where it is less efficient. The most efficient shape for both directions in 2D is a box (a square shell) however the most efficient shape for bending in any direction is a cylindrical shell or tube. But, for unidirectional bending, the I or wide flange beam is superior.

Efficiency means that for the same cross sectional area (volume of beam per length) subjected to the same loading conditions, the beam deflects less.

Other shapes, like L (angles), C (channels) or tubes, are also used in construction when there are special requirements.

When the beam is adequately supported against lateral buckling, the beam failure occurs by yielding of the material at the point of maximum moment. The beam is thus capable of reaching its plastic moment capacity under the5 applied loads. Thus the design strength is governed by yield stress and the beam is classified as laterally supported beam.

Beams have much greater strength and stiffness while bending about the major axis. Unless they are braced against lateral deflection and twisting, they are vulnerable to failure by lateral torsional buckling prior to the attainment of their full in plane plastic moment capacity. Such beams are classified as laterally supported beam.

1.3 Beams which fail by flexural yielding:

1.3.1: Those Which Are Laterally Supported:

The design bending strength of beams, adequately supported against buckling (laterally supported beams) is governed by yielding. The bending strength of a laterally braced compact section is the plastic moment Mp. If the shape has a large shape factor (ratio of plastic moment to the moment corresponding to the onset of yielding at the extreme fiber), significant inelastic deformation may occur at service load, if the section is permitted to reach Mp at factored load. The limit of 1.5My at factored load will control the amount of inelastic deformation for sections with shape factors greater than 1.5. This provision is not intended to limit the plastic moment of a hybrid section with a web yield stress lower than the flange yield stress. Yielding in the web does not result in significant inelastic deformations.

1.3.2: Those Which Are Laterally Shift:

Lateral-tensional buckling cannot occur, if the moment of inertia about the bending axis is equal to or less than the moment of inertia out of plane. Thus, for shapes bent about the minor axis and shapes with Iz = Iy such as square or circular Design of Steel Structures Prof. S.R.Satish Kumar and Prof. A.R.Santha Kumar Indian Institute of Technology Madras shapes, the limit state of lateral-torsional buckling is not applicable and yielding controls provided the section is compact.

1.4. Laterally Supported Beam:

When the lateral support to the compression flange is adequate, the lateral buckling of the beam is prevented and the section flexural strength of the beam can be developed. The strength of I-sections depends upon the width to thickness ratio of the compression flange. When the width to thickness ratio is sufficiently small, the beam can be fully plastified and reach the plastic moment, such section are classified as compact sections. However provided the section can also sustain the moment during the additional plastic hinge rotation till the failure mechanism is formed. Such sections are referred to as plastic sections. When the compression flange width to thickness ratio is larger, the compression flange may buckle locally before the complete plastification of the section occurs and the plastic moment is reached. Such sections are referred to as non-compact sections. When the width to thickness ratio of the compression flange is sufficiently large, local buckling of compression flange may occur even before extreme fiber yields. Such sections are referred to as slender sections.

The section classified as slender cannot attain the first yield moment, because of a premature local buckling of the web or flange. The next curve represents the beam classified as 'semi-compact' in which, extreme fibre stress in the beam attains yield stress but the beam may fail by local buckling before further plastic redistribution of stress can take place towards the neutral axis of the beam. The factored design moment is calculated as per Section 8.2 of the IS code.

The curve shown as 'compact beam' in which the entire section, both compression and tension portion of the beam, attains yield stress. Because of this plastic redistribution of stress, the member o attains its plastic moment capacity (Mp) but fails by local buckling before developing plastic mechanism by sufficient plastic hinge Design of Steel Structures Prof. S.R.Satish Kumar and Prof. A.R.Santha Kumar Indian Institute of Technology Madras rotation. The moment capacity of such a section can be calculated by provisions given in Section 8.2.1.2. This provision is for the moment capacity with low shear load.

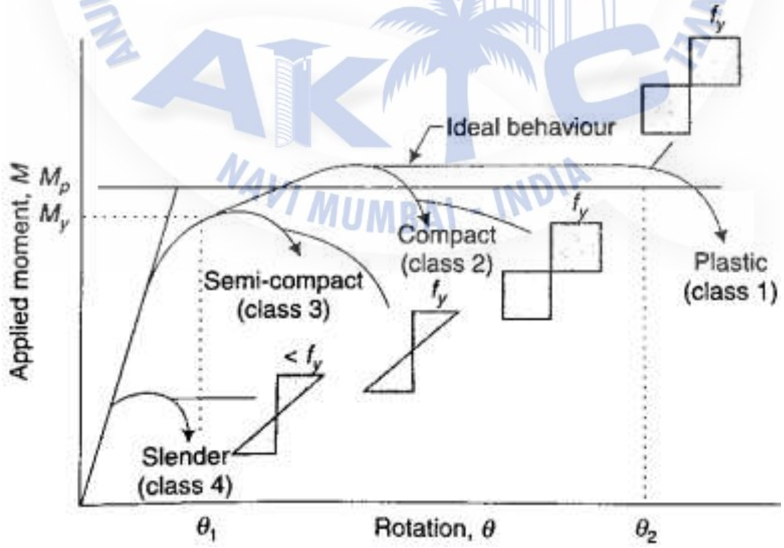

Fig. 1.8 Moment-Rotation Behaviour Of The Four Classes Of Cross Section

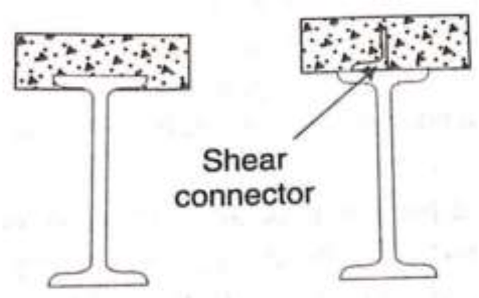

Fig. 1.9 Beam with lateral support

1.5 Laterally unsupported beams

Under increasing transverse loads, a beam should attain its full plastic moment capacity. This type of behavior in a laterally supported beam has been covered in Design of Steel Structures Prof. S.R.Satish Kumar and Prof. A.R.Santha Kumar Indian Institute of Technology Madras. Two important assumptions have been made therein to achieve the ideal beam behavior.

- The compression flange of the beam is restrained from moving laterally
- Any form of local buckling is prevented

A beam experiencing bending about major axis and its compression flange not restrained against buckling may not attain its material capacity. If the laterally unrestrained length of the compression flange of the beam is relatively long then a phenomenon known as lateral buckling or lateral torsional buckling of the beam may take place and the beam would fail well before it can attain its full moment capacity. This phenomenon has close similarity with the Euler buckling of columns triggering collapse before attaining its squash load (full compressive yield load).

If a point load is acting on the beam, then it will exhibit laterally torsion buckling and therefore such a beam Will be called laterally unsupported beam.

1.5.1.Modes Of Failure:

- Bending Failure.:

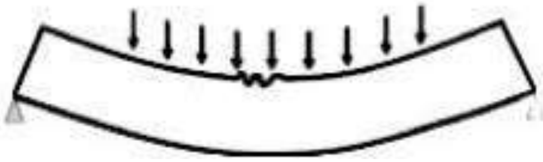

Fig. 1.10 Bending Failure

- Lateral Torsional Buckling.

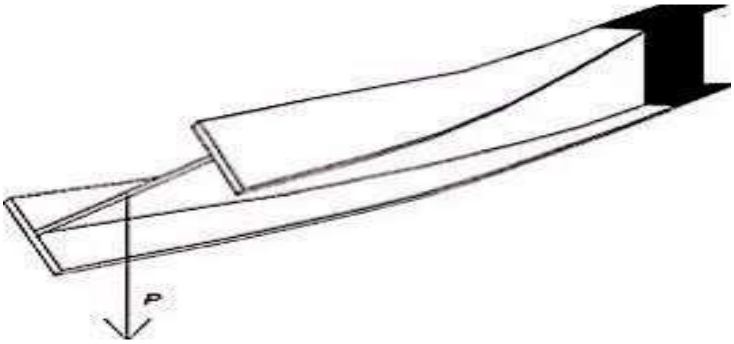

Fig. 1.11 Lateral torsional buckling

- Shear Failure.

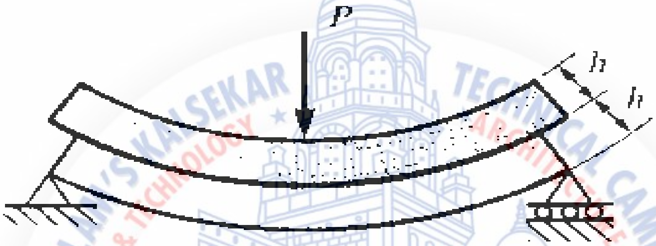

Fig. 1.12 Shear failure

- Bearing Failure(Web Crippling)

Fig. 1.13 Web crippling

1.6 MOTIVATION OF THE PRESENT STUDY

Steel design codes are consistently developing through the years to meet the needed execution of the structural components. The most recent version of Indian Code of practice for general steel development, IS 800-2007 is in light of the Limit State System. The design method has experienced a radical change in examination to the prior design code IS 800-1984, which was in view of the Elastic

Method of design. The same strives for the American Code of Specification for Structural Steel Structures and the British Standards also. The most recent form of the previous is AISC 360-2010 and that of the last being BS 5950-2000. The design in light of Limit State Method includes various complex comparisons and parameters. Henceforth flipping the pages of the design manual to turn upward a design quality parameter or a segment size for a given burden is time intensive as well as bulky for the designer in which case a spread sheet design tool for safety check and design considerations prove helpful for rapid analysis of different sections of the structure.

Chapter 2

Literature Review

In order to execute our work in this project, we needed to study the behaviour of the beam in various circumstances, therefore we studied number of literatures and some of the important literature's are listed below.

In this paper author **Yoshida, H.et al(1984)**distinguished the lateral torsional buckling load and the ultimate load carrying capacity .The horizontal deflection, eccentricity of loading and the types of residual stress distributions, have been examined and further the relation between the ultimate strength and the buckling strength were compared, 5 models of I-beams, simply supported at both ends against lateral displacement and twist were used. In this paper author said the design curve of ultimate strength on the plane should be proposed according to loading condition

The author **John, J. Zahn et al (1985)** studied that when a long beams were used with ends not restrained then the beam became potentially unstable so the designer must provide bracing internally and end must be restrained at critical section.

Mario, M.et al (1986) interpreted for a simply supported beam under pure bending, the approximate percentage increase in the buckling load when initial bending curvature is taken into account.

The critical lateral buckling of slander doubly symmetric beams with openings in web can be calculated by numerical method based on the energy approach as said by author**Thevendran, V. et al(1991)**and comparison of the both value obtained numerically and experimentally were near about same, In some conditions they kept wide openings in the web.

Yong Lin Pi et al (1992) analyzed two apparently different but closely related methods were used to study beam in lateral buckling problems. In the former, the nonlinear differential equilibrium equations of bending and torsion were established. These may be solved in closed form for a few special loading and restraint conditions and more generally by approximate numerical methods such as finite integrals (Brown and Trahair 1968), series solution, finite differences, numerical integration, and finite element methods (Zienkiewicz and Taylor 1989). For the latter method, an energy equation was established that represents the equality between the additional strain energy stored during lateral buckling and the additional work done by the applied forces. Approximations for the buckling loads were obtained by substituting approximate buckled.

The Authors D.K .Ghosh,V .kalyanaraman (1993) Stated thatDetails of a knowledge-based expert system for the design of steel structural elements (EXSEL) is presented. EXSEL forms a part of an overall system under development for the engineering of steel structures. The characteristics of the design problem are discussed first. The method EXSEL uses to address the characteristics of design problem are presented subsequently. The code require-ments, expert knowledge, basic strength of materials knowledge, and the handbook information used in the steel structural element design are represented appropri-ately using production rules, C functions, and a relational data base. An inference mechanism--with a backward-chaining algorithm, knowledge-based backtracking, and external C function access--is used to implement the system.

The Authors Yushshi Fukumoto (1993) Stated that Nominally identical 25 rolled bewms for each group of three different lenghts are tested carefully under aconcentrated load applied vertically at the midspan of compressive flange of span center .The variation of geometrical and material imperfections are measured and the influences of various parameters on the scattered test point s of the lateral buckling are reveiwed .the main parameter which highly influences the variation of ultimate strength is the variable value of actual plastic moment .The obtained test results are also compared with existing test data and design formulas .The coefficients of variation of strength increases with beam length and these value are considerably low as compared with the past scattered data.Finally a design formula is proposed to ensure empirically the lower bound for the scattered test values.

The elastic critical moments for built-in cantilevers gave results that may either be overly conservative or un-conservative because original limitations had been either overlooked or interpreted differently was determined by **Hesham S. Essa et al (1994)**. Effective-length factors were proposed for built-in cantilevers as functions of the beam torsional parameter X that were in good agreement with results based on a distortional buckling finite-element model. The model itself was in good agreement with extensive test results. The method presented for interpolating the effective-length factor for positions of the concentrated load at the cantilever tip between the shear centre and the top flange.

The Authors N.E .Shanmugan,fellow ,V.Thevendrum et al (1995) Stated that the paper is concerned with the ultimate load behaviour of I-beams curved in plan. Results obtained from experiments on two sets of I-beams (one comprising rolled sections and the other built-up sections) are presented. The test results for deformations and ultimate strength are found to be in good agreement with the corresponding values predicted by using the elastoplastic finite-element analysis. The effects of residual stresses and radius of curvature to span-length ratio (RIL) n ultimate strength are considered. Each beam was subjected to a concentrated load applied at an intermediate point where the beam was laterally restrained. Test results indicate that the load-carrying capacity decreases with the decrease in the RIL ratio.

Trahair, N. S. (1996) says that A beam which is bent in its stiff principal plane may buckle out of this plane by deflecting laterally and twisting. Elastic local buckling of a very thin compression flange may significantly reduce the resistance of a beam to flexural-torsional buckling. In the case of uniform bending, local buckles appear along the whole length of the compression flange, and even though local failure is postponed by the flange post-local buckling resistance, the flexural and torsional stiffness of the flange are reduced, so that the effective out-of-plane rigidities of the beam are also reduced along the whole length of the beam. Web distortion may significantly reduce the flexural-torsional buckling resistance. The pre-buckling deflections transform the beam into a 'negative' arch. The concave curvature of the deflected beam increases its buckling resistance, just as the convex curvature of an arch decreases its buckling resistance.

A central elastic torsional buckling restraint restrict the lateral buckling shape of an elastic I – beam and increase the elasticity of flexural buckling moment said by **Valentino, J. et al(1997)**. However the effect of torsion restraint on inelastic buckling has not been studied and its not known whether the limiting stiffness for elastic buckling can be applied to beam that buckle in elastically. This paper investigates the effects of central elastic torsional restraints on the inelastic flexural torsional buckling of steel I-beams.

A combined analytical and experimental evaluation of flexural – torsional and lateral distortional buckling of fibre reinforced plastic (FRP) composite wide flange (WF) beam is presented by **Julio F. Davalos and Pizhong Qiao (1997)**based on energy principle the total potential energy equation for instability of cultured FRP WF section are derived using nonlinear elastic theory for the analysis of lateral – distortional buckling a fifth – order polynomial shape function is adopted to model the deformed shape of web panels and predict the critical load.

Masayoshi Nakashima et al (2002) says that the lateral instability effect differs significantly between cyclic and monotonic loading. For slenderness ratios about the weak axis not smaller than 100, the strength that can be sustained in cyclic loading is significantly smaller than that obtained in monotonic loading due to the accumulation of out-of-plane deformations. Equations were proposed for the beam un-braced length at which no strength reduction was noticed in cyclic loading up to the maximum beam end rotation of 0.045 rad. The lateral bracing requirements stipulated in the AISC Seismic Provisions were found to be a reasonably conservative measure to ensure sufficient beam rotation capacity.

The present study employs experimentally verified nonlinear finite element modeling techniques for the study of hybrid high performance steel I-beam. It was observed by the **Gerco, N. et al(2003)** that compactness and burning provision will exhibit less than the half of the required flexural ductility needed.

In this paper author **Trahair, N.S. et al(2004)** develops a simple advanced method of designing steel member against out-of plane failure in which reduced elastic modules were used in an out of plan buckling analysis to model the effects of high moment residual stresses and geometrical imperfection on yielding.

In this investigation the main advantage of this innovative technique is delaying the local buckling of the beams web and allowing a slender I-section to reach its yield or plastic flexural capacity. Different details for bonding the CRPR strips to the web were investigated by **Ezzeldin**

Yazeed Sayed-Ahmed et al (2006). The study reveals that bonding the CFRP strips to the web of a slender I-section significantly increases the critical load and may allow the beam to reach its yield or plastic capacity.

The Authors Jason R .Ericksen (2006) stated that Microsoft Excel offers users the ability to create custom functions that can be used in spreadsheets in the same manner as built-in functions. The key to this process is the use of programming language included in Excel called Visual Basic for Applications(VBA). This paper discusses methods for creating useful custom functions, strategies for getting the most out of the functions, and examples of custom functions for structural steel design.

Tadeh Zirakian et al (2007) conducted a series of six tests on full-scale fabricated simply supported I-beams with central concentrated load and an effective lateral brace at the midspan of the top compression flange was carried out and reported herein, mainly for experimental verification and investigation of distortion in these thin-walled sections. Considering the testing conditions, the two "restrained distortional" and "lateral–distortional" modes of instability were expected to occur in the test specimens. On the basis of the obtained experimental data, distortion of the web was experimentally verified in the two restrained and lateral modes and consequently the occurrence of lateral– distortional buckling was confirmed in the tests.

In this paper a series of elastic buckling analyses was carried out by **Kurniawan (2009)** to obtain the elastic lateral buckling moments (LDB and LTB) of simply supported LSBs subject to moment-distribution and load- height effects of transverse loading. Elastic buckling behaviour of three LSB sections was investigated to include the effect of section geometry in the investigation.

The use of steel beams with web openings for structure such as industrial building and high rise buildings has turned out to be extensive in recent times the purpose of this study was to be evaluate the strength of steel beam with web openings therefore number of experiment are carried out by **Samadhan G. Morkhade. Laxmikant M. Gupta. (2015)** SBWOs all those are described here beams with different web opening configuration and web opening area have been tested until failure.

The Authors Mark D.Denavit ,Jerome f. Hajjar et al(2016) stated that the direct analysis method is the primary means of assessing system stability within a standard specification. This method, and in particular its use of reduced stiffness, has been thoroughly validated for use in frames consisting of structural steel members. However, appropriate stiffness reductions have not yet been established nor has the method as a whole been validated for frames with steel-concrete composite columns. Through comparisons between second-order inelastic analysis results and results from the design methodology on a parametric suite of small frames, the current design provisions are evaluated in this paper. The results indicate that while the current design provisions are safe and accurate for the majority of common cases, there exist cases in which the current provisions result in high levels of un-conservative error. Modifications to the current design provision.

Chapter 3

Objective of the study

After studying Literature review it's found that very less research work has been done on hot rolled I-Beams using IS code 800:2007. While studying the same in curriculum a need for proper constraints for selecting the right type of beams was felt. This unclear situation to decide the parameters for selecting either laterally supported or unsupported beam will be attempted to solve through this project.

1. To establish a design steps of laterally supported or unsupported beam in a spread sheet and compare them for various combination of bending moment and shear force.
2. To compare structural and economical performance of the beams at different bending moment and shear force ratio.
3. To perform a parametric study of the variables that can affect the structural and economical behavior of beams.
4. To establish relation between laterally supported or unsupported beams for same loads.
5. Comparisons of results obtained from both types of beams.
6. Conclusion and recommendation on the loading and economical behavior of beams.

Chapter 4

Methodology

4.1 Approach

The literature to date deals with laterally supported and unsupported beams is limited, as far as they are analyzed together. To our knowledge, there is no literature that has compared the structural performance with respect to economy of these beams. Though there are some research papers that compares different beam structures. In this approach the design procedure for both laterally supported beam and laterally unsupported beam will be completely designed in excel spreadsheet and the comparison between the different parameters of the these beams with respect to the cost will be shown graphically.

4.2 MS Office Microsoft Excel

4.2.1 What is Microsoft Excel?

Microsoft Excel is a spread sheet developed by microsoft for Windows, macOS, Android and iOS. It features calculation, graphing tools, pivot tables, and a macro programming language called Visual Basic for Applications. It has been a very widely applied spreadsheet for these platforms, especially since version 5 in 1993, and it has replaced Lotus 1-2-3 as the industry standard for spreadsheets.

4.2.2 Why it is being used?

Microsoft Excel is a spreadsheet program used to store and retrieve numerical data in a grid format of columns and rows. Excel is ideal for entering, calculating and analyzing company data such as sales figures, sales taxes or commissions.

4.2.3 What are its advantages?

1. Excel allows business users to unlock the potential of their data, by using formulas across a grid of cells. Data is inserted into individual cells in rows or columns, allowing it to be sorted and filtered, and then displayed in a visual presentation.
2. Excel users can format their spreadsheets using different colour shades, bolds and italics, to differentiate between columns and bring the most important data to the fore.
3. When presenting data in the form of charts or graphs, it can be helpful to include average lines, which explicitly detail the key trends emerging from the information.

We are using excel spread sheet because of the following reasons

- It is easily available
- It is low cost software tool
- Easy to use
- Very much compatible
- Gives us flexibility to use our data unlike other software

4.3 Assumptions for design

1. The material used in beam is assumed to be homogenous.
2. No imperfections were considered in these investigation.
3. No temperature effects are present.
4. Hot rolled I-Beams are taken as main member.
5. Only I-beam dimensions are considered in the design.
6. Only clear span of the beam will be considered.
7. Only shear force and bending moment is assumed.

4.4 Design Procedure

LATERALLY SUPPORTED:

STEP 1: FIND OUT ULTIMATE LOAD ON BEAM.

Factored Ultimate Load (Factored Load) w = 1.5 × Working Load

STEP 2: FIND OUT MAXIMUM BENDING MOMENT (M) AND SHEAR FORCE (V) ON BEAM.

STEP 3: CALCULATE PLASTIC SECTION MODULUS REQURIED FOR TRIAL SECTION.

$$Z_{P(required)} = \frac{M\gamma_O}{f_y}$$

STEP 4: SELECT SUITABLE SECTION BASED ON Z_p FROM IS: 800: 2007, PAGE NO. 138, 139. WRITE DOWN SE TIONAL PROPERTIES.

STEP 5: SECTION CLASSIFICATION.

a. Find out value of b/t_f and d/t_w . (refer Figure. 2, Page no. 19, IS 800: 2007 to find b and d) t_f = thickness of flange t_w = thickness of web.

b. Refer Table 2, Page no. 18, IS 800: 2007 and classify the section semi-compact, compact, plastic or slender.

STEP 6: CHECK FOR SHEAR. (Clause no. 8.4.1., Page no. 59, IS 800: 2007) **a. Find out design shear strength V_d.**

$$V_d = \frac{f_y}{\sqrt{3\gamma_{mo}}} h t_w$$

b. Beam is checked for high / low shear case

$V \leq 0.6\ V_d$ low shear case

$V > 0.6\ V_d$ high shear case

STEP 6: CHECK FOR BENDING.

a. For low shear Case (Clause no. 8.2.1.2, Page no. 53, IS 800: 2007)

$M_d > M$

M_d = Design Bending Strength

M = Bending Moment

$$M_d = \beta_b Z_p \frac{f_y}{\gamma_{mo}} \leq 1.2 Z_e \frac{f_y}{\gamma_{mo}}\ (for\ simply\ supported\ beam)$$

$$\leq 1.5 Z_e \frac{f_y}{\gamma_{mo}}\ (for\ cantilever\ beam)$$

β_b = 1 for plastic and compact sections.

= Z_e/Z_p for semi compact sections.

Z_e = Elastic section Modulus Z_p = Plastic section Modulus

b. For High shear Case (Clause no. 8.2.1.3, Page no. 53, IS 800: 2007)

Refer Clause no. 8.2.1.3, Page no. 53, IS 800: 2007. Generally low shear case is preferred.

STEP 7: CHECK FOR WEB BUCKLING AT SUPPORT (Clause no. 8.7.3.1, Page no. 67, IS 800: 2007) a. Capacity of section = $A_b f_{cd} > V$

b. $A_b = (b_1 + n_1)\, t_w$ when load is at support $A_b = (b_1 + 2n_1)\, t_w$ when load is not at support

Where, b_1= stiff bearing length of load = assume between 0 to 100mm

n_1 = for 45° dispersion consider h/2

d. Find out F_{cd} = Design Compressive Stress considering class c and f_y = 250 MPa.

Slenderness ratio $= \frac{kl}{r} = \frac{0.7d}{r}$

D = depth of the web between the flanges

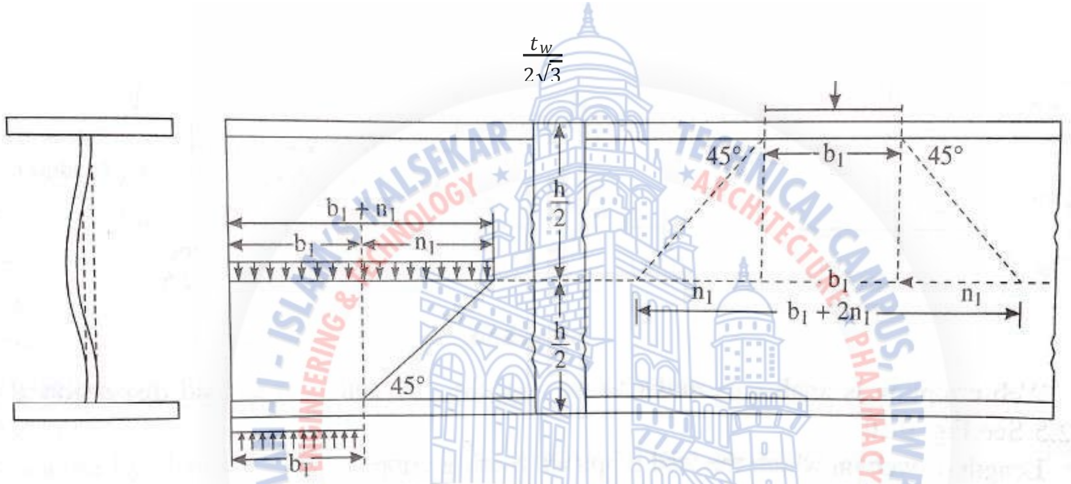

Fig. 3.1

r = least radius of gyration of the section =

STEP 7: CHECK FOR WEB CRIPPLING (Clause no. 8.7.4, Page no. 67, IS 800: 2007)

Design crippling strength $F_w = \frac{(\ _1+n_2)t_w f_{yw}}{\gamma_{mo}} > V$

Where, b_1 = stiff bearing length = 0 to 100 mm

$n_2 = 2.5\ (t_f + r_1)$

f_{yw} = yield stress of web

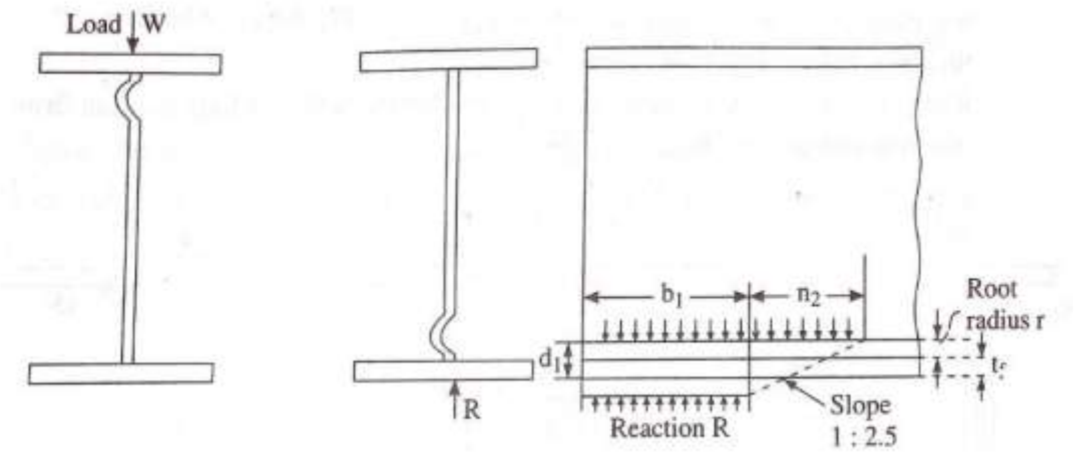

Fig. 3.2

STEP 8: CHECK FOR DEFLECTION

a.Actual deflection for simply supported

$$\delta_{max} = \frac{5}{384}\frac{wl^2}{EI}$$

b. Permissible deflection = Span/300 (table 6, Page no. 31, IS 800: 2007)

Design of laterally unsupported beam

Step 1: Calculate Loads, Max.Bending Moment, and Shear Force.

Where, factored load=1.5*service load.

Step 2: Trail section:

Find

Assume, Fbd=120to140 N/mm2 for i section ...using IS code 800:2007

Step 3: Effective length of beam:(cl.8.3.1 Table-15)

Depending upon the support condition, L_{LT} calculated using Table -15.

Step 4: Design shear strength (V_d):

As $V < 0.6\, V_d$, Strength in bending (M_d) need not reduced due to shear.

Step 5: Design bending strength (M_d):

$$M_d = Z_p * \beta_b * f_{bd}$$

Where Z_p = plastic sectional modules.

$f_{bd \backslash =}$ design bending compressive stress

$=X_{LT} * f_y / \gamma_{mo}$ or using Table 13(a) and (b) and value of f_{crb}.

X_{LT} = bending stress reduction factor

$= \leq 1$

$\phi_{LT} = 0.5 [1+ \alpha_{LT} (X_{LT} - 0.2) + \lambda_{LT}^2]$

α_{LT} = Imperfection parameter

= 0.21 for rolled steel section

=0.49 for welded steel section

X_{LT} = Non-dimensional slenderness ratio

$= \leq =$

f_{crb} = Extreme fibre bending compressive stress

= (Using Table 14 values of kL/r and L/tf calculated)

$M_d > M$

Step 6: Check

Deflection limit:

$\delta_{actual} < \delta_{limitin}$

Chapter 5

Results & Discussions

In this approach, the design procedure for different steel built-up column is completely done in an excel spreadsheet and the results of the differences between the geometries of the built-up column with respect to the cost is shown graphically.

The graphs that are formed below are showing the results that are occurred while conducting this project. The results were tested from 600kN to 2500kN, for a height varying from 3m to 13m. The testing was done only for ISMC Channel sections only and no other section is considered for this project.

In this chapter, the results obtained for the analytical investigation on steel laced and battened columns are discussed with the help of graphs,

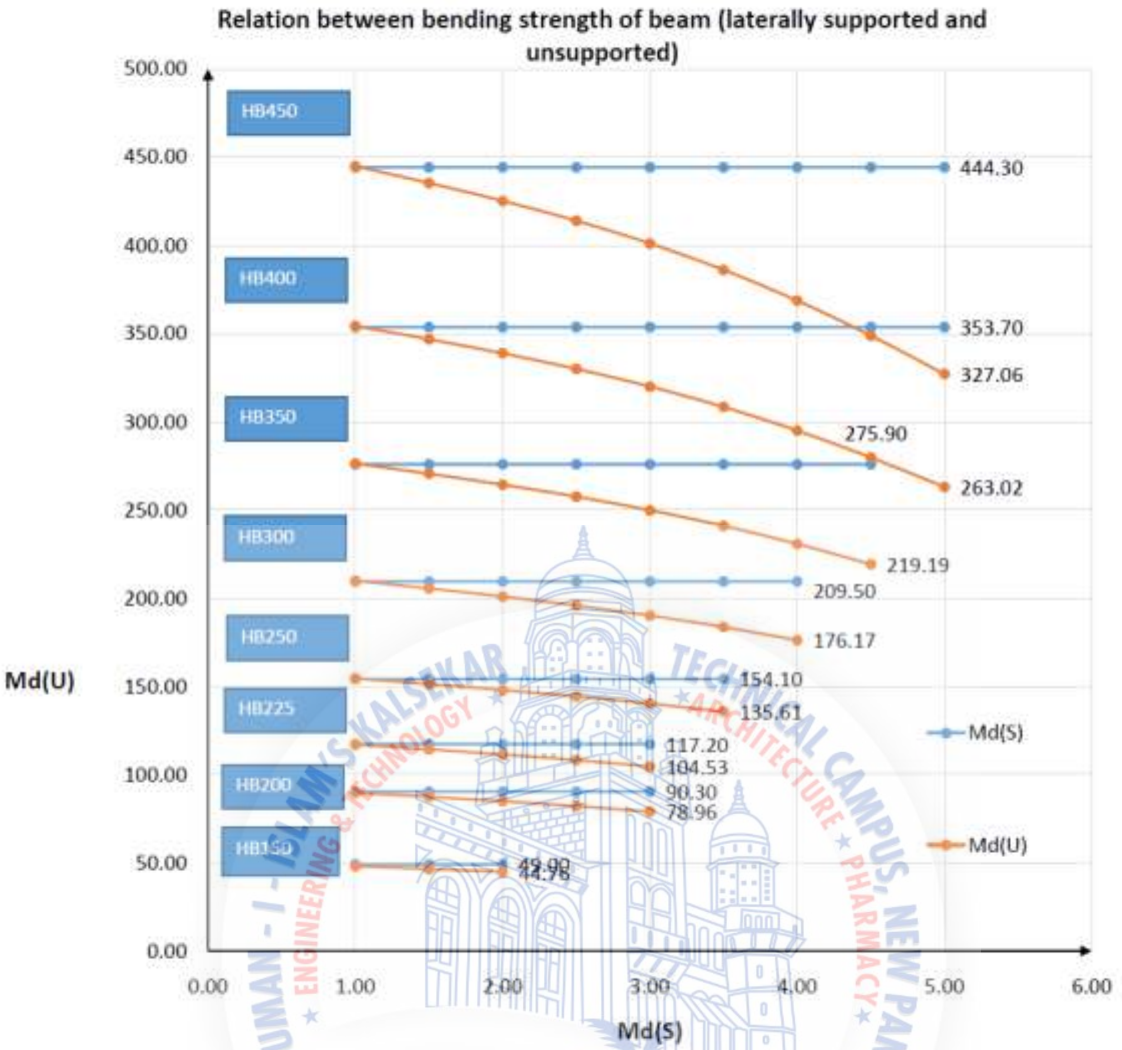

Fig. 4.1 Relation between bending strength of beam (laterally supported and unsupported) for ISHB

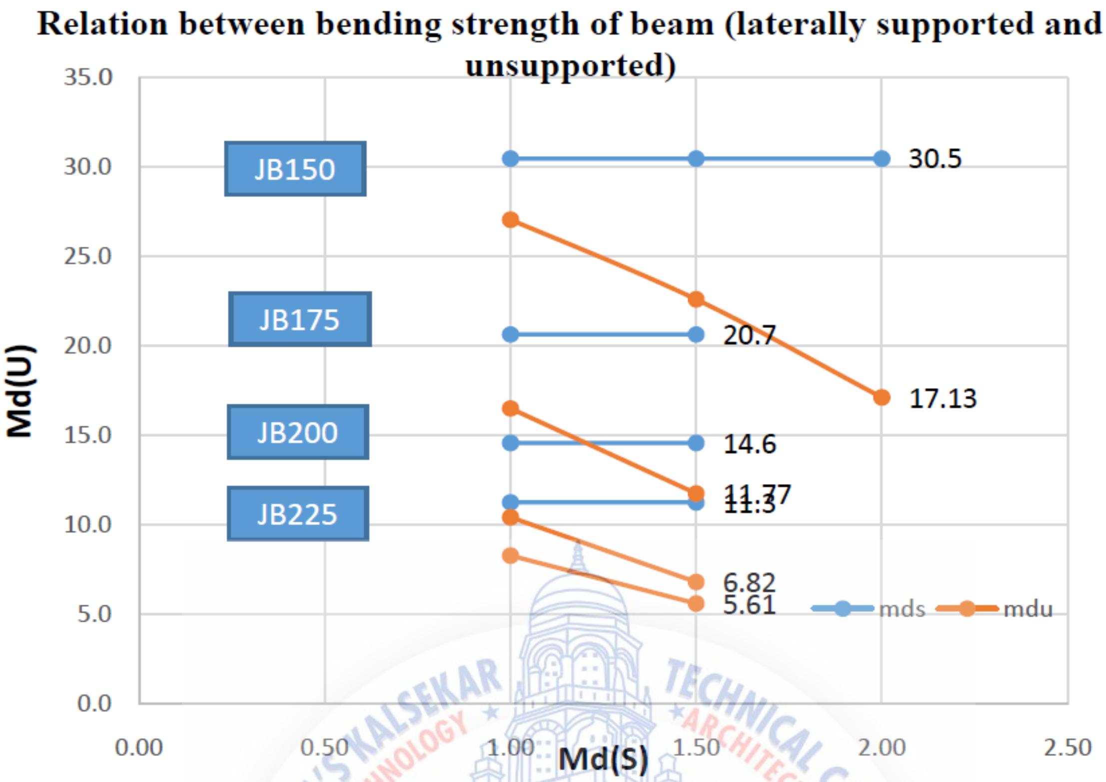

Fig. 4.2 Relation between bending strength of beam (laterally supported and unsupported) for ISJB

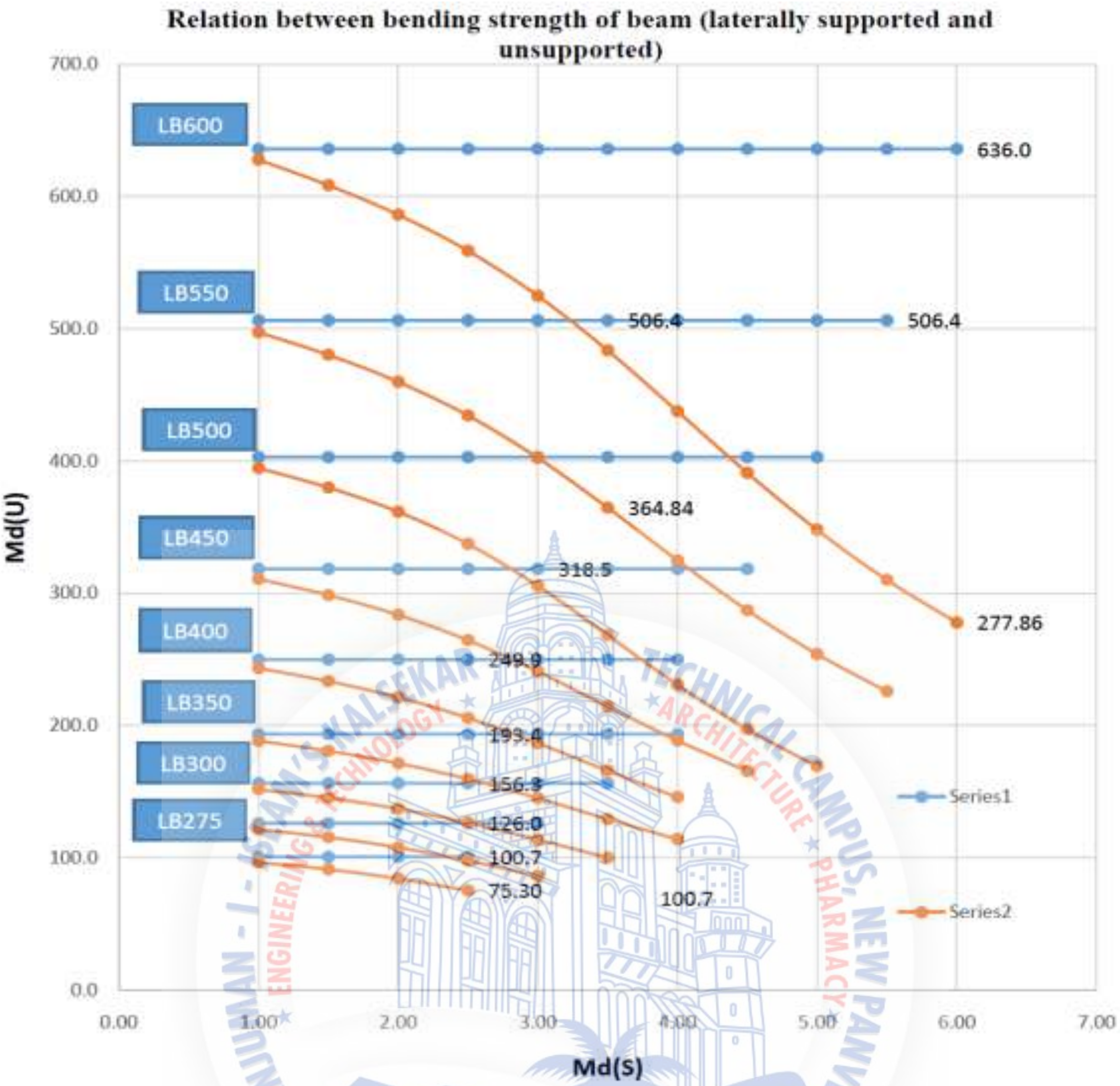

Fig. 4.3 Relation between bending strength of beam (laterally supported and unsupported) for ISLB

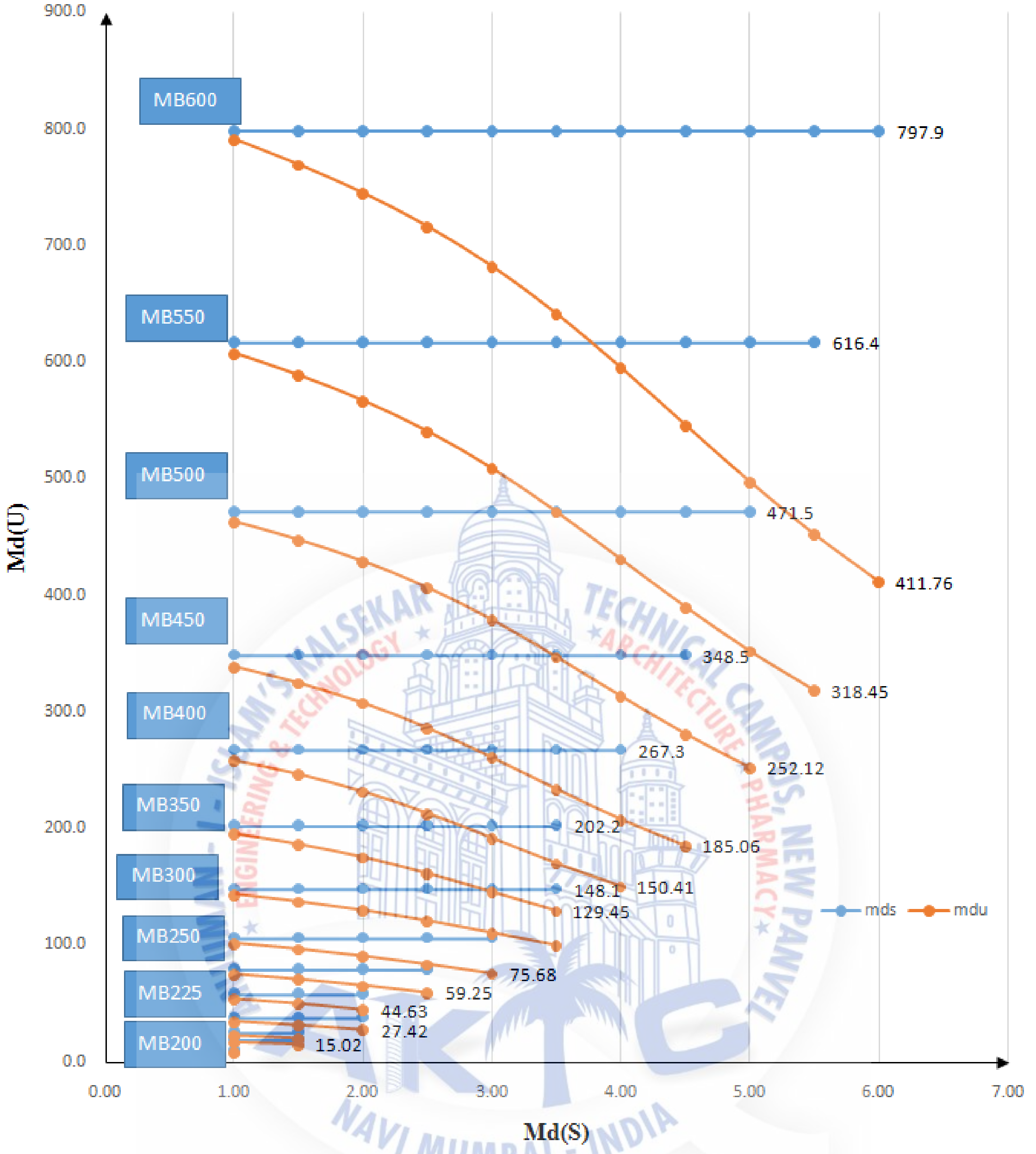

Fig. 4.4 Relation between bending strength of beam (laterally supported and unsupported) for ISMB

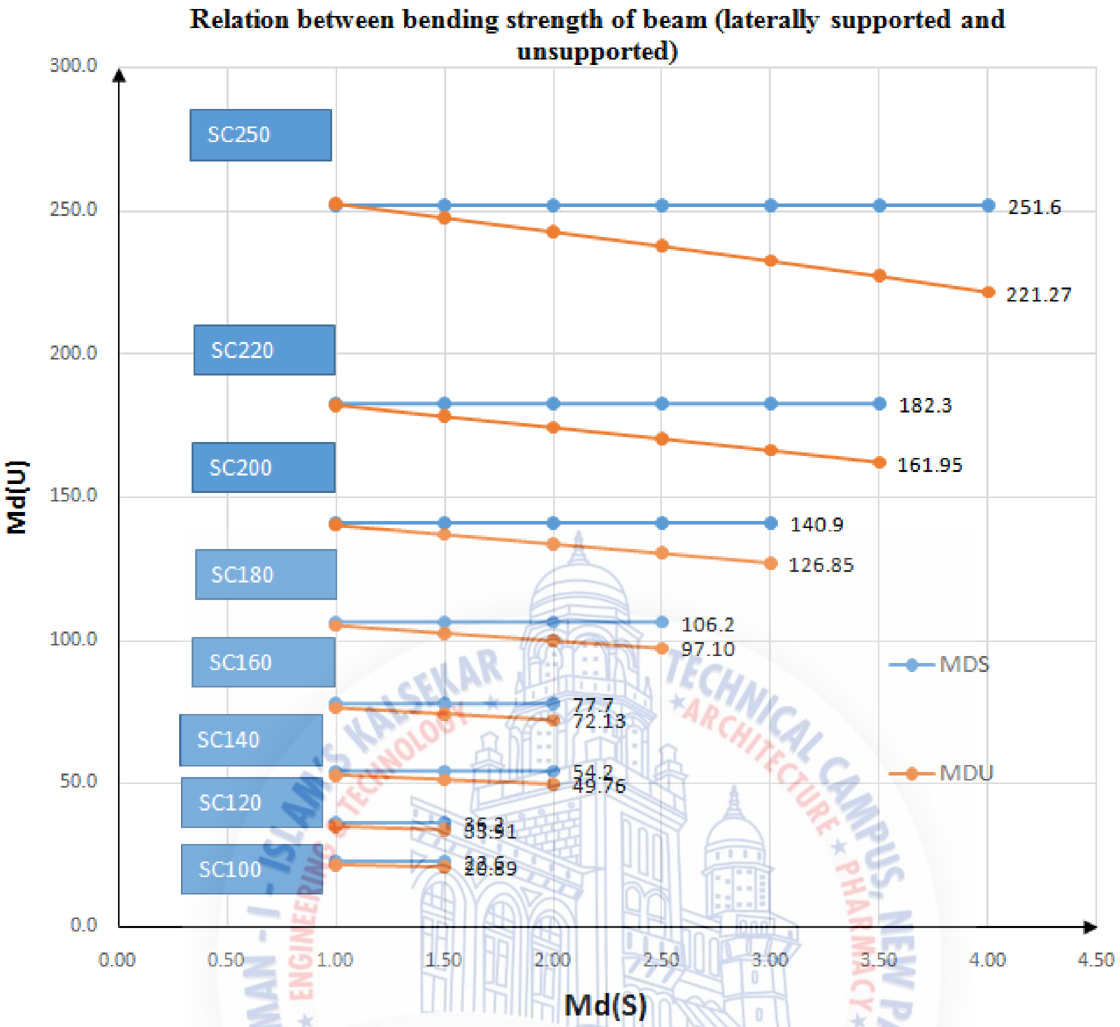

Fig. 4.5 Relation between bending strength of beam (laterally supported and unsupported) for ISSC

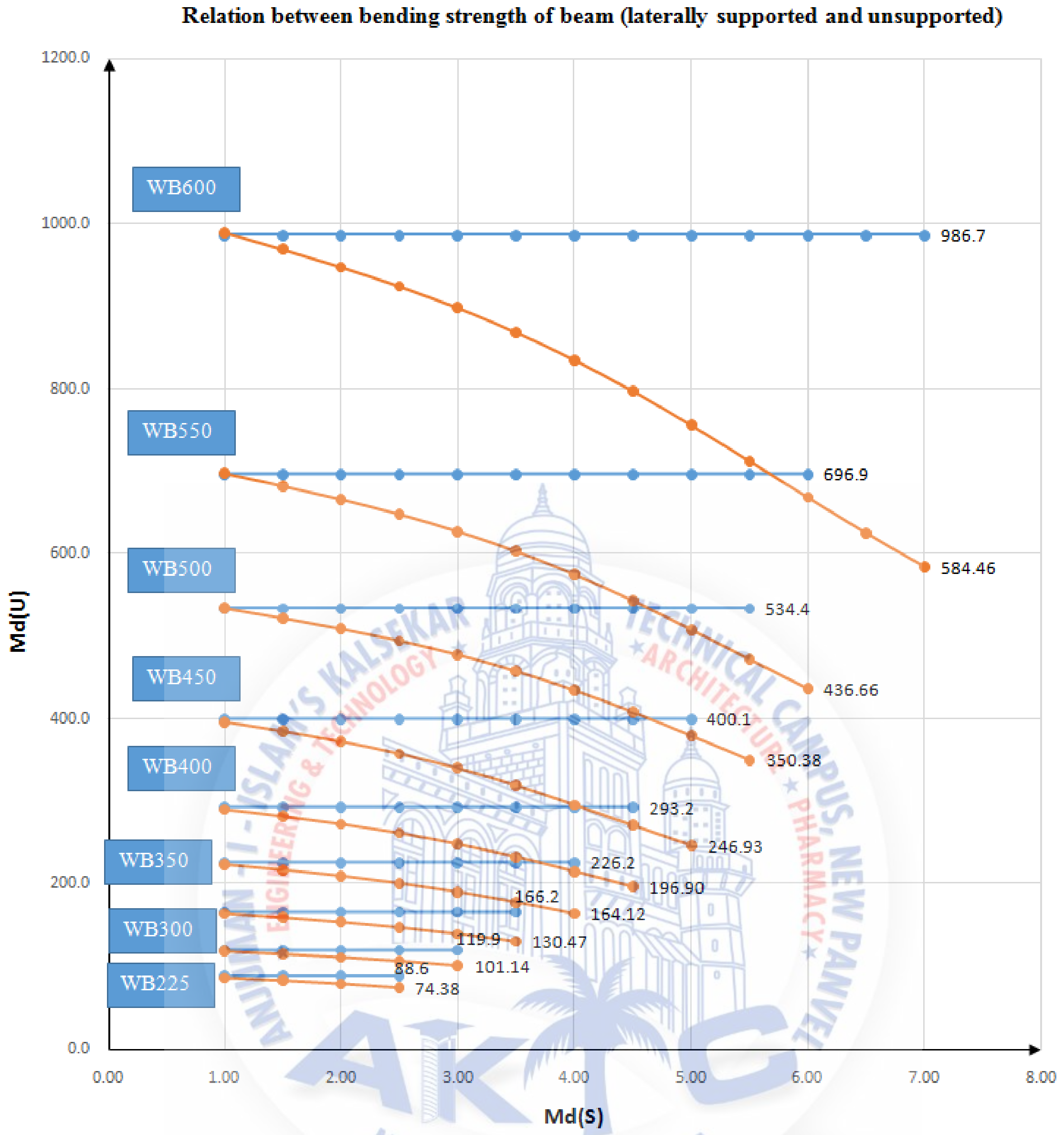

Fig. 4.6 Relation between bending strength of beam (laterally supported and unsupported) for ISWB

5.2 Discussions

From the numerous data obtained from calculations it is inferred that as length increases in supported condition no variation in bending strength Md(S) in fig.4.1 observed as the design procedure doesn't consider length as one of the parameters, consequently in laterally unsupported conditions there's variation observed as the design procedure considers length as one of the effective parameters and hence decrease in bending strength Md(U) is observed. After Comparing the results obtained under laterally supported and unsupported condition, The values of bending strength decreases in unsupported condition on an average **of 25% for ISHB sections** than supported condition. And it is also seemed that in most of the sections of ISHB lateral torsional buckling is needs to considered in between the length of 1.5m to 2.5m as the ratio of λ_{LT} increases by 0.4 at that range of the section

Similar result are also obtained for ISJB beam section but here the rate of fluctuation in bending strength's of laterally supported and laterally unsupported is 42% to 45% decrement in unsupported condition which is clearly visible in fig.4.2. But here the consideration range of lateral torsional buckling is at very initial length of 1.25m to 1.5m .

In light beam sections like ISLB the results which were analysed by the obtained data was something different by the previous two sections (ISHB AND ISJB) data, In it the sections which are lower like ISLB200, ISLB250,ISLB275, ISLB 300 and lower the rate of decrease in bending strength [Md(U)] was little bit about 25% to 29% than that of higher section [ISLB 600, ISLB550, ISLB500 etc.], Whose fluctuation rate exceeded above 50%.but the consideration range of lateral torsional buckling is vise versa of the bending strength result of these section ,lower section needed to consider LTB (LATERAL TORSIONAL BUCKLING) at very initial length of 0.75m to 1m and in higher sections it ranges from 1.5 m to 2.5m of length. Where as from the figure 4.4 the obtained result shows major decrease in the bending strength of unsupported beam as compared to the supported beam the fluctuation rate of strength is about 50% of the section of higher depth in ISMB and the sections with lesser depth shows no major fluctuations but consideration of LTB in these smaller sections is at very initial length i.e 1.25m to 1.5m, whereas the higher depth sections of ISMB takes the range from 2m to 2.5m for the consideration of LTB. Like ISMB sections, ISWB sections shows nearly similar results.

Generation of Formula for prediction of bending capacity Md(U) of beam section

For beam sections ISHB

To get accurate values to plot relation between load “Md(S)”, and size “Md(U)” (ISHB only), we have taken a ratio Φ_1 for each value of “Md(S)” and “Md(U)”.

$$\Phi_1 = \frac{\text{Md (U)+L}}{Md\,(S)} \qquad \ldots\ldots\ldots\text{(i)}$$

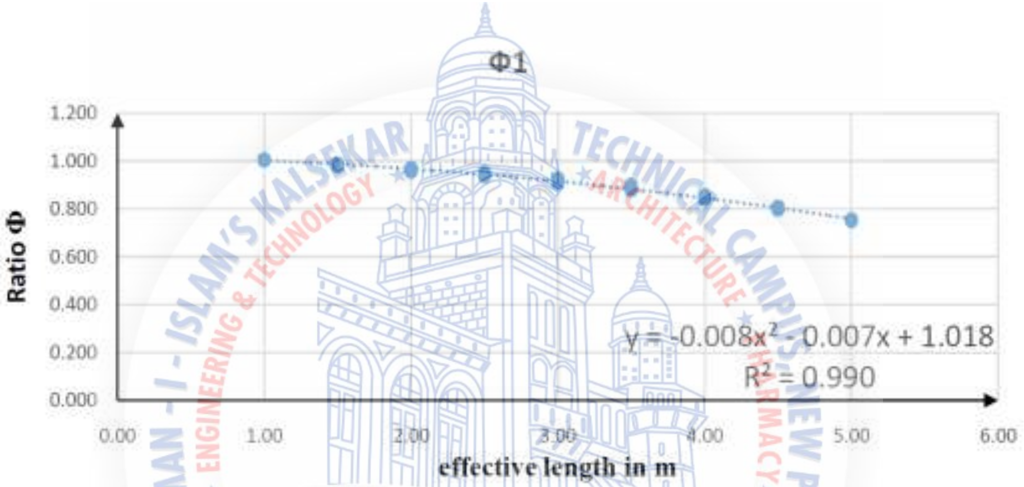

Fig. 4.2.1 Plot between **Φ1** and effective length

After plotting values of Φ with respect to length “L”, we get a graph as shown in Fig.4.1, from graph we are getting an equation (ii) that gives a relation between Φ and length in the form of power by plotting Φ_1 along y-axis and Length along x-axis.

$$\Phi1=0.008L^2-0.007L+1.018 \qquad \text{(ii)} \ldots$$

$$\frac{\text{Md (U)+L}}{Md\,(S)} = 0.008L^2-0.007L+1.018$$

$$Md(U) = Md(S)*[\ 0.008L^2-0.007L+1.018]-L$$

$$Md(U) = 90.30*[\ 0.008*2^2-0.007*2+1.018]-2$$

$$Md(U) = 87.15 \text{ KNm}$$

This above equation (iii) is valid for ISHB beam section only for other beam sction like ISMB,ISLB,ISWB etc,It is seemed that the above equation is not applicable . Therefore we have changed the ratio again to plot Φ_2 and effective length.

For beam sections ISJB

$$\Phi_2 = \frac{\mathrm{Md\,(U)+L}}{Md\,(S)} \qquad \text{.......(iv)}$$

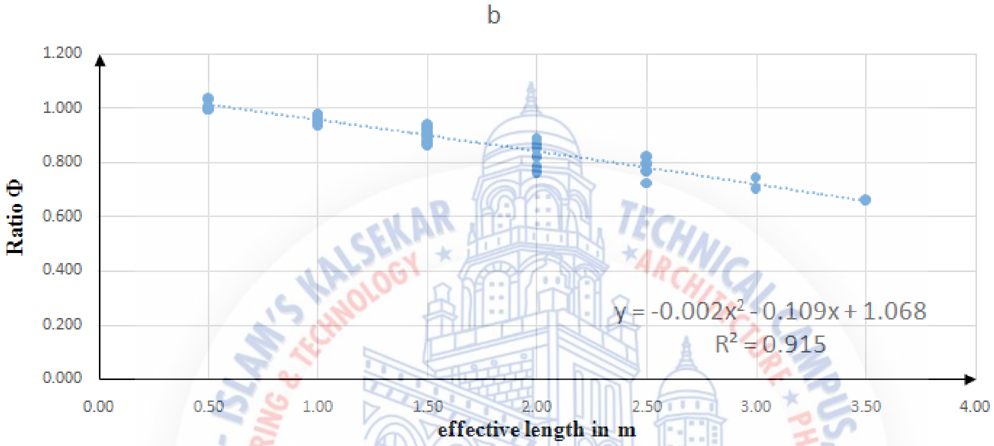

Fig. 4.2.2 Plot between **Φ2** and effective length

After plotting relation between Φ_2 and length “L” in above graph (Fig.4.20) we get again an equation in the power form, by plotting Φ_2 along y-axis and Length along x-axis.

$$\Phi_2 = -0.002L^2 - 0.109L + 1.068 \qquad \cdots\cdots\cdots\text{(v)}$$

$$\frac{\mathrm{Md\,(U)+L}}{Md\,(S)} = -0.002L^2 - 0.109L + 1.068$$

$\mathrm{Md(U)} = \mathrm{Md(S)}*[\,-0.002*1.5^2-0.109*1.5+1.068]-\mathrm{L}$

$\mathrm{Md(U)} = 16.8*[\,-0.002*2^2-0.109*2+1.068]-2$

Md(U) = 13.44 KNm

The above equation can be utilize for the beam section ISLB only, Therefore like wise these two beam section we had to plot other similar graphs for other beam sections. Hence for beam section ISMB, we have changed the ratio to plot Φ_3 and effective length.

For beam sections ISLB

$$\Phi_1 = \frac{\mathrm{Md\,(U)+L}}{Md\,(S)} \qquad \text{…….(vi)}$$

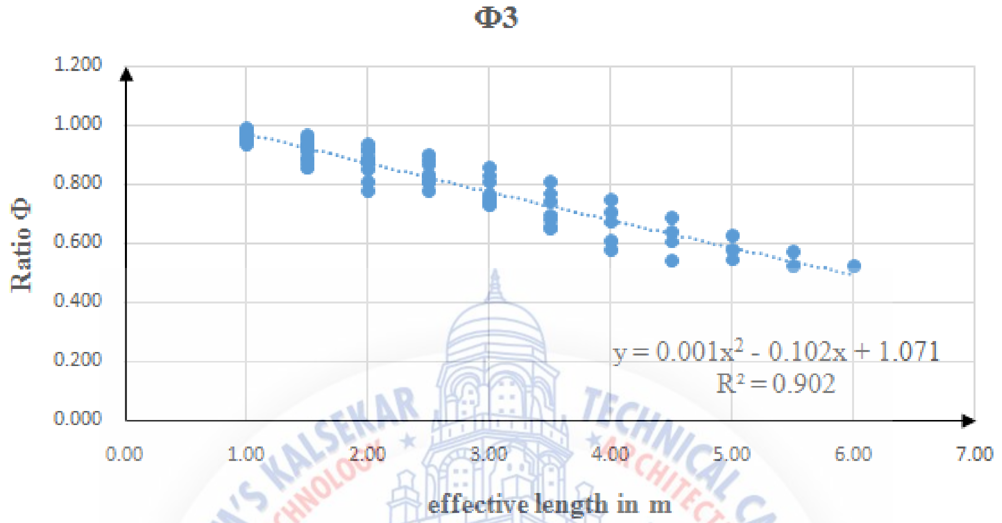

Fig. 4.2.3 Plot between **Φ_3** and effective length

After plotting relation between Φ_2 and length "L" in above graph (Fig.4.3) we get again an equation in the power form, by plotting Φ_3 along y-axis and Length along x-axis.

$$\Phi_3 = -0.001L^2 - 0.102L + 1.071 \qquad \cdots\cdots\cdots\text{(vii)}$$

$$\frac{\mathrm{Md\,(U)+L}}{Md\,(S)} = -0.001L^2 - 0.102L + 1.071$$

$$Md(U) = Md(S)*[\ 0.001L^2 - 0.102L + 1.071] - L$$

$$Md(U) = 37.7*[\ 0.001*2^2 - 0.102*2 + 1.071] - 2$$

$$Md(U) = 22.7\ KNm$$

For beam section ISMB

$$\Phi_4 = \frac{\mathrm{Md\,(U)+L}}{Md\,(S)} \qquad \text{…….(viii)}$$

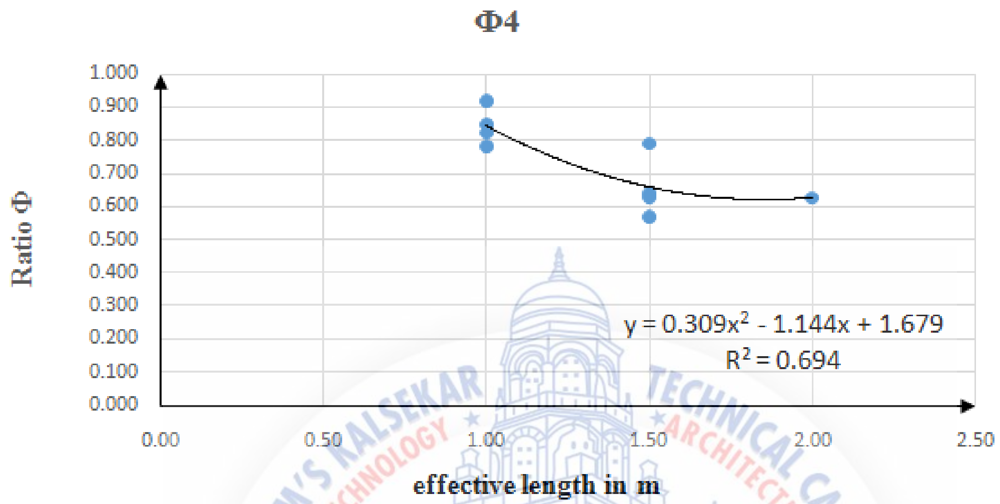

Fig. 4.2.4 Plot between **Φ_4** and effective length

After plotting relation between Φ_2 and length "L" in above graph (Fig.4.4) we get again an equation in the power form, by plotting Φ_4 along y-axis and Length along x-axis.

$$\Phi_4 = 0.309L^2 - 1.144L + 1.679 \qquad \text{………(ix)}$$

$$\frac{\mathrm{Md\,(U)+L}}{Md\,(S)} = 0.309L^2 - 1.144L + 1.679$$

$$Md(U) = Md(S)*[\,0.309L^2 - 1.144L + 1.679] - L$$

$$Md(U) = 14.6*[\,0.309*1^2 - 1.1447*1 + 1.679] - 1$$

$$Md(U) = 10.09 \text{ KNm}$$

For beam section ISSC

$$\Phi_5 = \frac{\mathrm{Md}\,(\mathrm{U})+\mathrm{L}}{Md\,(S)} \qquad \ldots\ldots.(\mathrm{x})$$

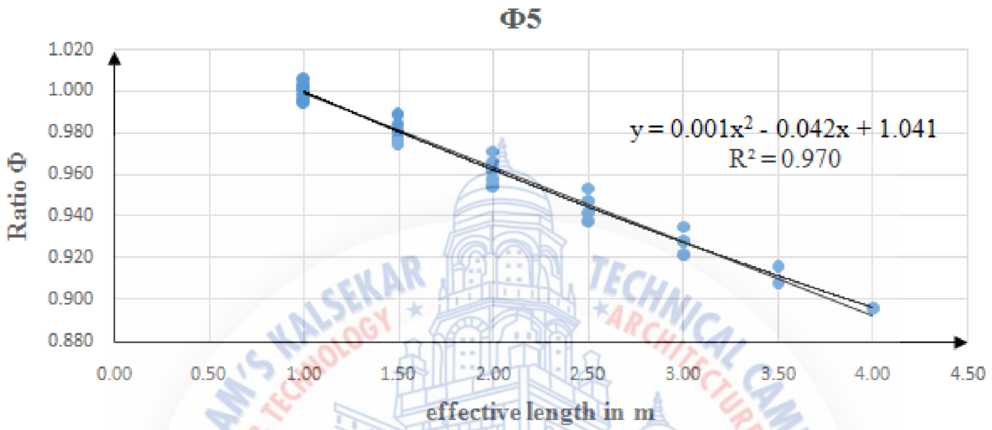

Fig. 4.2.5 Plot between Φ_5 and effective length

After plotting relation between Φ_2 and length "L" in above graph (Fig.4.5) we get again an equation in the power form, by plotting Φ_5 along y-axis and Length along x-axis.

$$\Phi_5=0.001L^2-1.144L+1.679 \qquad \cdots\cdots\cdots \text{(xi)}$$

$$\frac{\mathrm{Md}\,(\mathrm{U})+\mathrm{L}}{Md\,(S)} = 0.001L^2-1.144L+1.679$$

$\mathrm{Md(U)} = \mathrm{Md(S)}*[\ 0.001L^2-1.144L+1.679]-L$

$\mathrm{Md(U)} = 54.2*[\ 0.001*1.5^2-1.144*1.5+1.679]-1.5$

Md(U) = 54.07 KNm

For beam section ISWB

$$\Phi_6 = \frac{\mathrm{Md\,(U)+L}}{Md\,(S)} \qquad \text{.......(xii)}$$

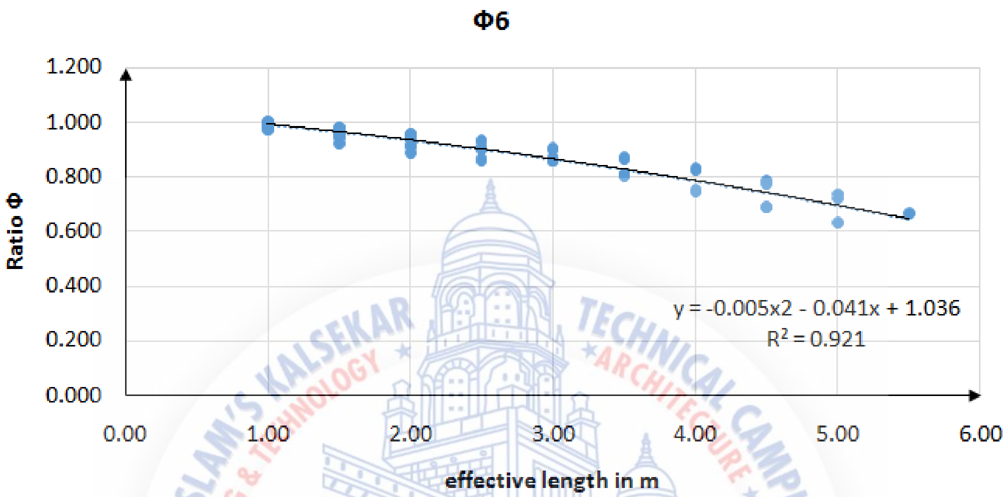

Fig. 4.2.6 Plot between Φ_6 and effective length

After plotting relation between Φ_2 and length "L" in above graph (Fig.4.5) we get again an equation in the power form, by plotting Φ_6 along y-axis and Length along x-axis.

$$\Phi_6 = -\ 0.005L^2 - 0.041L + 1.036 \qquad \cdots\cdots\cdots \text{(xiii)}$$

$$\frac{\mathrm{Md\,(U)+L}}{Md\,(S)} = 0.005L^2 - 0.041L + 1.036$$

$Md(U) = Md(S)*[\ 0.005L^2 - 0.041L + 1.036] - L$

$Md(U) = 66.8*[\ 0.005*2^2 - 0.041*2 + 1.036] - 2$

Md(U) = 57.29 KNm

Table.4.2.1 Obtained values of $\Phi_1$with respect to length (For ISHB section)

Length of the beam (m)	Original Md(U) (KNm)	Φ1 (m)	Predicted Md(U) (KNm)
1.00	48.02	1.001	47.44
1.50	46.45	0.979	46.20
2.00	44.76	0.954	44.75
1.00	89.67	1.004	88.26
1.50	87.36	0.984	86.41
2.00	84.87	0.962	84.15
2.50	82.10	0.937	81.48
3.00	78.96	0.91	78.41
1.00	116.97	1.01	114.85
1.50	114.26	0.99	112.59
2.00	111.36	0.97	109.81
2.50	108.16	0.94	106.50
3.00	104.53	0.92	102.66
1.00	154.48	1.01	151.33
1.50	151.29	0.99	148.52
2.00	147.93	0.97	145.01
2.50	144.28	0.95	140.81
3.00	140.21	0.93	135.92
3.50	135.61	0.90	130.34
1.00	209.90	1.01	206.09

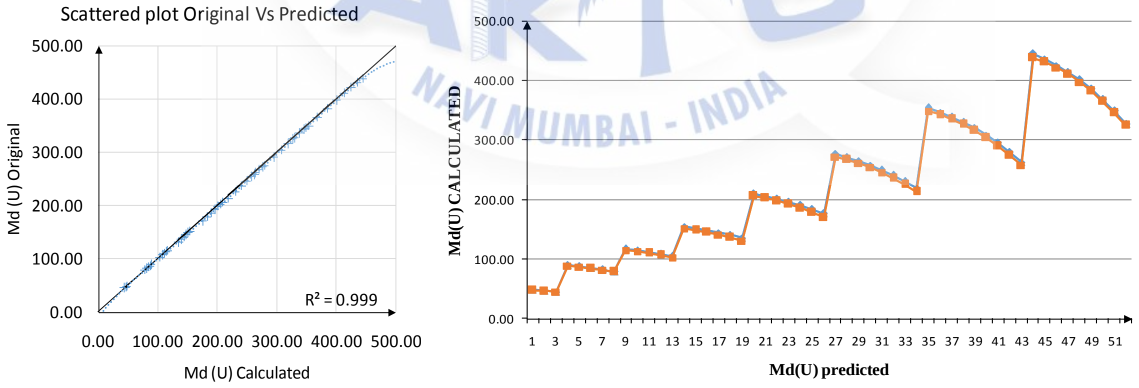

Fig.4.2.7 Comparison between predicted and Actual values of Md(U) and Scattered Plot For ISHB

Table.4.2.2 Obtained values of Φ_2 with respect to length (For ISLB section)

Length of the beam (m)	Original Md(U) (KNm)	Φ2 (m)	Predicted Md(U) (KNm)
0.50	4.82	1.038	4.60
0.50	8.37	0.998	8.37
1.00	7.39	0.938	7.37
0.50	16.45	1.006	16.36
1.00	15.25	0.961	14.91
1.50	13.71	0.897	13.44
0.50	23.30	1.000	23.33
1.00	21.63	0.949	21.48
1.50	19.39	0.873	19.61
0.50	32.15	1.001	32.18
1.00	30.11	0.952	29.83
1.50	27.37	0.882	27.45
2.00	23.78	0.785	25.03
0.50	41.65	1.005	41.54
1.00	39.41	0.962	38.67
1.50	36.53	0.904	35.75
2.00	32.70	0.823	32.78
1.00	53.61	0.942	53.81
1.50	48.75	0.865	49.96
2.00	42.31	0.762	46.04

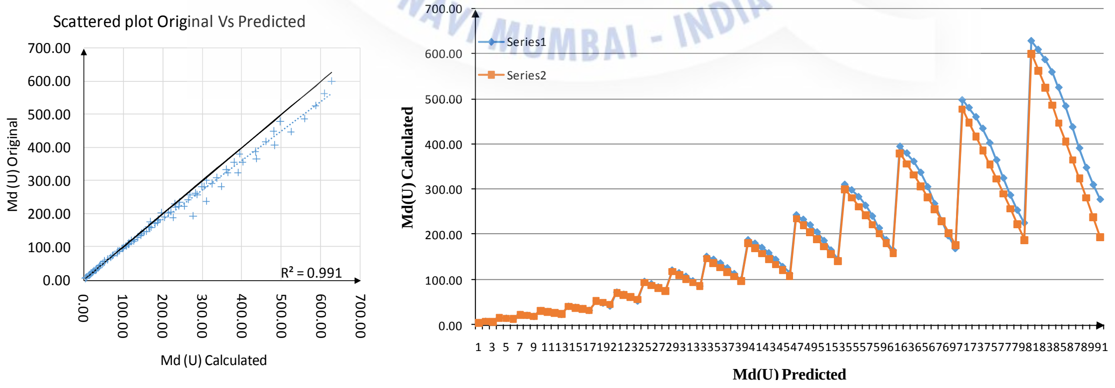

Fig.4.2.8 Comparison between predicted and Actual values of Md(U) and Scattered Plot For ISJB

Table.4.2.3 Obtained values of Φ_3 with respect to length (For ISMB section)

Length of the beam (m)	Original Md(U) (KNm)	Φ3 (m)	Predicted Md(U) (KNm)
1.00	7.92	0.951	7.16
1.00	16.68	0.950	15.20
1.50	15.02	0.888	13.82
1.00	22.49	0.936	20.87
1.50	19.95	0.854	19.17
1.00	34.52	0.941	31.87
1.50	31.29	0.869	29.58
2.00	27.42	0.779	27.27
1.00	53.84	0.951	49.24
1.50	49.75	0.888	46.01
2.00	44.63	0.808	42.74
1.00	75.11	0.962	67.93
1.50	70.71	0.912	63.67
2.00	65.38	0.851	59.38
2.50	59.25	0.780	55.04
1.00	101.62	0.970	91.17
1.50	96.60	0.927	85.65
2.00	90.58	0.875	80.08
2.50	83.45	0.812	74.45
3.00	75.68	0.743	68.77

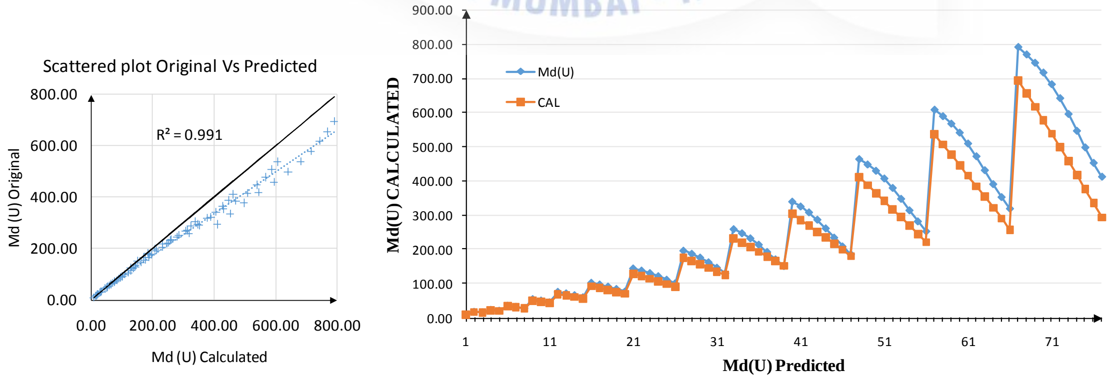

Fig4.2.9 Comparison between predicted and Actual values of Md(U) and Scattered Plot For ISLB

Table.4.2.4 Obtained values of Φ4 with respect to length (For ISMB section)

Length of the beam (m)	Original Md(U) (KNm)	Φ4 (m)	Predicted Md(U) (KNm)
1.00	7.92	0.951	7.16
1.00	16.68	0.950	15.20
1.50	15.02	0.888	13.82
1.00	22.49	0.936	20.87
1.50	19.95	0.854	19.17
1.00	34.52	0.941	31.87
1.50	31.29	0.869	29.58
2.00	27.42	0.779	27.27
1.00	53.84	0.951	49.24
1.50	49.75	0.888	46.01
2.00	44.63	0.808	42.74
1.00	75.11	0.962	67.93
1.50	70.71	0.912	63.67
2.00	65.38	0.851	59.38
2.50	59.25	0.780	55.04
1.00	101.62	0.970	91.17
1.50	96.60	0.927	85.65
2.00	90.58	0.875	80.08
2.50	83.45	0.812	74.45
3.00	75.68	0.743	68.77

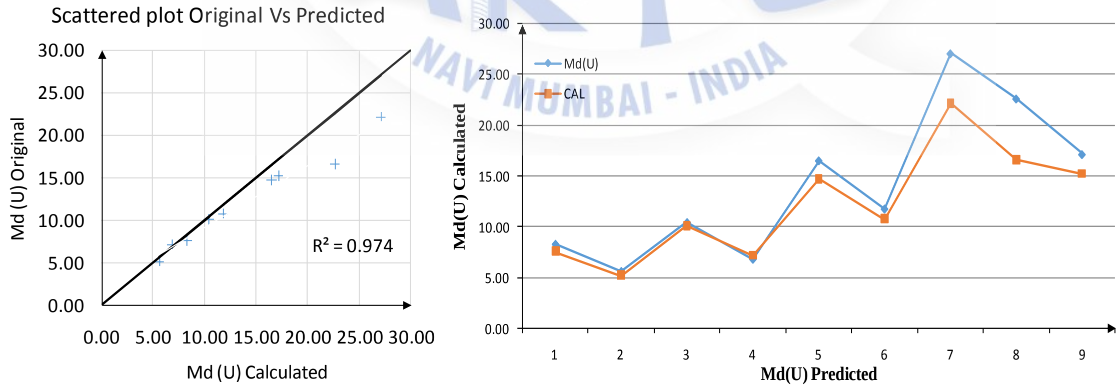

Fig.4.2.10 Comparison between predicted and Actual values of Md(U) and Scattered Plot For ISMB

Table.4.2.5 Obtained values of Φ5 with respect to length (For ISMB section)

Length of the beam (m)	Original Md(U) (KNm)	Φ5 (m)	Predicted Md(U) (KNm)
1.00	21.68	1.002	20.96
1.50	20.89	0.989	20.03
1.00	35.09	0.996	34.16
1.50	33.91	0.977	32.97
1.00	52.97	0.995	51.60
1.50	51.35	0.975	50.07
2.00	49.76	0.955	48.57
1.00	76.36	0.996	74.33
1.50	74.23	0.975	72.35
2.00	72.13	0.955	70.42
1.00	105.10	0.999	102.06
1.50	102.42	0.978	99.53
2.00	99.78	0.958	97.07
2.50	97.10	0.938	94.66
1.00	140.06	1.001	135.70
1.50	136.77	0.981	132.52
2.00	133.52	0.962	129.41
2.50	130.23	0.942	126.38
3.00	126.85	0.921	123.42
1.00	181.91	1.003	175.83

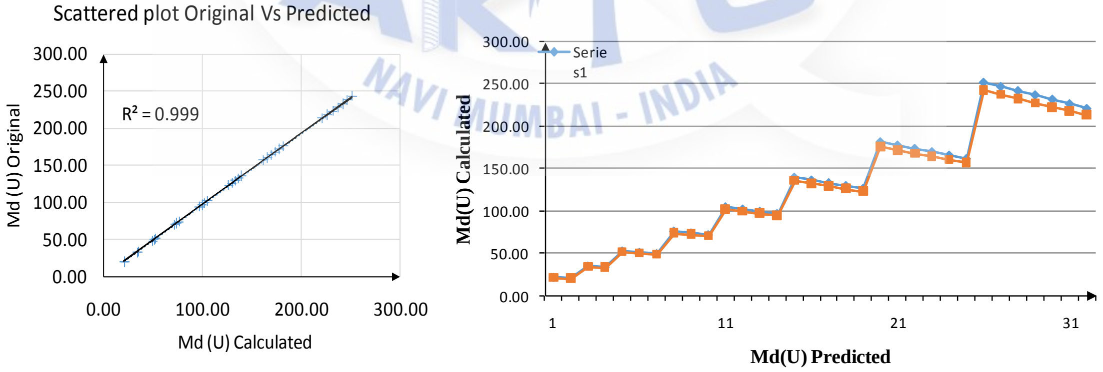

Fig.4.2.11 Comparison between predicted and Actual values of Md(U) and Scattered Plot For ISSC

Table.4.2.6 Obtained values of Φ_6 with respect to length (For ISMB section)

Length of the beam (m)	Original Md(U) (KNm)	Φ6 (m)	Predicted Md(U) (KNm)
1.00	26.98	0.971	26.12
1.50	25.02	0.920	24.88
1.00	42.26	0.980	40.51
1.50	40.01	0.940	38.89
2.00	37.22	0.889	37.16
1.00	64.74	0.984	61.84
1.50	61.97	0.950	59.64
2.00	58.68	0.908	57.29
2.5	54.73	0.857	54.77
1.00	86.35	0.986	82.35
1.50	83.00	0.953	79.60
2.00	79.08	0.915	76.63
2.50	74.38	0.868	73.46
1.00	118.52	0.997	111.77
1.50	115.05	0.972	108.22
2.00	111.15	0.944	104.39
2.50	106.58	0.910	100.27
3.00	101.14	0.869	95.87
1.00	164.27	0.994	155.30
1.50	159.43	0.968	150.57

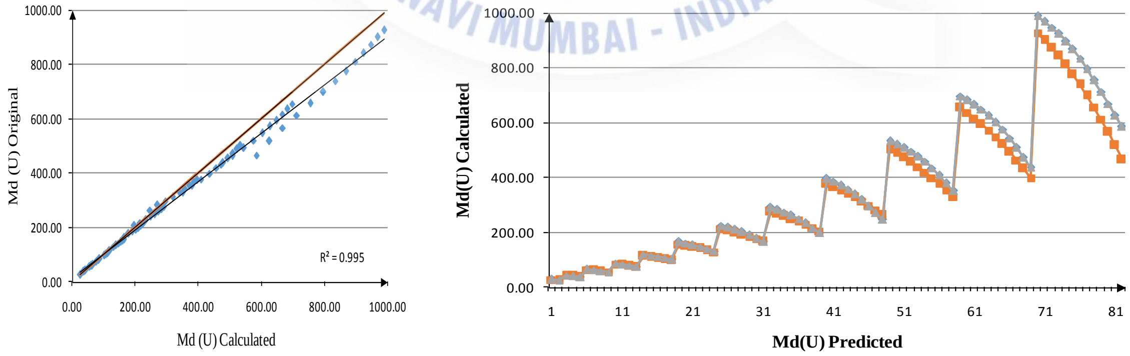

Fig.4.2.12 Comparison between predicted and Actual values of Md(U) and Scattered Plot For ISWB

Chapter 5

Conclusion

From many decades structures which are formed from steel became popular, but in countries like India only industrial and commercial structures are made from steel, while working with steel design it was found that very less work is available with steel and Indian Standards Code which is updated in 2007, i. e IS800-2007. Further it is difficult for beginner to select from typical beams. We have decided to work on the comparision of beams viz. laterally supported and unsupported based on various bending moment and shear force values and also IS code do not specify exact condition to select one. So we decided to work on these beams. Typically laterally supported and unsupported beams Design problems were worked out with the help of Microsoft Excel, to check various beam sections. These all were carried out by considering standard specifications provided by IS800-2007. The obtained result is then presented in the form of tables and graphs. And with the help of these data it was inferred that, There is a considerable variation in bending strength in case of laterally unsupported beam. The beams which are having higher depth have capacity to bear higher amount of bending stress like ISHB and ISMB. Whereas ISJB&ISLB have lesser capacity to bear bending stress as compared to ISMB & ISHB although these are having higher depth ratio it is due to smaller thickness of web as well as flange. The dimensional property of ISHB & ISSC are nearly same in the range 100mmto160mm but we can observe that the

ISSC section have more capacity as thickness of flange is slightly higher than ISHB. For low loading structure ISJB & ISLB best suitable, as these are having medium range. When we compare strength of the section for 450mm depth we can clearly say that HB is having more capacity than WB, MB, & LB respectively (LB<MB<WB<HB). For heavy loading we can choose, from MB & WB as these are having higher depth (600mm). HB &SC are more suitable as a column (as there are having nearly square section).As all the section above described are having different geometry so it is not possible to embed all in single equation. Formed equations will be more helpful for a design engineering to get idea about probable design strength as the particular section with respect to length.

We started to work out for typical selection between these beams (laterally supported and unsupported), We obtained the results of 63 beam sections. After checking out the results we decided to form an equation that was capable of predicting the bending strength of the beam as priorly decided we were working to get a universal equation for all the sections but due to time constraints we have come with equations for their respective section which can predict with efficiency of 99 %. And additionally it would aid the designer to get the desired result without any tedious calculations.

Further, the excel sheet that we have designed is also capable of helping the design engineers to check various sections of beams considering variation in length, bending moment, and shear force.

Future scope

- Further study can be extended for various sections other than I section.
- Further study can be extended for beam sections as well as column sections.
- Same excel sheet can further be utilized to check nature of beam with respect to length and external UDL or point load.
- Study can be extended considering temperature effects.
- In the further studies consideration of the imperfection for the beam can be taken in account.

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Appendix

Obtained result data for ISHB

Laterally supported beams						Laterally unsupported beams						
BM	SF	Section	area	Md	Vd	Length	UDL	Md	V	Fbd	Def	Max Def
29.4	63.8	HB150	3450.0	49.0	106.3	2.00	63.77	44.76	106.28	207.57	6.67	4.55
54.2	96.1	HB200	4750.0	90.3	160.1	3.00	64.03	78.96	160.08	198.77	10.00	9.38
70.3	115.1	HB225	5490.0	117.2	191.9	3.00	76.76	104.53	191.90	202.65	10.00	7.64
92.5	135.8	HB250	6500.0	154.1	226.3	3.50	77.60	135.61	226.35	199.95	11.67	9.80
125.7	179.5	HB300	7480.0	209.5	299.2	4.00	89.75	176.17	299.17	191.14	13.33	11.87
165.5	228.7	HB350	8590.0	275.9	381.2	4.50	101.65	219.19	381.18	180.58	15.00	14.13
212.2	286.6	HB400	9870.0	353.7	477.6	5.00	114.63	263.02	477.63	169.00	16.67	16.60
266.6	347.2	HB450	11100.0	444.3	578.7	5.00	138.88	327.06	578.66	167.29	16.67	14.42

Laterally supported beams						Laterally unsupported beams						
BM	SF	Section	Area	Md	Vd	Length	Udl	Md	V	Fbd	Def	Max Def
29.4	63.8	HB150	3450.0	49.0	106.3	1.00	127.54	48.02	106.28	222.71	3.33	0.57
						1.50	85.03	46.45	106.28	215.41	5.00	1.92
						2.00	63.77	44.76	106.28	207.57	6.67	4.55
54.2	96.1	HB200	4750.0	90.3	160.1	1.00	192.10	89.67	160.08	225.73	3.33	0.35
						1.50	128.07	87.36	160.08	219.92	5.00	1.17
						2.00	96.05	84.87	160.08	213.66	6.67	2.78
						2.50	76.84	82.10	160.08	206.68	8.33	5.43
						3.00	64.03	78.96	160.08	198.77	10.00	9.38
70.3	115.1	HB225	5490.0	117.2	191.9	1.00	230.28	116.97	191.90	226.77	3.33	0.28
						1.50	153.52	114.26	191.90	221.51	5.00	0.95
						2.00	115.14	111.36	191.90	215.89	6.67	2.26
						2.50	92.11	108.16	191.90	209.68	8.33	4.42
						3.00	76.76	104.53	191.90	202.65	10.00	7.64
92.5	135.8	HB250	6500.0	154.1	226.3	1.00	271.62	154.48	226.35	227.77	3.33	0.23
						1.50	181.08	151.29	226.35	223.06	5.00	0.77
						2.00	135.81	147.93	226.35	218.11	6.67	1.83
						2.50	108.65	144.28	226.35	212.72	8.33	3.57
						3.00	90.54	140.21	226.35	206.73	10.00	6.17
						3.50	77.60	135.61	226.35	199.95	11.67	9.80
125.7	179.5	HB300	7480.0	209.5	299.2	1.00	359.01	209.90	299.17	227.74	3.33	0.19
						1.50	239.34	205.53	299.17	222.99	5.00	0.63
						2.00	179.50	200.90	299.17	217.97	6.67	1.48
						2.50	143.60	195.83	299.17	212.47	8.33	2.90
						3.00	119.67	190.12	299.17	206.28	10.00	5.01
						3.50	102.57	183.61	299.17	199.22	11.67	7.95
						4.00	89.75	176.17	299.17	191.14	13.33	11.87
165.5	228.7	HB350	8590.0	275.9	381.2	1.00	457.42	276.36	381.18	227.68	3.33	0.16
						1.50	304.95	270.55	381.18	222.89	5.00	0.52
						2.00	228.71	264.37	381.18	217.80	6.67	1.24
						2.50	182.97	257.56	381.18	212.19	8.33	2.42
						3.00	152.47	249.86	381.18	205.84	10.00	4.19
						3.50	130.69	240.99	381.18	198.53	11.67	6.65
						4.00	114.35	230.77	381.18	190.12	13.33	9.93
						4.50	101.65	219.19	381.18	180.58	15.00	14.13
212.2	286.6	HB400	9870.0	353.7	477.6	1.00	573.15	354.30	477.63	227.65	3.33	0.13
						1.50	382.10	346.81	477.63	222.84	5.00	0.45
						2.00	286.58	338.83	477.63	217.71	6.67	1.06
						2.50	229.26	330.01	477.63	212.05	8.33	2.07
						3.00	191.05	319.99	477.63	205.61	10.00	3.59

						3.50	163.76	308.41	477.63	198.17	11.67	5.69
						4.00	143.29	295.01	477.63	189.56	13.33	8.50
						4.50	127.37	279.77	477.63	179.76	15.00	12.10
						5.00	114.63	263.02	477.63	169.00	16.67	16.60
266.6	347.2	HB450	11100.0	444.3	578.7	1.00	694.39	444.92	578.66	227.58	3.33	0.12
						1.50	462.93	435.42	578.66	222.72	5.00	0.39
						2.00	347.20	425.26	578.66	217.52	6.67	0.92
						2.50	277.76	413.99	578.66	211.76	8.33	1.80
						3.00	231.46	401.11	578.66	205.17	10.00	3.11
						3.50	198.40	386.14	578.66	197.51	11.67	4.94
						4.00	173.60	368.74	578.66	188.61	13.33	7.38
						4.50	154.31	348.87	578.66	178.45	15.00	10.51
						5.00	138.88	327.06	578.66	167.29	16.67	14.42

Obtained result data for ISJB

Laterally supported beams						Laterally unsupported beams						
BM	SF	Section	area	Md	Vd	Length	UDL	Md	V	Fbd	Def	Max Def
6.8	35.4	JB150	901.0	11.3	59.0	1.50	47.24	5.61	59.05	113.27	5.00	4.84
8.8	44.1	JB175	1030.0	14.6	73.5	1.50	58.78	6.82	73.48	106.13	5.00	4.04
12.4	53.5	JB200	1260.0	20.7	89.2	1.50	71.38	11.77	89.23	129.44	5.00	3.01
18.3	65.5	JB225	1630.0	30.5	109.2	2.00	65.54	17.13	109.24	127.71	6.67	5.21

Laterally supported beams						Laterally unsupported beams						
BM	SF	Section	area	Md	Vd	Length	UDL	Md	V	Fbd	Def	Max Def
6.8	35.4	JB150	901.0	11.3	59.0	1.00	70.86	8.29	59.05	167.29	3.33	1.43
						1.50	47.24	5.61	59.05	113.27	5.00	4.84
8.8	44.1	JB175	1030.0	14.6	73.5	1.00	88.18	10.43	73.48	162.46	3.33	1.20
						1.50	58.78	6.82	73.48	106.13	5.00	4.04
12.4	53.5	JB200	1260.0	20.7	89.2	1.00	107.07	16.52	89.23	181.72	3.33	0.89
						1.50	71.38	11.77	89.23	129.44	5.00	3.01
18.3	65.5	JB225	1630.0	30.5	109.2	1.00	131.08	27.07	109.24	201.78	3.33	0.65
						1.50	87.39	22.61	109.24	168.57	5.00	2.20

Obtained result data for ISLB

Laterally supported beams						Laterally unsupported beams						
BM	SF	Section	area	Md	Vd	Length	UDL	Md	V	Fbd	Def	Max Def
3.0	21.8	LB075	771.0	5.1	36.4	0.50	87.39	4.82	36.41	215.84	1.67	0.49
5.3	31.5	LB100	1020.0	8.8	52.5	1.00	62.98	7.39	52.49	190.05	3.33	2.44
10.1	43.3	LB125	1510.0	16.8	72.2	1.50	57.74	13.71	72.17	185.49	5.00	4.68
14.3	56.7	LB150	1810.0	23.8	94.5	1.50	75.58	19.39	94.48	185.56	5.00	3.61
19.5	70.3	LB175	2130.0	32.6	117.1	2.00	70.27	23.78	117.11	165.95	6.67	6.65
25.1	85.0	LB200	2530.0	41.9	141.7	2.00	85.03	32.70	141.71	177.34	6.67	5.21
34.7	102.7	LB225	2990.0	57.9	171.2	2.00	102.74	42.31	171.24	166.10	6.67	4.28
46.2	120.1	LB250	3550.0	77.0	200.1	2.50	96.05	53.36	200.10	157.54	8.33	6.57
60.4	138.6	LB275	4200.0	100.7	230.9	3.00	92.38	65.41	230.94	147.63	10.00	9.05
75.6	158.2	LB300	4810.0	126.0	263.7	3.00	105.50	86.24	263.74	155.57	10.00	7.59
93.8	179.1	LB325	5490.0	156.3	298.5	3.50	102.35	100.07	298.52	145.50	11.67	10.13
116.1	203.9	LB350	6300.0	193.4	339.8	4.00	101.95	114.05	339.85	134.01	13.33	12.87
149.9	251.9	LB400	7240.0	249.9	419.9	4.00	125.97	145.81	419.89	132.62	13.33	10.88
191.1	304.7	LB450	8310.0	318.5	507.8	4.50	135.41	165.70	507.81	118.24	15.00	13.15
241.9	362.2	LB500	9550.0	403.1	603.6	5.00	144.86	169.27	603.59	95.44	16.67	15.27
303.8	428.7	LB550	11000.0	506.4	714.5	5.50	155.88	225.90	714.47	101.39	18.33	17.46
381.6	496.0	LB600	12700.0	636.0	826.7	6.00	165.33	277.86	826.66	99.29	20.00	19.16

Laterally supported beams						Laterally unsupported beams						
BM	SF	Section	area	Md	Vd	Length	UDL	Md	V	Fbd	Def	Max Def
3.0	21.8	LB075	771.0	5.1	36.4	0.50	87.39	4.82	36.41	215.84	1.67	0.49
5.3	31.5	LB100	1020.0	8.8	52.5	0.50	125.97	8.37	52.49	215.30	1.67	0.31
						1.00	62.98	7.39	52.49	190.05	3.33	2.44
10.1	43.3	LB125	1510.0	16.8	72.2	0.50	173.21	16.45	72.17	222.47	1.67	0.17
						1.00	86.60	15.25	72.17	206.26	3.33	1.39
						1.50	57.74	13.71	72.17	185.49	5.00	4.68
14.3	56.7	LB150	1810.0	23.8	94.5	0.50	226.74	23.30	94.48	222.99	1.67	0.13
						1.00	113.37	21.63	94.48	206.99	3.33	1.07
						1.50	75.58	19.39	94.48	185.56	5.00	3.61
19.5	70.3	LB175	2130.0	32.6	117.1	0.50	281.06	32.15	117.11	224.37	1.67	0.10
						1.00	140.53	30.11	117.11	210.13	3.33	0.83
						1.50	93.69	27.37	117.11	190.98	5.00	2.81
						2.00	70.27	23.78	117.11	165.95	6.67	6.65
25.1	85.0	LB200	2530.0	41.9	141.7	0.50	340.11	41.65	141.71	225.88	1.67	0.08
						1.00	170.06	39.41	141.71	213.74	3.33	0.65
						1.50	113.37	36.53	141.71	198.14	5.00	2.20
						2.00	85.03	32.70	141.71	177.34	6.67	5.21
34.7	102.7	LB225	2990.0	57.9	171.2	1.00	205.48	53.61	171.24	210.45	3.33	0.54
						1.50	136.99	48.75	171.24	191.38	5.00	1.81
						2.00	102.74	42.31	171.24	166.10	6.67	4.28
46.2	120.1	LB250	3550.0	77.0	200.1	1.00	240.13	72.93	200.10	215.33	3.33	0.42
						1.50	160.08	68.07	200.10	200.98	5.00	1.42
						2.00	120.06	61.46	200.10	181.47	6.67	3.36
						2.50	96.05	53.36	200.10	157.54	8.33	6.57
60.4	138.6	LB275	4200.0	100.7	230.9	1.00	277.13	96.54	230.94	217.88	3.33	0.34
						1.50	184.75	91.25	230.94	205.93	5.00	1.13
						2.00	138.56	84.26	230.94	190.16	6.67	2.68
						2.50	110.85	75.30	230.94	169.94	8.33	5.24
75.6	158.2	LB300	4810.0	126.0	263.7	1.00	316.49	121.52	263.74	219.22	3.33	0.28
						1.50	211.00	115.54	263.74	208.44	5.00	0.95
						2.00	158.25	107.82	263.74	194.51	6.67	2.25
						2.50	126.60	97.83	263.74	176.48	8.33	4.39
						3.00	105.50	86.24	263.74	155.57	10.00	7.59
93.8	179.1	LB325	5490.0	156.3	298.5	1.00	358.22	151.84	298.52	220.78	3.33	0.24
						1.50	238.81	145.32	298.52	211.29	5.00	0.80
						2.00	179.11	137.12	298.52	199.37	6.67	1.89
						2.50	143.29	126.54	298.52	183.99	8.33	3.69
						3.00	119.41	113.71	298.52	165.34	10.00	6.38
						3.50	102.35	100.07	298.52	145.50	11.67	10.13
116.1	203.9	LB350	6300.0	193.4	339.8	1.00	407.82	188.44	339.85	221.40	3.33	0.20
						1.50	271.88	180.82	339.85	212.45	5.00	0.68
						2.00	203.91	171.46	339.85	201.45	6.67	1.61
						2.50	163.13	159.57	339.85	187.49	8.33	3.14
						3.00	135.94	145.09	339.85	170.48	10.00	5.43
						3.50	116.52	129.29	339.85	151.90	11.67	8.62
						4.00	101.95	114.05	339.85	134.01	13.33	12.87
149.9	251.9	LB400	7240.0	249.9	419.9	1.00	503.87	243.44	419.89	221.42	3.33	0.17
						1.50	335.91	233.57	419.89	212.44	5.00	0.57
						2.00	251.93	221.39	419.89	201.36	6.67	1.36
						2.50	201.55	205.81	419.89	187.20	8.33	2.66
						3.00	167.96	186.74	419.89	169.84	10.00	4.59
						3.50	143.96	165.87	419.89	150.87	11.67	7.29
						4.00	125.97	145.81	419.89	132.62	13.33	10.88
191.1	304.7	LB450	8310.0	318.5	507.8	1.00	609.37	310.85	507.81	221.83	3.33	0.14
						1.50	406.24	298.68	507.81	213.14	5.00	0.49
						2.00	304.68	283.71	507.81	202.46	6.67	1.15

						2.50	243.75	264.58	507.81	188.81	8.33	2.25
						3.00	203.12	240.89	507.81	171.90	10.00	3.90
						3.50	174.10	214.49	507.81	153.06	11.67	6.19
						4.00	152.34	188.65	507.81	134.62	13.33	9.23
						4.50	135.41	165.70	507.81	118.24	15.00	13.15
241.9	362.2	LB500	9550.0	403.1	603.6	1.00	724.31	394.79	603.59	222.59	3.33	0.12
						1.50	482.87	380.07	603.59	214.28	5.00	0.41
						2.00	362.16	361.71	603.59	203.93	6.67	0.98
						2.50	289.72	337.43	603.59	190.25	8.33	1.91
						3.00	241.44	305.72	603.59	172.37	10.00	3.30
						3.50	206.95	268.44	603.59	151.35	11.67	5.24
						4.00	181.08	230.84	603.59	130.15	13.33	7.82
						4.50	160.96	197.30	603.59	111.24	15.00	11.13
						5.00	144.86	169.27	603.59	95.44	16.67	15.27
303.8	428.7	LB550	11000.0	506.4	714.5	1.00	857.37	497.46	714.47	223.26	3.33	0.10
						1.50	571.58	480.40	714.47	215.60	5.00	0.35
						2.00	428.68	460.06	714.47	206.48	6.67	0.84
						2.50	342.95	434.56	714.47	195.03	8.33	1.64
						3.00	285.79	402.55	714.47	180.67	10.00	2.83
						3.50	244.96	364.84	714.47	163.74	11.67	4.50
						4.00	214.34	325.01	714.47	145.86	13.33	6.71
						4.50	190.53	287.28	714.47	128.93	15.00	9.56
						5.00	171.47	254.07	714.47	114.03	16.67	13.12
						5.50	155.88	225.90	714.47	101.39	18.33	17.46
381.6	496.0	LB600	12700.0	636.0	826.7	1.00	991.99	627.98	826.66	224.40	3.33	0.09
						1.50	661.33	608.75	826.66	217.52	5.00	0.30
						2.00	496.00	586.42	826.66	209.54	6.67	0.71
						2.50	396.80	559.10	826.66	199.78	8.33	1.39
						3.00	330.66	525.04	826.66	187.61	10.00	2.40
						3.50	283.43	483.81	826.66	172.88	11.67	3.80
						4.00	248.00	437.72	826.66	156.41	13.33	5.68
						4.50	220.44	391.18	826.66	139.78	15.00	8.08
						5.00	198.40	348.05	826.66	124.37	16.67	11.09
						5.50	180.36	310.20	826.66	110.84	18.33	14.76

Obtained result data for ISMB

Laterally supported beams						Laterally unsupported beams						
BM	SF	Section	area	Md	Vd	Length	UDL	Md	V	Fbd	Def	Max Def
5.6	37.0	MB100	1140.0	9.4	61.7	1.00	74.01	18.6	61.67	191.97	3.33	2.63
11.2	49.2	MB125	1700.0	18.6	82.0	1.50	65.61	15.02	82.01	183.50	5.00	4.86
15.1	59.0	MB150	1910.0	25.1	98.4	1.50	78.73	19.95	98.41	180.56	5.00	3.61
22.6	79.9	MB175	2500.0	37.7	133.2	2.00	79.91	27.42	133.18	165.12	6.67	6.61
34.6	89.8	MB200	3080.0	57.7	149.6	2.00	89.75	44.63	149.59	175.82	6.67	4.41
47.5	115.1	MB225	3970.0	79.2	191.9	2.50	92.11	59.25	191.90	170.12	8.33	6.81
63.5	135.8	MB250	4750.0	105.8	226.3	3.00	90.54	75.68	226.35	162.52	10.00	8.99
88.9	181.9	MB300	5860.0	148.1	303.1	3.50	103.92	99.82	303.11	153.16	11.67	11.29
121.3	223.2	MB350	6670.0	202.2	372.0	3.50	127.54	129.45	372.00	145.52	11.67	9.16
160.4	280.3	MB400	7840.0	267.3	467.1	4.00	140.14	150.41	467.13	127.88	13.33	11.39
209.1	333.0	MB450	9220.0	348.5	555.0	4.50	148.01	185.06	555.04	120.69	15.00	13.00
282.9	401.5	MB500	11100.0	471.5	669.2	5.00	160.61	252.12	669.20	121.52	16.67	14.46
369.8	485.0	MB550	13200.0	616.4	808.3	5.50	176.35	318.45	808.29	117.42	18.33	16.19
478.7	566.9	MB600	15600.0	797.9	944.8	6.00	188.95	411.76	944.75	117.29	20.00	17.37

Laterally supported beams						Laterally unsupported beams						
BM	SF	Section	area	Md	Vd	Length	UDL	Md	V	Fbd	Def	Max

												Def
5.62	37.00	MB100	1140	9.4	61.7	1.00	9.4	7.92	61.67	191.97	3.33	2.63
11.2	49.21	MB125	1700	18.6	82.0	1.00	18.6	16.68	82.01	203.80	3.33	1.44
						1.50	18.6	15.02	82.01	183.50	5.00	4.86
15.1	59.05	MB150	1910	25.1	98.4	1.00	25.1	22.49	98.41	203.58	3.33	1.07
						1.50	25.1	19.95	98.41	180.56	5.00	3.61
22.6	79.91	MB175	2500.0	37.7	133.2	1.00	37.7	34.52	133.18	207.87	3.33	0.83
						1.50	37.7	31.29	133.18	188.43	5.00	2.79
						2.00	37.7	27.42	133.18	165.12	6.67	6.61
34.6	89.75	MB200	3080	57.7	149.6	1.00	57.7	53.84	149.59	212.08	3.33	0.55
						1.50	57.7	49.75	149.59	195.99	5.00	1.86
						2.00	57.7	44.63	149.59	175.82	6.67	4.41
47.5	115.14	MB225	3970	79.2	191.9	1.00	79.2	75.11	191.90	215.65	3.33	0.44
						1.50	79.2	70.71	191.90	203.02	5.00	1.47
						2.00	79.2	65.38	191.90	187.71	6.67	3.49
						2.50	79.2	59.25	191.90	170.12	8.33	6.81
63.5	135.81	MB250	4750	105.8	226.3	1.00	105.8	101.62	226.35	218.21	3.33	0.33
						1.50	105.8	96.60	226.35	207.43	5.00	1.12
						2.00	105.8	90.58	226.35	194.49	6.67	2.66
						2.50	105.8	83.45	226.35	179.20	8.33	5.20
						3.00	105.8	75.68	226.35	162.52	10.00	8.99
88.9	181.87	MB300	5860	148.1	303.1	1.00	148.1	143.51	303.11	220.20	3.33	0.26
						1.50	148.1	137.31	303.11	210.68	5.00	0.89
						2.00	148.1	129.88	303.11	199.28	6.67	2.11
						2.50	148.1	120.88	303.11	185.47	8.33	4.12
						3.00	148.1	110.56	303.11	169.64	10.00	7.11
						3.50	148.1	99.82	303.11	153.16	11.67	11.29
121	223.20	MB350	6670	202.2	372.0	1.00	202.2	195.39	372.00	219.64	3.33	0.21
						1.50	202.2	186.39	372.00	209.52	5.00	0.72
						2.00	202.2	175.26	372.00	197.02	6.67	1.71
						2.50	202.2	161.46	372.00	181.50	8.33	3.34
						3.00	202.2	145.59	372.00	163.66	10.00	5.77
						3.50	202.2	129.45	372.00	145.52	11.67	9.16
160	280.28	MB400	7840	267.3	467.1	1.00	267.3	258.32	467.13	219.62	3.33	0.18
						1.50	267.3	246.36	467.13	209.46	5.00	0.60
						2.00	267.3	231.52	467.13	196.84	6.67	1.42
						2.50	267.3	213.02	467.13	181.11	8.33	2.78
						3.00	267.3	191.70	467.13	162.99	10.00	4.81
						3.50	267.3	170.07	467.13	144.60	11.67	7.63
						4.00	267.3	150.41	467.13	127.88	13.33	11.39
209	333.03	MB450	9220	348.5	555.0	1.00	348.5	338.74	555.04	220.91	3.33	0.14
						1.50	348.5	324.64	555.04	211.72	5.00	0.48
						2.00	348.5	307.48	555.04	200.52	6.67	1.14
						2.50	348.5	286.09	555.04	186.58	8.33	2.23
						3.00	348.5	260.72	555.04	170.03	10.00	3.85
						3.50	348.5	233.64	555.04	152.37	11.67	6.12
						4.00	348.5	207.82	555.04	135.53	13.33	9.13
						4.50	348.5	185.06	555.04	120.69	15.00	13.00

283	401.52	MB500	11100	471.5	669.2	1.00	471.5	463.15	669.20	223.24	3.33	0.12
						1.50	471.5	447.45	669.20	215.67	5.00	0.39
						2.00	471.5	429.04	669.20	206.80	6.67	0.93
						2.50	471.5	406.51	669.20	195.94	8.33	1.81
						3.00	471.5	378.96	669.20	182.66	10.00	3.12
						3.50	471.5	347.07	669.20	167.29	11.67	4.96
						4.00	471.5	313.41	669.20	151.07	13.33	7.40
						4.50	471.5	281.11	669.20	135.49	15.00	10.54
						5.00	471.5	252.12	669.20	121.52	16.67	14.46

Obtained result data for ISSC

Laterally supported beams						Laterally unsupported beams						
BM	SF	Section	area	Md	Vd	Length	UDL	Md	V	Fbd	Def	Max Def
13.6	47.2	SC100	2550.0	22.6	78.7	1.50	62.98	20.89	78.73	209.75	5.00	4.76
21.7	61.4	SC120	3340.0	36.2	102.3	1.50	81.88	33.91	102.35	212.64	5.00	3.21
32.5	77.2	SC140	4240.0	54.2	128.6	2.00	77.15	49.76	128.59	208.56	6.67	5.47
46.6	100.8	SC160	5340.0	77.7	168.0	2.00	100.77	72.13	167.96	211.10	6.67	4.34
63.7	120.5	SC180	6440.0	106.2	200.8	2.50	96.37	97.10	200.76	207.74	8.33	6.55
84.5	141.7	SC200	7680.0	140.9	236.2	3.00	94.48	126.85	236.19	204.58	10.00	9.01
109.4	164.5	SC220	8980.0	182.3	274.2	3.50	94.03	161.95	274.24	201.92	11.67	11.66
150.9	196.8	SC250	10900.0	251.6	328.0	4.00	98.41	221.27	328.04	199.90	13.33	13.12

Laterally supported beams						Laterally unsupported beams						
BM	SF	Section	area	Md	Vd	Length	UDL	Md	V	Fbd	Def	Max Def
13.6	47.24	SC100	2550	22.6	78.7	1.00	94.48	21.68	78.73	217.71	3.33	1.41
						1.50	62.98	20.89	78.73	209.75	5.00	4.76
21.7	61.4	SC120	3340.0	36.2	102.3	1.00	122.82	35.09	102.35	220.04	3.33	0.95
						1.50	81.88	33.91	102.35	212.64	5.00	3.21
32.5	77.15	SC140	4240	54.2	129	1.00	154.31	52.97	128.59	222.00	3.33	0.68
						1.50	102.87	51.35	128.59	215.21	5.00	2.31
						2.00	77.15	49.76	128.59	208.56	6.67	5.47
46.6	100.8	SC160	5340	77.7	168	1.00	201.55	76.36	167.96	223.50	3.33	0.54
						1.50	134.37	74.23	167.96	217.25	5.00	1.83
						2.00	100.77	72.13	167.96	211.10	6.67	4.34
63.7	120.5	SC180	6440	106	201	1.00	240.91	105.10	200.76	224.85	3.33	0.42
						1.50	160.61	102.42	200.76	219.12	5.00	1.42
						2.00	120.46	99.78	200.76	213.46	6.67	3.35
						2.50	96.37	97.10	200.76	207.74	8.33	6.55
84.5	141.7	SC200	7680	141	236	1.00	283.43	140.06	236.19	225.89	3.33	0.33
						1.50	188.95	136.77	236.19	220.59	5.00	1.13
						2.00	141.71	133.52	236.19	215.34	6.67	2.67
						2.50	113.37	130.23	236.19	210.03	8.33	5.21
						3.00	94.48	126.85	236.19	204.58	10.00	9.01
109	164.5	SC220	8980	182	274	1.00	329.09	181.91	274.24	226.82	3.33	0.27
						1.50	219.39	177.99	274.24	221.93	5.00	0.92
						2.00	164.54	174.10	274.24	217.08	6.67	2.18
						2.50	131.64	170.16	274.24	212.17	8.33	4.25
						3.00	109.70	166.13	274.24	207.13	10.00	7.34
						3.50	94.03	161.95	274.24	201.92	11.67	11.66
151	196.8	SC250	10900	252	328	1.00	393.65	252.19	328.04	227.84	3.33	0.21
						1.50	262.43	247.25	328.04	223.38	5.00	0.69

						2.00	196.82	242.33	328.04	218.93	6.67	1.64
						2.50	157.46	237.33	328.04	214.41	8.33	3.20
						3.00	131.22	232.19	328.04	209.77	10.00	5.54
						3.50	112.47	226.84	328.04	204.94	11.67	8.79
						4.00	98.41	221.27	328.04	199.90	13.33	13.12

Obtained result data for ISWB

Laterally supported beams						Laterally unsupported beams						
BM	SF	Section	area	Md	Vd	Length	UDL	Md	V	Fbd	Def	Max Def
17.3	63.8	WB150	2170.0	28.8	106.3	1.50	85.03	25.02	106.28	197.26	5.00	3.34
26.5	79.9	WB175	2810.0	44.1	133.2	2.00	79.91	37.22	133.18	191.64	6.67	5.51
40.1	96.1	WB200	3670.0	66.8	160.1	2.50	76.84	54.73	160.08	186.16	8.33	7.46
53.2	113.4	WB225	4320.0	88.6	189.0	2.50	90.70	74.38	188.95	190.75	8.33	5.88
71.9	131.9	WB250	5200.0	119.9	219.8	3.00	87.91	101.14	219.79	191.70	10.00	7.80
99.7	174.8	WB300	6130.0	166.2	291.3	3.50	99.87	130.47	291.30	178.43	11.67	9.94
135.7	220.4	WB350	7250.0	226.2	367.4	4.00	110.22	164.12	367.40	164.86	13.33	11.85
175.9	270.8	WB400	8500.0	293.2	451.4	4.50	120.37	196.90	451.38	152.62	15.00	13.73
240.1	325.9	WB450	10100.0	400.1	543.2	5.00	130.38	246.93	543.23	140.25	16.67	15.11
320.6	389.7	WB500	12100.0	534.4	649.5	5.50	141.71	350.38	649.52	149.01	18.33	16.14
418.1	454.7	WB550	14300.0	696.9	757.8	6.00	151.55	436.66	757.77	142.41	20.00	17.07
592.0	557.4	WB600	18500.0	986.7	929.0	7.00	159.26	584.46	929.01	134.62	23.33	21.46

Laterally supported beams						Laterally unsupported beams						
BM	SF	Section	area	Md	Vd	Length	UDL	Md	V	Fbd	Def	Max Def
17.3	63.77	WB150	2170	28.8	106	1.00	127.54	26.98	106.28	212.71	3.33	0.99
						1.50	85.03	25.02	106.28	197.26	5.00	3.34
26.5	79.91	WB175	2810	44.1	133	1.00	159.82	42.26	133.18	217.59	3.33	0.69
						1.50	106.55	40.01	133.18	206.02	5.00	2.33
						2.00	79.91	37.22	133.18	191.64	6.67	5.51
40.1	96.05	WB200	3670	66.8	160	1.00	192.10	64.74	160.08	220.22	3.33	0.48
						1.50	128.07	61.97	160.08	210.80	5.00	1.61
						2.00	96.05	58.68	160.08	199.60	6.67	3.82
						2.5	76.84	54.73	160.1	186.2	8.33	7.45857
53.2	113.4	WB225	4320.0	88.6	189.0	1.00	226.74	86.35	188.95	221.44	3.33	0.38
						1.50	151.16	83.00	188.95	212.85	5.00	1.27
						2.00	113.37	79.08	188.95	202.80	6.67	3.01
						2.50	90.70	74.38	188.95	190.75	8.33	5.88
71.9	131.9	WB250	5200.0	119.9	219.8	1.00	263.74	118.52	219.79	224.66	3.33	0.29
						1.50	175.83	115.05	219.79	218.08	5.00	0.98
						2.00	131.87	111.15	219.79	210.69	6.67	2.31
						2.50	105.50	106.58	219.79	202.02	8.33	4.52
						3.00	87.91	101.14	219.79	191.70	10.00	7.80
99.7	174.8	WB300	6130	166	291	1.00	349.56	164.27	291.30	224.65	3.33	0.23
						1.50	233.04	159.43	291.30	218.04	5.00	0.78
						2.00	174.78	153.96	291.30	210.55	6.67	1.85
						2.50	139.82	147.48	291.30	201.69	8.33	3.62
						3.00	116.52	139.67	291.30	191.02	10.00	6.26
						3.50	99.87	130.47	291.30	178.43	11.67	9.94
136	220.4	WB350	7250	226	367	1.00	440.89	223.77	367.40	224.78	3.33	0.19
						1.50	293.92	217.26	367.40	218.24	5.00	0.62
						2.00	220.44	209.89	367.40	210.84	6.67	1.48
						2.50	176.35	201.15	367.40	202.07	8.33	2.89

						3.00	146.96	190.62	367.40	191.48	10.00	5.00
						3.50	125.97	178.13	367.40	178.93	11.67	7.94
						4.00	110.22	164.12	367.40	164.86	13.33	11.85
176	270.8	WB400	8500	293	451	1.00	541.66	290.30	451.38	225.02	3.33	0.15
						1.50	361.11	282.06	451.38	218.63	5.00	0.51
						2.00	270.83	272.77	451.38	211.43	6.67	1.21
						2.50	216.66	261.83	451.38	202.95	8.33	2.35
						3.00	180.55	248.67	451.38	192.75	10.00	4.07
						3.50	154.76	233.05	451.38	180.64	11.67	6.46
						4.00	135.41	215.40	451.38	166.96	13.33	9.64
						4.50	120.37	196.90	451.38	152.62	15.00	13.73
240.1	325.9	WB450	10100.0	400.1	543.2	1.00	651.88	396.30	543.23	225.10	3.33	0.12
						1.50	434.59	385.15	543.23	218.76	5.00	0.41
						2.00	325.94	372.64	543.23	211.66	6.67	0.97
						2.50	260.75	357.95	543.23	203.31	8.33	1.89
						3.00	217.29	340.35	543.23	193.32	10.00	3.26
						3.50	186.25	319.51	543.23	181.48	11.67	5.18
						4.00	162.97	295.95	543.23	168.10	13.33	7.74
						4.50	144.86	271.17	543.23	154.02	15.00	11.02
						5.00	130.38	246.93	543.23	140.25	16.67	15.11
320.6	389.7	WB500	12100.0	534.4	649.5	1.00	779.42	534.17	649.52	227.18	3.33	0.10
						1.50	519.62	522.18	649.52	222.08	5.00	0.33
						2.00	389.71	509.24	649.52	216.57	6.67	0.78
						2.50	311.77	494.69	649.52	210.39	8.33	1.52
						3.00	259.81	477.83	649.52	203.22	10.00	2.62
						3.50	222.69	457.99	649.52	194.78	11.67	4.16
						4.00	194.86	434.76	649.52	184.90	13.33	6.21
						4.50	173.21	408.33	649.52	173.66	15.00	8.84
						5.00	155.88	379.68	649.52	161.47	16.67	12.13
						5.50	141.71	350.38	649.52	149.01	18.33	16.14
418.1	454.7	WB550	14300.0	696.9	757.8	1.00	909.33	697.37	757.77	227.43	3.33	0.08
						1.50	606.22	682.22	757.77	222.49	5.00	0.27
						2.00	454.66	665.99	757.77	217.20	6.67	0.63
						2.50	363.73	647.92	757.77	211.30	8.33	1.23
						3.00	303.11	627.22	757.77	204.55	10.00	2.13
						3.50	259.81	603.12	757.77	196.69	11.67	3.39
						4.00	227.33	575.10	757.77	187.55	13.33	5.06
						4.50	202.07	543.22	757.77	177.16	15.00	7.20
						5.00	181.87	508.39	757.77	165.80	16.67	9.88
						5.50	165.33	472.26	757.77	154.02	18.33	13.15
						6.00	151.55	436.66	757.77	142.41	20.00	17.07
592.0	557.4	WB600	18500.0	986.7	929.0	1.00	1114.81	989.15	929.01	227.83	3.33	0.06
						1.50	743.21	968.80	929.01	223.14	5.00	0.21
						2.00	557.41	947.36	929.01	218.20	6.67	0.50
						2.50	445.92	924.00	929.01	212.82	8.33	0.98
						3.00	371.60	897.91	929.01	206.81	10.00	1.69
						3.50	318.52	868.35	929.01	200.00	11.67	2.68
						4.00	278.70	834.75	929.01	192.27	13.33	4.00
						4.50	247.74	797.04	929.01	183.58	15.00	5.70
						5.00	222.96	755.79	929.01	174.08	16.67	7.82
						5.50	202.69	712.29	929.01	164.06	18.33	10.41
						6.00	185.80	668.21	929.01	153.91	20.00	13.51
						6.50	171.51	625.19	929.01	144.00	21.67	17.18
						7.00	159.26	584.46	929.01	134.62	23.33	21.46