Project Part- B Report

On

COMPARATIVE STUDY ON WELDED I BEAM AND HOT ROLLED STEEL BEAM

Submitted in partial fulfilment of the requirements

For the degree of

BACHELOR OF ENGINEERING

In

CIVIL ENGINEERING

BY

Mr. Chaudary Riyaz Ahmed (13CES14)

Mr. Mohd Ariz Ahmed Shakeel (13CES32)

Mr. Qureshi Fauwaz Javed (13CES40)

Under the guidance of

Prof. Hawelikar S. C.
(Asst.Professor AIKTC,Panvel)

Department of Civil engineering

Anjuman-I-Islam's Kalsekar Technical Campus

Thana Naka , Khandagaon, New Mumbai 410206,

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University of Mumbai

CERTIFICATE

This is to certify that **Mr. Chaudary Riyaz Ahmad (13CES14), Mr. Mohd Ariz Ahmed Shakeel (13CES32), Mr. Qureshi Fauwaz Javed (13CES40)** has satisfactorily completed and delivered a project-B seminar report entitled **,"Comparative study on Welded I beam and Hot Rolled steel beam "** in partial fulfilment for the completion of the **B.E**. in **Civil Engineering** course conducted by the Mumbai in Anjuman-I-Islam's Kalsekar Technical Campus,New Panvel,Navi Mumbai ,during the academic year 2017-18.

(Prof. Hawelikar S. C.)
(Guide)

(Dr. R. B. Magar)
Professor and Head

(Dr. Abdul Razak Honnutagi)
Director

Approval for B.E Project Part-B

This B. E. Project Part-B entitled "**Comparitive study on Welded I Beam and Hot-Rolled Steel Beam"** by Mr. Chaudary Riyaz Ahmad (13CES14), Mr. Mohd Ariz Ahmed Shakeel (13CES32) and Mr. Qureshi Fauwaz Javed, (13CES40) is approved for the **Bachelor of Engineering in Civil Engineering**

Examiners

1. …………………………

2. …………………………

Date:

Place: New Panvel

Declaration

We hereby declare that this written submission entitled **"Comparative Analysis of Welded I beam And Hot rolled steel beam,"** represents my idea in my own words and where other 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 data/fact in my submission. I understand that any violation of the above will be cause for disciplinary action by the institute and can also penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Place: New panvel

Date:

Mr. Chaudhary RiyazAhmed

Mr. Mohd Ariz Ahmed Shakeel

Mr. Qureshi Fauwaz Javed

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We take this opportunity to thank all our professors and Non-teaching staff who have directly or indirectly helped our project ,we pay our respects and love to our parents and all other family members for their love and encouragement throughout our career. Last but not the least we express our thanks to our friends for their cooperation and support.

Mr. ChaudaryRiyaz Ahmad

Mr.Mohd Ariz Ahmed Shakeel

Mr. Qureshi Fauwaz Javed

(Semester-VIII, B,E. Civil)

AIKTC – New Panvel, Navi Mumbai.

Abstract

Steel, as a building, material, has been used extensively in various types of structures. Some of the examples of civil engineering works in steel are high-rise building skeletons, industrial buildings, transmission towers, railway bridges, overhead tanks, chimneys (stacks), bunkers and silos. Steel Beams are widely used in steel construction for relatively all beams. Steel beams are often used in steel buildings and providing economical solutions in cases of large and heavy loads or in other words steel beams varies in its length under various loading conditions. The usual method of selecting a beam is based upon section modulus. Since these sections often shows that the web resists shear forces, while the flanges resist most of the bending moment experienced by the beam. Beam theory shows that the I-shaped section is a very efficient form for carrying both bending and shear loads in the plane of the web. The only real difference between welded and hot rolled beam design is that, since the designer has greater control over the dimensions of the section and may make the web thinner in proportion to its depth than in any of the rolled shapes, web buckling may be of greater concern. Mainly while considering designing of both beams the design procedure is different and it's observed that the selection of the beams depends upon the intensity of loads, length of the beams and economy.

As per structure requirement as engineer we have to select any one of these two i.e. either welded or hot rolled beams. So our aim is narrowed towards the study of behaviour of these two beams on various combinations of loading and length and accordingly the cost of the beams on stability criterion as per IS 800:2007. Also we will try to predict length of beams on the basis of amount of loading and for that purpose we will generate equations which can help designer and engineer to select a suitable beam.

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List of Abbrevations

Sr. No.	Designation	Name of parameter	SI Unit
1.	A	Area of cross section	mm^2
2.	A_e	Total area of section	mm^2
3.	A_g	Gross area of section	mm^2
4.	b	Width of flat	mm
5.	b_f	Width of flange	mm
6.	b_w	Width of web	mm
7.	d	Diameter of bolt	mm
8.	d_0	Diameter of hole	mm
9	f_{cd}	Compressive stress	N/mm^2
10.	P	Working load	KN
11.	$P_{dprovided}$	Designed load	KN
12.	$P_{drequired}$	Factored load	KN
13.	t	Thickness of flat	mm
14.	t_f	Thickness of flange	mm
15.	t_w	Thickness of web	mm
16.	γm_0	Partial safety factor for yielding bolt	-
17.	γmb	Partial safety factor for bearing bolt	-
18.	λ	Slenderness ratio	-
19.	λ_e	Effective slenderness ratio	-
20.	vd	Shear strength	N/mm^2
21.	δ	Max deflection	mm
22.	f_{yw}	Yield stress of web	N/mm^2

23.	Zp	Plastic sectional moduli	-
24.	f_{bd}	Design bending compressive stress	N/mm^2
25.	X_{lt}	Bending stress reduction factor	-
26.	α	Imperfection parameter	-
27.	F_{crb}	Extreme fibre bending compressive stress	Mpa
28.	ζ_{cr}	Elastic critical shear stress	N/mm^2

Chapter 1

Introduction

1.1 General

A structural member subjected to transverse loads (loads perpendicular to its longitudinal axis) is called a beam. A beam may, in general, be subjected to either simple, unsymmetrical, or bi-axial bending. For simple bending to occur, the loading plane must coincide with one of the principal planes of doubly symmetric section (I-section) and for singly symmetric section (a channel section) it must pass through the shear centre the bending is called unsymmetrical. Here, the bending is coupled with torsion. Bi-axial bending is characterized by the simple bending (with no torsion) occurring about both the principal planes.

Furthermore, it is assumed that the beam is acted on only by transverse loading and that all the loads and sections lie in the plane of symmetry. It follows that such a beam will primarily be subjected to bending accompanied by shear in the loading plane, with no external torsion and axial force. However, the problem of torsion is not completely avoided for a beam of structural shape, even if the beam shape is symmetrical and the loads are in the plane of symmetry. It is because instability caused by compressive stresses. This instability is characterized as lateral buckling when it is of general nature involving the entire span, or as local buckling, involving only he local components (i.e, compression flange or compression part of the web) of a beam.

The instability caused by lateral buckling involving the entire span can be prevented by providing lateral or torsional bracing. Beams for which this type of instability can be checked are classed as laterally restrained beams, and if cannot are called laterally unrestrained beams. Local buckling of compression elements of a beam, if occurs, causes a loss of integrity of the beam cross section. However, local buckling is generally a function of the width-to-thickness ratio of the beam components and can be controlled by following the limits specified by the codes

Beams are supposed to be the most critical members in any structure. Their design should therefore not only be economical but also safe. The main considerations in the design of beams are the following:

1. They should be proportioned for strength in bending keeping in view the lateral and local stability of the compression flange and the capacity of the selected shape to develop the necessary strength in shear and local bearing.
2. They should be proportioned for stiffness, keeping in mind their deflections and deformations under service conditions.

They should be proportioned for economy, paying attention to the size and grade of steel to yield the most economical design..It is a difficult task for a designer to select a beam size for a given span and load that will satisfy all the above three conditions. In its simplest form, beam design consists merely of the provision of adequate bending and shear resistance.

The design and structure of the I beam makes it uniquely capable of handling a variety of loads.

The shape and structure of the I beam:-

The I beam consists of two horizontal planes,known as flanges, connected by one vertical component, or the web. The shape of the flanges and the web creates an “I” or an “H” cross-section. Most I beams use structural steel, but some are made from aluminium.

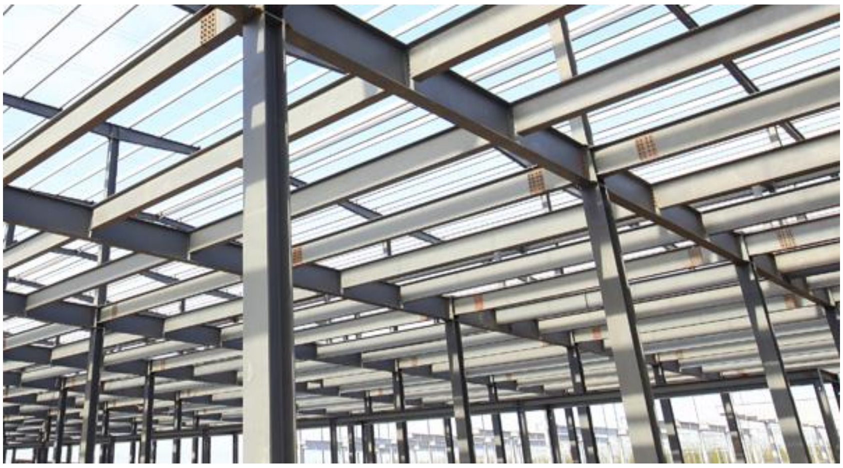


Fig 1.1 Steel Structure

1.2 Why are I beams used in structural steel construction ?

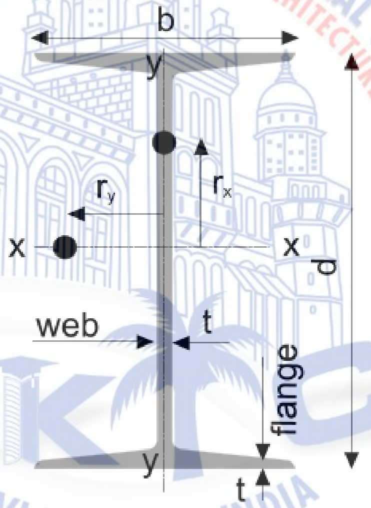


Fig 1.2 Typical I beam

I beams come in a variety of weights, section depths, flange widths, web thicknesses, and other specifications for different purposes. When ordering I beams, buyers classify them by their material and dimensions. For example, an 11x20 I beam would have an 11-inch depth and a weight of 20 pounds per foot. Builders choose specific sizes of I beams according to the needs of the particular building. A builder has to take many factors into account, such as:

1. **Deflection.** The builder will choose a thickness to minimize deformation of the beam.
2. **Vibration.** A certain mass and stiffness are selected to prevent vibrations in the building.
3. **Bend.** The strength of the I beam's cross-section should accommodate yield stress.
4. **Buckling.** The flanges are chosen to prevent buckling locally, sideways, or torsionally.
5. **Tension.** The builder chooses an I beam with a web thickness that won't fail, buckle, or ripple under tension.

The design of the I beam makes it capable of bending under high stress instead of buckling. To achieve this, most of the material in the I beam is located in the regions along the axial fibers – the location that experiences the most stress. Ideal beams have minimal cross-section area, requiring the least amount of material possible while still achieving the desired shape.

Uses of I Beams

I beams have a variety of important uses in the structural steel construction industry. They are often used as critical support trusses, or the main framework, in buildings. Steel I beams ensure a structure's integrity with relentless strength and support. The immense power of I beams reduces the need to include numerous support structures, saving time and money, as well as making the structure more stable. The versatility and dependability of I beams make them a coveted resource to every builder.

I beams are the choice shape for structural steel builds because of their high functionality. The shape of I beams makes them excellent for unidirectional bending parallel to the web. The horizontal flanges resist the bending movement, while the web resists the shear stress. They can take various types of loads and shear stresses without buckling. They are also cost effective, since the "I" shape is an economic design that doesn't use excess steel. With a wide variety of I beam types, there is a shape and weight for virtually any requirement.

Types of Steel Beams

1. Welded I beam
2. Hot-Rolled I beam

1.3 Welded I Beam

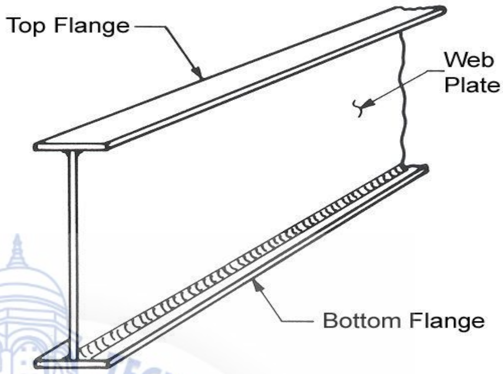


Fig 1.3 Welded Beam

Welded I beam are built-up flexural members. It can be built to any desired proportions to suit the particular requirements, and of a cross section with exactly the properties needed. For light loads and short spans (<10 m) welded I beam are uneconomical due to increase in the connection cost and rolled I sections are preferred. Their bending resistance can be increased by increasing the distance between the flanges. This in turn also increases the shear resistance as the web area increases. Plate girders or welded I beam are primarily provided in bridges but are also very common in buildings where heavy concentrated loads act on a long span beam, e.g a dining hall floor beam of a restaurant requiring a clear space all through.

Welded plate girders may be used up to 100m.It is economical as compared to the riveted/bolted plate girder because of the considerable reduction in its self-weight. It should be evident that the welded plate girder is far superior to the riveted or bolted girder in terms of simplicity and efficiency. The normal practice nowadays is to use welded plate girders because of the advancements in welding techniques. Also, the designer feels freer to proportion the welded plate girders with varying depths.

The design of a welded I beam is essentially an exercise in ordinary beam design; the proportioning of a member with a section modulus adequate to resist bending, a web capable of resisting shear in the normal fashion, and sufficient stiffness.

The only real difference between it and the design of a rolled beam is that, since the designer has greater control over the dimensions of the section and may make the web thinner in proportion to its depth than in any of the rolled shapes, web buckling may be of great concern. The designer has the choice of either making the web thick enough by itself to avoid premature buckling and this often defeats the purpose of plate girder construction or placing intermediate stiffeners along its length and thus, by dividing it into smaller panels and reducing the plate span, increasing the web buckling resistance.

When a plate girder is used, however the designer must account for factors that in many cases would not be a problem with a hot-rolled shape. Most of the flexural strength in plate girders is furnished by flanges. The limit states considered are yielding of tension flange and buckling of compression flange in the form of vertical buckling into the web or flange local buckling. Flange buckling can also be caused due to lateral torsional buckling. Since the flange provides most of the flexural strength, most of the steel must be concentrated in flanges and as far as possible away from the neutral axis of the girder which consequently result in deep, thin web. Such slender webs account for many of the special problems associated with plate girders, including local instability. The thin webs have a possibility of buckling before yielding. The three principal types of buckling to be considered are; shear or diagonal buckling, bending or longitudinal buckling, and bearing or vertical buckling. A thorough understanding of the basis of the IS: 800 provisions for plate girders requires a background in stability theory, particularly plate stability.

1.4 Hot Rolled Steel Beam

Fig 1.4 Hot Rolled Steel beam

In this manufacturing process of hot rolled beams which takes place in a rolling mill, molten steel is taken from the furnace and poured into a continuous casting system where the steel solidifies but is never allowed to cool completely. The hot steel passes through a series of roller that squeeze the material into the desired cross-sectional shapes. Rolling the steel while it is hot allows it to be deformed without any loss of ductility. While cooling, the variation in the cooling rates for the different thicknesses of various elements of the rolled section, residual stresses are introduced which may be removed by subsequent strengthening processes. During the rolling process, the member increases in length and is cut to standard lengths, which are subsequently cut (in fabricating shop) to the length required for particular structure.

Its Design Types:-

A) Laterally Supported Beam

When a beam is in bending, there is a tendency for the top flange, which is in compression, to pull the section out- of- plane and cause buckling. In order to prevent this and allow the section to achieve is full moment capacity it is important that the compression flange is restrained so that only vertical movement of the beam is allowed such beams are called as laterally supported beams..

B) Laterally Unsupported Beam

If a point load is acting on the beam, then it will exhibit laterally torsion buckling and therefore such beam will be called laterally unsupported beam. This type of beam will fail by yielding if it is short, elastic buckling if it is long or by inelastic lateral buckling if it is of intermediate length. Such beams are stocky and are capable of attaining full plastic moment without buckling

1.5 Modes of failure of beams:-

1) Bending Failure

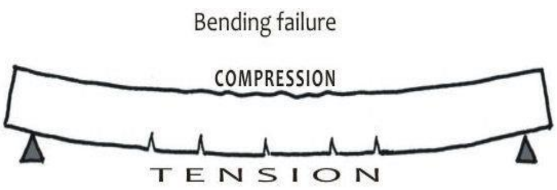


Fig 1.5 Bending failure of beam

2) Lateral Torsional Buckling.

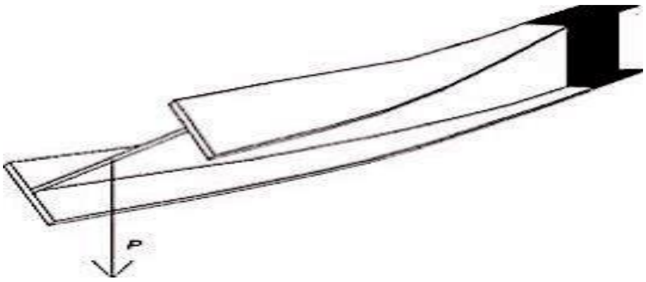


Fig 1.6 Torsional Failure

3) Shear Failure.

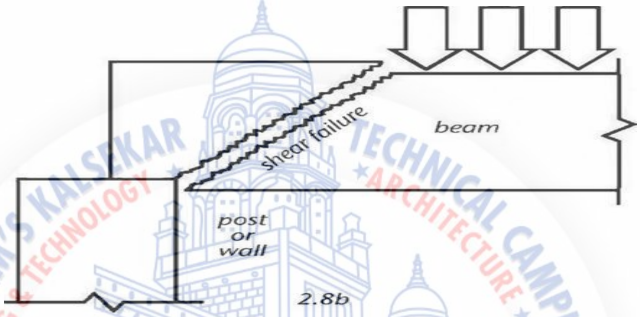
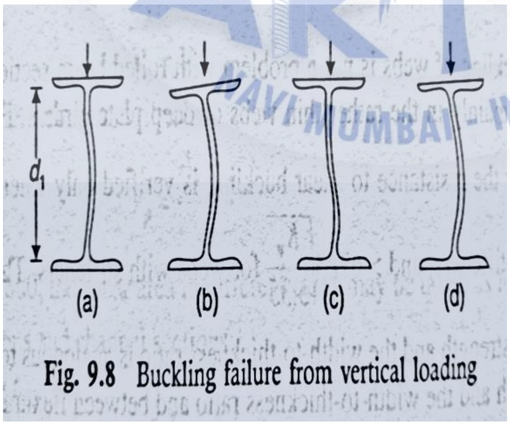


Fig 1.7 Shear failure of beam

4) Web Buckling and Web Crippling



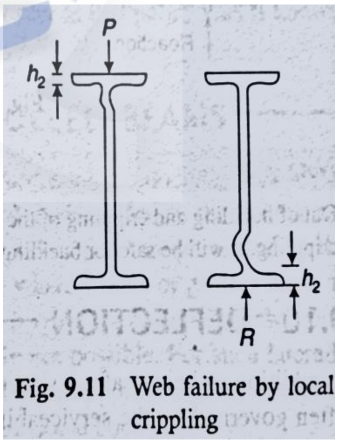


Fig 1.8 Web buckling failure

Fig 1.9 Web crippling failure

Chapter 2

Literature Review

The authors Sritawat Kitipornchai, Alain D.Wong-Chung (1987) stated that The inelastic buckling of welded mono symmetric I-beams under uniform moment has been investigated. The assumed welding residual stress is based on the so-called "tendon force concept" developed by the Cambridge group. A simple method of determining the inelastic buckling moment for welded mono symmetric I-beams is proposed.

The author presented that the inelastic buckling of a beam is governed primarily by the stiffness of the compression flange. Theoretical results indicate that a welded beam buckles in elastically when the regions of compressive residual stress in the compression flange become fully yielded. The remaining elastic core in the tensile stress block contributes little to beam stability

The authors S. Bild, et al. (1992) proposed a general finite element method of analysing the nonlinear effects of instability and yielding on the biaxial bending and torsion of steel I-section members with residual stresses and geometrical imperfections is presented. The analysis assumes tangent modulus behaviour of the elastic-plastic strain-hardening material, and makes simple approximations for the effects of shear on yielding and for the shear modulus of the yielded and strain-hardened material. The results obtained from a computer program based on the element are compared with a wide range of available solutions to confirm the high accuracy of the method in predicting the effects of geometrical imperfections, instability, biaxial bending and torsion, residual stresses, and yielding and strain hardening.

The author developed a method that has been verified by demonstrating close agreement between the results predicted by a computer program based on the method and the solutions of a range of elastic and inelastic problems. These include the elastic in-plane bending of a crooked column and of tension and compression members with end moments, the twisting of a compression member with end moments, the out-of-plane twisting of an eccentrically loaded beam, and the biaxial bending and twisting of beams with initial crookedness and twist or transverse loads and torque.

The authors Todd A Helwig,Karl H.Frank et al (1997) demonstrated on Finite-element buckling analyses of singly symmetric I-shaped girders subjected to transverse loading applied at different heights on the cross section were conducted. Moment gradient factors based on the finite-element results were calculated and compared with traditional values used to predict the buckling capacity of I-shaped doubly symmetric sections. The results from the computational study show that, for many cases, traditional moment gradient factors can be used for singly symmetric girders if effects of load height are measured relative to mid height of the cross section. The author observed that the finite-element results demonstrated that the height of load application on the cross section has a significant effect on the buckling capacity

The author M.A Bradford (1998) investigated an I-section beams may be restrained continuously along one flange. Two common applications of this are in composite tee-beams where buckling may occur in the hogging region, and half through girder bridges consisting of two parallel I-section beams connected by a deck at the bottom flange level. In these applications, the compression flange is restrained only by the stiffness of the web, and the buckling mode is generally lateral-distortional The paper uses an energy method of analysis to study the inelastic buckling of beams continuously and elastically restrained at the tension flange level, being typical of half-through girders.

The author presented an energy method of the inelastic buckling of I-beams that has been described, and augmented to include the effects of continuous twist restraint on the buckling of I beams with tension flange restraint when loaded in uniform bending. This behavior is related more to local buckling than to lateral-torsional buckling. The U-frame model often used in bridge design was described, and it was shown that this model is conservative, particularly so when the torsional restraint applied at the bottom flange level is small. The slight conservatism for high values of torsional restraint, approaching a rigid deck in a half-through girder application, is desirable as the strength curve in the AS4100 standard upon which the failure moment is calculated allows for the effects of geometric nonlinearity, as well as the material nonlinearities considered in the present study

The author Michael C. H. Yam, Angus C.C. Lam et al (2003) stated that beam flange is coped to allow clearance at the connection, the strength of the coped region will be reduced. Local web buckling at the coped region may occur when the cope length is long and/or the compression flange is braced. Experimental and analytical investigation of the strength of coped steel I beams were conducted by a number of researchers and design formula was also proposed.

The author derived that Local web buckling behaviour of the coped I beam was investigated both experimentally and analytically. In the experimental program, four full-scale tests on the local web buckling strength of coped steel I beams were carried out. The test results were compared with the predictions proposed by Cheng et al. 1984. It was found the Cheng et al. equation gave a very conservative prediction, especially

The authors Maurice Loong-Hon Ng and Hamid Reza Ronagh (2004) discussed about Lateral-distortional buckling may occur in I-section beams with slender webs and stocky flanges. A computationally efficient method is presented in this paper to study this phenomenon. Beams of different cross-sectional dimensions, load cases and restraint conditions are examined and compared. The accuracy and versatility of the method are verified by calibrating against the results of other published studies. The present method is believed to be a simple and efficient way of determining the buckling load and mode shapes of I-section beams that are susceptible to lateral-distortional buckling modes.

The authors concluded that when beams of different cross-sectional dimensions, load cases and restraint conditions are examined and compared. The accuracy and versatility of the method are verified by calibrating against the results of other published studies. The present method is believed to be a simple and efficient way of determining the buckling load and mode shapes of I-section beams that are susceptible to lateral-distortional buckling modes. The model can be used to analyse the distortional buckling of simply supported I-beams that are subjected to any type of loading either being at the shear centre, or at the level of top flange. The beams may also possess any type of continuous restraints.

The author Kuan-Chen Fu et al (2005) stated that the genetic algorithm is a general optimization technique that has some unique features that are especially suitable for structural engineering problems. This work uses a simple GA with elitism to find the optimum design of welded steel plate girder bridges. The objectives are to minimize the weight and the cost of the girders. Two types of plate-girder bridges are studied: a single-span bridge and a two-equal-span continuous bridge. Bridges with various span lengths, in increments of 20 ft, are investigated; results are tabulated, parametric studies are made, and meaningful conclusions are drawn.

The author proposed that a modified GA has been successfully applied to the design of welded plate-girder bridges. Three special features made it suitable for structural optimization: First, the GA can handle discrete variables with ease, which is very important in structural design since standardized steel products vary discretely, not continuously

The author AkhrawatLenwari, Thaksin Thepchatri et al (2005) stated that the flexural behaviour of rolled steel beams that were strengthened with partial-length, adhesive-bonded carbon fibre-reinforced polymer CFRP plates. The hybrid beams had two types of failure mode, depending on the length of the plate: 1) plate de bonding in beams with short plates; and 2) plate rupture at mid span in beams with long plates. The flexural behaviour that was investigated includes the development of tensile stresses in the plate, the moment-curvature of the strengthened section, and the load deflection of the strengthened beam. The analytical methods used include shear lag analysis, section analysis, and application of the virtual work principle. Agreement between the experimental results and the analytical predictions is discussed.

The author discussed that Adhesive bonding of the CFRP plate significantly increased the strength of the strengthened steel beams and extended the range of the elastic region of the beams. This paper presents the analytical methods to evaluate important flexural behaviours of the strengthened beams. The main conclusions are as follows: 1. The hybrid beams had two types of failure modes: a) Plate debonding; and b) plate rupture at mid span. As the plate length increased, the failure load increased until the failure mode changed. 2. The use of a modified shear lag analysis for predicting the distance that the bonded plate requires to achieve flexural conformance develop a composite action seems to be reasonable. 3. The failure load in the case of the plate rupture can be conservatively predicted by the section analysis.

The authors Z.kala, J.kala (2005) proposed the effect of the initial geometric and material imperfections on the load-carrying capacity of bending stressed beams made of an IPE profile solved including the lateral buckling effect is studied by means of sensitivity analysis. Several variants of beams with different degrees of slenderness are solved. Members are modelled, assuming a thin walled effect. Imperfections are considered to be random quantities. The histograms of the main quantities were determined experimentally. Random quantities which were not measured were taken over from specialized literature. For taking the variability of input quantities into consideration, the numerical simulation method (a method of the Monte Carlo type) has been used. The random load-carrying capacity is, in each simulation method run, solved by a geometrically and materially nonlinear FEM solution.

The author insisted that the sensitivity coefficient of the flange thickness, is more important than the sensitivity coefficient of the flange width, as its relative change has a more significant effect on the flange area affecting the stability resistance of a slender beam under bending.

The authors Rupen Goswami, et al. (2005) stated that steel hot rolled I-sections have been in use in construction since long in India. With advancement of technology to build moment resisting frames (MRFs) to resist seismic actions, a review of the existing available sections is required to assess their applicability. This paper reiterates the important aspects of the seismic design philosophy and investigates the available sections in light of the same. The sectional properties (strength and stability) are studied in light of the different code requirements for desired performance under strong seismic conditions. Indian hot-rolled I-sections (tapered and parallel flanges) are found inadequate for use in tall structures in high seismic regions.

The authors concluded that there is an urgent need to manufacture hot-rolled structural steel sections with higher plastic moment capacity. In the manufacture of the hot-rolled sections, tapered sections may be discontinued and parallel flange sections with higher plastic moment capacity may be developed. Until such time these sections become commonly available, the professional practice will require to design and construct based on built-up sections. However, built-up sections for use in severe seismic zones require special weld electrodes and processes; this aspect also requires to be developed in India. To facilitate building of tall structures, both these aspects, namely sections and welding technology require significant reconsideration. In closing, the Indian steel industry needs to research on both these aspects immediately.

The authors Tadeh Zirakian and Hossein Showkati (2007) described a test program on full-scale fabricated simply supported I-beams with central concentrated load and an effective lateral brace at the mid span of the top compression flange that was performed mainly with the aim of experimental verification and investigation of distortion in doubly symmetric I-section beams.

The authors presented result of experimental investigation of distortion of the top compression flange in a typical test beam, it was found that despite the relatively large amounts of strains developed in the flange, flange distortion was small in comparison with that of the web that was comparatively slender.

The author Chris Sundberg (2008) stated that Welded steel wye branches are a key component of most water projects where flows must be divided. They are also a specialty item that requires many engineering considerations. This paper will address several areas of wye branch fabrication that are not well covered by other sources including steel selection, geometry, welding, heat treatment, and non-destructive testing. Welding code provisions can be a valuable resource and their contribution to steel wye branch fabrication will be explored.

The author discussed that the Fabrication of wye branches requires a high degree of skill on the part of the fabricator to complete the design and to make it function reliably as a safe, integral part of a conveyance system as intended by the designer. The tools presented in this paper are intended to make both the designer and fabricator's job easier for proper steel selection, geometry, welding, heat treatment, and non-destructive testing. Welding code provisions are a valuable resource and their contribution to steel wye branch fabrication has been demonstrated.

The authors Fatimah denan et al. (2010) conducted Experimental and numerical study on lateral torsional buckling behavior of steel section with trapezoid web is presented in this paper. Comparison is made with conventional beams with flat web. In the experimental work, sections with nominal dimension 200 x 80 mm and 5 m length were loaded vertically while the lateral deflection were unrestrained to allow for the lateral torsional buckling. In the analytical study, eigen-value buckling analysis in the finite element method was used to determine the critical buckling load. It is concluded that steel beam with trapezoidally corrugated web section have higher resistance to lateral torsional buckling compared to that of section with flat web. The result shows that corrugation thickness influence the resistance to lateral torsional buckling.

The author from the experimental and analytical study on the lateral torsional buckling on trapezoid web section, it can be concluded that :

(1) Steel beam with trapezoidally corrugated web section have higher resistance to lateral torsional buckling. compared to that of section with flat web.

(2) The result shows that corrugation thickness influence the resistance to lateral torsional buckling. Sections with thicker corrugation have higher resistance to lateral torsional buckling.

(3) Higher value of moment of inertia about minor axis for the section with thicker corrugation contributes to the higher resistance to lateral torsional buckling.

(4) Finite element can be used to determine the elastic lateral torsional buckling moment of the section.

The author Naiwei Lu, Mohammad Noori et al (2016) stated that Welded joints in steel bridge decks are vulnerable to the fatigue damage caused by heavy-loaded trucks. In this paper, a stochastic fatigue truck load model was developed for probabilistic modeling of fatigue stress ranges to investigate the fatigue reliability of welded steel girder bridges.

The author concluded that the stochastic fatigue truck-load model was developed for probabilistic modeling of fatigue stress ranges for the purpose of investigating fatigue reliability of welded steel bridge decks. To deal with the uncertainty-induced computational complexity, a framework including deterministic finite-element-based hot-spot analysis and probabilistic modeling approaches was presented

The authors Qian-Qian Yu, Yu-Fei Wu (2016) stated that an experimental study on the fatigue behaviour of cracked steel beams strengthened using different patch systems and high-strength materials. These materials included normal modulus carbon fiber–reinforced polymer (CFRP) laminate, high strength steel (HSS) plate, and Saf Strip (SAF) plate. This study extends the understanding of fatigue repair for steel beams and provides some useful suggestions for the strengthening method.

The author stated that a total of nine cracked steel beams were tested under fatigue loading. Different patch configurations and strengthening materials were adopted. Based on the experimental investigations, the following observations can be made and conclusions drawn. Application of the overlays significantly retarded the fatigue crack propagation and improved the fatigue behaviour.

The authors Md. Imran Kabir, Anjan K Bhowmick (2016) stated that lateral Torsional Buckling (LTB) can be defined as a combination of lateral displacement and twisting due to an application of load on an unsupported beam. A recent study has shown that the current code equations might overestimate the capacity of the welded wide shape beams, which make them unsafe to use. Thus a detailed study is required to evaluate the existing LTB equations for welded wide flange (WWF) shapes. This paper evaluates the performance of current equations in providing LTB capacities of WWF shape beams. A nonlinear finite element (FE) model is developed using the commercial finite element software ABAQUS. In total 75 FE model for 15 WWF shape beams are analysed. For the FE analysis, the beams are considered simply supported beams with uniform moments applied at the ends. Initial residual stresses in the WWF shapes that are reported in the literature are also included in the FE model.

The author presented a nonlinear FE model for studying the lateral torsional buckling capacity of welded wide flange beams. It was observed from FE analysis that, CSA S16-09 approach is somewhat unconservative for intermediate WWF beams failing in inelastic LTB compared to slender beams. The difference between FE and code results were large for beams within the inelastic range and becomes small as it goes to elastic range. In addition, it showed more discrepancies in case of deep beam than shallow one. It should be noted that a limited number of beams are analysed in this study. In addition, a simplified residual stress pattern is assumed for this study. Thus, the above conclusions must be considered with caution.

Chapter 3

Objectives of the study

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

1. To establish a design procedure of welded I beam or hot rolled beam in a spreadsheet and compare them at different loading conditions.
2. To compare structural and economic performance of the welded I beam or Hot rolled beam of same design at different load ratios, over a range of length.
3. To perform a parametric study of the variables that can affect the structural and economical behaviour of beams.
4. To establish relation between load and length of beams to select the suitable beams for that loading condition.
5. Comparison of results obtained from all types of beams.
6. Conclusion and recommendation on the loading and economical behaviour of beams.

Chapter 4

Methodology

4.1 Approach

The literature to date deals with beams is limited , as far as they are analysed together. To our knowledge, there is no literature that has compared the structural performance with respect to the economy of beams . Though there are some research paper that compares different structures of beams and some paper compare the structural behaviour of these beams with different loading conditions. But, they were done separate showed below will be completely designed in an excel spreadsheet and the comparison between the different geometries of the beams with respects to the cost will be shown graphically.

4.2 MS Office Microsoft Excel

4.2.1 What is Microsoft excel?

Microsoft excel is a software program produced by Microsoft .that allows users to organize, format and calculate data with formulas using a spreadsheet system. This software is a part of the Microsoft office suite and is compatible with other application in the office suite.

4.2.2 Why it is being used?

Excel is a commercial spread sheet application produced and distributed by Microsoft for Microsoft Windows and Mac OS X. It features the ability to perform basic calculations, use graphic tools, create pivot tables and create macro programming language. Excel has the same basic features as every spread sheet, which use a collection of cells arranged into rows and columns to organize data manipulation. They also display data as charts, histograms and line graphs.

4.2.3 What are its advantages?

1. Excel permits users to select data so as to view various factors from a different perspective.
2. Visual Basic is used for application in Excel, allowing users to create variety of complex numerical methods.
3. Programmers are given an option to code directly using the Visual Basic Editor, including Windows for writing code, debugging and code module organization.
4. It is easy available, it is low cost software tool and easy to use
5. It is very much compatible and gives us flexibility to use our data unlike other software.

4.2.4 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. No imperfection were considered in these investigations.
2. No temperature effects are present.
3. Only I-sections dimensions are considered in the design of beams.
4. Grade of steel used will be Fe410.
5. Stress are assumed to be $F_y=250N/mm^2$ and $F_u=410N/mm^2$ throughout the design.
6. We have taken d/t_w ratio between 75 to 175

7. We have taken total design processes of beam as per IS 8000:2007 and for welded beam we have considered it as plate girder

4.4 Design Procedure

As per standard IS 800:2007 code

4.5 Sequence of Project Compilation

This study was approached in the following sequence:

- A literature survey was conducted which investigated the design and behaviour of hot rolled I beam and welded I beam and heir parametric factors.
- Review of recommendations on beams from code Bureau of Indian Standard 800:2007 and, handbook for structural steel. The literature survey also gathered information on effects of load ratios on the grade and cost of steel.
- Designing and making spread sheet using the MS Office Excel.
- Comparison of results obtained from the beams.
- Conclusion and recommendation on the structural and economical behaviour of hot rolled I beam and welded I beam.
- Generation of equation to predict length on the basis of loading.and Final submission.

4.6 Design Steps

Hot-Rolled Steel Beam:-

A) Design of Laterally Supported Beams

Assume

- Plastic and Compact Sections, $\beta b=1$
- $fy = 250\ N/mm^2$.

Procedure:

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

Step 2: Equate formula: Mu = (fy / γmo) Zp and Find Zp required

Step 3: Choose I-Section from Steel Tables for required Zp

Step 4: Check for Plastic Section d/tw <= 84 and b/tf <= 8.4

Step 5: Check for Shear Strength Vd > Vu where, Vd = shear area x (stress/√3 stress = (fy/ γmo)

shear area = h. tw h = height of I-Section tw = Thickness of Web.

Step 6: Check for Moment Carrying Capacity Md > Mu where Md = (fy / γmo) Zp

Step 7: Check for Deflection δ < Deflection Limit where δ = Max. Deflection = 5wL4 /384EI for UDL on simply supported beam Deflection Limit = L/300 Table 6 of IS 800-2007

Step 8: Check for Web Buckling fcdw > Vu where fcdw = (b1+n1) tw fc fc = buckling stress

Table 9a of IS 800-2007 (similar to compression member) b1 = width of stiff bearing on flange n1 = h/2

Step 9: Check for Web Crippling Fw > Vu where Fw = (b1+n2) tw (fyw/ γmo) n^2 = 2.5 (flange thickness + radius at root) fyw = yield stress of web = 250 N/mm^2

B) 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 $Zp\ required = \frac{Md}{\beta b * Fbd}$

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):

$$Vd = \frac{Vn}{\gamma mo} = Av * \frac{Fyw}{\sqrt{3}*\gamma mo}\, greater\ than\ V$$

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 *β_b*f_{bd}

Where Z_p = plastic sectional moduli.

f_{bd} = design bending compressive stress

=X_{LT} *f_y /γ_{mo} or using Table 13(a) and (b) andvalue of f_{crb}.

X_{LT} = bending stress reduction factor

$$=1/\left\{\phi LT + \sqrt{(\phi LT2 - \lambda LT2)}\right\} \leq 1$$

ϕ_{LT} = 0.5 [1+ α_{LT} (X_{LT} - 0.2) + λ_{LT}^2]

α_{LT} = Imperfection parameter

= 0.21 for rolled steel section

=0.49 for welded steel section

X_{LT} = Non-dimensional slenderness ratio

$$= \sqrt{\frac{\beta b * Zp * fy}{Mcr}} \leq \sqrt{\frac{1.2\, Ze * fy}{Mcr}} = \sqrt{\frac{fy}{fcrb}}$$

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 :

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

Welded I-Beam:-

Step 1: Calculation of design forces, factored load=1.5*working load.

Self-weight of plate girder=wl/400.

Step 2: To calculate bending moment and shear force.

Step 3: Design of Web

Optimum depth=$(Mz*k/fy)^{0.33}$

When intermediate transverse stiffeners are not to be provided

d/tw≤200€ (from serviceability)

≤345€f^2 (from flange buckling) where k=d/tw

Optimum web thickness tw=$(Mz/fy*k^2)^{0.33}$.

Step 4: Design of flanges

Af=(mz* γ_{mo}/fy*d) Assume width of flange thickness tf=Af/bf.

Step 5: Classification of flanges

b/tf≤8.4€

The outstand of flange b=bf-tw/2

Step 6: Check for bending strength

Zpz=2bf*tf*(D-tf)/2

Moment capacity Md=β*Zpz*fy/ γ_{mo} >Mz . . . Safe.

Step 7: Shear capacity of web

d/tw<200€

<345€f^2

Elastic critical shear stress $\tau cr,e = kv*\pi^{2*}E/12(1-\mu^2)*(d/tw)^2$

$$\lambda = \sqrt{\frac{fyw}{\sqrt{3}*\tau cr,e}} \quad >1.20$$

$\tau b = fyw/(1.71*\lambda w^2)$

Shear force corresponding to web buckling

Vcr = d*tw* τb > V (shear foce) . . . Safe.

Chapter 5

Results and Discussions

In this approach, the design procedure for different welded I beam and hot rolled steel beams is completely done in an excel spreadsheet and the results of the differences between the geometrics of the steel beams with respect to the variation in d/t_w is shown graphically. The graphs that are formed below are showing the results that are occurred while conducting this project. The testing was done for ISHB, ISJB, ISLB, ISMB and ISWB beam section only and no other sections are considered for this project. In this chapter, the results obtained for the analytical investigation on steel beams are discussed with the help of graphs

5.1 Discussion on ISHB beam results

We have started comparison with first section. ISHB (Indian standard heavy weight beam) its heavy weight section and normally not used as beam. The d/t_w ratio is changed within 75 to 175. For each value of d/tw we have plotted a graph for Bending capacity (Md), shear capacity (Vd) and area. The above values are plotted with the data which we are getting from welded section.

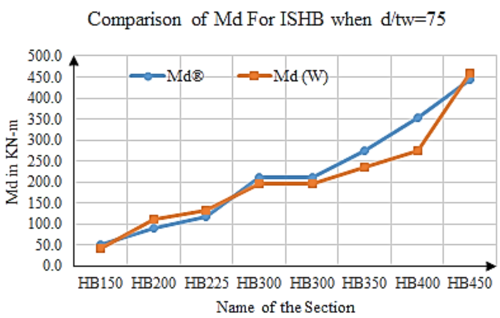
In fig 5.1.1 a, when d/t_w =75 the values of Md, Vd and area are slightly greater than the parameters of rolled section ,whereas for smaller section (up to HB300) whereas for other heavy section the d/tw section is not much economic.

For fig 5.1.2 a,b and c for d/t_w =100,the nature is slightly shifting upward after HB200 the Md which are getting is higher than the rolled section but after the section HB350 again it falls down. Same nature we can observe in the remaining graph of Vd & area.

For fig 5.1.3. a,b and c for d/t_w =125,Md for welded is getting slightly higher than rolled section but eventually it is giving the same bending capacity in higher section . But in graph of Vd and area we are getting near about same values in both the section of rolled and welded to be exact Vd of welded is falling after HB350 and in Area of welded and rolled are approximately same. But in case for bigger section it is seen that Md of welded is high and its relative area is somewhat same. Hence we can achieve higher strength with relative same area when compared with area of rolled section

For fig 5.1.4 a,b and c we can see the sudden changes in values of Md of welded after the HB250 and bending capacity is slightly lesser in Md of rolled. In fig 5.1.4 b Vd of rolled gets slightly increase after the section HB225 and uniformly it is getting increased with the higher section. In relative area the graph have near about same values in both rolled and welded beam.

In fig 5.1.5 a,b and c when d/t_w=175 we can observe that Md of welded was near about same till section HB300 but after that it gets suddenly higher values than rolled section. In fig 5.1.5 b Vd of rolled is getting higher uniformly after HB250 but in relative area shows same graph in both area of rolled and welded HB350. Therefore we can see area is near about same as it is seen in fig 5.1.5 c. It is therefore welded section is economical for HB350 to HB450 due to the higher bending capacity with near about same area for both sections.



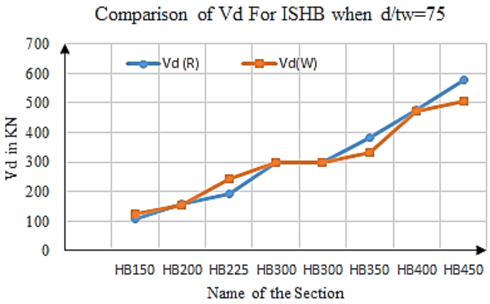


Fig 5.1.1 a- Comparison of Md (d/t_w =75) & Fig 5.1.1 b- Comparison of Vd (d/t_w =75)

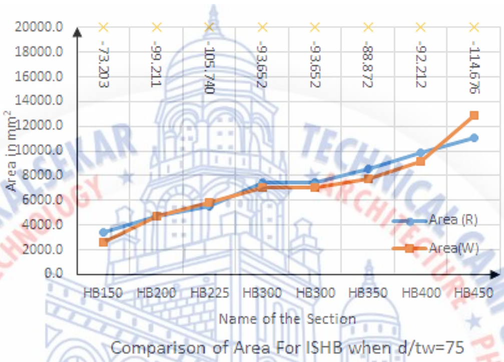
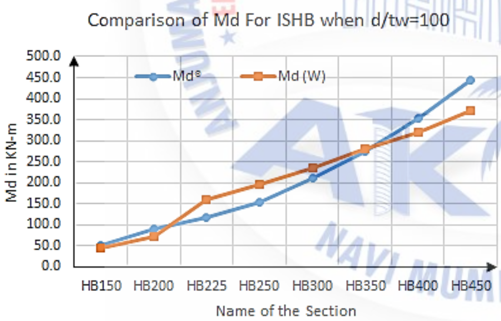


Fig 5.1.1 a- Comparison of Area (d/t_w =75)



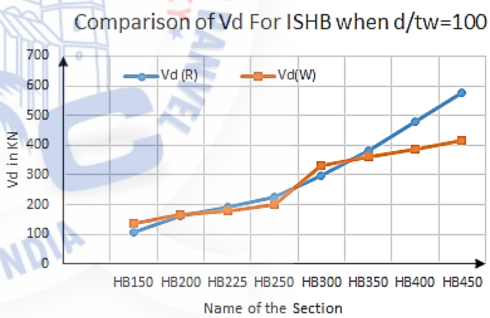


Fig 5.1.2 a- Comparison of Md (d/t_w =100) & Fig 5.1.2 b- Comparison of Vd (d/t_w =100)

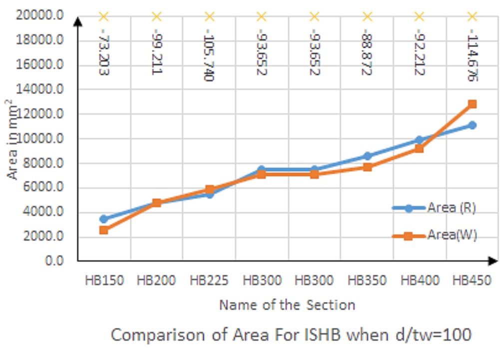
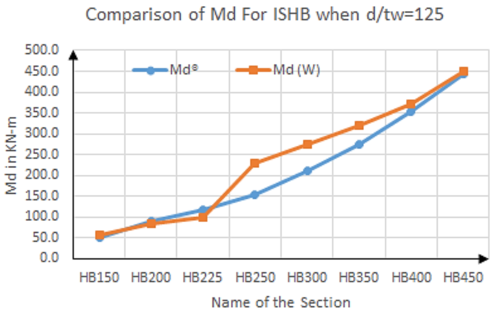


Fig 5.1.2 c- Comparison of Area (d/t_w =100)



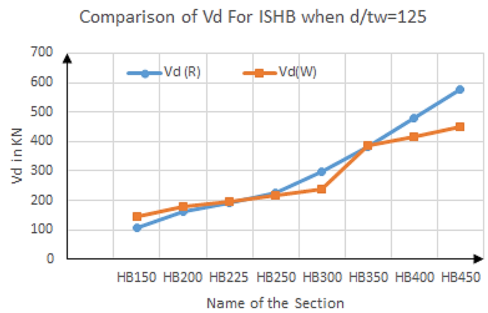


Fig 5.1.3 a-Comparison of Md (d/t_w=125) & Fig 5.1.3 b- Comparison of Vd

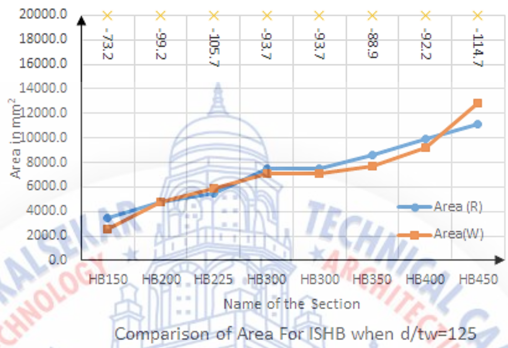
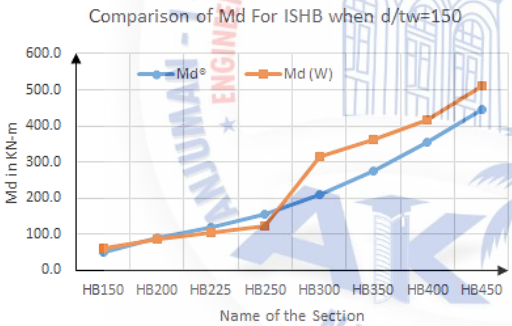


Fig 5.1.3 c- Comparison of Area (d/t_w =125)



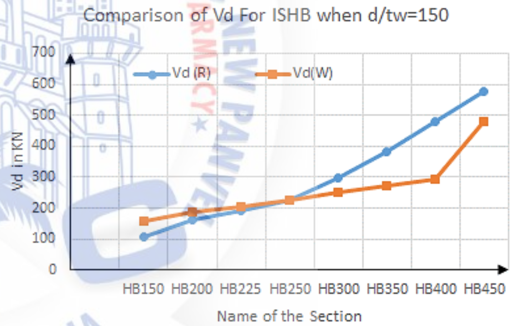


Fig 5.1.4 a-Comparison of Md (d/t_w=150) & Fig 5.1.4 b- Comparison of Vd

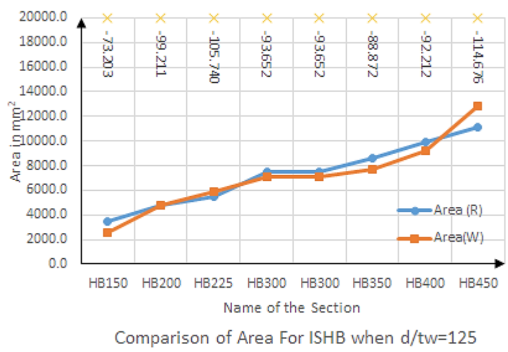
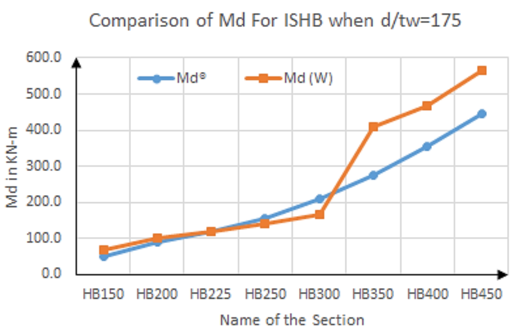


Fig 5.1.4 c- Comparison of Area (d/t_w =150)



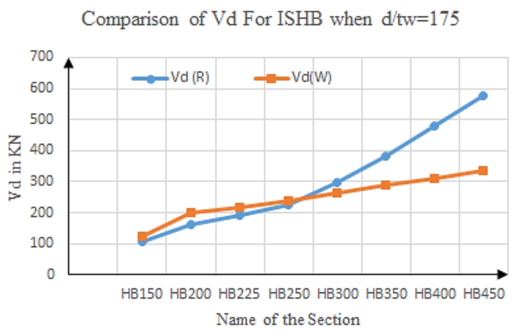


Fig 5.1.5 a-Comparison of Md (d/t_w=175) & Fig 5.1.5 b- Comparison of Vd

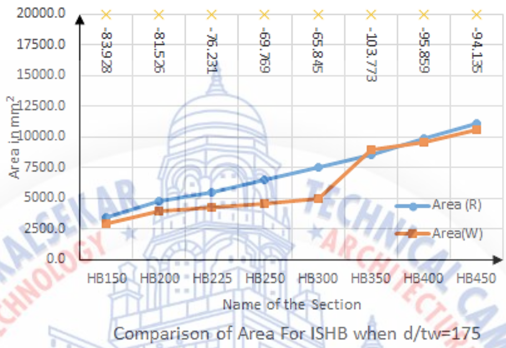


Fig 5.1.5 c- Comparison of Area (d/t_w =175)

5.2 Discussion on ISJB beam results

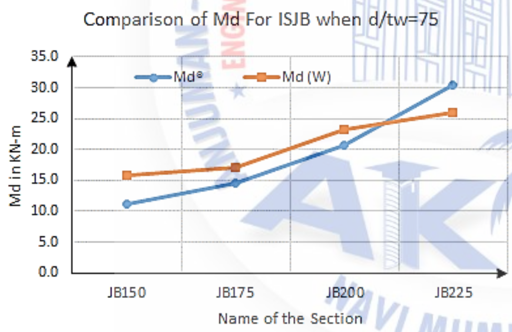
In ISJB section (Indian standard junior beam). The d/t_w ratio is changed within 75 to 175. For each value of d/t_w . we have plotted a graph for Md, Vd and relative area .

In fig 5.2.1 a,b and c for d/t_w =75. We can observe that sudden fall of bending capacity in section JB225 . but for higher section strength achieve is lesser than bending capacity for rolled when the d/tw ratio is 75 then the Vd is near about same in all sections but in fig 5.2.1 c . it can be clearly seen that the area for welded is higher in every aspect from the relative area of rolled section. We can say that the junior beam is not so economical in case for welded

For fig 5.2.2 a,b and c when the d/t_w=100. It can be clearly seen that for all aspect and section Md of welded is higher. It means Md,Vd and area of welded section is higher in all the section of the beam and in fig 5.2.2 b the Vd is slightly higher of the welded section than the rolled section. So this is also uneconomical for this ratio as the area of welded is much higher than the rolled section

In fig 5.2.3 a,b and c and d/t_w= 125 we can see that bending and area of welded is higher in every section as comparison with rolled section for Md and area. But in fig 5.2.3 b we can see that shear capacity was higher before section JB175 and its starts to fall slightly after that. Since for achieving greater strength ISJB we can go for welded as it is fair enough but its lack in case of area for the same.

In fig 5.2.4 a,b and c when the (d/t_w=150) we can observe that the Md and area of welded is higher in all section of welded beam compare to rolled beam . But in Vd for welded we can see that it starts uniform fall after JB175 but before it was also getting higher values than Vd for rolled section. As the nature of graph is neutral for both its area and Md, In fig 5.2.5 a,b and c for the d/t_w=175 graph of welded beam is getting higher values in all the aspects namely Md, Vd and relative area .when it is compared to the values of rolled section. Which are getting smaller values in bending capacity (Md), shear capacity(Vd) and relative area. So it can be said that the nature of graph is neutral and is similar as in case of Md and area. With the increase in Md there also been increase in area. At last we can say that ISJB is good enough in case of bending strength but uneconomical in area as it have more area than rolled section



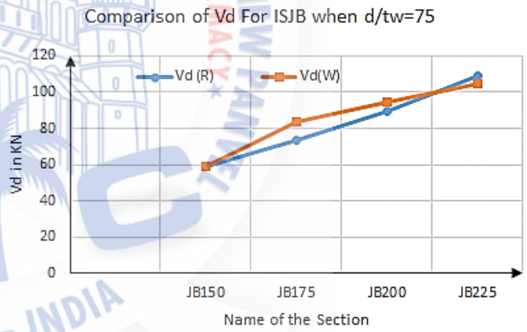


Fig 5.2.1 a-Comparison of Md (d/t_w=75) & Fig 5.2.1 b- Comparison of Vd (d/t_w =75)

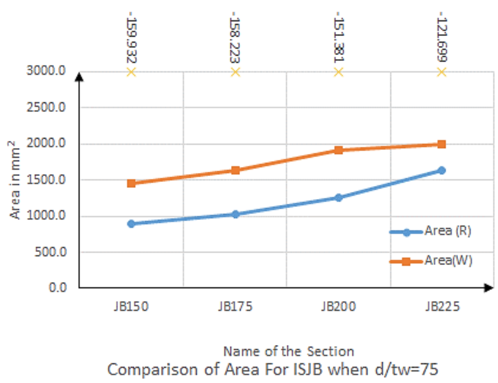
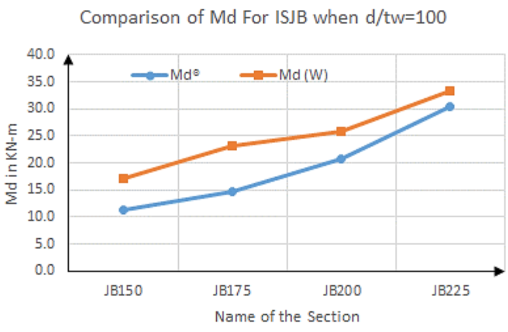


Fig 5.2.1 c- Comparison of Area (d/t_w =75)



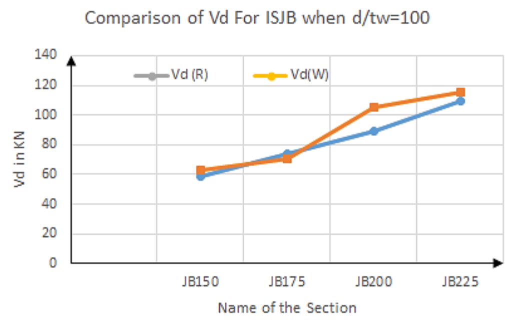


Fig 5.2.2 a- Comparison of Md (d/t_w=100) & Fig 5.2.2 b- Comparison of Vd

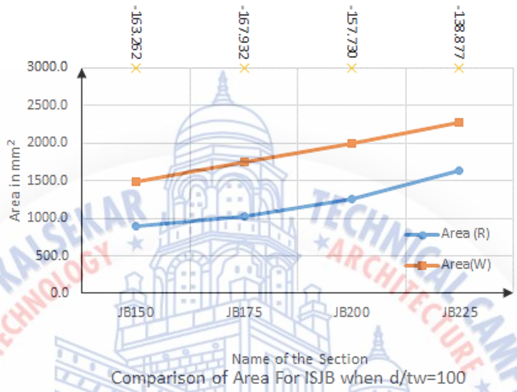
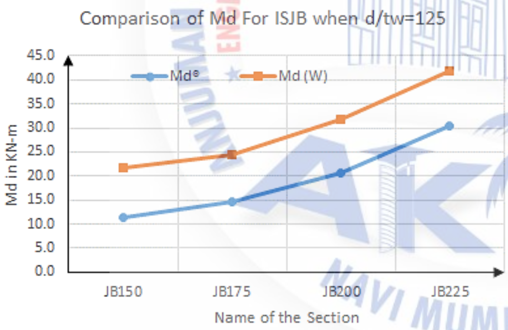


Fig 5.2.2 c- Comparison of Area (d/t_w =100)



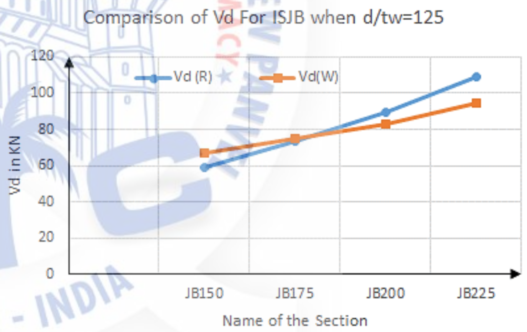


Fig 5.2.3 a- Comparison of Md (d/t_w=125) & Fig 5.2.3 b- Comparison of Vd

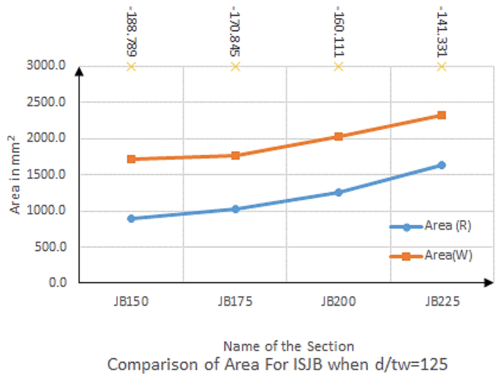
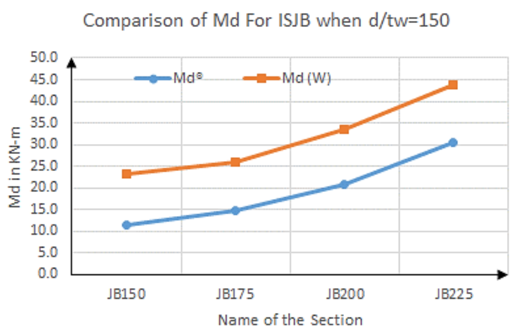


Fig 5.2.3 c- Comparison of Area (d/t_w =125)



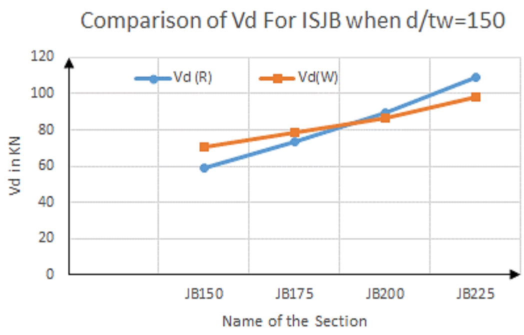


Fig 5.2.4 a- Comparison of Md (d/t_w=150) & Fig 5.2.4 b- Comparison of Vd

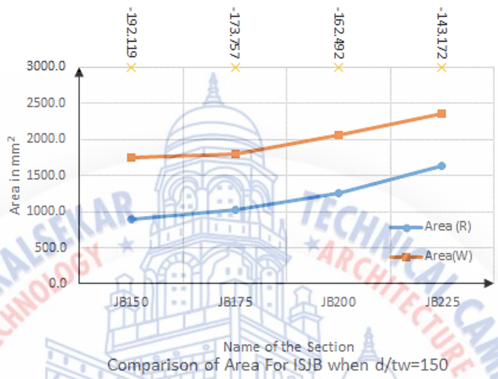
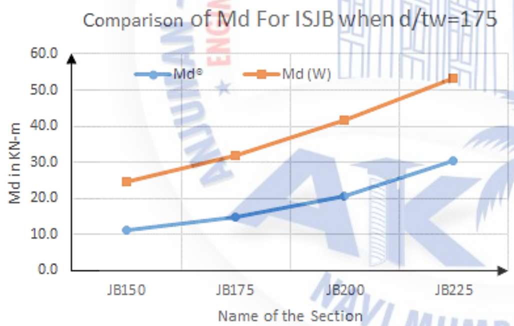


Fig 5.2.4 c- Comparison of Area (d/t_w =150)



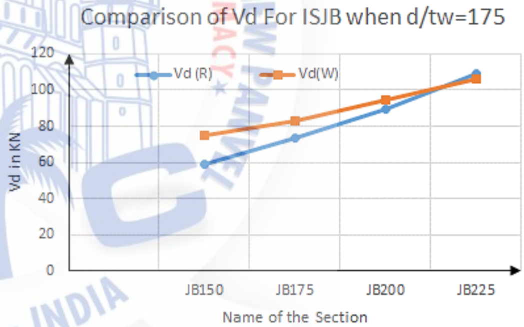


Fig 5.2.5 a- Comparison of Md (d/t_w=175) & Fig 5.2.5 b- Comparison of Vd

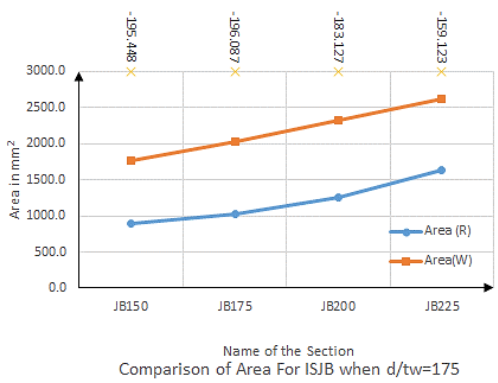


Fig 5.2.5 c- Comparison of Area (d/t_w =175)

5.3 Discussion on ISLB beam results

In ISLB(Indian standard light weight beam) as name suggest it is lighter weight beam. In this section d/tw ratio changes within 75 to 175. For each value of d/t_w ,we have plotted a graph for Md,Vd and area. With the help of graph we are trying to compare both rolled and welded I section.

In fig 5.3.1 a,b and c (d/t_w=75) we can observe that for bending capacity (Md), we are getting the approximately same values for both the rolled and welded section in all sections from LB75 to LB600. But in fig 5.3.1.6 graph of shear capacity for rolled is getting uniformly higher values LB175 when compared to Vd of welded but in the fig 5.3.1 c we can see that the area of welded section is higher and is near about all the section when compared to area of rolled which is getting uniformly same value till LB200 and slight increase in Md after that till LB400 and a sudden increase till LB600. In fig 5.3.2 a,b and c when d/tw=100 Md and area of both the rolled and welded section is near about same but in fig 5.3.2.b we can clearly see that the values of Vd rolled section starts to increase uniformly than Vd of welded. So Vd of rolled section gives higher shear capacity than Vd for welded section. This is also the same case of neutral graph as increase in results of bending capcity and also increase in area thereby becoming not so economical.

In fig 5.3.3 a,b and c when d/tw=125, Md and area of both the rolled and welded section is near about same but in fig 5.3.3 b we can clearly see that the values of resisting shear starts to increase uniformly than welded after LB200. It means Vd for rolled is giving higher shear capacity than welded and therefore the graphs seems to be neutral for bending capacity and shear parameters. So we cannot completely predict that this section is suitable or not as its graph tends to change at every section.

In fig 5.3.4 a,b and c when d/t_w=150 Md and area of both the rolled and welded section is near about same but in fig 5.3.4 b we can clearly see that the values of shear parameters starts to increase uniformly than welded after LB175. It means Vd of rolled section is giving higher shear capacity than welded. It is been observed that bigger section from LB325 TO 550 it is seen bending capacity is more and near about equal area of rolled and welded section.In fig 5.3.5 a,b and c when d/t_w=175, the results for this ratio is same from above. Hence for higher section Md achieve is more with near about same area for both. Thereby it is clearly economy for LB30 to LB600.

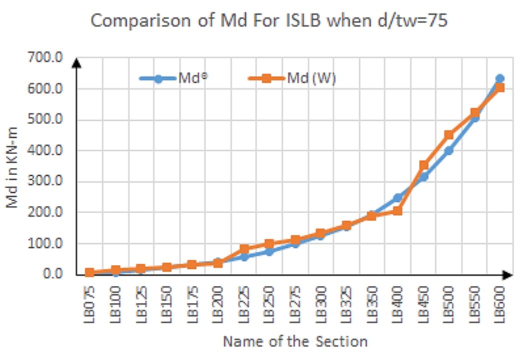


Fig 5.3.1 a- Comparison of Md (d/t_w=75)

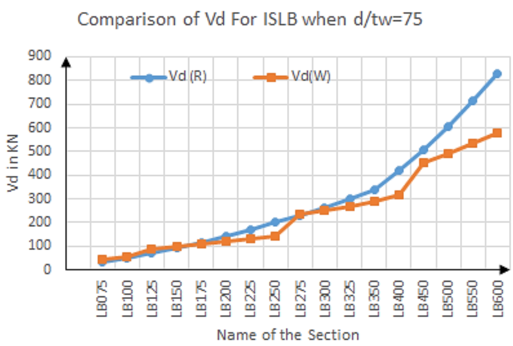


Fig 5.3.1 b- Comparison of Vd

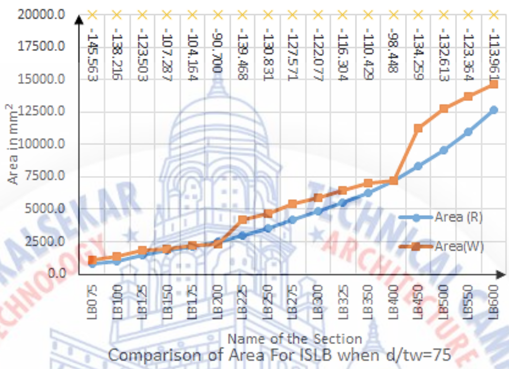
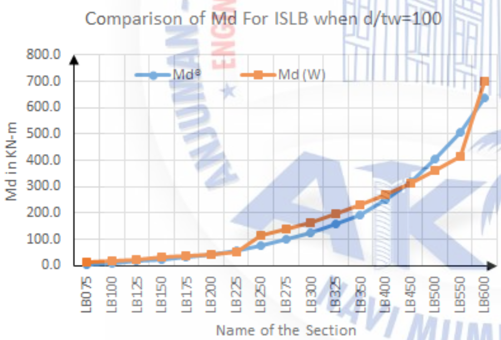


Fig 5.3.1 c- Comparison of Area (d/t_w =75)



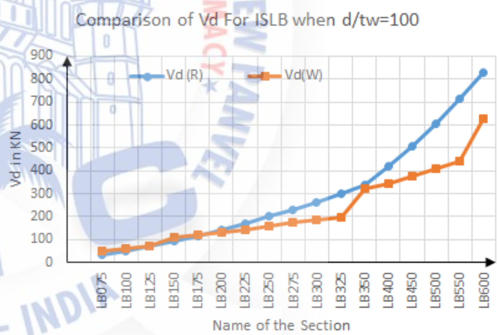


Fig 5.3.2 a- Comparison of Md (d/t_w=100) Fig 5.3.2 b- Comparison of Vd

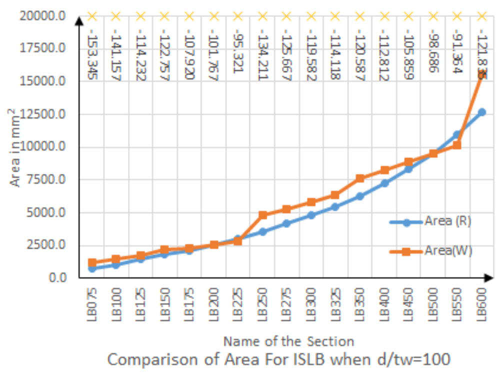


Fig 5.3.2 c- Comparison of Area (d/t_w =100)

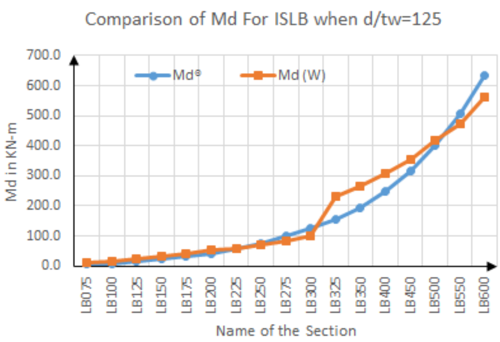


Fig 5.3.3 a- Comparison of Md (d/t_w=125)

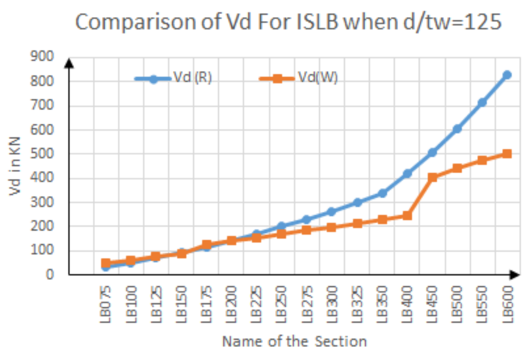


Fig 5.3.3 b- Comparison of Vd

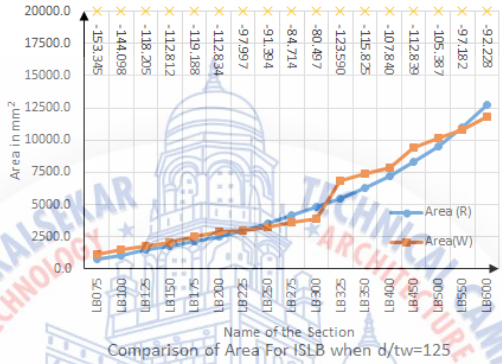


Fig 5.3.3 c- Comparison of Area (d/t_w =125)

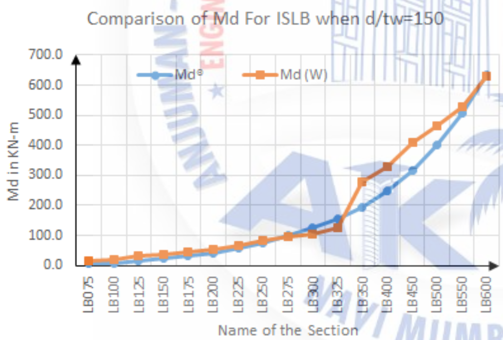


Fig 5.3.4 a- Comparison of Md (d/t_w=150)

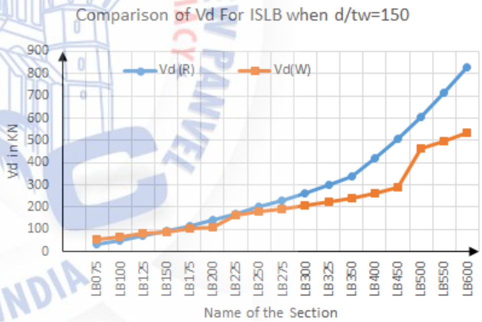


Fig 5.3.4 b- Comparison of Vd

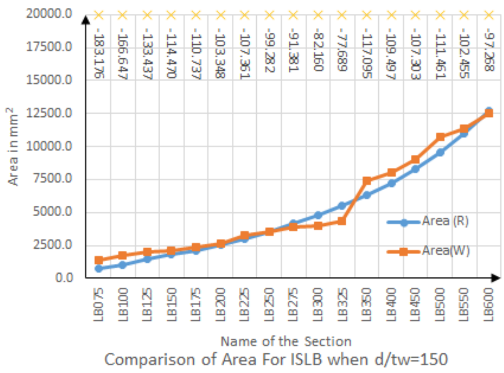


Fig 5.3.4 c- Comparison of Area (d/t_w =150)

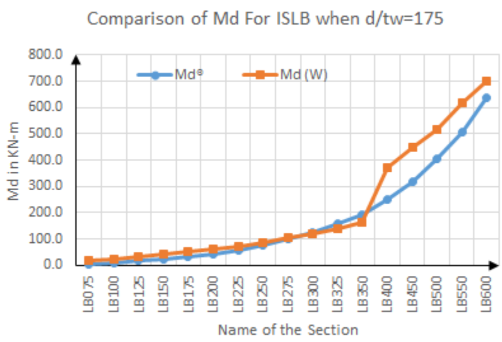


Fig 5.3.5 a- Comparison of Md (d/t_w=175)

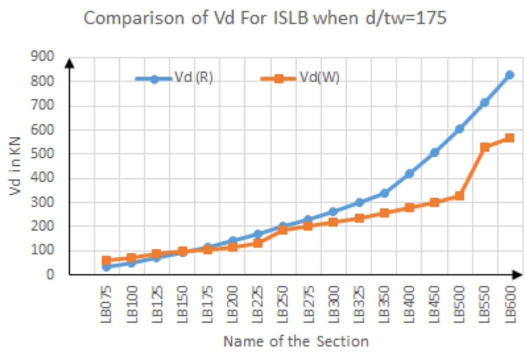


Fig 5.3.5 b- Comparison of Vd

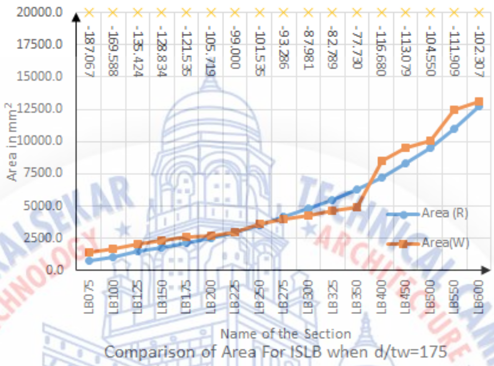


Fig 5.3.5 c- Comparison of Area (d/t_w =175)

5.4 Discussion on ISMB beam results

As the name suggests Indian Standard Medium Beam (ISMB) it's a medium weight section and are fairly used as a beam. In fig 5.4.1 a,b and c when d/t_w is 75 its been observed that the bending moment (Md) is near about same except for ISMB 400 and 450 there is a slight dropdown in between both the sections. But for resisting shear the case is different it's been seen that for ISMB 300 to 600 the values are lesser than the rolled section and for area it's near about same till ISMB 400 after that it's been slightly upward till ISMB 600. At higher section it is suitable for rolled steel section as it gives comparatively better results than welded section.

After observing fig 5.4.2 a and c it can be stated that the nature of the graph is neutral, as the bending moment decreases the area also get reduced but irrespective of the shear force. Therefore at (d/t_w =100) the rolled section is capable enough than other section.

It is again been observed that at d/t_w=125in fig 5.4.3 a and c as the bending moment increases at higher section with the increase in area so this is also the neutral case. But for shear case the values are lower for welded section as compared to the other.

At d/t_w=150 in fig 5.4.4 a it's been seen that bending moment is greater for higher section and for area in fig 5.4.4 c its near about same for both section. As in the case for shear the values are limiting for welded section. But closely observing its been found that welded section gives higher Md with near about same area for both section. At MB 600 the area is lesser than rolled section with high bending moment capacity which summarized that the welded section is comparatively economical.

In fig 5.4.5 a the bending capacity is near about same till MB 350 and simultaneously observing the fig 5.4.5 c its been found that the area tends downward means the area is lesser as compared with rolled sections till MB 350. After observing further section its been found that there's been a sudden increase in Md for higher sections with respect to the area which is nearly same and somewhat lesser at last section that is MB 600. As also in fig 5.4.5 the shear capacity is lesser for welded section. So it can be said that for higher MB sections the welded section is suitable as compared to the rolled section.

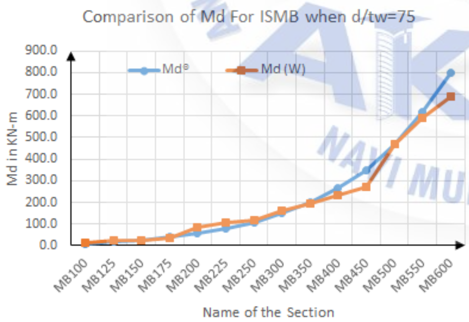


Fig 5.4.1 a- Comparison of Md (d/t_w=75)

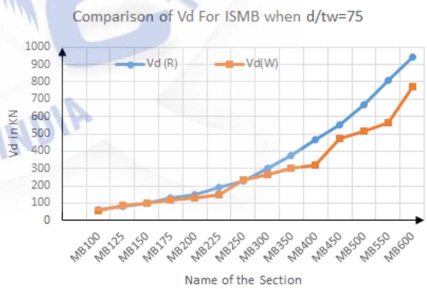


Fig 5.4.1 b- Comparison of Vd

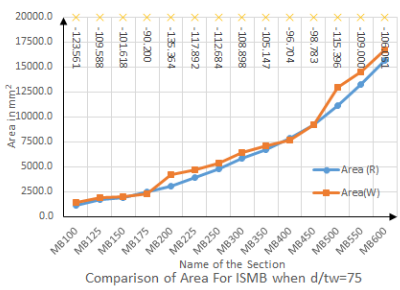


Fig 5.4.1 c- Comparison of Area (d/t_w =75)

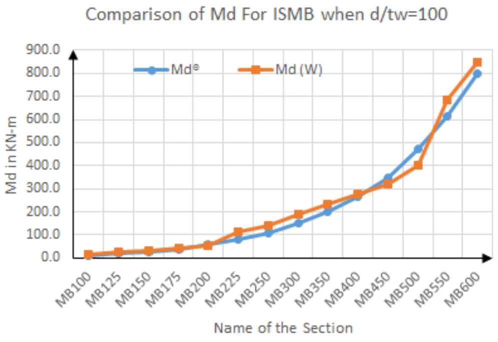


Fig 5.4.2 a- Comparison of Md (d/t_w=100)

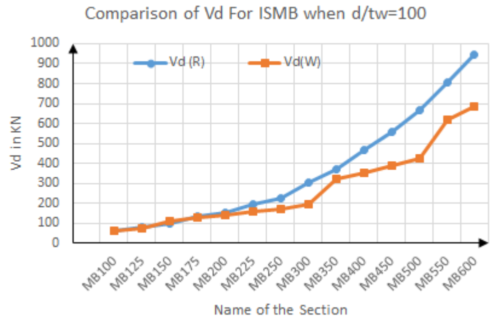


Fig 5.4.2 b- Comparison of Vd

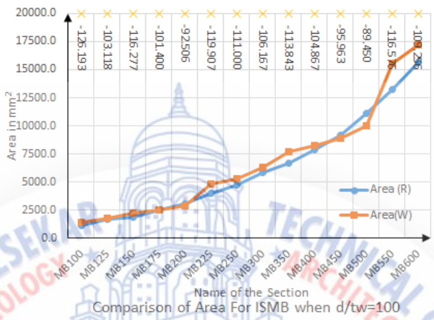


Fig 5.4.2 c- Comparison of Area (d/t_w =100)

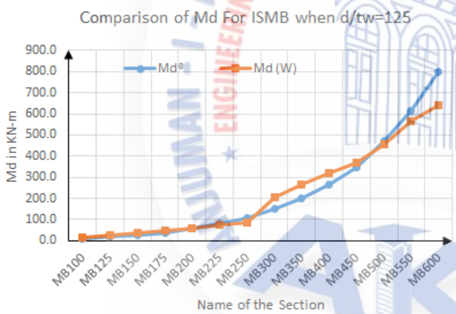


Fig 5.4.3 a- Comparison of Md (d/t_w=125)

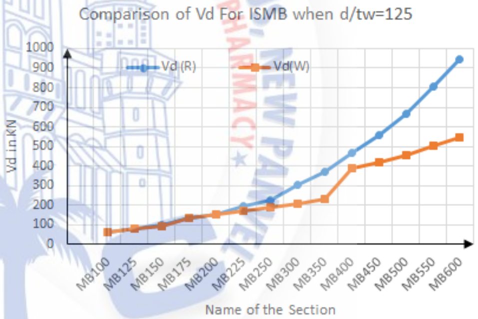


Fig 5.4.3 b- Comparison of Vd

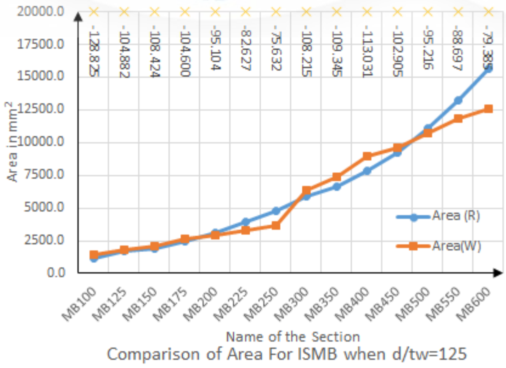


Fig 5.4.3 c- Comparison of Area (d/t_w =125)

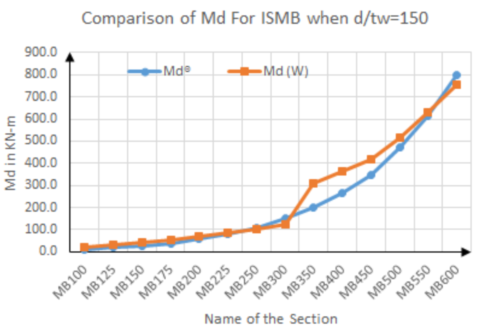


Fig 5.4.4 a- Comparison of Md (d/t_w=150)

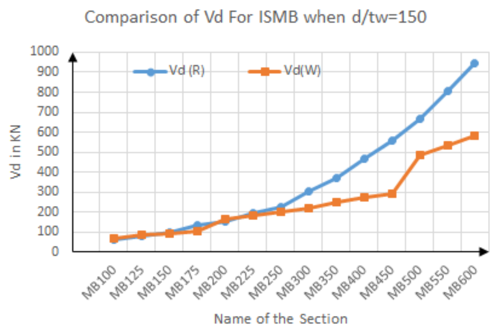


Fig 5.4.4 b- Comparison of Vd

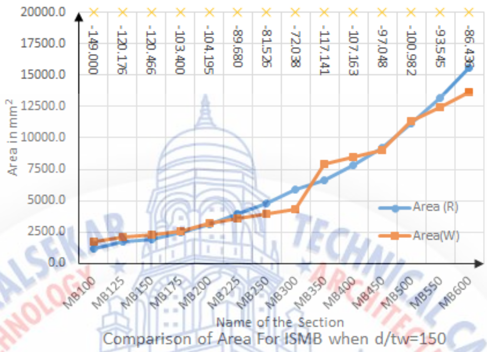


Fig 5.4.4 c- Comparison of Area (d/t_w =150)

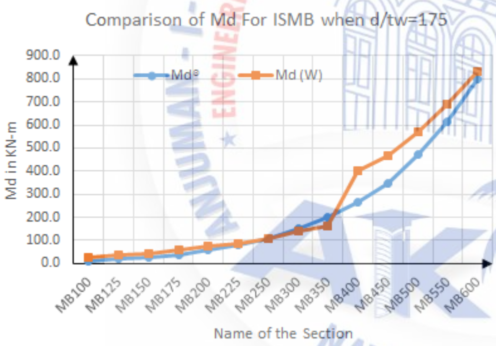


Fig 5.4.5 a- Comparison of Md (d/t_w=175)

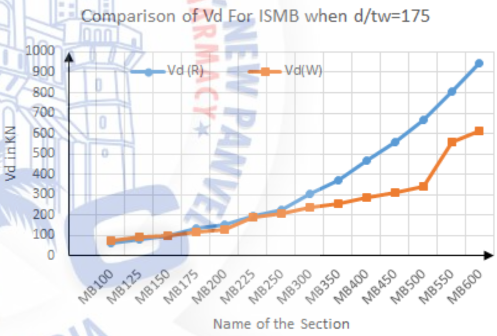


Fig 5.4.5 b- Comparison of Vd

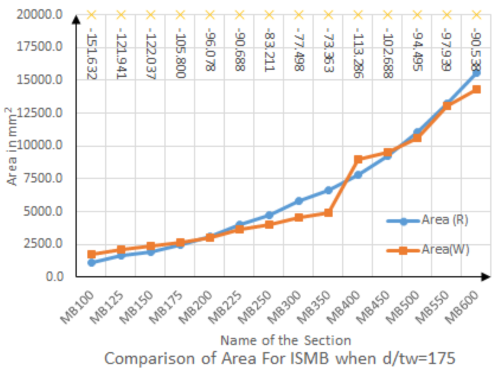


Fig 5.4.5 c- Comparison of Area (d/t_w =175)

5.5 Discussions on ISWB beam results

In fig 5.5.1 a the Md is somewhat same for both the sections upto WB 350 and the values goes on decreasing and become nearly equal WB 500 and again gets dropdown till the last section. As in the case for area fig5.5.1 c the values are changing slightly up and down at various sections. In fig 5.1.1 b the resisting shear force is lesser from WB 300 to 600. So at (d/t_w =75) the welded section is not so capable and economical as with the rolled sections.

At (d/t_w=100) the nature of graph for fig 5.5.2 a is neutral with fig 5.5.2 b, as the Md decreases the value of area is also got reduced at some point the value for Md increases and also an increase with area as, this happened to occur several intervals of graphs so thereby causing the graph in neutral as therefore it is difficult to predict choice of section. In fig 5.5.2 c the shear capacity got to be decreasing in case of welded section as and when compared with rolled section However rolled steel section can be adopted.

When d/t_w=125 the nature of the graphs happens to be same as discussed in above. In fig 5.5.3 c the area parameter is near about same for WB 300 to 450 as it gets decreased down with decreases in Md which is seen in fig 5.5.3 a, the value of Md at section WB 250 some what equal with respect to rolled section but there is a slightly downward at WB 250 section. So it can be observed that it is economical to WB 250. As for higher sections with the increase in values for Md the area also get increased.

As in fig 5.5.4 a when d/t_w=150 the bending capacity for lower sections seems to be nearly about same till WB 300 as when compared with fig 5.5.4 c the area tends to go slightly down till WB 300 which results in economical and capable. After WB 300 the parameter of Md increases upward till WB 500 with the equal values of area as compared with rolled section . hence it can said that it is economical for lower sections of ISWB 150 to 500. Above these section it is uneconomical .

In fig 5.5.5 a the bending moment capacity is near about same till WB 350 as in fig 5.5.5 c the value of area parameters tends to go down which makes the section economical as it goes reverse now, the value of Md goes upward from WB 400 to 550 and in area case the values is near about same with the rolled section. As also in fig 5.5.5 b the shear force fall downward with respect to rolled section. So at (d/t_w=175) it suitable for WB 150 to 550. Above 550 it is uneconomical.

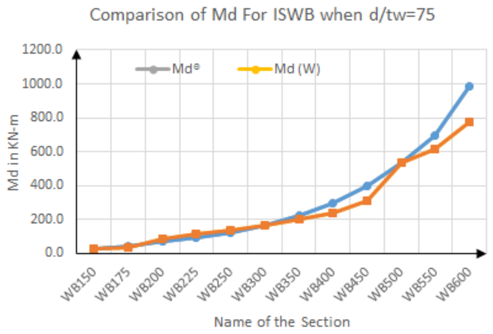


Fig 5.5.1 a- Comparison of Md (d/t_w=75)

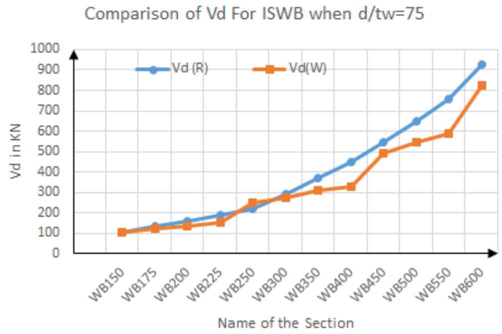


Fig 5.5.1 b- Comparison of Vd

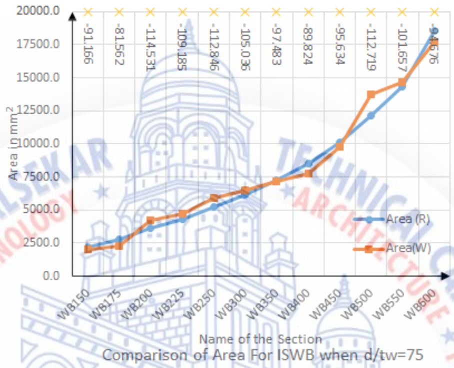


Fig 5.5.1 c- Comparison of Area (d/t_w =75)

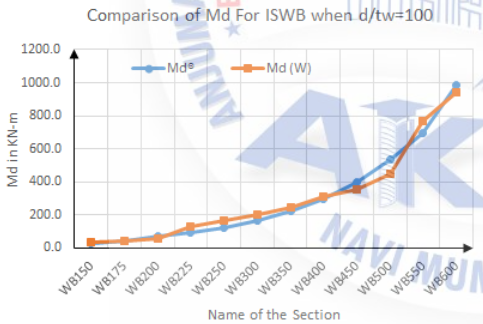


Fig 5.5.2 a- Comparison of Md (d/t_w=100)

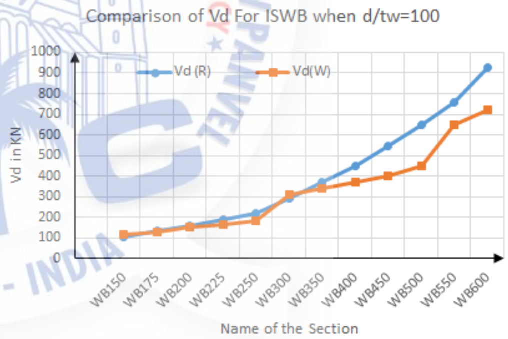


Fig 5.5.2 b- Comparison of Vd

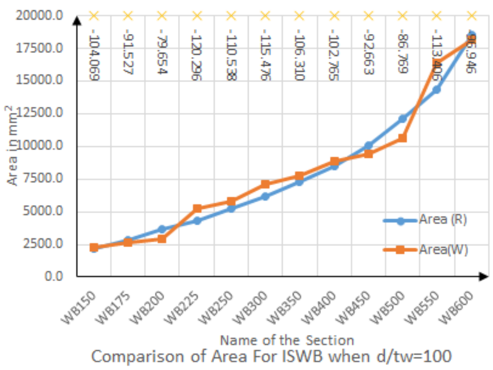


Fig 5.5.2 c- Comparison of Area (d/t_w =100)

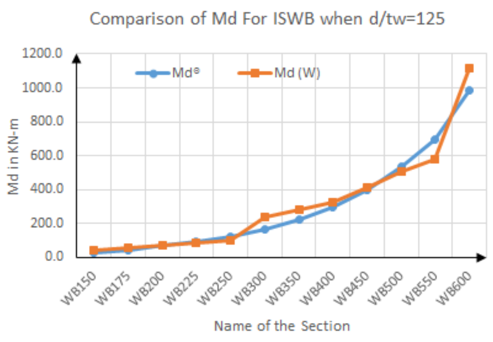


Fig 5.5.3 a- Comparison of Md (d/t_w=125)

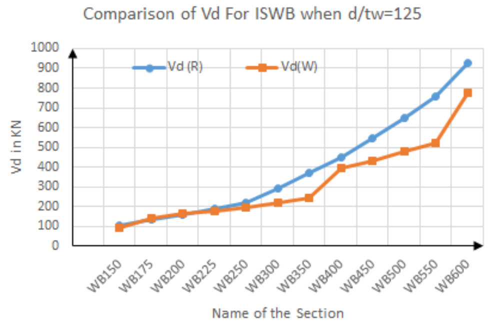


Fig 5.5.3 b- Comparison of Vd

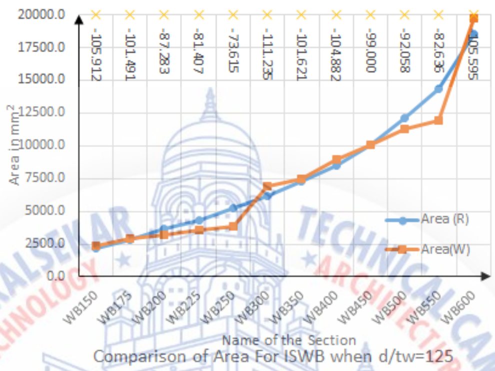


Fig 5.5.3 c- Comparison of Area (d/t_w =125)

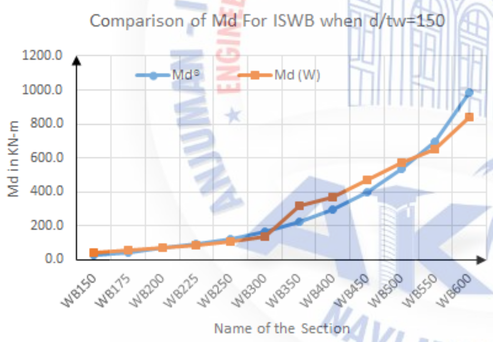


Fig 5.5.4 a- Comparison of Md (d/t_w=150)

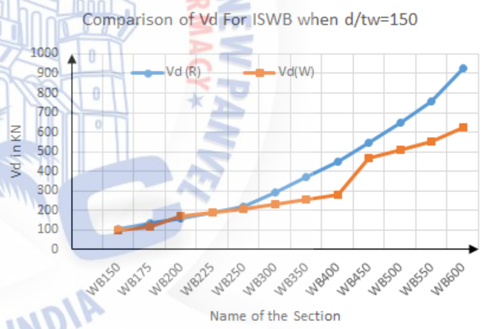


Fig 5.5.4 b- Comparison of Vd

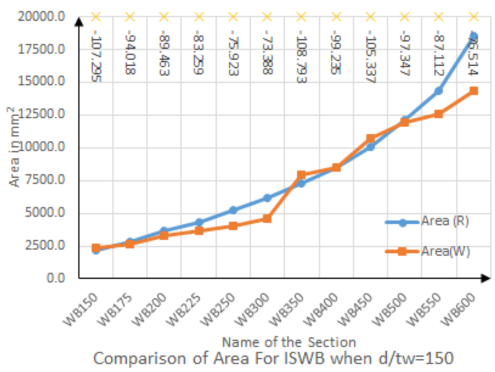


Fig 5.5.4 c- Comparison of Area (d/t_w =150)

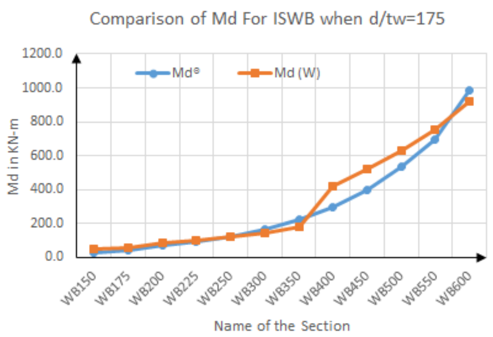


Fig 5.5.5 a- Comparison of Md (d/t_w=175)

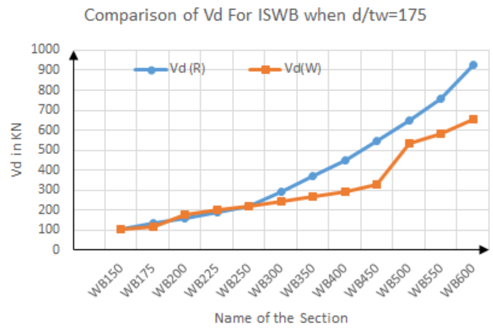


Fig 5.5.5 b- Comparison of Vd

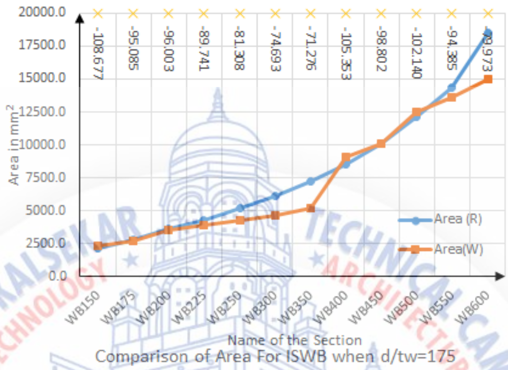


Fig 5.5.5 c- Comparison of Area (d/t_w =175)

5.6 Discussions on Average area of all sections

For ISHB fig 5.6.1 the rolled section is not so economical but the welded section is efficient and economical. This graph is based on the averages of all areas

For ISJB fig 5.6.2 there is big difference between rolled and welded section values of area, but rolled section is preferred due to its less value of area with respect to welded section on various (d/t_w) ratio.

In fig 5.6.3 for ISLB both the section are near about same possessing the same value of area at d/t_w ratio. Both the sections can be suitable based on the requirement needed. From fig 5.6.3 its been seen that it is not so economical from d/t_w =75 to 100, as on further its nearly the same .

From fig 5.6.4 its been seen that for ISMB welded occupy a large average area from d/t_w =75 to 110. From 125 to 175 the value of area been lesser than the rolled section which makes it economical.

In fig 5.6.5 for ISWB, from d/t_w =75 to 110 the rolled section has lesser value of area as compared to welded secion but from d/t_w =125 to 175 the welded section has a lesser area value than rolled making it more safe and economical.

5.6 Comparison of average area

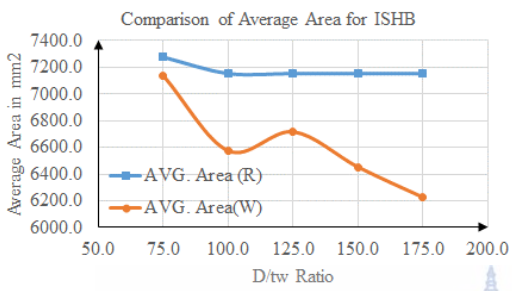


Fig 5.6.1 Comparison of Average Area for ISHB

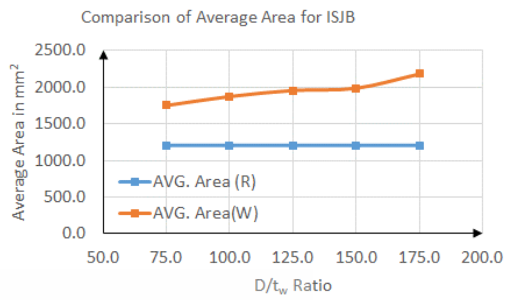


Fig 5.6.2 Comparison of Average Area for ISJB

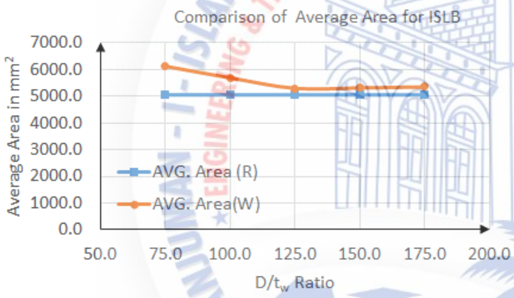


Fig 5.6.3 Comparison of Average Area for ISLB

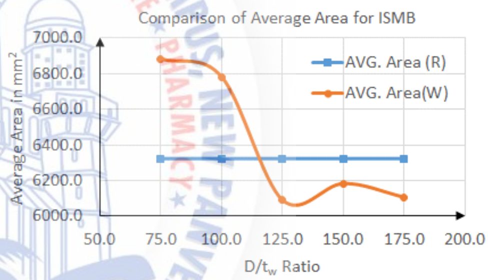


Fig 5.6.4 Comparison of Average Area for ISMB

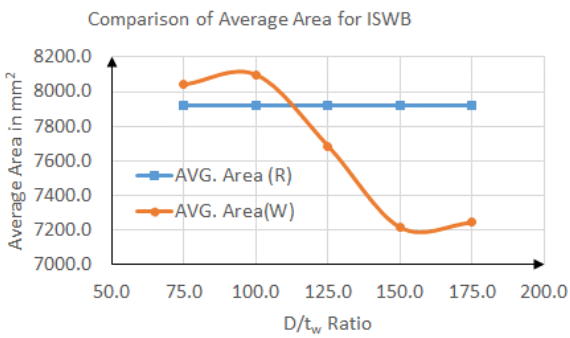


Fig 5.6.5 Comparison of Average Area for ISWB

5.7 Snapshot of Excel Sheet

Span	1	**BM (Fact)**	2.25		OK
UDL	12	**SF (Fact)**	9	LOW SHEAR	OK
					OK
Bending Momemt	337.566	KNm			OK
Shear Force	285.788	KN			OK

	.				
			Falnge outstand (b)	95	mm
Zpz Req. (UnSuppo)	1930878.893		(d)	484	
Zpz Req. (Suppo)	1485291.456		b/Tf	6.333	
Poperties of IS	**LB550**	LB550	d/Tw	48.889	
			CHECK Outstand	PLASTIC	
Zpz	2228160.0		CHECK NA	PLASTIC	
Zez	1933200.0	OK	CHECK for SHEAR capacity		
D	550.0		Design Sher Force	285.788383	kN
B	190.0		**Design Shear**	714.471	kN
Tw	9.9		**Strength of Sec (Vd)**		OK
Tf	15.0		**CHECK for HIGH and**		
Flange Slope	98.0		**LOW Shear (0.6 Vd)**	428.683	
R1	18.0		Case Is of	LOW SHEAR	
R2	9.0		**Design Bendibg**	506.400	OK
Ix	53200.0		**Strength (Md)**	527.236	OK
Iy	1340.0				
rx	22.0		Permissible Deflection	3.33333333	
ry	3.5		Maximum Deflection	0.00146852	OK
Zx	1930.0		In case of High Shear		
Zy	140.0		Beta (β)	0.04	
d	484		Zfd	1479472.5	
A	11000.0		Mfd	336.24	
			Mdv	499.59375	OK
		55.5555556			
E	200000.00		Optimum Depth (d)	692.609243	mm
Mu	0.3			700	mm
d/tw	200		Otimum web thickness (tw)	4	
Kv	5.35			4	
(λw<0.8)	144.3375673		Af	2121.84494	
(0.8<λw<1.2	-33.96067228		bf	210	
(λw>1.2)	26.26782589		tf	20	
			Falnge outstand (b)	103	mm
			(d)	700	
			b/Tf	5.150	
			CHECK Outstand	PLASTIC	
			Zpz	2856000	
			Md	649.090909	OK
			By post critical method	31.5460028	
			λw	2.34410805	
			τb	26.2678259	
			Vcr	367.749562	OK
			Vd	367.404717	OK
			Cross Sec Area	7000	

Chapter 6

Conclusion

From many decades structures which are formed from steel became popular, but in countries like Indian 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 IS 800-2007. further it is difficult for a beginner to select on from typical Hot Rolled I beam and Welded I beam based on loading variation considering economy and also IS code do not specify exact loading range to select appropriate one. so, we have decided to work on beams. Typical Hot Rolled I beam and Welded I beam design problems will be worked out with the help of Microsoft excel, to check these Hot Rolled I beam and Welded I beam for economy by designing same for various loadings. These all will be carried out by considering standard specification provided by IS 800-2007 and grade of steel fe410. The obtained results will be presented in the form of tables and graphs.

Aim of our project was to compare Rolled and Welded Section. We have started to work on it by using standard processes and specifications given by IS 800:2007. While solving the problems for this subject design of steel structures in third year we had decided to compare both to check their economy. We have taken total design processes of beam as per IS 800:2007 and for welded beam we have considered it as plate girder without stiffeners.

The results which we have got are very promising and gives comparative results. We have taken d/t_w ratio between 75 to 175 and checked stability of welded section and rolled section as per IS. If we are not providing intermediate stiffeners to the beam then d/t_w ratio should not be greater than 200.

The capacity of section we have calculated and the same is converted into service load i.e if any beam is having capacity=150KNm then the factored BM=150/1.5=100 KNm on same manner we have considered the shear force. So, each and every member we have designed are within safety check as we have not applied load more than capacity.

Further, the excel sheet that we have designed is also capable of helping the design engineers to design the beams for various sections for various Shear force and Bending moments at a glance. The obtained results will be presented in the form of tables and graphs. After getting results we can conclude that,

a) For ISHB in case of welded section it can observe that the strength of bending increases with the increase in d/t_w ratios and having near about same area for both the sections. As it is seen that when d/t_w =125 and 150 the section ranges between ISHB 250 to 350 and ISHB 300 to 450.
b) For ISJB and welded section for ratios ranging from 75 to 175 it is been found that it gives comparatively better bending strength as compared to rolled steel section but the area also increases only in welded section and which makes it not so economical.
c) For ISLB, d/t_w =75 to150 its been concluded that the nature of graph is neutral that is increase in bending strength results in increase of area . but at ratio 175 there is a chance for bigger sections as the strength achieves is more and area is near about the same for both sections.
d) For ISMB, d/t_w =75 to 150 its been the same conclusion as above for ISLB since the graph is neutral till the ratio 150 and after that there is a chance for bigger sections as the strength achieves is more and area is near about the same for both rolled and welded sections.

e) For ISWB its again been the same situation as the neutral graphs occurs between ratio 75 to125. Between the ratio 150 and 175 bigger section such as ISWB 300 and furthers stand a chance of getting higher bending strength with respect to the near about the same areas for both sections.

f) The final conclusion is that anyone who wants to design flexural member should have thorough knowledge of both Welded and rolled section designs, in overall we can say the for higher size rolled sections replacement is possible with welded I girder. But in such cases we need to compromise with low shear capacity of welded sections, as we can get higher value of bending strength as well as economy (Lower cross sectional area) with capable welded section that can replace the rolled section.

g) These observations are not valid when we design welded beam for comparatively lower sections and that needs to do more iterations for proper design of welded section perhaps it will not be economical.

Future Scope

- Further study can be extended for various sections other than I section.
- Further in hot rolled sections design external UDL or point load can be considered.
- Same excel sheet can further be modified to calculate the intermediate stiffeners and thereby making plate girder.
- Study can be extended considering temperature effects.
- Grade of steel used in this study is Fe410, so further study can be extended for various grade of steel.
- We have taken d/t_w ratio between 75 to 175

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APPENDIX

Annexure-1

VALIDATION

Rolled Steel Sections									Welded Beam					
BM	SF	Section	area	Md	Vd	D	Bf	D/tw	area	Md	Vd	D	Bf	D/tw
268.7	241.4	LB500	9550.0	403.1	603.6	500	180	54.3	12760.0	450.0	493.4	530	150	75

1) Laterally supported

Data:- BM=268.7×10^6 N /mm

SF=241.4×10^3 N

Plastic section modulus

ZPz req =Mγm$_\circ$/fy

=268.7×10^6×1.1/250 = 1182× 10^3 mm^3

From IS code (ISLB500)

ZPz=1773.67×10^3 mm^3

Zez=1543.2×10^3 mm^3

Area=9550mm^3

h=D=500mm

bf=180mm,tf=14.1mm,tw=9.2mm,R1=17mm,I2=38579×10^4mm^4

d=h-2(tf-R1)

=500-2(14.1+17)

=437.8mm

d/tw=437.8/9.2

=47.5 < 84∈

$= 84\sqrt{(\frac{250}{fy})}$

= 84

Shear capacity

Design max SF= 241.4× $10^3 N$

Vd=(design shear strength)

Vd= fyhtw/$\sqrt{3} \times \gamma m_\circ$

$=(250\times500\times 9.2)/(\sqrt{3}\times 1.1)$

$=603.59\times 10^3 N$

=603.59KN > design SF =241.4KN

∴safe

0.6vd=0.6× 603.59

=362.154KN > V

∴This is the case of low shear

∴Design bending strength (Md)

Md=$(\beta b \times Zpz \times fy)/(\gamma m_{\circ})$

=$(1\times 1773.6 \times 10^3 \times 250)/1.1$

=403.10 KNm >30KNm

<$(1.2\times Zez \times fy)/\gamma m_{\circ}$

=$(1.2\times 1543.2 \times 10^3 \times 250)/1.1$

=420.87 KNm

∴Safe

2) Welded section

Data :_ BM=269 KNm

SF=242 KN

Optimum depth

d= ((Mz×k)/fy)^0.33

=468.69~470mm

Optimum web thickness

tw=(Mz/(fy× k^2)^0.33)

=6.47~8mm

Web plate 470× $8mm$

A_f=(($M_z\times \gamma m_{\circ})/(fy \times d)$)

=$(1.2\times 269 \times 10^6 \times 1.1)/(250 \times 470)$

=3019.55~3020mm

b_f=0.3× 470

=141~150mm

A_f =A_f/b_f =3020/150 =20.13~30mm

Flange 150×30

b= $(b_f\text{-}t_w)/2$

=(150-8)/2 =71mm

b/t_f =6071/30

=1.85 < 8×∈

(section is plastic)

$\therefore \beta = 1$

Zp=$b_f\times t_f(D\text{-}t_f)$

$=1.98\times 10^6 mm^6$

Md=Zp$\times\left(\frac{fy}{\gamma m\circ}\right)\times\beta$

=1980$\times\left(\frac{250}{1.1}\right)\times 1$

=450000

Z_{cr}=(k$\times\pi^2\times E$)/(12(1-μ^2)$\times(d/tw)$^2)

=279.89

Λw =$\frac{\sqrt{fyw}}{\sqrt{3}\times\zeta cr}$

=0.71

ζb=fyw/$\sqrt{3}\times\lambda w^2$

=250/$\sqrt{3}\times(0.71)^2$

=143.16~144.3325

V_{cr}=d$\times tw\times\zeta b$

=1356.77

Vd=(tw$\times d\times fy/\sqrt{3}\times\gamma m_\circ)\times 1.1$

=493.37KN

A=2$\times bf\times tf + d\times tw$

=2$\times 180\times 30 + 470\times 8$

Area = 12760mm …… safe

Annexure-II

Rolled Steel Sections									Welded Beam					
BM	SF	Section	area	Md	Vd	D	Bf	D/tw	area	Md	Vd	D	Bf	D/tw
ISHB									**75**					
32.7	42.5	**HB150**	3450.0	49.0	106.3	150	150	27.78	2560.0	41.8	126.0	260	80	**75**
60.2	64.0	**HB200**	4750.0	90.3	160.1	200	200	32.79	4760.0	110.5	152.2	330	90	**75**
78.1	76.8	**HB225**	5490.0	117.2	191.9	225	225	34.62	5860.0	131.8	244.1	350	100	**75**
139.6	119.7	**HB300**	7480.0	209.5	299.2	300	250	39.47	7080.0	196.4	299.2	420	120	**75**
139.6	119.7	**HB300**	7480.0	209.5	299.2	300	250	39.47	7080.0	196.4	299.2	420	120	**75**
183.9	152.5	**HB350**	8590.0	275.9	381.2	350	250	42.17	7720.0	236.4	330.7	460	130	**75**
235.8	191.1	**HB400**	9870.0	353.7	477.6	400	250	43.96	9200.0	273.6	472.4	490	140	**75**
296.2	231.5	**HB450**	11100.0	444.3	578.7	450	250	45.92	12840.0	460.2	503.9	540	150	**75**
									100					
32.7	42.5	**HB150**	3450.0	49.0	106.3	150	150	27.78	2640.0	45.5	136.5	280	80	**100**
60.2	64.0	**HB200**	4750.0	90.3	160.1	200	200	32.79	3280.0	70.5	168.0	340	100	**100**
78.1	76.8	**HB225**	5490.0	117.2	191.9	225	225	34.62	5760.0	160.0	178.5	380	110	**100**
102.8	90.5	**HB250**	6500.0	154.1	226.3	250	250	36.23	6320.0	196.4	199.4	420	120	**100**
139.6	119.7	**HB300**	7480.0	209.5	299.2	300	250	39.47	7720.0	236.4	330.7	460	130	**100**
183.9	152.5	**HB350**	8590.0	275.9	381.2	350	250	42.17	8360.0	280.0	362.2	500	140	**100**
235.8	191.1	**HB400**	9870.0	353.7	477.6	400	250	43.96	8940.0	320.5	385.8	530	150	**100**
296.2	231.5	**HB450**	11100.0	444.3	578.7	450	250	45.92	9580.0	370.9	417.3	570	160	**100**
									125					
32.7	42.5	**HB150**	3450.0	49.0	106.3	150	150	27.78	2920.0	55.2	147.0	300	90	**125**
60.2	64.0	**HB200**	4750.0	90.3	160.1	200	200	32.79	3560.0	82.5	178.5	360	110	**125**
78.1	76.8	**HB225**	5490.0	117.2	191.9	225	225	34.62	3880.0	98.2	194.2	390	120	**125**
102.8	90.5	**HB250**	6500.0	154.1	226.3	250	250	36.23	6840.0	230.5	215.2	450	130	**125**
139.6	119.7	**HB300**	7480.0	209.5	299.2	300	250	39.47	7400.0	273.6	236.2	490	140	**125**
183.9	152.5	**HB350**	8590.0	275.9	381.2	350	250	42.17	8940.0	320.5	385.8	530	150	**125**
235.8	191.1	**HB400**	9870.0	353.7	477.6	400	250	43.96	9580.0	370.9	417.3	570	160	**125**
296.2	231.5	**HB450**	11100.0	444.3	578.7	450	250	45.92	10620.0	450.0	448.8	610	180	**125**
									150					
32.7	42.5	**HB150**	3450.0	49.0	106.3	150	150	27.78	3000.0	59.3	157.5	320	90	**150**
60.2	64.0	**HB200**	4750.0	90.3	160.1	200	200	32.79	3640.0	87.5	189.0	380	110	**150**
78.1	76.8	**HB225**	5490.0	117.2	191.9	225	225	34.62	3960.0	103.6	204.7	410	120	**150**
102.8	90.5	**HB250**	6500.0	154.1	226.3	250	250	36.23	4320.0	124.1	225.7	450	130	**150**
139.6	119.7	**HB300**	7480.0	209.5	299.2	300	250	39.47	7920.0	313.6	251.9	520	150	**150**
183.9	152.5	**HB350**	8590.0	275.9	381.2	350	250	42.17	8480.0	363.6	272.9	560	160	**150**
235.8	191.1	**HB400**	9870.0	353.7	477.6	400	250	43.96	9040.0	417.3	293.9	600	170	**150**
296.2	231.5	**HB450**	11100.0	444.3	578.7	450	250	45.92	11260.0	509.5	480.3	650	190	**150**
									175					
32.7	42.5	**HB150**	3450.0	49.0	106.3	150	150	27.78	2930.0	68.2	122.0	330	100	**175**
60.2	64.0	**HB200**	4750.0	90.3	160.1	200	200	32.79	3920.0	100.9	199.4	400	120	**175**
78.1	76.8	**HB225**	5490.0	117.2	191.9	225	225	34.62	4240.0	118.2	215.2	430	130	**175**

102.8	90.5	**HB250**	6500.0	154.1	226.3	250	250	36.23	4600.0	140.0	236.2	470	140	**175**
139.6	119.7	**HB300**	7480.0	209.5	299.2	300	250	39.47	5000.0	167.0	262.4	520	150	**175**
183.9	152.5	**HB350**	8590.0	275.9	381.2	350	250	42.17	9000.0	409.5	288.7	590	170	**175**
235.8	191.1	**HB400**	9870.0	353.7	477.6	400	250	43.96	9560.0	466.4	309.7	630	180	**175**
296.2	231.5	**HB450**	11100.0	444.3	578.7	450	250	45.92	10560.0	563.6	335.9	680	200	**175**
ISJB									**75**					
7.5	23.6	**JB150**	901.0	11.3	59.0	150	50	50.0	1450.0	15.9	59.0	170	50	**75**
9.7	29.4	**JB175**	1030.0	14.6	73.5	175	50	54.7	1640.0	17.0	84.0	180	50	**75**
13.8	35.7	**JB200**	1260.0	20.7	89.2	200	60	58.8	1920.0	23.2	94.5	200	60	**75**
20.3	43.7	**JB225**	1630.0	30.5	109.2	225	80	60.8	2000.0	25.9	105.0	220	60	**75**
									100					
7.5	23.6	**JB150**	901.0	11.3	59.0	150	50	50.0	1480.0	17.0	63.0	180	50	**100**
9.7	29.4	**JB175**	1030.0	14.6	73.5	175	50	54.7	1740.0	23.2	70.9	200	60	**100**
13.8	35.7	**JB200**	1260.0	20.7	89.2	200	60	58.8	2000.0	25.9	105.0	220	60	**100**
20.3	43.7	**JB225**	1630.0	30.5	109.2	225	80	60.8	2280.0	33.4	115.5	240	70	**100**
									125					
7.5	23.6	**JB150**	901.0	11.3	59.0	150	50	50.0	1710.0	21.8	66.9	190	60	**125**
9.7	29.4	**JB175**	1030.0	14.6	73.5	175	50	54.7	1770.0	24.5	74.8	210	60	**125**
13.8	35.7	**JB200**	1260.0	20.7	89.2	200	60	58.8	2030.0	31.8	82.7	230	70	**125**
20.3	43.7	**JB225**	1630.0	30.5	109.2	225	80	60.8	2320.0	41.8	94.5	260	80	**125**
									150					
7.5	23.6	**JB150**	901.0	11.3	59.0	150	50	50.0	1740.0	23.2	70.9	200	60	**150**
9.7	29.4	**JB175**	1030.0	14.6	73.5	175	50	54.7	1800.0	25.9	78.7	220	60	**150**
13.8	35.7	**JB200**	1260.0	20.7	89.2	200	60	58.8	2060.0	33.4	86.6	240	70	**150**
20.3	43.7	**JB225**	1630.0	30.5	109.2	225	80	60.8	2350.0	43.6	98.4	270	80	**150**
									175					
7.5	23.6	**JB150**	901.0	11.3	59.0	150	50	50.0	1770.0	24.5	74.8	210	60	**175**
9.7	29.4	**JB175**	1030.0	14.6	73.5	175	50	54.7	2030.0	31.8	82.7	230	70	**175**
13.8	35.7	**JB200**	1260.0	20.7	89.2	200	60	58.8	2320.0	41.8	94.5	260	80	**175**
20.3	43.7	**JB225**	1630.0	30.5	109.2	225	80	60.8	2610.0	53.2	106.3	290	90	**175**
ISLB									**75**					
3.4	14.6	**LB075**	771.0	5.1	36.4	75	50	20.3	1130.0	9.1	43.3	130	40	**75**
5.9	21.0	**LB100**	1020.0	8.8	52.5	100	50	25.0	1420.0	14.8	55.1	160	50	**75**
11.2	28.9	**LB125**	1510.0	16.8	72.2	125	75	28.4	1880.0	21.8	89.2	190	60	**75**
15.8	37.8	**LB150**	1810.0	23.8	94.5	150	80	31.3	1960.0	24.5	99.7	210	60	**75**
21.7	46.8	**LB175**	2130.0	32.6	117.1	175	90	34.3	2240.0	31.8	110.2	230	70	**75**
27.9	56.7	**LB200**	2530.0	41.9	141.7	200	100	37.0	2320.0	35.0	120.7	250	70	**75**
38.6	68.5	**LB225**	2990.0	57.9	171.2	225	100	38.8	4200.0	83.6	131.2	290	80	**75**
51.3	80.0	**LB250**	3550.0	77.0	200.1	250	125	41.0	4680.0	102.3	141.7	310	90	**75**
67.1	92.4	**LB275**	4200.0	100.7	230.9	275	140	43.0	5400.0	114.5	236.2	340	90	**75**
84.0	105.5	**LB300**	4810.0	126.0	263.7	300	150	44.8	5920.0	136.4	251.9	360	100	**75**
104.2	119.4	**LB325**	5490.0	156.3	298.5	325	165	46.4	6440.0	160.0	267.7	380	110	**75**

128.9	135.9	LB350	6300.0	193.4	339.8	350	165	47.3	7020.0	190.9	291.3	410	120	75
166.6	168.0	LB400	7240.0	249.9	419.9	400	165	50.0	7200.0	207.3	314.9	440	120	75
212.3	203.1	LB450	8310.0	318.5	507.8	450	170	52.3	11240.0	354.5	451.4	490	130	75
268.7	241.4	LB500	9550.0	403.1	603.6	500	180	54.3	12760.0	450.0	493.4	530	150	75
337.6	285.8	LB550	11000.0	506.4	714.5	550	190	55.6	13680.0	523.6	535.4	570	160	75
424.0	330.7	LB600	12700.0	636.0	826.7	600	210	57.1	14600.0	602.7	577.4	610	170	75
									100					
3.4	14.6	LB075	771.0	5.1	36.4	75	50	20.3	1190.0	10.9	51.2	150	40	100
5.9	21.0	LB100	1020.0	8.8	52.5	100	50	25.0	1450.0	15.9	59.0	170	50	100
11.2	28.9	LB125	1510.0	16.8	72.2	125	75	28.4	1740.0	23.2	70.9	200	60	100
15.8	37.8	LB150	1810.0	23.8	94.5	150	80	31.3	2240.0	31.8	110.2	230	70	100
21.7	46.8	LB175	2130.0	32.6	117.1	175	90	34.3	2320.0	35.0	120.7	250	70	100
27.9	56.7	LB200	2530.0	41.9	141.7	200	100	37.0	2600.0	43.6	131.2	270	80	100
38.6	68.5	LB225	2990.0	57.9	171.2	225	100	38.8	2880.0	53.2	141.7	290	90	100
51.3	80.0	LB250	3550.0	77.0	200.1	250	125	41.0	4800.0	114.5	157.5	340	90	100
67.1	92.4	LB275	4200.0	100.7	230.9	275	140	43.0	5320.0	140.9	173.2	370	100	100
84.0	105.5	LB300	4810.0	126.0	263.7	300	150	44.8	5800.0	165.0	183.7	390	110	100
104.2	119.4	LB325	5490.0	156.3	298.5	325	165	46.4	6320.0	196.4	199.4	420	120	100
128.9	135.9	LB350	6300.0	193.4	339.8	350	165	47.3	7660.0	230.5	322.8	450	130	100
166.6	168.0	LB400	7240.0	249.9	419.9	400	165	50.0	8240.0	267.3	346.4	480	140	100
212.3	203.1	LB450	8310.0	318.5	507.8	450	170	52.3	8880.0	313.6	377.9	520	150	100
268.7	241.4	LB500	9550.0	403.1	603.6	500	180	54.3	9520.0	363.6	409.4	560	160	100
337.6	285.8	LB550	11000.0	506.4	714.5	550	190	55.6	10160.0	417.3	440.9	600	170	100
424.0	330.7	LB600	12700.0	636.0	826.7	600	210	57.1	15600.0	699.5	629.8	660	180	100
									125					
3.4	14.6	LB075	771.0	5.1	36.4	75	50	20.3	1190.0	10.9	51.2	150	40	125
5.9	21.0	LB100	1020.0	8.8	52.5	100	50	25.0	1480.0	17.0	63.0	180	50	125
11.2	28.9	LB125	1510.0	16.8	72.2	125	75	28.4	1800.0	25.9	78.7	220	60	125
15.8	37.8	LB150	1810.0	23.8	94.5	150	80	31.3	2060.0	33.4	86.6	240	70	125
21.7	46.8	LB175	2130.0	32.6	117.1	175	90	34.3	2560.0	41.8	126.0	260	80	125
27.9	56.7	LB200	2530.0	41.9	141.7	200	100	37.0	2880.0	53.2	141.7	290	90	125
38.6	68.5	LB225	2990.0	57.9	171.2	225	100	38.8	2960.0	57.3	152.2	310	90	125
51.3	80.0	LB250	3550.0	77.0	200.1	250	125	41.0	3280.0	70.5	168.0	340	100	125
67.1	92.4	LB275	4200.0	100.7	230.9	275	140	43.0	3600.0	85.0	183.7	370	110	125
84.0	105.5	LB300	4810.0	126.0	263.7	300	150	44.8	3920.0	100.9	199.4	400	120	125
104.2	119.4	LB325	5490.0	156.3	298.5	325	165	46.4	6840.0	230.5	215.2	450	130	125
128.9	135.9	LB350	6300.0	193.4	339.8	350	165	47.3	7360.0	267.3	230.9	480	140	125
166.6	168.0	LB400	7240.0	249.9	419.9	400	165	50.0	7880.0	306.8	246.7	510	150	125
212.3	203.1	LB450	8310.0	318.5	507.8	450	170	52.3	9460.0	356.4	401.5	550	160	125
268.7	241.4	LB500	9550.0	403.1	603.6	500	180	54.3	10160.0	417.3	440.9	600	170	125
337.6	285.8	LB550	11000.0	506.4	714.5	550	190	55.6	10800.0	474.5	472.4	640	180	125
424.0	330.7	LB600	12700.0	636.0	826.7	600	210	57.1	11840.0	563.6	503.9	680	200	125
									150					
3.4	14.6	LB075	771.0	5.1	36.4	75	50	20.3	1420.0	14.8	55.1	160	50	150

5.9	21.0	**LB100**	1020.0	8.8	52.5	100	50	25.0	1710.0	21.8	66.9	190	60	**150**
11.2	28.9	**LB125**	1510.0	16.8	72.2	125	75	28.4	2030.0	31.8	82.7	230	70	**150**
15.8	37.8	**LB150**	1810.0	23.8	94.5	150	80	31.3	2090.0	35.0	90.5	250	70	**150**
21.7	46.8	**LB175**	2130.0	32.6	117.1	175	90	34.3	2380.0	45.5	102.3	280	80	**150**
27.9	56.7	**LB200**	2530.0	41.9	141.7	200	100	37.0	2640.0	55.2	110.2	300	90	**150**
38.6	68.5	**LB225**	2990.0	57.9	171.2	225	100	38.8	3240.0	68.2	162.7	330	100	**150**
51.3	80.0	**LB250**	3550.0	77.0	200.1	250	125	41.0	3560.0	82.5	178.5	360	110	**150**
67.1	92.4	**LB275**	4200.0	100.7	230.9	275	140	43.0	3880.0	98.2	194.2	390	120	**150**
84.0	105.5	**LB300**	4810.0	126.0	263.7	300	150	44.8	4000.0	106.4	209.9	420	120	**150**
104.2	119.4	**LB325**	5490.0	156.3	298.5	325	165	46.4	4320.0	124.1	225.7	450	130	**150**
128.9	135.9	**LB350**	6300.0	193.4	339.8	350	165	47.3	7440.0	280.0	241.4	500	140	**150**
166.6	168.0	**LB400**	7240.0	249.9	419.9	400	165	50.0	8000.0	327.3	262.4	540	150	**150**
212.3	203.1	**LB450**	8310.0	318.5	507.8	450	170	52.3	9000.0	409.5	288.7	590	170	**150**
268.7	241.4	**LB500**	9550.0	403.1	603.6	500	180	54.3	10740.0	466.4	464.5	630	180	**150**
337.6	285.8	**LB550**	11000.0	506.4	714.5	550	190	55.6	11380.0	526.8	496.0	670	190	**150**
424.0	330.7	**LB600**	12700.0	636.0	826.7	600	210	57.1	12480.0	630.0	535.4	720	210	**150**
											175			
3.4	14.6	**LB075**	771.0	5.1	36.4	75	50	20.3	1450.0	15.9	59.0	170	50	**175**
5.9	21.0	**LB100**	1020.0	8.8	52.5	100	50	25.0	1740.0	23.2	70.9	200	60	**175**
11.2	28.9	**LB125**	1510.0	16.8	72.2	125	75	28.4	2060.0	33.4	86.6	240	70	**175**
15.8	37.8	**LB150**	1810.0	23.8	94.5	150	80	31.3	2350.0	43.6	98.4	270	80	**175**
21.7	46.8	**LB175**	2130.0	32.6	117.1	175	90	34.3	2610.0	53.2	106.3	290	90	**175**
27.9	56.7	**LB200**	2530.0	41.9	141.7	200	100	37.0	2700.0	59.3	118.1	320	90	**175**
38.6	68.5	**LB225**	2990.0	57.9	171.2	225	100	38.8	2990.0	72.7	129.9	350	100	**175**
51.3	80.0	**LB250**	3550.0	77.0	200.1	250	125	41.0	3640.0	87.5	189.0	380	110	**175**
67.1	92.4	**LB275**	4200.0	100.7	230.9	275	140	43.0	3960.0	103.6	204.7	410	120	**175**
84.0	105.5	**LB300**	4810.0	126.0	263.7	300	150	44.8	4280.0	121.1	220.4	440	130	**175**
104.2	119.4	**LB325**	5490.0	156.3	298.5	325	165	46.4	4600.0	140.0	236.2	470	140	**175**
128.9	135.9	**LB350**	6300.0	193.4	339.8	350	165	47.3	4960.0	163.6	257.2	510	150	**175**
166.6	168.0	**LB400**	7240.0	249.9	419.9	400	165	50.0	8520.0	370.9	278.2	570	160	**175**
212.3	203.1	**LB450**	8310.0	318.5	507.8	450	170	52.3	9480.0	450.0	299.2	610	180	**175**
268.7	241.4	**LB500**	9550.0	403.1	603.6	500	180	54.3	10080.0	518.2	325.4	660	190	**175**
337.6	285.8	**LB550**	11000.0	506.4	714.5	550	190	55.6	12420.0	620.5	527.5	710	210	**175**
424.0	330.7	**LB600**	12700.0	636.0	826.7	600	210	57.1	13120.0	700.0	566.9	760	220	**175**
			ISMB								**75**			
6.2	24.7	**MB100**	1140.0	9.4	61.7	100	50	21.28	1420.0	14.8	55.1	160	50	**75**
12.4	32.8	**MB125**	1700.0	18.6	82.0	125	70	25.00	1880.0	21.8	89.2	190	60	**75**
16.7	39.4	**MB150**	1910.0	25.1	98.4	150	75	30.00	1960.0	24.5	99.7	210	60	**75**
25.2	53.3	**MB175**	2500.0	37.7	133.2	175	85	30.17	2280.0	33.4	115.5	240	70	**75**
38.5	59.8	**MB200**	3080.0	57.7	149.6	200	100	35.09	4200.0	83.6	131.2	290	80	**75**
52.8	76.8	**MB225**	3970.0	79.2	191.9	225	110	34.62	4720.0	106.4	147.0	320	90	**75**
70.6	90.5	**MB250**	4750.0	105.8	226.3	250	125	36.23	5400.0	114.5	236.2	340	90	**75**
98.7	121.2	**MB300**	5860.0	148.1	303.1	300	140	38.96	6440.0	160.0	267.7	380	110	**75**

134.8	148.8	**MB350**	6670.0	202.2	372.0	350	140	43.21	7080.0	196.4	299.2	420	120	**75**
178.2	186.9	**MB400**	7840.0	267.3	467.1	400	140	44.94	7660.0	230.5	322.8	450	130	**75**
232.3	222.0	**MB450**	9220.0	348.5	555.0	450	150	47.87	9200.0	273.6	472.4	490	140	**75**
314.3	267.7	**MB500**	11100.0	471.5	669.2	500	180	49.02	12920.0	470.5	514.4	550	150	**75**
410.9	323.3	**MB550**	13200.0	616.4	808.3	550	190	49.11	14520.0	591.1	566.9	600	170	**75**
531.9	377.9	**MB600**	15600.0	797.9	944.8	600	210	50.00	16700.0	687.3	774.2	650	180	**75**
									100					
6.2	24.7	**MB100**	1140.0	9.4	61.7	100	50	21.28	1450.0	15.9	59.0	170	50	**100**
12.4	32.8	**MB125**	1700.0	18.6	82.0	125	70	25.00	1770.0	24.5	74.8	210	60	**100**
16.7	39.4	**MB150**	1910.0	25.1	98.4	150	75	30.00	2240.0	31.8	110.2	230	70	**100**
25.2	53.3	**MB175**	2500.0	37.7	133.2	175	85	30.17	2560.0	41.8	126.0	260	80	**100**
38.5	59.8	**MB200**	3080.0	57.7	149.6	200	100	35.09	2880.0	53.2	141.7	290	90	**100**
52.8	76.8	**MB225**	3970.0	79.2	191.9	225	110	34.62	4800.0	114.5	157.5	340	90	**100**
70.6	90.5	**MB250**	4750.0	105.8	226.3	250	125	36.23	5320.0	140.9	173.2	370	100	**100**
98.7	121.2	**MB300**	5860.0	148.1	303.1	300	140	38.96	6280.0	190.9	194.2	410	120	**100**
134.8	148.8	**MB350**	6670.0	202.2	372.0	350	140	43.21	7660.0	230.5	322.8	450	130	**100**
178.2	186.9	**MB400**	7840.0	267.3	467.1	400	140	44.94	8300.0	273.6	354.3	490	140	**100**
232.3	222.0	**MB450**	9220.0	348.5	555.0	450	150	47.87	8940.0	320.5	385.8	530	150	**100**
314.3	267.7	**MB500**	11100.0	471.5	669.2	500	180	49.02	10040.0	401.8	425.1	580	170	**100**
410.9	323.3	**MB550**	13200.0	616.4	808.3	550	190	49.11	15520.0	687.3	619.3	650	180	**100**
531.9	377.9	**MB600**	15600.0	797.9	944.8	600	210	50.00	17200.0	845.5	682.3	710	200	**100**
									125					
6.2	24.7	**MB100**	1140.0	9.4	61.7	100	50	21.28	1480.0	17.0	63.0	180	50	**125**
12.4	32.8	**MB125**	1700.0	18.6	82.0	125	70	25.00	1800.0	25.9	78.7	220	60	**125**
16.7	39.4	**MB150**	1910.0	25.1	98.4	150	75	30.00	2090.0	35.0	90.5	250	70	**125**
25.2	53.3	**MB175**	2500.0	37.7	133.2	175	85	30.17	2640.0	45.5	136.5	280	80	**125**
38.5	59.8	**MB200**	3080.0	57.7	149.6	200	100	35.09	2960.0	57.3	152.2	310	90	**125**
52.8	76.8	**MB225**	3970.0	79.2	191.9	225	110	34.62	3320.0	72.7	173.2	350	100	**125**
70.6	90.5	**MB250**	4750.0	105.8	226.3	250	125	36.23	3640.0	87.5	189.0	380	110	**125**
98.7	121.2	**MB300**	5860.0	148.1	303.1	300	140	38.96	6400.0	207.3	209.9	440	120	**125**
134.8	148.8	**MB350**	6670.0	202.2	372.0	350	140	43.21	7360.0	267.3	230.9	480	140	**125**
178.2	186.9	**MB400**	7840.0	267.3	467.1	400	140	44.94	8940.0	320.5	385.8	530	150	**125**
232.3	222.0	**MB450**	9220.0	348.5	555.0	450	150	47.87	9580.0	370.9	417.3	570	160	**125**
314.3	267.7	**MB500**	11100.0	471.5	669.2	500	180	49.02	10680.0	458.2	456.6	620	180	**125**
410.9	323.3	**MB550**	13200.0	616.4	808.3	550	190	49.11	11840.0	563.6	503.9	680	200	**125**
531.9	377.9	**MB600**	15600.0	797.9	944.8	600	210	50.00	12540.0	639.5	543.2	730	210	**125**
									150					
6.2	24.7	**MB100**	1140.0	9.4	61.7	100	50	21.28	1710.0	21.8	66.9	190	60	**150**
12.4	32.8	**MB125**	1700.0	18.6	82.0	125	70	25.00	2060.0	33.4	86.6	240	70	**150**
16.7	39.4	**MB150**	1910.0	25.1	98.4	150	75	30.00	2320.0	41.8	94.5	260	80	**150**
25.2	53.3	**MB175**	2500.0	37.7	133.2	175	85	30.17	2610.0	53.2	106.3	290	90	**150**
38.5	59.8	**MB200**	3080.0	57.7	149.6	200	100	35.09	3240.0	68.2	162.7	330	100	**150**
52.8	76.8	**MB225**	3970.0	79.2	191.9	225	110	34.62	3600.0	85.0	183.7	370	110	**150**
70.6	90.5	**MB250**	4750.0	105.8	226.3	250	125	36.23	3920.0	100.9	199.4	400	120	**150**

98.7	121.2	**MB300**	5860.0	148.1	303.1	300	140	38.96	4280.0	121.1	220.4	440	130	**150**
134.8	148.8	**MB350**	6670.0	202.2	372.0	350	140	43.21	7880.0	306.8	246.7	510	150	**150**
178.2	186.9	**MB400**	7840.0	267.3	467.1	400	140	44.94	8480.0	363.6	272.9	560	160	**150**
232.3	222.0	**MB450**	9220.0	348.5	555.0	450	150	47.87	9040.0	417.3	293.9	600	170	**150**
314.3	267.7	**MB500**	11100.0	471.5	669.2	500	180	49.02	11320.0	518.2	488.1	660	190	**150**
410.9	323.3	**MB550**	13200.0	616.4	808.3	550	190	49.11	12480.0	630.0	535.4	720	210	**150**
531.9	377.9	**MB600**	15600.0	797.9	944.8	600	210	50.00	13640.0	752.7	582.6	780	230	**150**
									175					
6.2	24.7	**MB100**	1140.0	9.4	61.7	100	50	21.28	1740.0	23.2	70.9	200	60	**175**
12.4	32.8	**MB125**	1700.0	18.6	82.0	125	70	25.00	2090.0	35.0	90.5	250	70	**175**
16.7	39.4	**MB150**	1910.0	25.1	98.4	150	75	30.00	2350.0	43.6	98.4	270	80	**175**
25.2	53.3	**MB175**	2500.0	37.7	133.2	175	85	30.17	2670.0	57.3	114.2	310	90	**175**
38.5	59.8	**MB200**	3080.0	57.7	149.6	200	100	35.09	2990.0	72.7	129.9	350	100	**175**
52.8	76.8	**MB225**	3970.0	79.2	191.9	225	110	34.62	3640.0	87.5	189.0	380	110	**175**
70.6	90.5	**MB250**	4750.0	105.8	226.3	250	125	36.23	4000.0	106.4	209.9	420	120	**175**
98.7	121.2	**MB300**	5860.0	148.1	303.1	300	140	38.96	4600.0	140.0	236.2	470	140	**175**
134.8	148.8	**MB350**	6670.0	202.2	372.0	350	140	43.21	4960.0	163.6	257.2	510	150	**175**
178.2	186.9	**MB400**	7840.0	267.3	467.1	400	140	44.94	8960.0	401.8	283.4	580	170	**175**
232.3	222.0	**MB450**	9220.0	348.5	555.0	450	150	47.87	9560.0	466.4	309.7	630	180	**175**
314.3	267.7	**MB500**	11100.0	471.5	669.2	500	180	49.02	10600.0	572.7	341.2	690	200	**175**
410.9	323.3	**MB550**	13200.0	616.4	808.3	550	190	49.11	13060.0	690.0	559.0	750	220	**175**
531.9	377.9	**MB600**	15600.0	797.9	944.8	600	210	50.00	14280.0	829.1	614.1	820	240	**175**
ISWB									**75**					
19.2	42.5	**WB150**	2170.0	28.8	106.3	150	100	27.7	2000.0	25.9	105.0	220	60	**75**
29.4	53.3	**WB175**	2810.0	44.1	133.2	175	125	30.17	2320.0	35.0	120.7	250	70	**75**
44.5	64.0	**WB200**	3670.0	66.8	160.1	200	140	32.7	4240.0	87.3	136.5	300	80	**75**
59.1	75.6	**WB225**	4320.0	88.6	189.0	225	150	35.1	4760.0	110.5	152.2	330	90	**75**
79.9	87.9	**WB250**	5200.0	119.9	219.8	250	200	37.3	5920.0	136.4	251.9	360	100	**75**
110.8	116.5	**WB300**	6130.0	166.2	291.3	300	200	40.5	6500.0	165.0	275.6	390	110	**75**
150.8	147.0	**WB350**	7250.0	226.2	367.4	350	200	43.75	7140.0	201.8	307.0	430	120	**75**
195.5	180.6	**WB400**	8500.0	293.2	451.4	400	200	46.5	7720.0	236.4	330.7	460	130	**75**
266.7	217.3	**WB450**	10100.0	400.1	543.2	450	200	48.91	9760.0	306.8	493.4	510	150	**75**
356.2	259.8	**WB500**	12100.0	534.4	649.5	500	250	50.50	13760.0	534.5	545.9	580	160	**75**
464.5	303.1	**WB550**	14300.0	696.9	757.8	550	250	52.38	14680.0	614.3	587.8	620	170	**75**
657.8	371.6	**WB600**	18500.0	986.7	929.0	600	250	50.84	17700.0	777.3	826.7	690	190	**75**
									100					
19.2	42.5	**WB150**	2170.0	28.8	106.3	150	100	27.7	2280.0	33.4	115.5	240	70	**100**
29.4	53.3	**WB175**	2810.0	44.1	133.2	175	125	30.17	2600.0	43.6	131.2	270	80	**100**
44.5	64.0	**WB200**	3670.0	66.8	160.1	200	140	32.78	2960.0	57.3	152.2	310	90	**100**
59.1	75.6	**WB225**	4320.0	88.6	189.0	225	150	35.15	5240.0	131.8	162.7	350	100	**100**
79.9	87.9	**WB250**	5200.0	119.9	219.8	250	200	37.3	5800.0	165.0	183.7	390	110	**100**
110.8	116.5	**WB300**	6130.0	166.2	291.3	300	200	40.54	7140.0	201.8	307.0	430	120	**100**
150.8	147.0	**WB350**	7250.0	226.2	367.4	350	200	43.75	7780.0	242.3	338.5	470	130	**100**

195.5	180.6	**WB400**	8500.0	293.2	451.4	400	200	46.51	8820.0	306.8	370.0	510	150	**100**
266.7	217.3	**WB450**	10100.0	400.1	543.2	450	200	48.91	9460.0	356.4	401.5	550	160	**100**
356.2	259.8	**WB500**	12100.0	534.4	649.5	500	250	50.50	10620.0	450.0	448.8	610	180	**100**
464.5	303.1	**WB550**	14300.0	696.9	757.8	550	250	52.3	16360.0	764.3	650.8	680	190	**100**
657.8	371.6	**WB600**	18500.0	986.7	929.0	600	250	50.84	18120.0	945.0	724.3	750	210	**100**
									125					
19.2	42.5	**WB150**	2170.0	28.8	106.3	150	100	27.7	2320.0	41.8	94.5	260	80	**125**
29.4	53.3	**WB175**	2810.0	44.1	133.2	175	125	30.17	2880.0	53.2	141.7	290	90	**125**
44.5	64.0	**WB200**	3670.0	66.8	160.1	200	140	32.78	3240.0	68.2	162.7	330	100	**125**
59.1	75.6	**WB225**	4320.0	88.6	189.0	225	150	35.15	3560.0	82.5	178.5	360	110	**125**
79.9	87.9	**WB250**	5200.0	119.9	219.8	250	200	37.31	3880.0	98.2	194.2	390	120	**125**
110.8	116.5	**WB300**	6130.0	166.2	291.3	300	200	40.54	6880.0	236.4	220.4	460	130	**125**
150.8	147.0	**WB350**	7250.0	226.2	367.4	350	200	43.75	7440.0	280.0	241.4	500	140	**125**
195.5	180.6	**WB400**	8500.0	293.2	451.4	400	200	46.51	9000.0	327.3	393.6	540	150	**125**
266.7	217.3	**WB450**	10100.0	400.1	543.2	450	200	48.91	10100.0	409.5	433.0	590	170	**125**
356.2	259.8	**WB500**	12100.0	534.4	649.5	500	250	50.50	11260.0	509.5	480.3	650	190	**125**
464.5	303.1	**WB550**	14300.0	696.9	757.8	550	250	52.38	11960.0	581.8	519.6	700	200	**125**
657.8	371.6	**WB600**	18500.0	986.7	929.0	600	250	50.84	19720.0	1113.4	776.8	800	230	**125**
									150					
19.2	42.5	**WB150**	2170.0	28.8	106.3	150	100	27.7	2350.0	43.6	98.4	270	80	**150**
29.4	53.3	**WB175**	2810.0	44.1	133.2	175	125	30.17	2670.0	57.3	114.2	310	90	**150**
44.5	64.0	**WB200**	3670.0	66.8	160.1	200	140	32.78	3320.0	72.7	173.2	350	100	**150**
59.1	75.6	**WB225**	4320.0	88.6	189.0	225	150	35.15	3640.0	87.5	189.0	380	110	**150**
79.9	87.9	**WB250**	5200.0	119.9	219.8	250	200	37.31	4000.0	106.4	209.9	420	120	**150**
110.8	116.5	**WB300**	6130.0	166.2	291.3	300	200	40.54	4560.0	136.8	230.9	460	140	**150**
150.8	147.0	**WB350**	7250.0	226.2	367.4	350	200	43.75	5240.0	181.8	267.7	530	160	**175**
195.5	180.6	**WB400**	8500.0	293.2	451.4	400	200	46.51	8520.0	370.9	278.2	570	160	**150**
266.7	217.3	**WB450**	10100.0	400.1	543.2	450	200	48.91	10740.0	466.4	464.5	630	180	**150**
356.2	259.8	**WB500**	12100.0	534.4	649.5	500	250	50.50	11900.0	572.7	511.7	690	200	**150**
464.5	303.1	**WB550**	14300.0	696.9	757.8	550	250	52.38	12600.0	649.1	551.1	740	210	**150**
657.8	371.6	**WB600**	18500.0	986.7	929.0	600	250	50.84	14340.0	840.0	622.0	830	240	**150**
									175					
19.2	42.5	**WB150**	2170.0	28.8	106.3	150	100	27.77	2380.0	45.5	102.3	280	80	**175**
29.4	53.3	**WB175**	2810.0	44.1	133.2	175	125	30.1	2700.0	59.3	118.1	320	90	**175**
44.5	64.0	**WB200**	3670.0	66.8	160.1	200	140	32.78	3560.0	82.5	178.5	360	110	**175**
59.1	75.6	**WB225**	4320.0	88.6	189.0	225	150	35.15	3920.0	100.9	199.4	400	120	**175**
79.9	87.9	**WB250**	5200.0	119.9	219.8	250	200	37.31	4280.0	121.1	220.4	440	130	**175**
110.8	116.5	**WB300**	6130.0	166.2	291.3	300	200	40.54	4640.0	143.2	241.4	480	140	**175**
150.8	147.0	**WB350**	7250.0	226.2	367.4	350	200	43.75	5240.0	181.8	267.7	530	160	**175**
195.5	180.6	**WB400**	8500.0	293.2	451.4	400	200	46.51	9040.0	417.3	293.9	600	170	**175**
266.7	217.3	**WB450**	10100.0	400.1	543.2	450	200	48.91	10080.0	518.2	325.4	660	190	**175**
356.2	259.8	**WB500**	12100.0	534.4	649.5	500	250	50.50	12480.0	630.0	535.4	720	210	**175**
464.5	303.1	**WB550**	14300.0	696.9	757.8	550	250	52.38	13640.0	752.7	582.6	780	230	**175**
657.8	371.6	**WB600**	18500.0	986.7	929.0	600	250	50.84	14980.0	920.5	653.5	870	250	**175**