DESIGN AND FABRICATION OF FIXTURE FOR BENDING AN I-BEAM IN TRANSVERSE SECTION

Srinivasan, R and A. Mathivanan
Department of mechanical Engineering, SRM University, Ramapuram campus, Chennai, Tamilnadu, India
Corresponding author: rsrinivasan.89@gmail.com

ABSTRACT

This paper deals with lateral bending of I - Beam in the transverse direction using a fixture and a hydraulic press. This helps in reduction of time and effort of a manufacturer. I- section beams are usually used as a supports in various buildings and machine parts. In some cases the I sections are used as curved beams in transverse section in structures and as industrial crane rail tracks. These beams usually longitudinally bend by a normal roller machine, and some rolling machines are available for transverse bending also. But they can be installed for mass production only. So in this paper, a fixture is designed and it can be used for pilot production i.e. less number of beams and this fixture will be cost-efficient and power efficient.

INTRODUCTION

In general Structural steel members can be classified as tension or compression members, beams, beam-columns, torsion members or plates. When a beam is transversely loaded in such a manner that the resultant force passes through the longitudinal shear centre axis, the beam only bends and no torsion will occur. When the resultant acts away from the shear centre axis, then the beam will not only bend but also twist. When a beam is subjected to a pure bending moment, originally plane transverse sections before the load was applied, remain plane after the member is loaded. Even in the presence of shear, the modification of stress distribution in most practical cases is very small so that the Engineer's Theory of Bending is sufficiently accurate. The beams subjected to flexure typically have strength and stiffness in the plane associated with bending about their major principal axis (in the plane in which the loads are applied) much greater than in the plane associated with bending about their minor principal axis (Zdenek Kala, 2013). When a beam is bent about its major axis, it may twist and move laterally, before it reaches its elastic/plastic resistance in bending. Although the problem of lateral-torsional buckling of doubly symmetric I-beams has a well-established solution, the same beam with singly symmetric I-beam has not (Dessouki *et al.,* 2014).

Stochastic analysis of bending stability problem of simply supported hot-rolled I-beam with initial random imperfections (Zdenek Kala, 2013). The first theoretical studies of the bending stability problem for a beam with thin rectangular cross-section were elaborated, independently of each other (Yukio Takashima and Naoki Nakata, 2014). The first time who presented the analysis of lateral beam buckling of horizontally loaded thin-walled steel beams which was of significance for practice.

***Main failure modes of hot-rolled beams*:** Excessive bending triggering collapse, this is the basic failure mode provided 1. The beam is prevented from buckling laterally; 2.the component elements are at least compact, so that they do not buckle locally. Such "stocky" beams will collapse by plastic hinge formation. Lateral torsional buckling of long beams which are not suitably braced in the lateral direction. (i.e. "Unrestrained bending" beams). Failure occurs by a combination of lateral deflection and twist. The proportions of the beam, support conditions and the way the load is applied are all factors, which affect failure by lateral torsional buckling. Failure by local buckling of a flange in compression or web due to shear or web under compression due to concentrated loads. Unlikely for hot rolled sections, which are generally stocky. Fabricated box sections may require flange stiffening to prevent premature collapse (Timoshenko, 1936). Web stiffening may be required for plate girders to prevent shear buckling. Load bearing stiffeners are sometimes needed under point loads to resist web buckling (Selda Ucuncuoglu *et al.,* 2014).

Local failure by

(1) Shear yield of web can only occur in very short spans and suitable web stiffeners will have to be designed.
(2) Local crushing of web, Local crushing is possible when concentrated loads act on unstiffened thin webs. Suitable stiffeners can be designed.
(3) Buckling of thin flanges, this is a problem only when very wide flanges are employed. Welding of additional flange plates will reduce the plate b / t ratio and thus flange buckling failure can be avoided.

It is well known that slender members under compression are prone to instability. When slender structural elements are loaded in their strong planes, they have a tendency to fail by buckling in their weaker planes. Both axially loaded columns and transversely loaded beams exhibit closely similar failure characteristics due to buckling. Column buckling has been dealt with in detail in an earlier chapter. In this section, lateral buckling of beams is described and its close similarity to column buckling is brought out. Consider a simply supported and laterally unsupported (except at ends) beam of "short-span" subjected to incremental transverse load at its mid section. The beam will deflect downwards i.e. in the direction of the load (Andrew Liew and Leroy Gardner, 2014).

PROBLEM STATEMENT

To overcome the lateral torsional buckling of I-section while bending, lateral support (stiffener) is given to the beam. The design of beams is generally governed by the maximum allowable bending stress and the allowable deflection. Its design is controlled by shear only when the spans are short and loads are heavy. The member is selected such that the section is symmetrical about the plane of loading and the unsymmetrical bending and torsion are eliminated. From the study made in Dessouki *et al.,* (2014), it is found that as the depth of the stiffener increase, the stiffness of the web against distortion is increased which leads to the increase of the ultimate moment capacity of the beam. The results show that the ultimate moment capacity of the beam can be increased by adding a full depth stiffener at the root support when compared to the point restrained root support results.

The Lateral Torsional Buckling Of An I-Section Is Considered With The Following Assumptions.

1. The beam is initially undistorted
2. Its behaviour is elastic (no yielding)
3. It is loaded by equal and opposite end moments in the plane of the web.
4. The loads act in the plane of the web only (there are no externally applied lateral or torsional loads)
5. Its ends are simply supported vertically and laterally.

Fixture: Fixture is used for locating and holding the work piece. Fixture is always fixed to machine or bench. Fixture is generally used for mass production. Fixture reduces operator's fatigue. The fixture also follows the principle of locating and clamping. The various types of fixture such as vise, milling, grinding, facing, turning, faceplate and boring fixture. The design of fixture depends upon the shape and size of workpiece. The fixture may be different for different work piece (Table 1).

Design Considerations For Jigs And Fixtures: Jigs and fixtures are manually or partially power operated devices. To fulfill their basic purposes, jigs and fixtures are comprised of several elements

•base and body or frame with clamping features
•locating elements for proper positioning and orientation of the blank
•supporting surfaces and base
•clamping elements
•tool guiding frame and bushes (for jig)
•indexing plates or systems, if necessary
•auxiliary elements
•fastening part

Therefore keeping in view increase in productivity, product quality, repeatability i.e. interchangeability and overall economy in batch production by machining, the following factors are essentially considered during design, fabrication and assembly of jigs and fixtures :

•easy, quick and consistently accurate locating of the blank in the jig or fixture in reference to the cutting tool
•providing strong, rigid and stable support to the blank
•quick, strong and rigid clamping of the blank in the jig or fixture without interrupting any other operations
•tool guidance for slender cutting tools like drills and reamers
•easy and quick loading and unloading the job to and from the jig or fixture
•use of minimum number of parts for making the jig or fixture
•use of standard parts as much as possible
•reasonable amount of flexibility or adjustability, if feasible, to accommodate slight variation in the job - dimensions.
•prevention of jamming of chips, i.e. wide chips-space and easy chip disposal
•easy, quick and accurate indexing system if required.
•easy and safe handling and moving the jig or fixture on the machine table, i.e., their shape, size, weight and sharp edges and corners
•easy removal and replacement of small parts
•manufacturability i.e. ease of manufacture
•durability and maintainability
•service life and overall expenses clamping screw drill jig bush adjustable locating pin machine table supporting pins jig bracket locating pins base

METHODOLOGY USED

The 3D - model was first prepared using Auto CAD. The specification of I beam to be bent for which the model is being fabricated is listed in Table 2. The fixture used here is for bending the I- beam by protecting it from web buckling. And it is designed accordingly to absorbing the load to be applied. In general the I- beams is bent using bending machines to resolve it this fixture is designed (Fig 1). In existing rolling machine, the beam is made to drawn between three rollers, there will be an roller which is used to support the web. These rollers are actuated by hydraulic power due to high load required (Timoshenko and Gere, 1961). This fixture helps in bending the beam by supporting the beam by web section using stiffener making it close. And single hydraulic press is used for bending, so the beam is bent in a single pass (Fig. 2) (http://engineeringhut.blogspot.in/2010/11/types-of-drilling-jigs.html accessed on 2nd March 2014.).

Calculations Load To Be Applied On I- Beam:
Material of M.S beam: Young's modulus, E = 2.08×10^5 N/mm^2
Modulus of rigidity, G = 0.79×10^5 N/mm^2, Poisson ratio = 0.3 and Specific weight = 0.0785 N/cc (Table 3 and Fig 3).

Length between the support, L= 500mm,
Maximum deflection required, Ymax = 1.5mm
Maximum deflection of simply supported beam (SSB) with point load, $Ymax = \frac{PL}{48EI}$
1.5 = P x 500^3/(48 x 2.08x 10^5x 168x10^4)
P= 201277.44 N
Maximum bending momentum for SSB with point load,
$M_{b\ max}$ = PL/ 4
$M_{b\ max}$ = (201277.44x 500)/ 4
$M_{b\ max}$ = 25,159,680Nmm
According to theory of simple bending

$$\frac{M_{b\ max}}{I} = \frac{fb}{y} = \frac{E}{R}$$

$$\frac{M_{b\ max}}{I} = \frac{fb}{y}$$

Where y= height of beam/2 = 100/2 = 50mm
Moment of inertia in x-x direction, I =168x10^4 mm^4

$$\frac{25159680}{1680000} = \frac{fb}{50}$$

Maximum bending stress
due to applied load, $fb\ max$ = 748.8 N/mm^2

According to Curved Beam equation (Fig 4):
Breath of flange inner and outer, $b_i = b_o$ = 50mm
Thickness of flange inner and outer, $t_i = t_o$ = 6mm
Depth or height of I-beam, h = 100 mm
Thickness of web t_w = 4.6mm
Inner and outer radii r_i =3000mm
r_o = 3100mm
Distance from the centre of Curvature of neutral axis,

$$r_n = \frac{(bi-t)ti + (bo-t)to + th}{bi \ln(\frac{ri+ti}{ri}) + t \ln(\frac{(ro-to)}{(ri+ti)}) + bo \ln(\frac{ro}{(ro-to)})}$$

$$= \frac{(50-4.6)6 + (50-4.6)6 + 4.6x100}{50 \ln(\frac{3000+6}{3000}) + 4.6 \ln(\frac{(3100-6)}{(3000+6)}) + 50 \ln(\frac{3100}{(3100-6)})}$$

r_n = 3049.48 mm

Distance from the centre of Curvature of centroidal axis,

$$R = ri + (\frac{.5h^2t + .5\ ti^2(bi-t) + (bo-t)to(h-.5to)}{(bi-t)ti + (bo-to)to + th})$$

$$= 3000 + (\frac{.5x\ 100^2x4.6 + .5x\ 6^2(50-4.6) + (50-4.6)x\ 6\ x(100 - .5\ x\ 6)}{(50-4.6)6 + (50-4.6)6 + 4.6x100})$$

R = 3050 mm

Eccentricity, e = R- r_n = 3050 - 3049.48 =0.52mm

Calculation of Bending stress due to curved beam

$$f_b = \frac{M_{b\ max}\ y}{a\ e\ (r_n - y)}$$

$$= \frac{25{,}159{,}680\ x50}{1021\ x\ 0.52\ (3049.48 - 50)}$$

Bending stress of curved beam, f_b = 789.941N/mm^2
Since, *the bending stress due to applied load is 748.8N/mm^2 is lesser than the bending stress due to curved beam.* Hence, the applied loads will not failure the beam for bending and it is safe (Colvin and Haas, 1938).

Design of fixture (Table 4 and Fig 5-8):
According to the design consideration fixture, material selected for the fixture should be equal or greater in strength. So, mild steel C 15 is taken.
Type of fixture: bending fixture
Material property of C 15 steel
Young's modulus, E = 2.08×10^5 N/mm^2
Modulus of rigidity, G = 0.79×10^5 N/mm^2
Poisson ratio = 0.3
Specific weight = 0.0785 N/cc = 0.0785x 10^{-3} N/mm^3

RESULT
The object according to the given dimension and specification was fabricated in the workshop. The parts of fixtures were then assembled with the I-beam kept at its position and leaves spread. The bolts & nuts tightened in the frame in order to hold the beam and eventually the beam fixed rigidly in fixture position. Load is applied on the mid of the beam between the supports and required radius is achieved (http://www.psgdesigndata.org/home.php.).

Advantages of this fixture: This concept can be used for pilot production. Hydraulic Power sources only required, Construction of fixture is simple, Fixtures increase the productivity by eliminating the individual marking, positioning and frequent checking, The operation time is also reduced due to increase, Fixtures facilitate the production of articles in large quantities with high degree of accuracy, uniform quality and interchange ability at a competitive cost.

CONCLUSION
In this project, a complete model of work holding device for bending of I- beam was fabricated in the separate workshop. Before fabrication a complete CAD model was prepared for optimum use of material and space. All the components were made locally. The device is controlled by tightening the bolts & nuts provided on the frame. The fixture can hold I- beam and the load applied and are operated manually by a hydraulic press.

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Table 1. Comparison between jigs and fixtures

Basis	Jig	Fixture
Definition	It is a work holding device that holds, supports and locates the workpiece and guides the tool for a very specific operation.	It is also a device that holds supports and locates the workpiece. But it differs from jig in way that it does not guide the tool for the operation.
Clamping	Jigs are not clamped to the drill table unless and until large diameter holes are to be drilled. Also there is necessity to move the jig to bring one bush directly under the drill.	Whereas fixtures should be securely clamped to the table of the machine upon which the work needs to be done. Also there is no requirement of alignment as bush is absent in fixture.
Operation	Jigs are special tools in operation particularly in reaming, tapping and boring.	Fixtures are specific tools used in milling, shapers and slotting machine.
Gauge block	Gauge blocks are not necessary.	Gauge blocks are necessary for effective handling.
Weight	Jigs are generally lighter in construction.	Fixtures are usually heavier in construction.

Table 2. Specifications of I- beam.

Specifications	Values
Beam size	ISLB 100: 100mm x 45mm
Flange thickness	6mm
Web thickness	4.5mm
Area of cross section	$10.21x10^2mm^2$
Weight per meter	8kg/m
Moment of inertia	I_{xx}=168x10^4 mm^4 I_{yy}= 12.7x10^4 mm^4
Radii of gyration	r_{xx}= 40.6 mm r_{yy}= 11.2 mm

Table 3. Specification of I- beam

Specifications	Values
Beam size	ISLB 100: 100mm x 50mm
Flange thickness	6mm
Web thickness	4.5mm
Area of cross section	$10.21x10^2mm^2$
Weight per meter	8kg/m
Moment of inertia	I_{xx}=168x10^4 mm^4 I_{yy}= 12.7x10^4 mm^4
Radii of gyration	r_{xx}= 40.6 mm r_{yy}= 11.2 mm

Table 4. Parts of fixture

S. no	Material	Qty	Weight of material
1.	Stiffener 32mm x 32mmx93mm	14	104.65N
2.	Support plates 270mm x 80mm x 20mm	2	67.82N
3.	Supports columns 25mm x 25 mm x 400 mm	4	78.5N

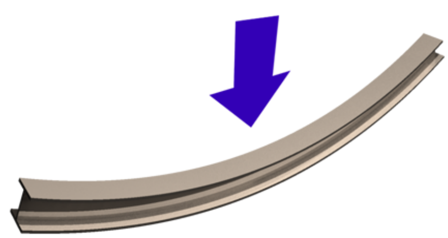

Figure 2. How The Load Is Applied

Figure 1. Beam Bending Machine

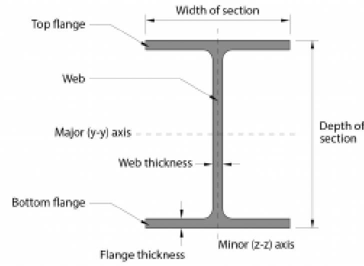

Figure 3. Nomenclature Of I-Beam

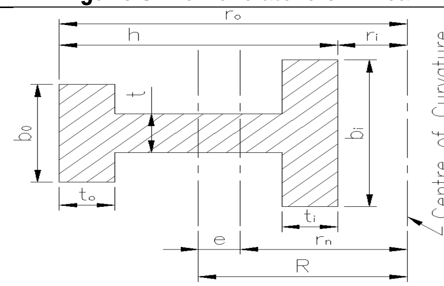

Figure 4: Section Of Curved Beam

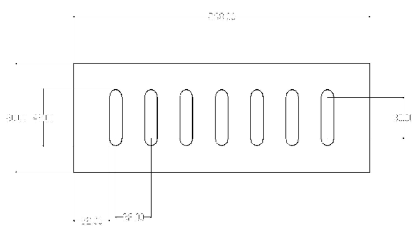

Figure 5. Support Plate

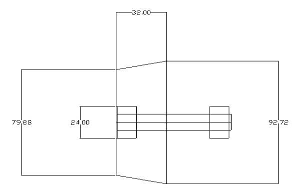

Figure 6. Stiffener And Bolt & Nut

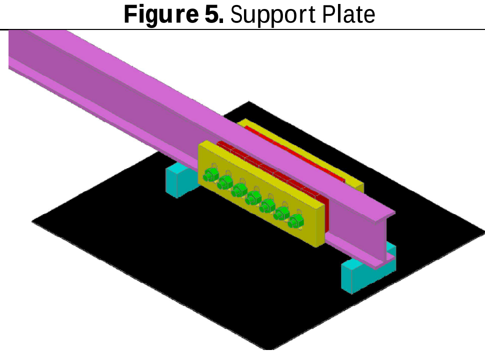

Figure 7: Assembly Of Stiffener, Support Plate And Bolt &Nut

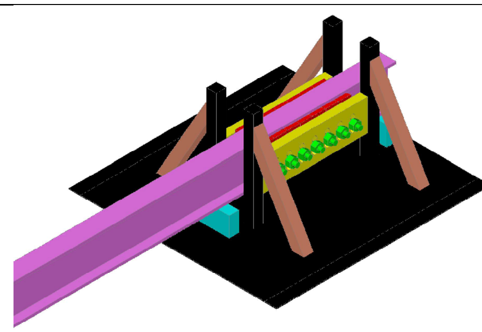

Figure 8. Full Assembly Fixture On I- Beam

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