COMPARATIVE STUDY OF CODAL PROVISIONS FOR PRE-ENGINEERED BUILDINGS

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Abstract - *For a construction of single storey industrial building the pre-engineered building (PEB) is a new thought in the construction field. It is a concept of steel structures introduced in early 1960's. In this type of construction the entire structure uses of built up "I" sections, the main advantage in this concept is no welding process will be carried out in the site. The structure will be designed and manufactured in the plant and are transported to the site and then erected. The sectional properties will depends on the moments at those specific locations hence there won't be any excess of steel utilisation. In this study, an industrial ware house is analyzed and designed according to Indian standards, I.S. 800-2007 and also referring MBMA- 2002/AISC-89 with members built up, rectangular and tapered sections. In this study, a structure with a length of 30m,width of 20m, clear height of 9m and roof slope of 1: 10 is considered to carry out analysis and design(The members are assigned with the built up sections of rectangle and tapered sections).*

The behaviour and economy of the structure is discussed with respect to its analysis results and weight, between Indian code (IS 800 -2007) and American code (MBMA- 2002, AISC-89). In this study the structures considered was analyzed and designed with structural engineering software STAAD.Pro.

Key Words: Pre-Engineered Building, Rectangle Sections, Tapered Sections, MBMA- 2002/AISC-89, I.S. 800-2007.

1. INTRODUCTION

1.1 General:

In all parts of the earth almost steel industry is growing quickly. When there is a situation of resources availability, use of steel structures is economical solution, here word "economical" is used by considering duration and expenditure. The more important aspect in steel structures is time; these are built in very minimum duration of time. For the construction within the short duration, one such method is pre-engineered building construction. These are the buildings consists of steel sections, more amount of steel is avoided by considering the tapered section as per requirement of various analysis. Much more people are not aware of these kinds of structures but someone has to think about its prospect. Regular steel construction requires long duration and more expenditure, hence construction stages consumes more time and cost it results in an uneconomical. In these, type of buildings the all fabrication is done in factory, based on the design, pre fabrication is been carried out for the members. After that transportation of members to the site and the process of erection is carried out in a less duration.

The performances of these buildings is structurally well understood, to ensure the satisfactory behaviour in high winds for the most part the code provisions are currently in place and adequate. The dismantling process of steel structures is easy because these buildings are connected with the bolts. When compared with strength to weight ratio the steel structures have better ratios than RCC structures. These members can be reused after dismantled.

1.2 Conventional steel building:

Steel structures are low rise with the truss system of roofing with roof coverings are termed as conventional steel buildings. For these kind of structures can be utilisation of various types of the roof trusses. According to pitch of truss the type of roof system is used. The steel structures also termed as metal structures. In this construction process producing the shapes of structural steel material used is steel. The shape of steel structure is unique, built with a specific cross section and also including certain chemical composition.

1.3 Pre-Engineered Building and it's Components:

These buildings are the composed with the combination of various sections they are built up sections, hot rolled sections and the elements of cold formed sections. The basic steel frame work is provided by these elements. For roofing and wall cladding with a selection of sheeting of single skin with added insulation or insulated sandwiched panels are provided.

1.3.1 Component of Pre-engineered Building:

The PEB components may be broadly classified into following parts they are as follows:

- Main Frame
- Secondary frame
- Material for Sheeting (or) cladding
- Accessories

For the construction of these structures use of hot rolled tapered sections for primary framing and cold formed sections such as "Z" and "C" may be used as per the internal requirements for the stress for secondary framing, thus the control of wastage of steel and the own weight of the structure and hence lighter foundations. These kinds of structures are basically rigid jointed structure frames from hot rolled or cold formed sections, the roofs and side wall cladding is supported by main and secondary frames by purlins and sheeting rails. For the selection of PEB roof slope is selected from 5 to 12 degree, because of least volume of air occupied during heating and cooling of the structure.

To achieve the reduction in time of design, fabrication and installation the pre-engineered building system concentrates on use of pre-designed connections and pre-determined material stocks for structure to design and fabricate

1.4 Technical Parameters of Pre-engineered Building:

PEBs are termed for detailed measurements. These are designed to provide the comfort to clients and to meet their requirements. The dimensions of the members are designed and produced to meet accuracy in standards. The measurements for the requirements of the structure are taken accurately. Some of the basic parameters that can be taken are: Span of the building, Length of the building, Height of the building, Sloop of the roof, Bay spacing, and Clear span.

1.5 Applications of Pre Engineered buildings (PEB):

This type of building system is new concept in structural engineering field, found itself in a construction and the erection variety building structures, this concept have widely used for Ware Houses, Workshops, Gas Stations, Parking for Vehicle Sheds, Showrooms, Aircraft Hangers, Roofs of Indoor Stadium, Canopies for Outdoor Stadium, Bridges, Railway platform Shelters and Industrial sheds.

1.6 Advantages of Pre Engineered buildings (PEB):

After the study shows that the use of PEB will decrease duration of construction of the project by at least less than time required by conventional Steel structures. Due to modern systems approach, there is saving in design, production of members and on site erection costs. Steel structures are completely manufactured in factory in the presence of controlled conditions hence the quality control is assured. The applications of PEB are Ability to span long distances, Faster occupancy, Cost efficient, Low cost maintenance, Architecture design are unique and aesthetically pleasing , Reduction in time, Structures are light weight, Greater durability, Higher tensile strength, Provides flexibility in expansion, Quality control is assured.

2. METHODOLOGY

The details of various steel structural configurations are explained and details of the members and their properties are discussed. Normal steel structures and pre-engineered structures are discussed with available information and design concepts.

2.1 Design procedures:

The procedures and standards are adapted to analysis and design of pre-engineered buildings. The design is done by IS 800:2007, " Code of practice for General Construction in Steel Structures" as well as IS 875:1987(Part 1,2&3), "Indian Standard code of Practice for loads on Buildings and Structures". With the various combination as specified in Indian Standard Dead load , Live load and Wind load had been considered for structure and also MBMA -2002 (Metal Building Manufacturer Codes) and AISC – 1989 (American Institute of Steel Construction Manual).

2.2 Practice of Code – Steel Construction by Indian Standard (IS 800:2007):

The bureau of the Indian standards had adopted this Indian standard. This code had been considered by the experts in civil engineering divisional council after the methods and standards for construction are finalized by the engineers of structural department and the selection committee of structural sections.

In the year 1950 Indian standard institution was initiated the programme of steel economy by establishing rational, efficient and optimum steel product standards and their use. For general construction of steel basic code is I.S 800:2007. It is the suitable document for any design in structures. The other codes governing the design of other steel structures, such as bridges, towers, silos, chimneys, etc., has influenced by this code only. In the country and abroad the developments taking place and the consideration has been given to them. Any additive and changes to the code have been included to make more useful standard.

2.3 Manual for Metal Systems of Building (2002):

In this type of code practices the research is undertaken by MBMA that is metal building systems manual provides all details and design procedures for design of metal structures. The companies and other group of industries are the members of MBMA. In the load application aspects and design this provides the greater refinement and advances in loading methods. The MBMA low rise building system manual is replaced by this manual and represents the new way for criteria's of design.

When most of the municipalities comes to the building codes in the United States have adopted this system. In the past it won't allow to govern the design in the building code, in the MBMA low rise buildings the pre recommended loads were often specified. There is a decrease for MBMA loads after reorganization in the system. This manual now deals with how to deals with load apply under International building code and ASCE- 7 specified by them. This new manual system can be also deals with low rise buildings generally. This method of practices purely related to design, compliance of codes and metal building systems specifications. It purposes for design community.

2.4 Structure Configuration:

The Industrial ware house is assumed to be located in Karnataka, India. The area is considered as 35m x 25m. Span of the frames is 20m and total bay length 30m.

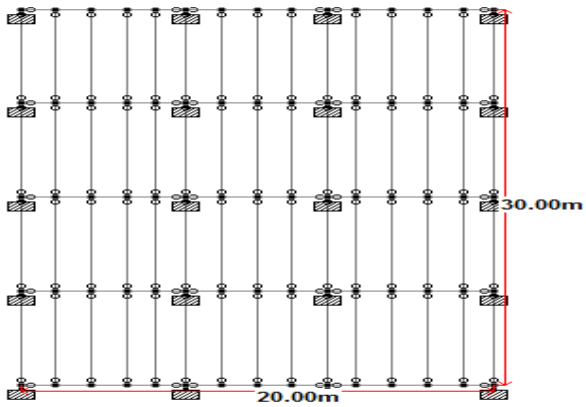

Fig -1: Plan of the structure

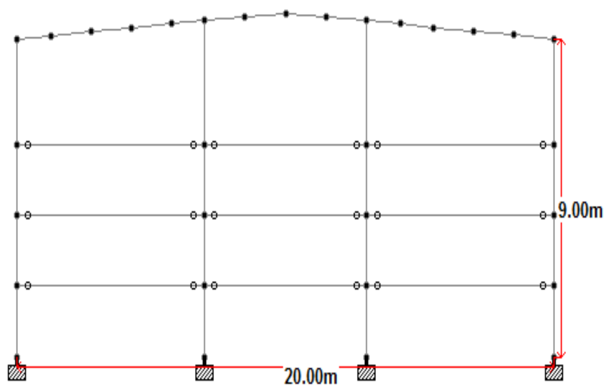

Fig -2: Elevation of the structure

Table -1: Structure configuration

Location	Karnataka, India
Total bay length	30 m
Width (Span)	20 m
Eave height	9 m
Number of bays	4
Type of building	Industrial ware house
Wind speed	33 m/sec
Roof slope	1:10
Purlin spacing	1.5 m
Girt spacing	1.5 m
Bay spacing	7.5 m
Class of ware house	50 years
Terrain	Category 2
Permeability	Medium
Angle of frame	5 degrees

2.5 Properties of the Materials Assigned:

The materials used for the PEB structures are built up sections for primary and secondary frames, for the purlins and the grits channel section are provided. In this study of PEB structures the fabricated rectangular section and the tapered section which are referred as the built up section. The flanges of these members are welded to the web. At the end of the tapered section and rectangular sections splice plates are welded. By connecting the sections together the frame is erected by the bolting the splice plates. These section are welded to make the rigid frames to form the built up "I" sections.

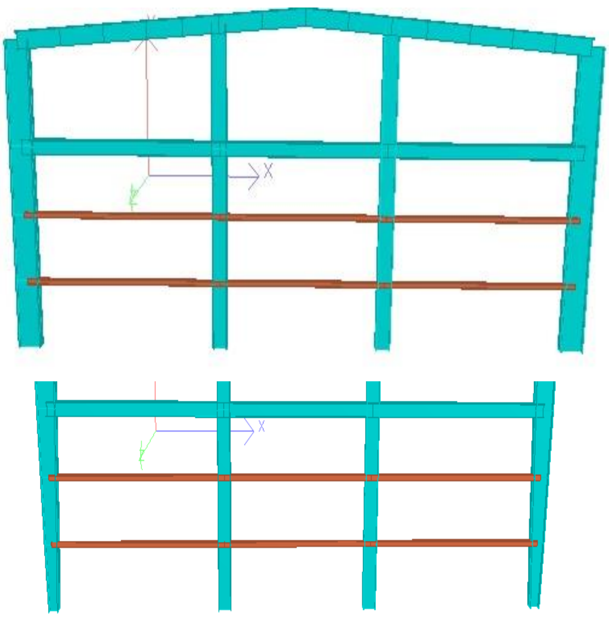

Fig -4: 3D Tapered Section

2.6 Design Procedure as per MBMA -2002 (Metal Building Manufacturer Codes) and AISC – 1989 (American Institute of Steel Construction Manual):

According to this codes the structural configuration of the building is considered as same as for designed with the IS – 800: 2007. Load consideration for the structure according to MBMA – 2002, ASCE-7 (American society of civil engineers) and combination of loads are taken from AISC – 1989. In this structure the design and analysis of main frames and the comparison between rectangular sections and tapered sections are carried out. The methods to design and analyse the structure is as follows.

2.7 Basic Data of the Structure:

Table-2: Data of the structure

Building type	Industrial ware house
Basic wind speed	33 m/s
Exposure category	Exposure C (open terrain with scattered object)
Purlin spacing	1.5 m
Girt spacing	1.5 m
Bay spacing	7.5 m
Eave height	9 m

3. RESULTS AND DISCUSSIONS

3.1 Loads and load combination details of the structure:

The structure is designed as per the recommended codes and details of various loads and load combination are shown in the table. The loads combinations include different combinations of loads according to standard codes (IS 800 – 2007 and AISC -89/ MBMA – 2002) by considering both serviceability and strength criteria.

3.2 Calculation of steel for the Structure (IS 800 – 2007):

Table -3: Calculation of Steel for Rectangular Sections

Description of Members	Length (Meter)	Weight (kg)
End Column	90	13320.12
Intermediate Column	95	14618.23
Main Rafter	100	15386.35
Intermediate Beam	220	21069.72
Purlin	450	5535.63
Girt	160	2132.31
	Total	72061.86

Table -4: Calculation of Steel for Tapered Sections

Description of Members	Length (Meter)	Weight (kg)
End Column	90	10784.56
Intermediate Column	95	14618.23
Main Rafter	100	12386.35
Intermediate Beam	220	21069.72
Purlin	450	5535.61
Girt	160	2132.32
	Total	66524.89

3.3 Calculation of steel for the Structure (AISC -89/ MBMA – 2002):

Table -5: Calculation of Steel for Rectangular Sections

Description of Members	Length (Meter)	Weight (kg)
End Column	90	13300.34
Main Rafter	100	12246.81
Beam	90	10173.61
Purlin	450	5535.62
Girt	160	2132.36
	Total	40129.68

Table -6: Calculation of Steel for Tapered Sections

Description of Members	Length (Meter)	Weight (kg)
End column	90	12200.32
Main Rafter	100	12246.84
Beam	90	10173.61
Purlin	450	5535.67
Girt	160	2132.35
	Total	37129.89

3.4 Summary of the Results from Software (IS 800 – 2007):

Table -7: Results from Software

Description of Results	Rectangle Sections	Tapered Sections
Steel Take Off (kN)	706.681	652.464
Support Reaction (kN)	231.182	219.563
Maximum Deflection (mm)	40.866	42.090
Maximum Shear Force(kN)	187.904	184.223

After the analysis of the results from the software as per the Table -8, it is clear that support reaction is less for tapered sections, the deflection is more for tapered sections and the maximum shear force is more for the rectangular sections. The steel take off for the rectangle section is higher than the tapered sections.

3.5 Summary of the Results from Software (AISC - 89/ MBMA – 2002):

Table -8: Results from Software

Description of Results	Rectangle Sections	Tapered Sections
Steel Take Off (kN)	390.496	339.877
Support Reaction (kN)	85.350	79.281
Maximum Deflection (mm)	8.346	10.265

After the analysis of the results from the software as per the Table -8, it is clear that support reaction is less for tapered sections, the deflection is more for tapered sections and the maximum shear force is more for the rectangular sections. The steel take off is also more for rectangular sections.

3.6 Summary of the Results Comparison (IS 800 – 2007):

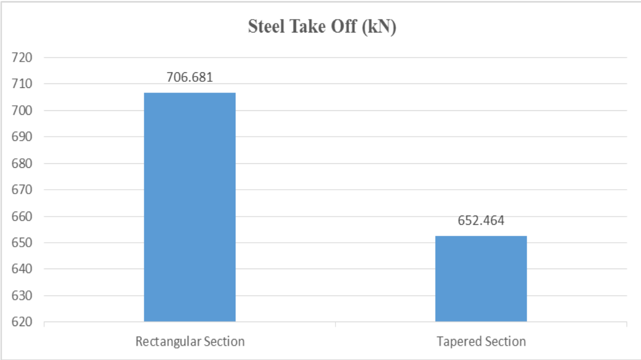

Fig -5: Comparison of Steel Take Off

Fig -5 represents the steel take off comparison between rectangular sections and tapered sections. It is noticed that the value of steel take off for tapered section is less compared to rectangular sections

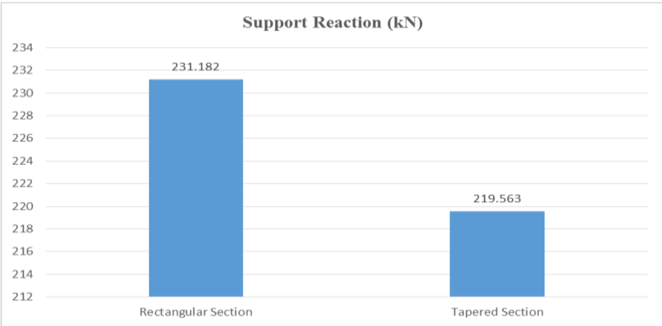

Fig -6: Comparison of Support Reaction

Fig -6 represents the Support Reaction comparison between Rectangular sections and tapered sections. It is noticed that the value of Support Reaction for tapered section is less compared to rectangular sections

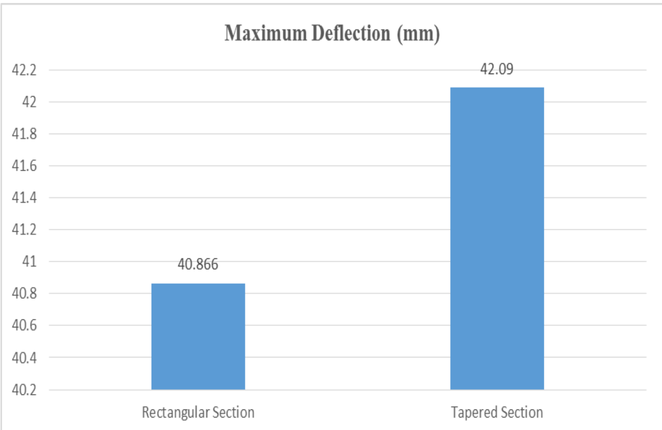

Fig -7: Comparison of Maximum Deflection

Fig -7 represents the Maximum Deflection comparison between Rectangular sections and tapered sections. It is noticed that the value of Support Reaction for tapered section is high compared to rectangular sections

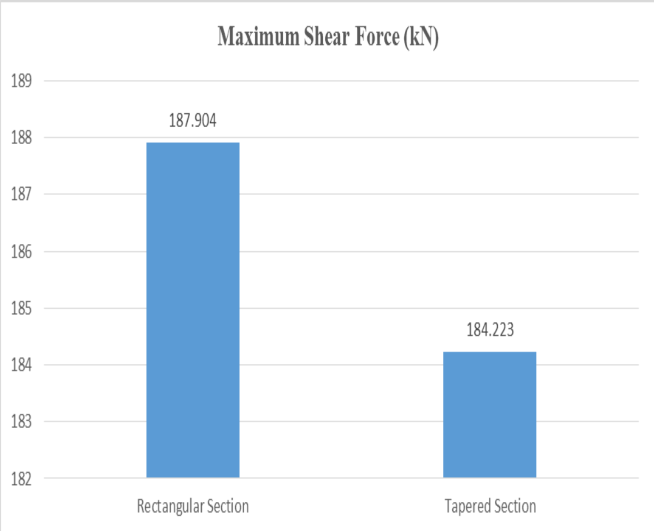

Fig -8: Comparison of Maximum Shear Force

Fig -8 represents the Maximum Shear Force comparison between Rectangular sections and tapered sections. It is noticed that the value of Support Reaction for tapered section is less compared to rectangular sections

3.7 Summary of the Results Comparison (AISC -89/ MBMA – 2002):

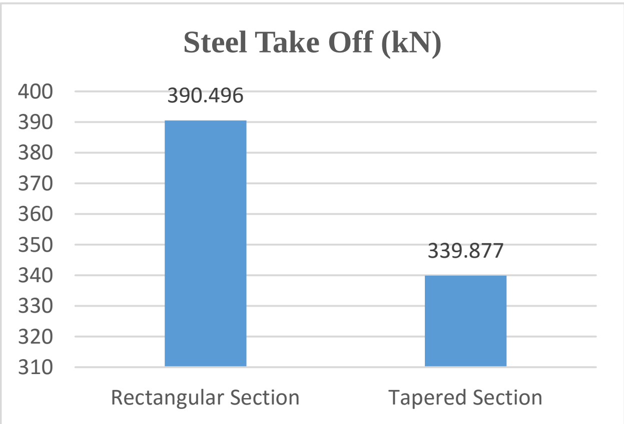

Fig -9: Comparison of Steel Take Off

Fig -9 represents the steel take off comparison between Rectangular sections and tapered sections. It is noticed that the value of steel take off for tapered section is less compared to rectangular sections

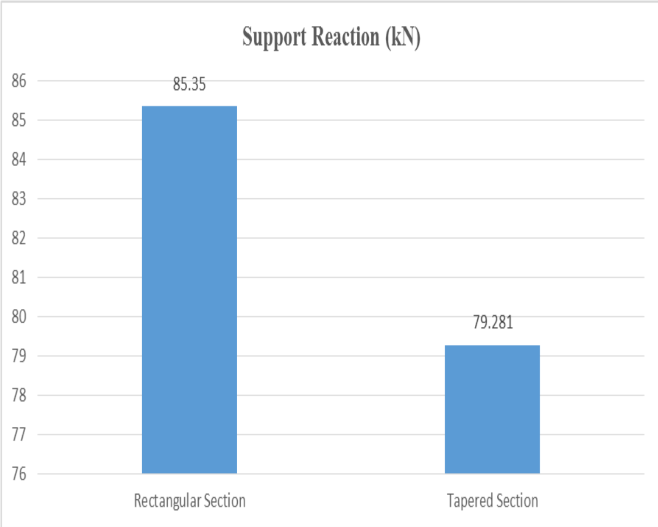

Fig -10: Comparison of Support Reaction

Fig -10 represents the Support Reaction comparison between Rectangular sections and tapered sections. It is noticed that the value of Support Reaction for tapered section is less compared to rectangular sections

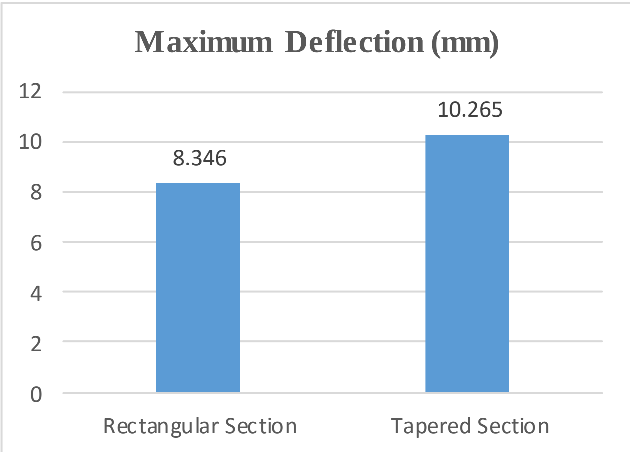

Fig -11: Comparison of Maximum Deflection

Fig -11 represents the Maximum Deflection comparison between Rectangular sections and tapered sections. It is noticed that the value of Support Reaction for tapered section is high compared to rectangular sections

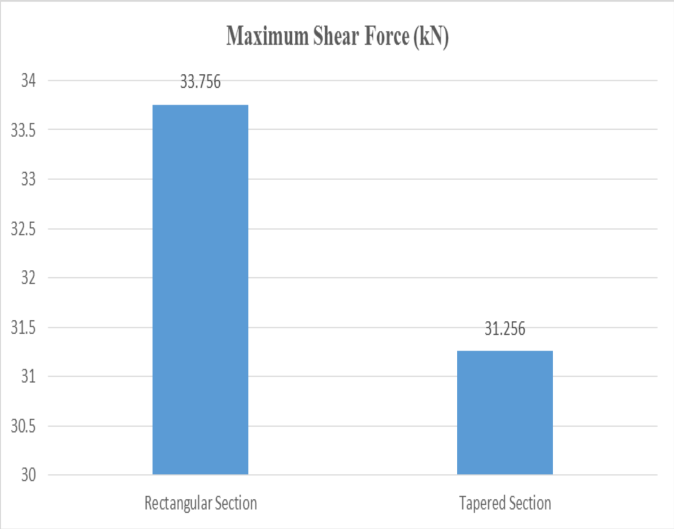

Fig -12: Comparison of Maximum Shear force

Fig -12 represents the Maximum Shear Force comparison between Rectangular sections and tapered sections. It is noticed that the value of Support Reaction for tapered section is less compared to rectangular sections.

3.8 Percentage of Decrease in Weight:

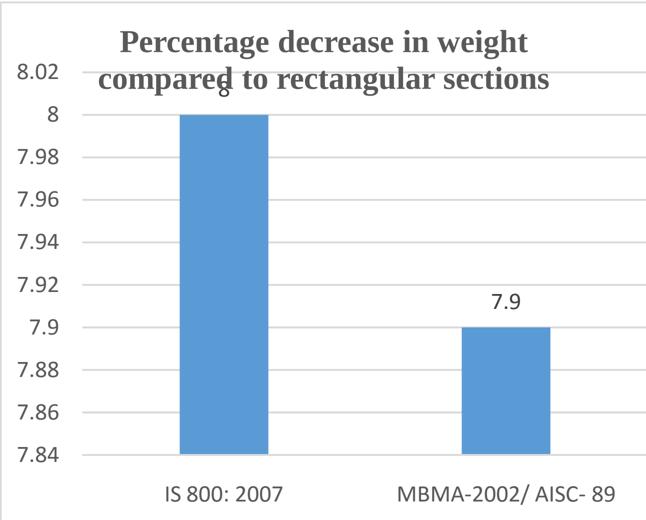

Fig -13: Percentage Decrease in Weight

Fig -13 represents percentage decrease of weight between tapered and rectangular sections. It is noticed that the utilisation of steel is less for tapered sections when compared to rectangular sections. The figure represents the percentage of weight decrease of the structure for both the codes.

4. CONCLUSIONS

1. Pre- engineered steel building offers the minimum cost, less time in construction, more strength, durable in the life span, flexibility in design, recyclability. In the construction of Pre-engineered steel building the basic material used for the construction is steel. It is recyclable up to infinite times. The present study is discussed about the comparison of design procedures for pre-engineered building with two different code standards are IS 800 – 2007 and MBMA – 2002/AISC -89. On the direction of current studies we can conclude that:
2. The structure is analysed and designed as per IS 800 – 2007 with two different specifications are rectangular section and tapered section, there it is noticed that the steel take off is more for rectangular section, increase in maximum support reaction and shear force but when it comes to deflection it shows more for tapered section.
3. The structure is analysed and designed as per MBMA – 2002/AISC -89with two different specifications are rectangular section and tapered section, there it is noticed that the steel take off is more for rectangular section, increase in maximum support reaction and shear force but when it comes to deflection it shows more for tapered section.
4. When the results summary of two different design procedures of the current study are compared, there is much difference appeared in steel take off, maximum deflection, maximum shear force and maximum support reaction.
5. There is increase in weight in IS 800 – 2007 compared to MBMA – 2002/AISC -89 due to "Serviceability criteria". And also deflection limits by Indian standards are higher than deflection limits by MBMA – 2002/AISC -89.
6. Higher weight in Indian standards is mainly due to the limiting ratios of the sections (Table 2, Clauses 3.7.2 and 3.7.4).
7. The loading as per Indian codes is greater than MBMA codes that is live load is 1.08kN/m in Indian code and where as it is 0.55kN/m in MBMA.
8. It was observed in the most of the industrial projects are done with tapered sections, the reason preferring these sections it leads to an economical structural solution as compared to rectangular Sections.

5. FUTURE SCOPE

Pre-engineered buildings have found the various applications in the construction field. It has enhanced that it provides the quality of various new products and services and technical improvement over the year has changed immensely towards its contribution. It termed as a new technological wave called pre-engineered buildings. In this study the comparison of codes is carried out in order to provide a designer to have benefit over the cost, design and time which will leads to the designer, resulting in behaviour of the structure and economy in the construction.

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