Advantages of Pre-Engineered Building over Conventional Building

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Abstract: In these days, the cost and time of construction is in more priority for the client with the large working area for various uses. For the economically and minimum loss of material, pre-engineered building system (PEBs) has many advantage, because it gives more column free space at low cost. Pre-engineered metal buildings are more reliable for various uses like complex industrial facilities, warehouses and distribution centers, stock-house, shopping malls, resort, motor court, office, cabin, service complex, aircraft-hanger, athletics and fun stadium, study places, temples, hospitals, and any types of industrial structures. In the pre-engineered metal building system, the rigid frame consists of slab, wall are connected with primary member (beam and column). This frame can spanlarge spacing without any intermediate columns. The frameworks are spaced at spacing between 15 m to 60 m and span can increase with column-free up to 300 m in proposed building structures. Therefore in this paper, an attempt has been made to analyze a pre-engineered metal building with a span of 40 m with the help of finite element based software ETABS (2013). For the comparison, for the same span of 40 m length a conventional steel building is analyzed in same software. The results were found from both analysis indicated the pre-engineered steel building is economic with the conventional steel building as well as stable also.

Keywords: Pre-engineered metal building, Conventional building, ETAB

I. INTRODUCTION

The efficient and economic construction over conventional method of building construction Pre-engineered building (PEB) system were induced. the concept of pre-engineered steel metal building systemmade over all structural component like, beam, column, purlin, rafter as well as roof wall sheeting, primary members, secondary members, connected with each other and different structural components [Ref.8 and 9]. Thistechnology is a built, structure with precast and prefabricated members which are erected at site. Pre-engineered steel buildings are mainly low height buildings which are useful for residential building, show-rooms, shopping malls etc.[Ref.2]. The PEBs system are very economical and faster to application for the low height buildings, with this system the construction time is reduced about half than conventional Steel building. Although pre-engineered steel building are widely used for any industrial purpose building or non-residential building construction globalized, In India, it is now new structural concept.[Ref.3and4].Now a days, large spaced area is the utmost requirement for any type of industry and with the approach of computer software’s it is now easily possible.

With the improvement in technology, computer software’s have contributed immensely to the enhancement of quality of life through new researches. Pre-engineered building (PEB) is one of such revolution. “Pre-engineered buildings” are fully fabricated in the factory in the robotic manner after designing, then transported to the site directly in completely knocked down (CKD) condition and all components are assembled and erected with connection like, nut-bolts, hence it reducing the time of completion[Ref.1 and 7].

With increased significance on the green buildings ensuring sustainable construction, the PEB structures are designed with a high proportion of recycled content making them lighter in weight by about 30% to 40% than the conventional steel buildings (CSB). Since the PEB system based construction technique is contributing the ultimate modernization with high-technology and faster methods of construction ensuring efficient, cost effectiveness and speedy completion of projects [Ref.3, 4 and 6]. As a result today the PEB system is the most favored choice among the consultant, architects, builders, developers, and industrialists.

A. PEBs Structural Members Concept

Pre-engineered buildings use a prearranged supply of raw materials in lighter weight that has verified over time to satisfy a broad range of structural and unique aesthetic design requirements. This flexibility allows PEBs to fulfill and almost unlimited range of building configurations, custom design, requirements and applications. The pre-engineered steel building is a building shell utilizing three distinct product categories as:

Built-up “I” shaped primary structural framing members(columns and rafters) Refer fig. 1 Cold-formed “Z” and “C” shaped secondary structural members (roof purlin, eave struts and wall girts) Refer fig. 2Roll formed profiled sheeting (roof and wall panels) Refer fig 3
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B. Comparison Between Pre-Engineered Building System And Conventional Building System (Table 1 and fig.4)

Fig.4 Difference between PEBs and Conventional steel building

Table 1: Comparison between PEBs and Conventional steel building

| Function Type | Pre-engineered Building system(PEBs) | Conventional building system (CSBs) |
|---------------|-------------------------------------|-----------------------------------|
| 1.Construction cost and time | Cost and time of construction are calculated based upon extensive experience with similar building. 30% cost is reduced in overall. | They are 20% more expensive than PEBs. Building construction cost and time are not estimated accurately in advance. |
| 2.Building weight | In PEBs, Primary framing member are tapered, so the system is about 30 to 40% advantages for the main rigid frame than conventional hot rolled section as primary member | Section and members have constant cross-section, are selected from standard hot rolled I-section as the Primary steel members so they are heavier than what is actually required |
| 3.Delivery to site | Approx.42 to 56 days | Approx. 140 to 182 days. |
| 4.Foundation | designis Simple and easily constructed with light weight foundation | Extensive, foundation required is heavy in weight |
5. Earthquake resistance

The less-weight flexible frames produced higher resistance seismic forces.

Do not perform well in seismic zones because of heavy in weight and rigid

6. Architectural appearance

Aesthetic architectural design and appearance can be achieved at low cost.

Architectural design required for each project in the consideration of esthetic appearance.

7. Source of material and component

Building is supplied complete with cladding and all accessories, from one single source.

Many source of supply is required to coordinates suppliers and contractors.

8. Quality control

Designed and fabricated at single in-house unit with strict quality control

It is not possible to control the quality because there are many sources and many manufactures.

II. PROCESS OF MODELLING

In the present attempt a three dimensional single storey industrial frame having symmetry along X and Y direction and rectangle (110m X 40m) in shape is considered (Table 2: Description of building). Steel frame having tapered “I” section is used in pre-engineered frame model (Table 3: Pre-engineered building members) and standard hot rolled “I” section constant cross section are used in conventional steel frame model (Table 4: Conventional steel building members). For the bracings (X-type) 25mm diameter of steel rod is used in both of the model. The structure having fixed support and all joints designed asperfectly rigid. IS: 875-1987 (Parts – I to V), IS: 1893-2002, and IS: 800-2007 are used in the process of calculating forces and load (national codes).

Table 2: Description of building

| Location | Ujjain |
|----------|--------|
| Length   | 110m   |
| Width    | 40     |
| Eave height | 9     |
| Seismic zone | II   |
| Wind speed | 39m/s  |
| Wind terrain category | 2 |
| Wind class | C |
| Life span | 50 years |
| Slope of roof | 1 in 10 |
| Soil type | Medium |

Table 3: Pre-engineered building members

| S.no | Structural steel member | Section properties |
|------|--------------------------|--------------------|
| 1    | Frame rafter 1 (prismatic 1200_750mm) | I tapered section |
| 2    | Frame rafter 2 (prismatic 750_900mm) | I tapered section |
| 3    | Frame rafter 3 (prismatic 900_750mm) | I tapered section |
| 4    | Frame rafter 4 | I section 750mm |
| 5    | Frame purlin and gable end purlin | ISMC_350 |
| 6    | End column (prismatic 350_900mm) | I tapered section |
| 7    | Centre column | ISMB350 |
| 8    | Bracings (X-Type) | 25mm dia of steel rod |

Fig. 5 Pre-engineered building with tapered member

Fig. 6 Conventional steel building
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### Table 4: Conventional steel building members

| S.no | Structural steel member          | Section properties  |
|------|----------------------------------|---------------------|
| 1    | Frame rafter                     | ISLB900             |
| 2    | Purlin                           | ISLB500             |
| 3    | End column                       | ISWB600₂            |
| 4    | Centre column                    | ISWB450             |
| 5    | Bracings (X-Type)                | 25x200mm Rec. steel Plate |

#### LOAD COMBINATIONS

In the limit state design of steel structure, load combination is taken as per clause no. 6.3.1.1 of IS 1893(Part I):2002 and IS800:2007.

- (DL+LL)
- (DL+WL/EL)
- (DL+0.8LL+0.8WL/EL)
- 1.5(DL+LL)
- 1.5(DL+WL/EL)
- (0.9DL+1.5WL/EL)
- 1.2(DL+LL)+0.6WL/EL
- 1.2(DL+LL+WL/EL)
- (1.2DL+0.5LL+2.5EL)
- (0.9DL+2.5EL)
- 1.7(DL+LL)
- 1.3 (DL+LL +EL_X)
- 1.3(DL+LL –EL_X)
- 1.3(DL+LL +EL_Y)
- 1.3(DL+LL –EL_Y)
- 1.7(DL+EL_X)
- 1.7(DL-EL_X)
- 1.7(DL+EL_Y)
- 1.7(DL-EL_Y)
- (DL denotes (Dead Load) and EL_X/EL_Y denotes Earthquake load in X-direction and Y-direction
- WL, wind load respectively

#### III. RESULTS AND DISCUSSION

Table 5 and table6 shows the design weight of structure and total steel take off and reduction of steel in pre-engineered building(Table 6:Pre-engineered building steel take off)comparison with conventional steel building(Table 5: Conventional building steel take off).

### Table 5:Conventional building steel take off

| Structure Member | Cross Section Area (cm²) | Weight Of Single Member (kg) | Number Of Member | Cumulative Weight (kg) |
|------------------|--------------------------|------------------------------|------------------|------------------------|
| Frame Rafter1    | 335.5                    | 1764.084                     | 44               | 77619.726             |
| Frame Rafter2    | 335.5                    | 882.174                      | 44               | 38815.656             |
| Frame            | 95.5                     | 749.58                       | 90               | 67462.55              |
| Tapered rafter   |                          |                              |                  |                        |
| Tapered rafter 1 | 295.25                   | 1552.447                     | 22               | 34153.836             |
| Tapered rafter 2 | 275.75                   | 1449.914                     | 22               | 31898.121             |
| Tapered rafter 3 | 275.75                   | 725.065                      | 22               | 15951.441             |
| Tapered rafter 4 | 266                      | 699.428                      | 22               | 15387.428             |
| Frame purlin     | 53.7                     | 421.49                       | 90               | 37934.444             |
| Tapered outer    | 151.14                   | 830.413                      | 26               | 21590.750             |

### Table 6:Pre-engineered building steel take off

| Structure Member | Cross Section Area (cm²) | Weight Of Single Member (kg) | Number Of Member | Cumulative Weight (kg) |
|------------------|--------------------------|------------------------------|------------------|------------------------|
| Frame Rafter1    | 335.5                    |                              |                  |                        |
| Frame Rafter2    | 335.5                    |                              |                  |                        |
| Frame            | 95.5                     |                              |                  |                        |
| Tapered rafter   |                          |                              |                  |                        |
| Tapered rafter 1 | 295.25                   | 1552.447                     | 22               | 34153.836             |
| Tapered rafter 2 | 275.75                   | 1449.914                     | 22               | 31898.121             |
| Tapered rafter 3 | 275.75                   | 725.065                      | 22               | 15951.441             |
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| Frame purlin     | 53.7                     | 421.49                       | 90               | 37934.444             |
| Tapered outer    | 151.14                   | 830.413                      | 26               | 21590.750             |
The structural design and comparative analysis of a
industrial steel frame has been done with very effective
and user friendly software ETAB. A typical steel frame
is analysed with both the concept (PEBs and CSB) in all
structural and loading criteria and the results were
obtained as following in table 7.

| Sl. No. | Structural description | PEBs   | CSBs    |
|---------|------------------------|--------|---------|
| 1       | Total steel take off (kg) | 191898.41 | 311879.68 |
| 2       | Maximum deflection (mm) | 5.2    | 9.4     |
| 3       | Maximum shear force (kN) | 463.23 | 546.41  |
| 4       | Maximum moment (kN-m) | 160.45 | 204.71  |
| 5       | Axial force (kN) | 387.78 | 542.43  |
| 6       | Maximum storey force (kN) | 13445.72 | 16762.54 |
| 7       | Maximum column force (kN) | 342.94 | 573.88  |

| Center column | 89.4 | 631.534 | 13 | 8209.946 |
|---------------|------|---------|----|----------|
| Gable end rafter 1 | 266  | 1258.950 | 4  | 5035.802 |
| Gable end rafter | 266  | 1468.779 | 8  | 11750.233 |
| Gable end column 1 | 89.4 | 512.24  | 4  | 2048.97  |
| Gable end column 2 | 89.4 | 582.414 | 4  | 2329.659 |
| Gable end purlin 1 | 53.7 | 210.746 | 6  | 1264.481 |
| Gable end purlin 2 | 53.7 | 212.630 | 4  | 850.523  |
| Gable end purlin 3 | 53.7 | 211.218 | 4  | 844.875  |
| Bracings | 4.9 | -       | -   | 2647.901 |
| Total weight (kg) | 191898.41 |        |     |          |

The clean lines of welded members also produce a better
appearance.

IV. CONCLUSION

Basically in pre-engineered building the sections used are
built up sections and built-up member are specified by the
designer when the desired properties or configuration cannot
be obtained in a single hot-rolled section. In this pre-
engineered steel building 38.47% steel weight is reduced.
Built-up section can be bolted or Welded, in general it is
less expensive because much less handling is required in the
shop and because of more efficient utilization of material.

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