Comparative Study of Super Structure of Conventional Industrial Steel Structure with Innovative Truss Less Roofing System

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Abstract - *Construction industry in India which is about 10% of its GDP is growing at a rapid pace highest amongst other developing countries, in terms of usages of construction equipment, technology and materials. The importance of completing any projects on time is essential for progress time compression is seen as an important aspect of innovation. The present research work deals with the comparative study of Industrial steel structure with conventional roofing system which is time consuming and tedious with the innovative self-supporting roofing system which has the potential to reduce the fabrication work and erection time considerably. On comparing design parameters like maximum shear force, bending moment, axial force and deflection along with structural tonnage, an effort is made to arrive at possible/probable cost for recommendation. The geometric configuration of structure with self-supporting roof has larger enclosed volume and offers optimum utilization of space. Results also shows 7 to 8% saving in super structure is achieved by using innovative self-supporting truss less roofing system. Structure with conventional roofing system produces less support reaction hence overall cost of structure i.e super and sub-structure need to be studied to know the cost effectiveness of both building structure.*

***Key Words*: Industrial Building, Conventional framed roof truss, self-supporting roof, truss less roof, wind load, seismic load, STAAD Pro, Deflection, Cost.**

1. INTRODUCTION

Industrial buildings, are an essential part of any Industry. Industries such as steel, power, manufacturing units, oil and gas etc form the back bone of any economy. The use of steel structures is not only economical but also ecofriendly especially in current times when the effects of global warming is evident like never before[1].The use of word "economical" here is not just with respect to time and cost it also engulfs the various advantages steel offers as a structural material compared to other conventional materials like highest strength-to-weight ratio, strength, hardness, toughness, ductility, fire resistance and high melting point. Due to superior structural properties of steel compared to concrete, for a given structural situation

The quantity of steel used is far less than that of concrete or RCC in similar situation. Thus, from the environmental stand point also, the lesser quantity of steel thus used would liberate less Greenhouse gases as compared to bulky concrete or RCC sections in similar situation. Further saving of steel through innovative design would result in further reduction in carbon footprints. Another vital aspect of comparison of use of structural steel with conventional concrete or RCC structure is its scrap value. The creation of waste during the manufacturing process of steel elements and during the construction stage is also less. The steel can also be recycled and reused, hence they are considered as a better sustainable material for construction [2].

Timely completion of project is another important aspect in any industrial projects, steel structures which are prefabricated, assembled and erected leads to faster construction of a building as compared to RCC structure. Modification works which are inevitable in industrial projects can be done easily in steel structure as compared to RCC structure. The design of industrial steel building includes designing of various structural elements like roof truss or rafter, column and column base, purlins, sag rods, tie rods, gantry girder, bracings, etc. Since roof occupies large area and it consumes huge amounts of material and time in its construction, hence an optimal design of the same is very important. With the use of self-supporting structural elements as roof covering like profiled sheeting, it is now possible to develop innovative shapes of roofs especially for industrial, sports and other service buildings and public areas where long spans are desirable [3].

1.1 Non structural metal roofing

Nonstructural roofing like G.I sheets, A.C sheet, roof tiles etc need a continuous support or closely spaced Purlins, Channels etc , which in turn are supported on roof truss or rafter. [3]

1.2 Structural metal roofing

Structural roofing can span the distance between the supporting roof purlins or beam by itself, similar to metal decking. It is also called "Self Supported Roofing ".Self Supporting Roof system is a revolutionary system where roofing sheets do not need intermediate support like purlins or trusses. The system comprises of profiled roof sheeting which are fixed directly to the structure supporting it at the sides and provide stability due to its curved shape. The shape and size of roofing element is chosen to satisfy the general requirement of strength and stiffness, lightness and economy, ease of handling and erection, proper sealing and leak proof joints. It is based on the arch-principle. It can span from 9 meters to 35 meters.[3]

2. OBJECTIVE

To compare various relevant design parameters of the super structure of an industrial steel structure with conventional framed truss roof to a similar structure with an innovative self-supporting roof the following objectives are outlined

- To study the innovative truss less roofing system, its effect on the structural system on which it is supported and its effect on the support reaction an essential design parameter for the sub structure.
- To compare various structural response parameters of conventional type of roofing system with innovative roofing system in order to calculate potential steel, time and cost savings.
- To provide an analytical comparative study using the-state-of-the-art design tool STADD Pro V8i to build greater confidence amongst the stakeholders for wider application.

3. PURPOSE OF STUDY

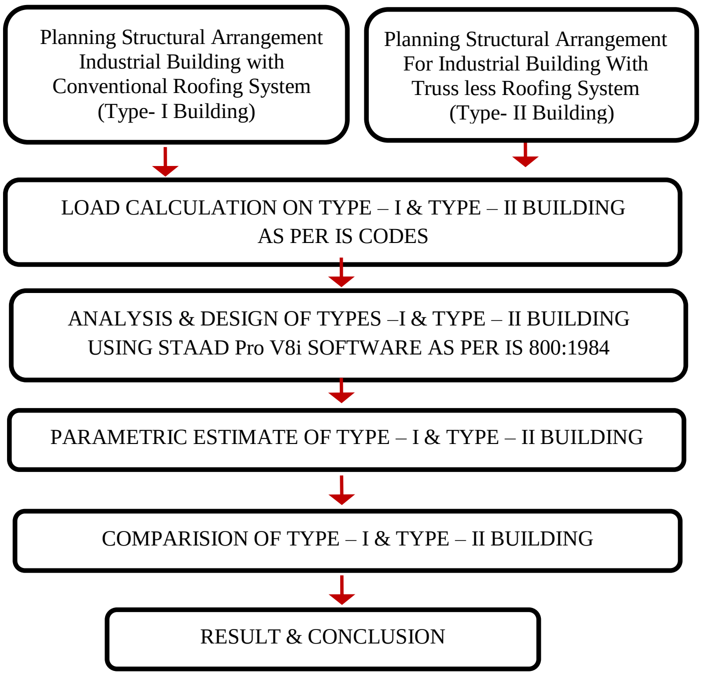
Fabrication, transportation and erection of conventional roofing system especially for large spans are tedious, which involves large amount of labour, machinery and time, whereas self-supporting roofing system as an alternative is light in weight and can be easily fabricated at site with galvalume sheet rolls with the help of hydraulic profile machine. thus, the time required for the installation of truss less roof is much less than conventional roof. Most of the study done earlier is either mainly concentrated on the geometric design of roof structure or comparative study of conventional roofing system with self supporting roofing system in terms of cost and time, but the effect of these roofing system on its supporting system is not considered.

This study is helpful to understand the behavior and effect of innovative truss less roofing system on its structural support system i.e main column, gable column and its bracings also on the load data for the design of its foundation, in the design and construction of an Industrial steel structure. The study also helps in deciding the type of roofing system from the aspect of safety, speedy construction and cost effectiveness.

4. METHODOLOGY

For the study of an Industrial steel structure with conventional roofing system (Type I) and another industrial structure with self supporting truss less roofing system (Type II) of same dimensions, at same location have been considered. To achieve the objective following step-by-step procedures are followed: -

1. Select an existing Industrial building with self supporting roof, of which support reaction data of self-supporting roof is available from vendor for comparison with Industrial building with conventional roofing system of same dimension.
2. Plan the structural arrangement of building, like type of roof (framed roof), top chord ties & bracing, bottom chord ties & bracing in case of conventional building, height of column, bracing in longitudinal direction with ties, Gable end column & it's bracing along with opening, purlins & girts for both type of building.
3. Calculate the load acting on both type of Industrial building as per IS 875: part 1 to part 3, IS 1893: part-1 and load combinations.
4. Analyze & design both type of buildings using STAAD Pro software as per IS. 800: 1984 (WSM) & IS 800:2007 (LSM), calculate the size of base plates & bolts using excel spread sheet.
5. Study of maximum bending moment, axial load, shear force and deflection in columns for both types.
6. Study of support reaction i.e., design loads for foundation of column, like maximum bending moment, axial load, horizontal load for both types of building
7. Estimate the Quantity of steel & roof covering required for both types of building



For the comparative study, two Industrial building of same length width and eaves height with conventional framed roof truss (Type I building) and other with self-supporting roof (Type II building), at Bilaspur is analyzed and designed. Span of 42m along Length, Width of 25m and clear eaves height of 3.65m is considered. Pitch of conventional truss is taken as 1:10 and rise for self-supporting roof as 1:5. Dead load, live load is applied as per Is 875 part 1 & 2, wind pressure is calculated as per IS-875 (part 3), earthquake forces are calculated as per IS-1893 (part 1&4). Both type of industrial building is analyzed and designed with STAAD pro V8i.as per IS: 800:1984 (working stress method) and IS: 800:2007 (LSM).

SN O	ITEM	QTY	RATE Rs/unit	AMOUNT (Rs)
1	Structural steel work including material, fabrication, erection & primer coat	39540 Kg	106	4191240
2	Color coated Galvanized Iron corrugated Sheet for roof & sides	2024 SqM	915	1851960
3	G.I Ridging	179 RM	712	127448
4	Painting two coats on structural steel	956 SqM	60	57360
	TOTAL cost in Rs			6228008

Table -1: Parameter for Type I & II Building

PARAMETER	(TYPE I)	(TYPE II)
Location	Bilaspur, C.G, India	
Eaves Height	5.65m	3.65m
Span/ Width	25m	25m
No. of Bay	7	7
Single Bay Length	6.0m	6.0m
Total Bay Length	42.0m	42.0m
Support condition	Fixed	Fixed
Type of Roof	Framed truss	Curved
Roof slope /pitch /Rise	1:10 (5.71^0)	1:5 (Rise)
Ridge Height	6.9m	8.65m
Purlin/Girts Spacing	1.5m	1.5m Girts
Type of Purlin/Girts	Cold form 'Z' Type	Cold form 'Z' Type
Roof sheet thickness	22 gauge (0.63mm)	1.2mm

Table -2: Cost estimate of Type IA

5. DESIGN AND CALCULATION

For analysis & design of members of Industrial building, both type of structure is modeled using STAAD pro V8i Software & designed as per IS 800:1984 (WSM) & IS 800:2007 (LSM) . For estimation of steel & cost, excel spread sheet is used.

SNO	ITEM	QTY	RATE (Rs/unit)	AMOUNT (Rs)
1	Structural steel work including material, fabrication, erection & primer coat	39540 Kg	106	4191240
2	Color coated Galvanized Iron corrugated Sheet for roof & sides	2024 SQM	915	1851960
3	G.I Ridging	179 RM	712	127448
4	Painting two coats on structural steel	956 SQM	60	57360
		TOTAL cost in Rs		6228008

Table -3: Cost estimate of Type IIA

SNO	ITEM	QTY	RATE (Rs/unit)	AMOUNT (Rs)
1	Structural steel work including material, fabrication, erection & primer coat	26620 Kg	106	2821720
2	Color coated Galvanized Iron corrugated Sheet for roof & sides	642.9 SQM	915	588299
3	Color coated Galvalume profiled sheet roofing	1186. 8 SQM	2100	2492280
4	Painting two coats on structural steel	455 SQM	60	27300
		TOTAL cost in Rs		5929599

Table -4: Cost estimate of Type I**B**

Table -5: Cost estimate of Type IIB

SN O	ITEM	QTY	RATE (Rs/unit)	AMOUNT (Rs)
1	Structural steel work including material, fabrication, erection & primer coat	24970 Kg	106	2646820
2	Color coated Galvanized Iron corrugated Sheet for roof & sides	642.9 SQM	915	588299
3	Color coated Galvalume profiled sheet roofing	1186. 8 SQM	2100	2492280
4	Painting two coats on structural steel	503 SQM	60	30180
		TOTAL cost in Rs		5757579

6. RESULTS AND DISCUSSION

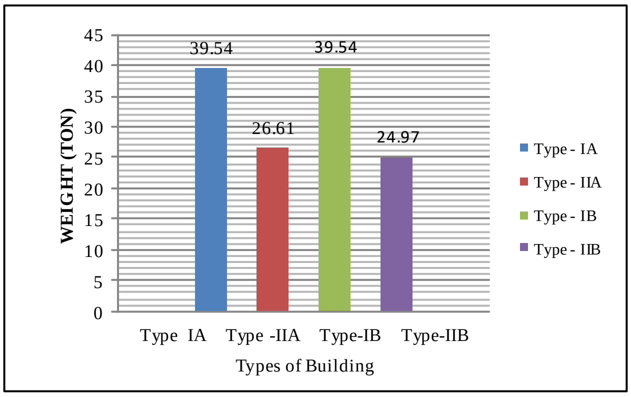


Fig-1: Graph of gross tonnage (weight)

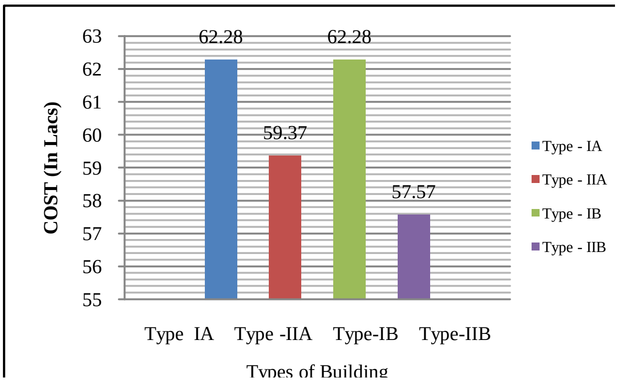


Fig-2: Graph for cost of building

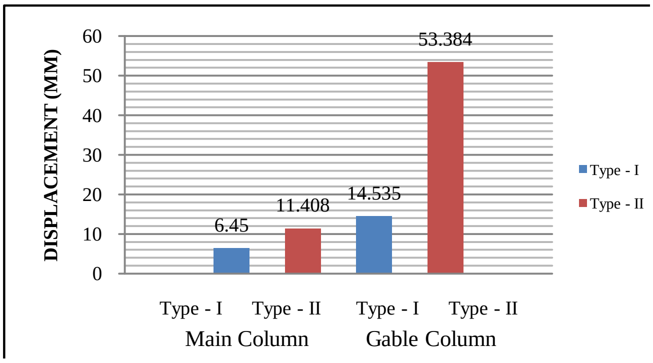


Fig-3: Graph of max displacement in Main & Gable Column

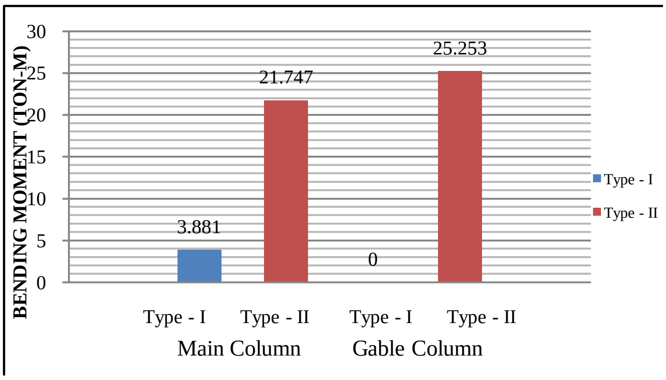


Fig-4: Graph of max B,M at supports in Main & Gable Column

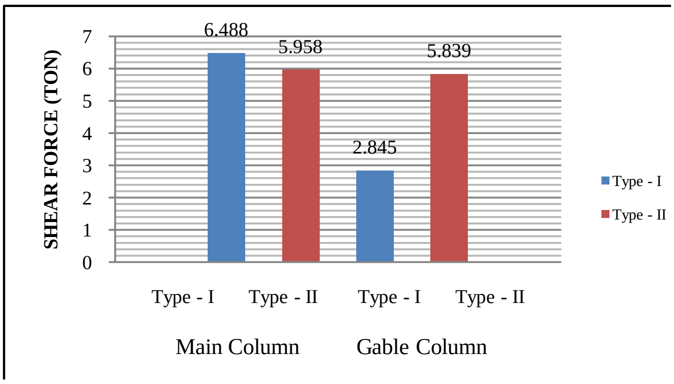


Fig-5: Graph of max S.F at supports in Main & Gable Column

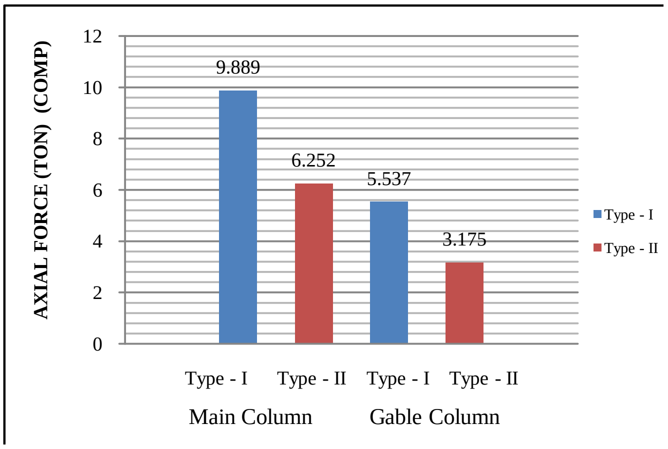


Fig-6: Graph of max Axial Compressive force at supports in Main & Gable Column

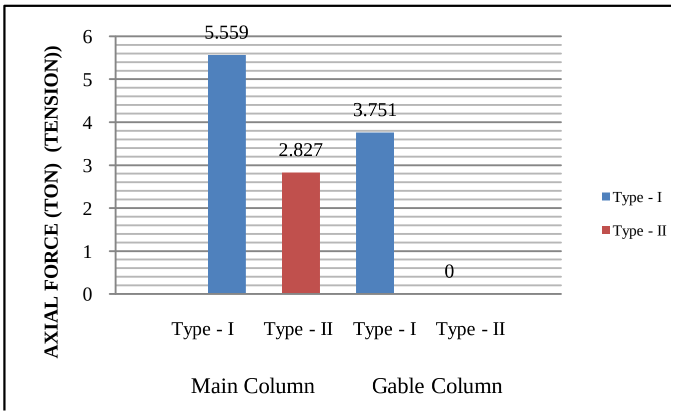


Fig-7: Graph of max Axial Tensile force at supports in Main & Gable Column

- From fig 1, it can be seen that Type IIA building consumes almost 32.7% less structural steel than Type IA Building and Type IIB building consumes almost 36.8 % less structural steel than Type IB building. Type II B has the lowest weight.
- Refer fig 2 , the cost of construction of Type IIA building is approximately 4.8% cheaper than Type IA Building and the cost of construction of Type IIB building is approximately 7.0 to 8.0 % cheaper than Type IB Building . Type II B is the most economical.
- As per fig 3, displacement at top of main and gable column is mainly governed by the configuration of structure. Lateral displacement is more in Type II Building as top of column is unsupported in one direction.
- Refer fig 4 for maximum bending moment at supports of main column and gable column, for main column bending moment in Type II building is 5.6 times that of Type I building where as in gable column, bending moment in Type I building is zero but it is 25.2 Ton-m in Type II building, it should be noted that bending moment is one of the main governing parameter in the design of its sub structure, foundation.
- Refer fig 5 for maximum shear force at supports of main column and gable column , shear force is 10% greater than in Type I building in case of main column and for gable column shear force is approximately twice in Type II building .
- Refer fig 6 and 7 for maximum axial compressive and tensile force at supports of main column and gable column : Axial Load (compressive and tensile) in Type I building is 50- 60% higher than Type II Building for main column. Axial Load (compressive) in Type I building is 60-65% higher than Type II Building.

7. CONCLUSIONS

The paper deals with the comparative study of Industrial steel structure with conventional roofing system with the innovative self-supporting roofing system which shows the potential to reduce the fabrication work and erection time considerably. the inferences of the study are as follows:

1. The geometric configuration of Type II building is such that it results in 60% more enclosed volume hence offer optimum utilization of space, it can be effectively used in storage building.
2. Type II-A Building designed using as per IS: 800: 1984 working stress method with self-supporting roof consumes 32.7% less structural steel than Type IA building which will result in considerable amount of time saving for fabrication and erection of the super structure.
3. Type II-B Building designed using as per IS: 800: 2007 Limit state method with self-supporting roof consumes 36.8 % less structural steel than Type IB building which will result in considerable amount of time saving for fabrication and erection of the super structure
4. Estimated structural tonnage:
   i. Type IA building (Structure with conventional roof, designed using IS: 800: 1984, WSM) is 39.54 tons
   ii. Type IB (Structure with conventional roof, designed with LSM) is also 39.54 tons
   iii. Type IIA (Structure with truss less roof, designed with WSM) is 26.61 tons.
   iv. Type IIB (Structure with truss less roof, designed with LSM) is 24.97 tons. Type II B has lowest weight.
5. The cost of construction (including material, fabrication, erection, primer coat, painting, roof sheeting, GI ridging) of super structure (excluding all taxes)
   - Type IIA building is 4.8 % cheaper than Type IA Building
   - Type IIB building is 7.6 % cheaper than Type IB Building.
6. The estimated cost of construction
   - Type IA &IB is Rs 62.28 Lakhs
   - Type IIA is Rs 59.37 lakhs
   - Type IIB is Rs 57.57 Lakhs

   The cost of construction is lowest in Type IIB Building as compared to Type IA and Type IB for the same length, width and eaves height of the Industrial structure considered.

7. Serviceability criteria: Deflection of main column and Gable column in Type II Building is more hence it may not be economical to adopt for Industrial structures with considerable height or Industrial structures with high-capacity overhead crane where deflection is a major criterion, also may not be economical for hilly areas or terrain with high wind speed.
8. Type I building produces less support reactions as compared to Type II building. Hence overall cost of structure i.e super and sub-structure need to be studied to know the cost effectiveness of Type II building.

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