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COMPARITIVE ANALYSIS OF TRUSS BRIDGES BY CHANGE OF MATERIAL FROM STEEL TO ALUMINIUM USING ANSYS

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Abstract: Truss bridges are the load bearing structures which are made of wooden or metal triangles i.e., truss. Trusses gives stable and supporting form to withstand the considerable amount of different loads over span of bridge. These joint elements which are straight typically may have stressed from tension and compression or sometimes even both due to acting of dynamic loads. This study represents the use of aluminum alloy to replace the structural steel in truss bridges. Aluminum is being used in different structures since 19th century as it has very similar properties as structural steel. ANSYS, a finite element analysis software is put to use for this work. The particular bridge conditions such as type of bridges, its length, height, thickness of deck slab and loading condition has been defined prior the analysis of the bridge structure in ANSYS. Also, the sectional properties of truss members and girder has been provided with reference of locally available steel profiles. And the obtained results such as direct stress, equivalent stress, total deformation, total bending moment and axial forces have been compared. This comparison of results gives the idea of behavior of the bridge structure when subjected to defined loading and its specification. Also, the software is able to give a simulation of these results so, it's easy to understand the results by running these simulations.

***Index Terms* - Truss bridge, Material steel and aluminum, Analysis of bridges.**

1. INTRODUCTION:

The structure which carries a road, train, or other service across different obstacles such as a valley, river, or other railway or road lines is called a bridge. Bridges differ in size from small single span bridges to large suspension bridges and are an essential component of the transportation infrastructure. Steel is used as material in truss bridge system because of its advantages over other material of srength and ductilness. The truss system of steel wrought iron were developed from the industrial revolution of 19th centuary for large bridges, but iron dis not have the tensile strength to support large and varying load conditions. With the advantage of steel of having greater tensile strength the larger bridges were built. As we are living in the 21st centuary the industrial revolution have come so far in developing different structural materials and its combinations to get better structural strength and durability over steel and concrete. This study presents the use of aluminium in truss bridges instead of structural steel. In history there are many projects that were executed by using this approach of substituting steel by aluminium as material.

TRUSS BRIDGE:

A truss is a triangulated system of components that are constructed and connected so that only axial force is applied. These members are classified as two-force members because the forces are delivered only at one end of the member, resulting in compression or tension. Because of their capacity to span great distances efficiently, they are frequently employed as bridge designs.

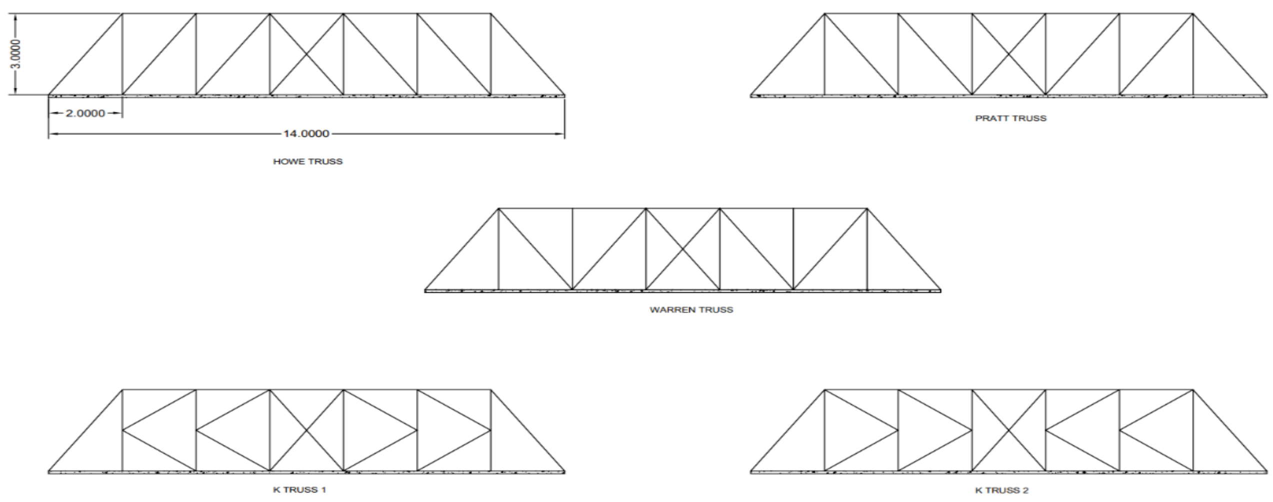

Fig.1.1 Types of truss bridges

As shown in **Fig.1.1** the total of five different truss bridge's models have been selected to perform this task. The bridges are the howe truss bridge, the Pratt truss bridge, the warren truss bridge and with changed pattern of members 2 types of K truss bridges.

2. LITERATURE REVIEW

2.1. 1. Sachin Saj T K, 2. Shruthy Aravind Menon, (2018) performed an analysis in ANSYS (which is a software of analysis based on finite element analysis) of a system of truss bridge. The final outcome was having the results of the direct stress, the equivalent stresses, the axial forces, the total deformation and the total bending moment. These results were able to give a basic idea of behavior of this bridge system when assigned material is changed from steel to aluminum. [1]

2.2. Alpesh Jain et. al. (2016), used ANSYS software to investigate a bridge structure made of four different materials and to do a modal evaluation of bridge hassle. For each of the four substances, eight node solid elements are chosen and meshing is performed. Each material's material properties are chosen in accordance with the literature database in the ANSYS software program. The modal evaluation in ANSYS is completed to obtain the natural frequency and mode shapes of the bridge in order to avoid the bridge's resonance. It has been determined that the bridge should not be used at received frequencies. [2]

2. 3. 1. Ankit Sharma, 2. Sumit Pahwa, Bridge truss structures have been examined. A look back the study looked into the feasibility of analyzing and developing steel bridges using a variety of easily available steel profiles in the area. The study has shown that building a steel bridge utilizing locally available steel profiles is a viable option based on the analysis and design done so far. Even when local manufacturing costs are comparable to imports, it is still a sensible choice because it helps to strengthen the capacity of local design, fabrication, and construction firms, creates jobs for a large number of people, and saves foreign currency. These locally constructed steel truss bridges can be used as temporary bridges for a variety of small-span road construction projects. [3]

2.4 Alika Koshi et. Al. (2016), The length of a through arch bridge was measured at various arch points and compared. A pure compression shape is an arch. By resolving forces into compressive stresses and then casting off tensile stresses, it can span a large region. This form of movement is referred to as arch motion. The arch will push outward at the bottom as the forces inside it are transmitted to the floor. The importance of the arch peak in the transfer of forces and stresses cannot be overstated. This study employs a three-dimensional bridge model in the Finite Element Analysis software program ANSYS to characterize the behavioral components of a through arch bridge with certain arch placements and compare them to the actual structure. [4]

3. Methodology

This study is carried out by using ANSYS, a finite element analysis software. The software enables the user to define his/her own material properties and to run a dedicated analysis to any generated model. It shows the simulation of any analysis that has been caried out so that the user is able to understand the exact behavior of any element or structure. The 5 different bridge models mentioned in **Fig.1.1** has been put to use to perform this analysis of truss bridge structure. The analysis results of 'the axil forces, the direct stresses, the equivalent stresses, the total deformation and the total bending moment' has been carried out and compared.

3.1 Structural Modeling

For the analysis five bridge models has been considered.

1 - Howe Truss
2 - Pratt Truss
3 - Warren Truss
4 - K Truss Type-1
5 - K Truss Type-2

For above mentioned bridges the specifications and loading condition has been decided as given below in **Table 3.1.** The modeling of bridge structure has been done as shown in **Figure 3.1 to Figure 3.6.**

Table 3.1: - Structural details

1. Model Specification			
Width of bridge	2.5m		
Height of bridge	3m		
Length of bridge	14m		
Truss member	ISMC 200		22.10 kg/m
Bottom Girder of bridge	ISMB 300		44.20 kg/m
Deck slab thickness	150mm		
Materials	Steel	Aluminum	Concrete
2. Loading data			
Self-weight	-		
Live Load	500 Kg/m^2		
Factor of safety	1.5		
Total	Self-weight + 750 Kg/m^2		

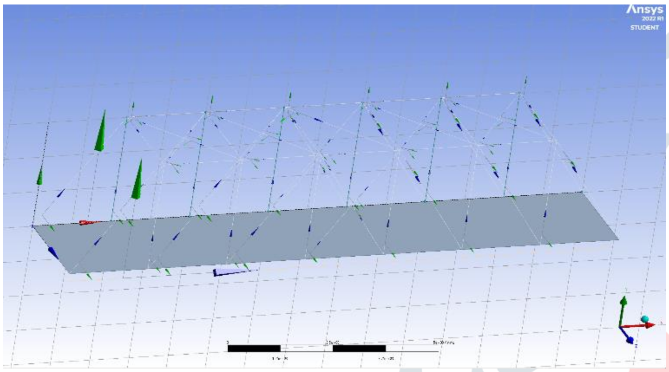

Figure 3.1: - Generating geometry of bridge as per specification data

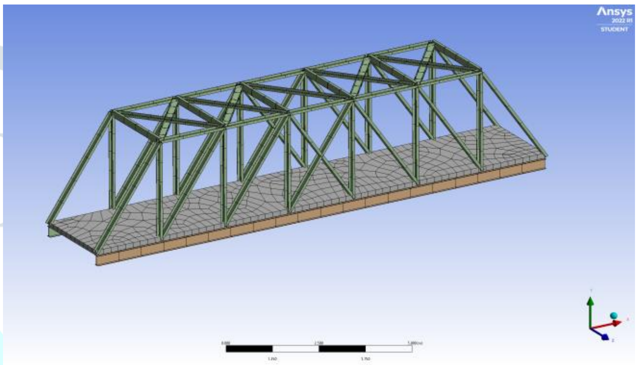

Figure 3.2: - Generating Mash

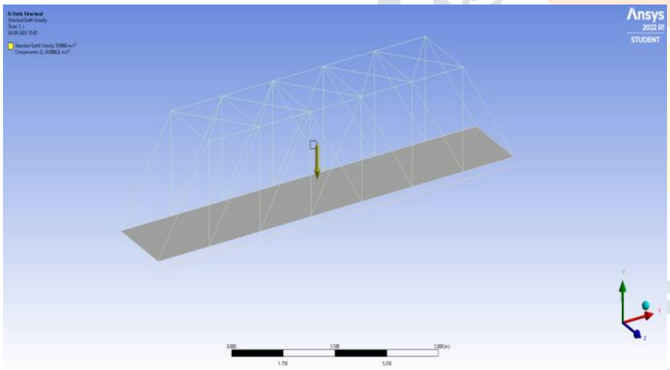

Figure 3.3: - Applying standard Earth gravity

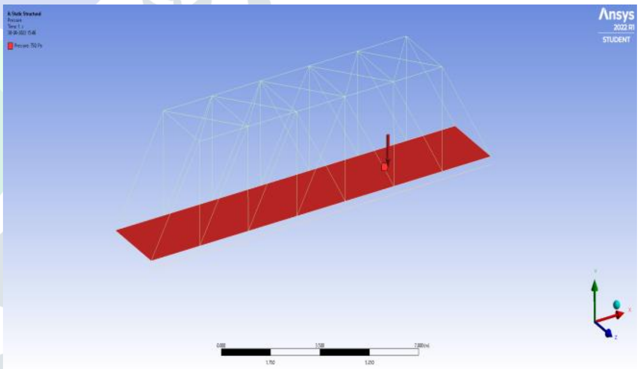

Figure 3.4: - Assigning Live Load

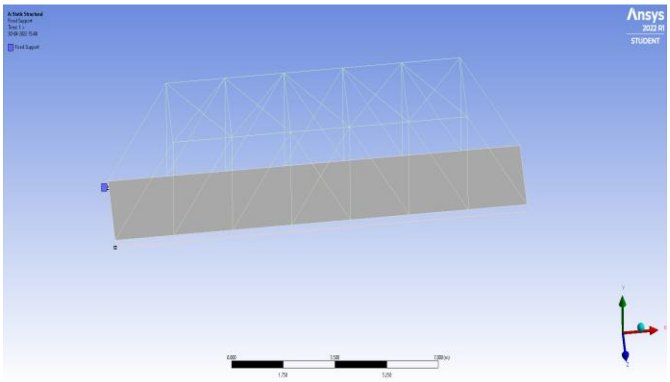

Figure 3.5: - Assigning Fixed Support

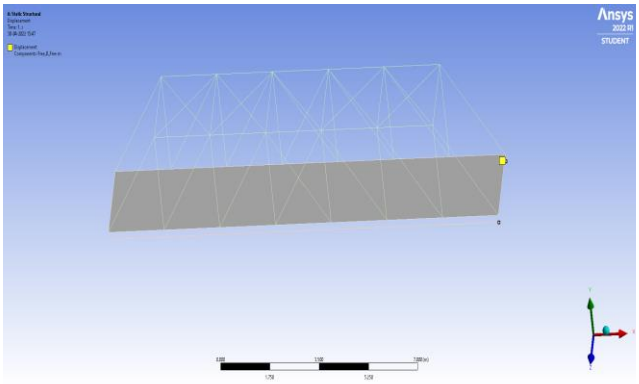

Figure 3.6: - Assigning Displacement Support

3.2 Result

After the modeling part of bridges and assigning its specifications and loading conditions, a static analysis has been carried out for all five bridges using ANSYS. The analysis results of 'the axil forces, the direct stresses, the equivalent stresses, the total deformation and the total bending moment' has been carried out and compared. **Figure 3.7 to Figure 3.16** shows these results for howe truss bridge side by side for steel and aluminium.

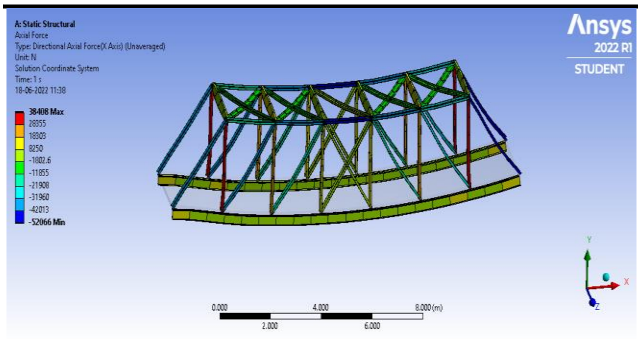

Figure 3.7: - Axial Forces for steel Howe truss bridge

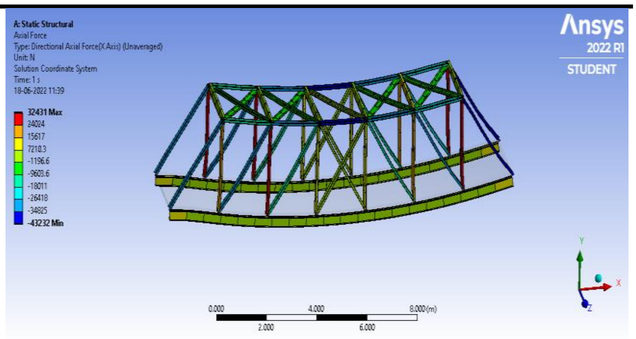

Figure 3.8: - Axial Forces for aluminum Howe truss bridge

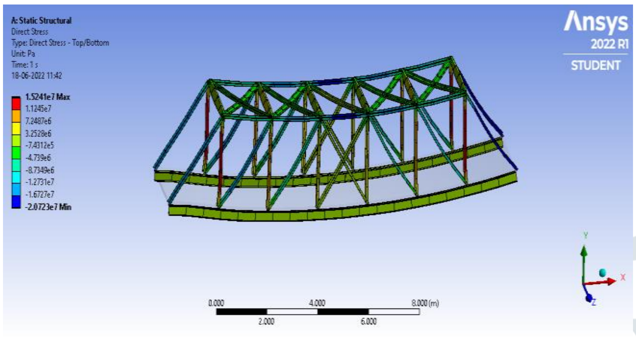

Figure 3.9: - Direct stress for steel Howe truss bridge

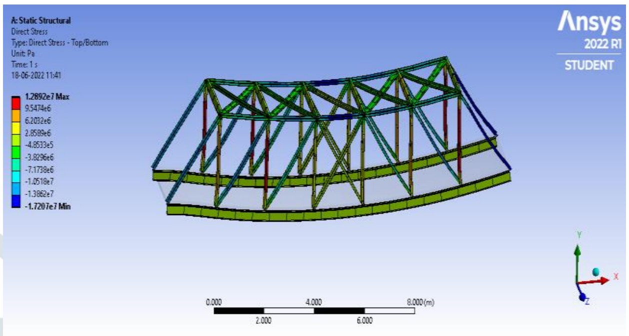

Figure 3.10: - Direct stress for aluminum Howe truss bridge

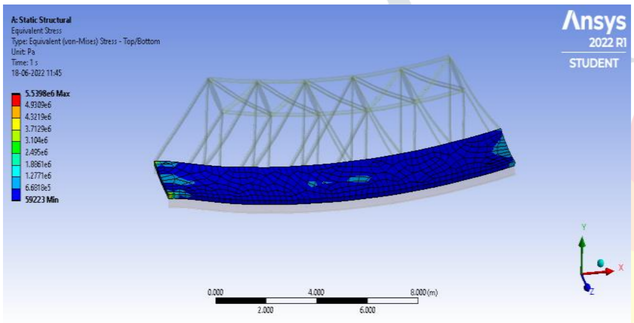

Figure 3.11: - Equivalent stress for steel Howe truss bridge

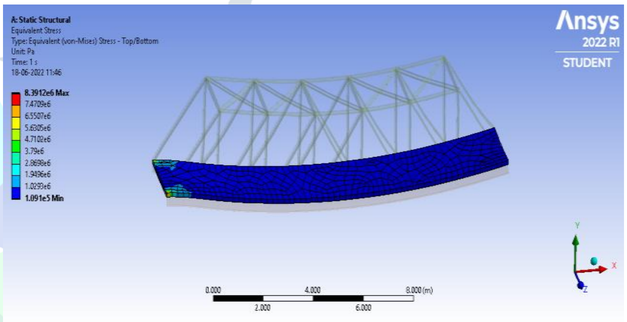

Figure 3.12: - Equivalent stress for aluminum Howe truss bridge

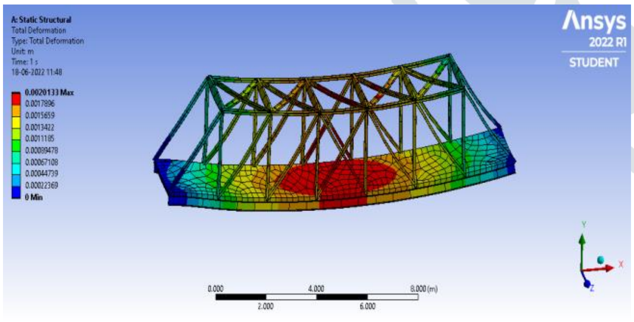

Figure 3.13: - Total deformation for steel Howe truss bridge

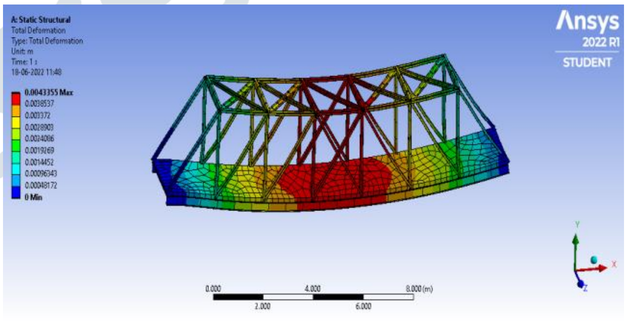

Figure 3.14: - Total deformation for aluminum Howe truss bridge

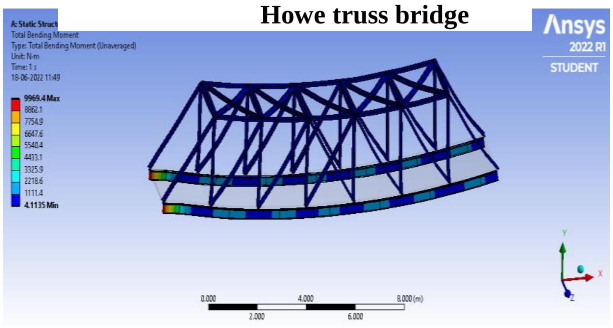

Figure 3.15: - Total bending moment for steel Howe truss bridge

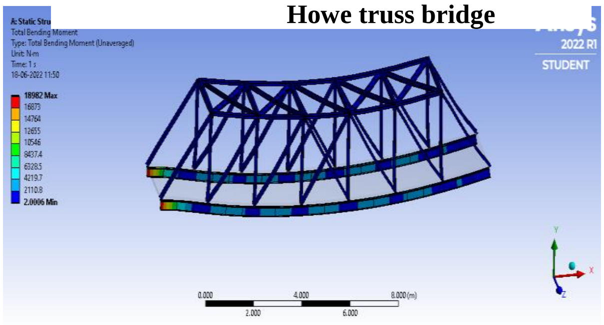

Figure 3.16: - Total bending moment for aluminum Howe truss bridge

As mentioned before **Figure 3.7 to Figure 3.16** shows the analysis results for Howe truss bridge. It shows the values for both combination of concrete + steel (LHS) and concrete + aluminium (RHS). Similarly other remaining bridge structures also has been analysed. For better understanding of results and to corelate that with the behaviour of bridge structure from all the output data the maximum values for each term has been classified and compared. Given below are the tables for each bridge structure which contains the respective data of analysis.

Table 3.2: - Howe Truss

Maximum results	Structural steel	Aluminum
Axial Force	38408 N	32431 N
Direct Stress	$1.52 * e^7$ Pa	$1.28 * e^7$ Pa
Equivalent Stress	$5.53 * e^6$ Pa	$8.39 * e^6$ Pa
Total bending moment	9969.4 Nm	18982 Nm
Total deformation	0.002m	0.0043m

Table 3.3: - Pratt Truss

	Structural steel	Aluminum
Axial Force	34527 N	27120 N
Direct Stress	$1.37 * e^7$ Pa	$1.07 * e^7$ Pa
Equivalent Stress	$1.35 * e^6$ Pa	$2.09 * e^6$ Pa
Total bending moment	4944.1 Nm	8816.4 Nm
Total deformation	0.0013m	0.0027m

Table 3.4: - Warren Truss

	Structural steel	Aluminum
Axial Force	34328 N	30422 N
Direct Stress	$1.36 * e^7$ Pa	$1.2 * e^7$ Pa
Equivalent Stress	$1.9 * e^6$ Pa	$3.13 * e^6$ Pa
Total bending moment	6849.4 Nm	13147 Nm
Total deformation	0.0017m	0.0038m

Table 3.5: - K Truss - 1

	Structural steel	Aluminum
Axial Force	37959 N	31038 N
Direct Stress	$1.5 * e^7$ Pa	$1.23 * e^7$ Pa
Equivalent Stress	$2.0 * e^6$ Pa	$3.13 * e^6$ Pa
Total bending moment	7448.4 Nm	13451 Nm
Total deformation	0.0014m	0.0031m

Table 3.6: - K Truss - 2

	Structural steel	Aluminum
Axial Force	26429 N	23573 N
Direct Stress	$1.04 * e^7$ Pa	$9.36 * e^6$ Pa
Equivalent Stress	$2.11 * e^6$ Pa	$3.39 * e^6$ Pa
Total bending moment	8003.8 Nm	14666 Nm
Total deformation	0.0018m	0.0038m

As mentioned in **Table 3.2,** when Howe truss is subjected to defined loading condition, for axial forces in model having steel as a material for truss is 38408N. where as in aluminum it is 32431. So axial forces that is acting through howe truss bridge having steel as material are greater than bridge having aluminum as material. Following the effect of axial forces the developed direct stress that is maximum in bridge for steel material is $1.52 * e^7$ Pa and for aluminum it is $1.28 * e^7$ Pa. The representation of stresses from X, Y and Z coordinates in single value of stress is known as equivalent stress. For this howe truss bridge model the value for equivalent stress when assigned material to truss is steel is $5.53 * e^6$ Pa and for aluminum it is $8.39 * e^6$ Pa. Due to the actions of external forces the moment is generated in structure. As per the analysis data a total bending moment is derived by use of ANSYS. For the case when steel is truss material the value of total bending moment is 9969.4 Nm and similarly for aluminum assigned bridge it is 18982 Nm. Due to this all acting of external forces and following of them the developed reactions the structure tends to deform. In physics, deformation is the continuum mechanics transformation of a body from a reference configuration to current configuration. With total deformation option you can see all the deformation results of your model, in three coordinates that are X, Y, and Z. The total deformation in steel howe truss bridge is 0.002m and in aluminum howe truss bridge is 0.0043m. Aluminum shows more deformation and moment results than that of steel.

Similarly other four bridges which are Pratt truss bridge, warren truss bridge and both defined type of K – type truss bridge 1 and 2 have their results mentioned in **Table 3.3, 3.4, 3.5 and 3.6** respectively. The results for other bridges show the similar effect on the structure when material is changed from steel to aluminium for truss members.

4. Conclusion

The results shows that axial force is experienced less by the aluminum structure than that of steel structure. The direct stress which is the following effect of axial forces is also less in aluminum than that of steel. Equivalent stress and total bending moment is experienced more by aluminum structure than that of steel structure. The total deformation for aluminum is more than that of steel. The predefined length of bridge is 14m. The permissible deflection for truss bridge is 'L/800'. For L = 14m, the permissible deflection will be 17.5mm. From results of analysis, it is clear that all types of bridges that have been used in this study stays within permissible range of deflection for both the cases of truss having material as steel and aluminum. Hence, by executing this study aluminum seems to be a good replacement for structural steel. It also has lesser density than steel so overall weight of the structure will also be decreased. The process of construction can also be faster than that of the steel structure.

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