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Analysis of Prototype Truss Bridge Models

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Abstract—*Trusses play a major role in civil engineering structures. The various uses of trusses can be summarized as in roof trusses of industrial sheds or residential buildings, bridge trusses etc. Trusses can be defined as a single object consisting of horizontal, vertical or inclined members who are connected at joints referred to as nodes. Trusses can have members in any shape in stable configuration but it is conventional to have straight members connected in triangular units. The basic truss types in bridges are Warren, Pratt, Howe and K truss. The members in the truss can have only two forces- tension or compression. Prototype models of these basic types are created in the present research work and the same are tested for their strength against load bearing capacity. In order to arrive at a conclusion more precisely, the material of all prototypes are kept similar and light weight with same technique of making joints and same span. An experimental review is conducted and load to weight ratio is calculated. In this research paper, the prototype which showed the maximum load bearing capacity is analyzed with respect to the superimposed load and also with the manner it distributes and bears the acting load. The truss mechanism of bearing loads is also discussed. The paper justifies the prototype results and also concludes with the reasons in support of the experimental verification conforming proper analysis with superimposed and permanent loads.*

Keywords*: Truss, tension, compression, strength, permanent load, superimposed load, load bearing capacity.*

1. INTRODUCTION

Truss is a structure built with single members connected at joints or nodes. In the truss design, shear, torsion and moment is completely eliminated and the members can take only axial tension or compression. For a statically determinate truss m= 2j-r where m is the no. of members, j is no. of joints and r is no. of reactions=3. If tensile forces are greater than compressive forces then there is every likelihood that the truss will buckle. On the other hand if the compressive forces are greater the truss will break. To keep the truss bridges on safer side, the structure can be made indeterminate (m > 2j-r) so that even some members break the truss remains structurally safe. The four different types of truss bridges are Warren, Pratt, Howe and K trusses. The Warren truss is the most common and continuous bridge type trusses. James Warren from Britain developed this type of truss during mid 1800s and this type was extensively used for railway infrastructure and railway bridges. For smaller spans, no vertical members are present but for larger spans, the warren truss consists of vertical members for extra strength. It uses equilateral triangles to spread out the load on the bridge. It may consist of vertical members also added at the each apex of triangle. Compression and tension forces are spread between the diagonal and vertical members alternatively. For a moving load across a bridge, the forces changes from compression to tension in the members close to the moving load.

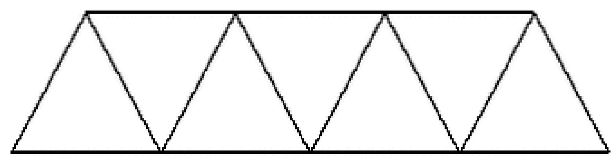


Fig. 1: Warren truss

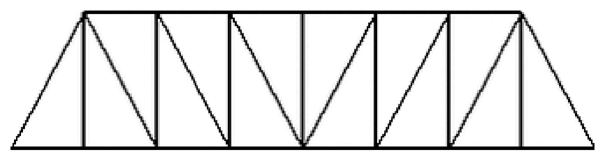


Fig. 2: Pratt truss

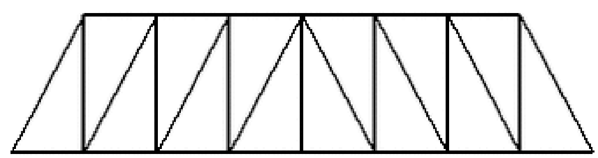


Fig. 3: Howe truss

S. No.	TRUSS BRIDGE TYPE	WEIGHT OF TRUSS BRIDGE (W) in gms	MAX. WITHSTANDLOAD (L) in Kg	EFFICIENCY= L/W
1.	PRATT TRUSS	115	32	278.26
2.	WARREN TRUSS	118	53	449.5
3.	K TRUSS	127	23	181.1
4.	CROSS TRUSS	134	36	268.66

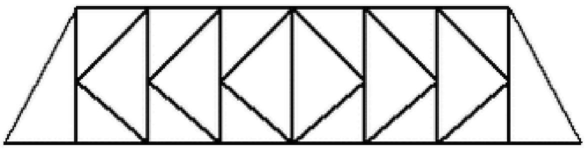


Fig. 4: K truss

Pratt truss was first developed by Thomas and Caleb Pratt in 1844. Pratt truss consists of diagonal members directing towards the center of the span. All diagonal members handle tension forces (except near the center) and vertical members handle compression. As a result diagonal members can be made of thin section which is resulted in an economical design.

William Howe from Spenser, Massachusetts, developed this truss in 1840. Howe truss looks like opposite of Pratt truss. In this type of truss diagonal members face in the opposite direction and handle compressive forces and vertical components handle tension.

In K truss, the vertical members are breaking up into smaller sections because they are in compression. The shorter a member is, it can resist buckling in compression. The Roadbed type can be deck truss (deck is attached above the truss), through truss (deck lies in between and through the truss) and half-through truss (similar to through truss but portion of truss above the road is not attached to the roadbed)

2. EXPERIMENTAL PROTOTYPE MODELS

The materials used for prototype models were mainly Popsicle sticks. The design criteria which was similar for all prototype models was: (a) Total Length Of Bridge: 55 cm (b) Total Width of Bridge: 10 cm (c) Overlapping of Sticks in a Joint up to 5 Sticks (d) Cover Distance 5 cm. Loading criteria for all prototypes trusses were kept as point load applied from base of the deck. In the design of prototypes, Popsicle sticks were cut as per required shape and size and these sticks were joined together with the help of glue and the truss was allowed to stand for minimum period of 24 hours before testing. The experimental procedure consisted of noting down the bridge weight, the bridge was placed between supports with the base of bridge isolated from the ground. Loading was done at steady rate with the help of a hook hung from the center of the base of bridge. The loading was continued till the truss started showing signs of buckling or breaking. This load was noted and efficiency of the bridge (load/weight) was calculated. The experimental observations were as follows:

The above observation clearly indicated that the Warren type truss has sustained much greater load as compared to other truss bridges. In structural design, the most important criteria of design is the structure's ability to carry load safely. The structural analysis is conducted by breaking the structure into its component parts and analyzing it mathematically. The structural analysis gives us result in the form of reactions, internal forces in members and deflections and is an integral part of design. The prototype was a mathematical idealization of the truss with assumptions about the truss configuration. The loading allowed us to predict the truss behavior mathematically.

Some of the assumptions are for example members are perfectly straight, joints are frictionless, loads and reactions are applied only at joints, members carry load either in pure tension or pure compression. This is true that assumptions produces inaccuracy in analysis but the variation is so small that these are neglected. All prototype models were statically determinate and therefore method of joints was used to analyze the forces.

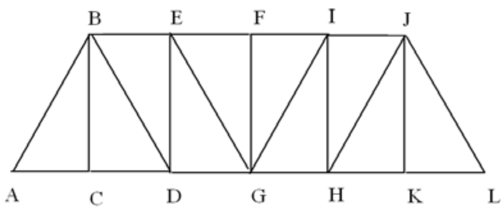
3. UNCERTAINTIES IN THE RESULT

There are certain uncertainties that affect a structural design. Firstly, there is always an uncertainty in predicting the loads which the structure may experience in future. Examples of such uncertainty can be heaviest truck that may pass the bridge, intensity of wind, snow or earthquake load. Secondly, there is an uncertainty in estimating the strength of materials with which the structure is composed of. For example some manufacturing defects and error in construction always happen in favor of this uncertainty. Thirdly, the methodology used for structural analysis cannot be 100% accurate. The assumptions made before analysis of structures also impart inaccuracy in the result.

4. CONCEPT OF LFRD

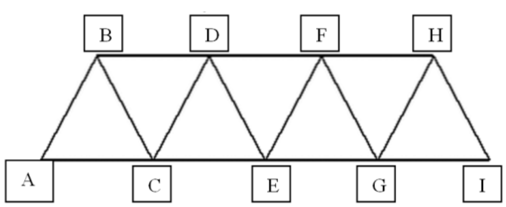
To overcome these uncertainties, a factor of safety is used in all design calculations. Factor of safety can be calculated as ratio of failure level and actual level. In trusses, the factor of safety can be calculated as Failure load/ Internal force in a member. Factor of safety less than 1 shows that structure is not safe and will probably fail. Factor of safety of 1.6 or more is considered safe and adequate. Recently, a new concept called load and resistance factor design (LRFD) is developed to replace factor of safety. LFRD is based on the principle that the largest loading that the structural member will experience in its lifetime should be less than the smallest possible strength of that member. The largest load is estimated by adjusting the loads in structural analysis. All loads are multiplied by a load factor greater than 1 as per specifications of code. The actual magnitude of load factor depends upon the uncertainty of the applied loads. The self weight load can be calculated with more accuracy so the load factor used for self weight is usually low e.g. 1.2 or 1.4. Wind, traffic and earthquake loads are very unpredictable in nature and therefore load factors used for these loads are much higher. In order to estimate the smallest possible strength of a structural member, the nominal member strength is multiplied by a code specified resistance factor which is always less than 1. The resistance factor accounts for the uncertainties and errors that may cause a structural member to weaken. The load factor and resistance factor serves the same purpose of factor of safety as they ensure the safety of the structure.

5. STRUCTURAL ANALYSIS PRATT TRUSS



S.NO	MEMBER	FORCE	S.NO	MEMBER	FORCE
1	AB	0.71W (COMPRESSIVE)	12	GH	W(TENSILE)
2	BC	0	13	GI	0.71W(TENSILE)
3	AC	0.5W(TENSILE)	14	FI	1.5W(COMPRESSIVE)
4	BD	0.71 (TENSILE)	15	HI	0.5W(COMPRESSIVE)
5	CD	0.5W(TENSILE)	16	IJ	W(COMPRESSIVE)
6	BE	W(COMPRESSIVE)	17	HJ	0.71W(TENSILE)
7	DE	0.5W(COMPRESSIVE)	18	HK	0.5W (TENSILE)
8	EF	1.5W(COMPRESSIVE)	19	JK	0
9	EG	0.71W(TENSILE)	20	KL	0.5W (TENSILE)
10	DG	W (TENSILE)	21	JL	0.71W(COMPRESSIVE)
11	GF	0			

6. STRUCTURAL ANALYSIS OF WARREN TRUSS



S.NO	MEMBER	FORCE	S.NO	MEMBER	FORCE
1	AB	0.58W (COMPRESSIVE)	9	EF	0.58W(TENSILE)
2	BC	0.58W (TENSILE)	10	FG	0.58W(COMPRESSIVE)
3	AC	0.29W (TENSILE)	11	EG	0.86W(TENSILE)
4	BD	0.58W(COMPRESSIVE)	12	FH	0.58W(COMPRESSIVE)
5	CD	0.58W(COMPRESSIVE)	13	GH	0.58W(TENSILE)
6	DE	0.58W(TENSILE)	14	GI	0.29W(TENSILE)
7	CE	0.86W(TENSILE)	15	HI	0.58W (COMPRESSIVE)
8	DF	1.16W(COMPRESSIVE)			

It is important to note that the structural evaluation is valid only for one particular loading. If magnitude or position of the load is changed, the member forces and factor of safety will also change.

It is also important to estimate the deflections in a bridge. Deflection is a distance that a structure moves when it is loaded. It is also essential that the bridge should be safe and public also perceives it to be safe. Thus careful calculation is required for structure's deflections under various loading condition and to ensure that these deflections comply with the code.

7. RESULT AND CONCLUSION FOR FUTURE SCOPE

In Warren truss, the members are better utilized and each member contributes towards internal forces. In case of Pratt truss some of the members do not show tension or compression and these are zero force members. This does not imply that these members can be removed as this will adversely affect the stability of the system. Warren truss may be economical on the basis of material consumption and may show greater strength for short span. For longer spans, Pratt truss may be proved beneficial. Truss bridges are economical with efficient use of materials and they offer an alternative to many types of beam bridges. However, the truss structure and the height of deck in relation to bridge are the crucial design factors that may vary as per situation. The analysis verified the experimental observation but proper design is required to be established by factor of safety which can be estimated by calculation of strength of each member experimentally.

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