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IMPLEMENTATION OF STRAW STRUCTURE USING TRUSSES AND ARCHES

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ABSTRACT

Trusses play an important role for building up any structure. The paper focuses on utilizing the lightest material like straws for building up a structure while implementing the trusses and arches with a focus on their suitability for utilization.

Keywords: Trusses, Arches, Failure and Hinge Joints.

I. INTRODUCTION

A truss is essentially a triangulated system of straight interconnected structured elements. It is sometimes referred to as an open web girder. The individual elements are connected at nodes. The connections are often allowed to be nominally pinned.

A truss consists of typically straight members connected at joint, traditionally termed panel points. Trusses are typically composed of triangles because of the structured stability of that shape and design.

Types of trusses:

1) Pratt Truss: Here vertical member responds to compression and horizontal member respond to tension.

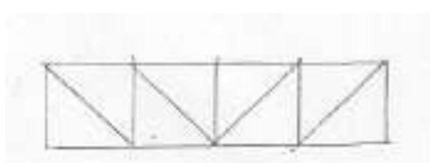


Figure 1.a

2) Warren Truss: In this type , diagonal members are alternatively in tension and in compression.

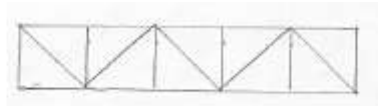


Figure 1.b.

3) North Light Truss: They are traditionally used for short spans in industrial workshop type building. They allow maximum benefit to be gained from natural lighting by the use of glazing on the steeper pitch which generally faces north or north-east to reduce solar gain.

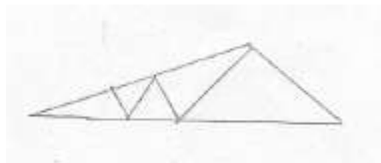


Figure 1.c.

4) Sawtooth Truss: They are used in multi-bay buildings. In this a truss perpendicular to the plane of saw tooth truss is included like in North Light truss.

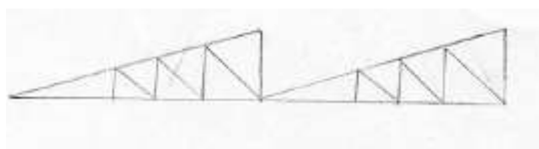


Figure 1.d.

5) Fink Truss: It offers economy in terms of steel weight for short-span high pitched roofs as the members are subdivided into shorter elements. There are many ways of arranging and subdividing the chord and internal members.

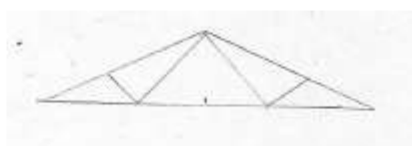
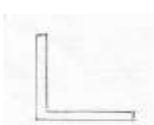


Figure 1.e.

Types of truss members section:

(1)



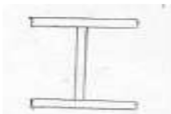
L-Section

(2)

Figure 2.a.

(3) **T-Section**

Figure 2.b.



(4) **I-Section**

Figure 2.c.

(5) **C-Section**

Figure 2.d.

(6) **Hollow Section**

Figure 2.e.

Types of Connections: Ribiting, bolting and welding.

Design of members:

1) The upper chord and the lower chord (horizontal members) respond to compression and tension.
2) The diagonal members and vertical members from the truss web and carry the shear forces.
3) For the members under tension the cross sectional area A can be found using $A = \frac{F*\gamma}{\sigma}$ where F = Force, γ = Safety Factor; σ = Yield tensile strength.

Designing of joints:

After determining the minimum cross section of the members the last step is the design of a truss would be detailing of the bolt connection used in the joints (see also shear stresses). According to the project, joints can be designed as rigid, semi rigid or hinged.

Calculation: When joints (j) are given, then to find the member (m) we use m=2j-3.There are two methods of calculation and they are joint method and section method.

1) Joint Method: Let F_N force is acting on B then to find the effect of force at joint A and C , we calculate the value of R_{Ax}, R_{Ay} , R_{Cx} and R_{Cy} at A using the following equation.

$$\sum M_A = 0 = F*\left(\frac{z}{2}\right) - R_{Cy}*z \qquad (1)$$

where $\sum M_A$ = Summation of moment at A.

$\sum x = 0 = R_{Ax} - R_{Cx}$ (2)

$\sum y = 0 = R_{Ay} + R_{Cy} - F$ (3)

Solving equations (1), (2) and (3) we get the value of R_{Ax}, R_{Ay}, R_{Cx} and R_{Cy} . This method is used when the force is to be determined at each member.

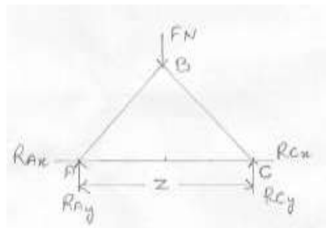


Figure 3

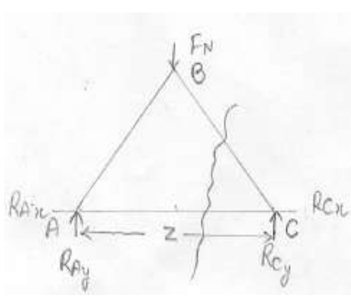
2) Section Method: Here force is applied only at B, F_N and we have to find the force at A only (R_{Ax}, R_{Ay}). Therefore we cut the section parallel as shown in figure after cutting shown in figure.
Now apply the equation

$\sum x = 0 = R_{Ax}$ (4)

$\sum y = 0 = R_{Ay} - F$ (5)

$\sum M_A = 0$ (6)

Solving (4), (5) and (6) we get the value. Note that when the forces in a few members of a truss are to be determined, then the method of section is used.



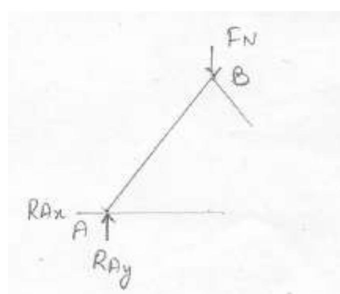


Figure 4.a **Figure 4.b**

Layman Terminology:

Trusses are simple members that are connected by pins. The load is not put on member, as they are weak and even if they are not weak, there can be sway i.e. bending which can leads to moment. In trusses there is no scope of moment. Moment means if we lay pressure on a beam for example, it will try to deflect and therefore unsymmetry occurs that gives rise to moment and therefore it can’t be truss. In trusses we use pin joints.

Assumptions: The self weight of member is to be neglected. The role of member is to transfer the load from joint to joint. The last joint where the load is to be transferred is grounded. Suppose there is a truss and it is connected to

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earth i.e. a truss bridge and the load is to be transferred to the earth. There is no role of member but it is essential for connection.

Quality of member: It should be of steel and should not be too ductile or brittle. There are different grades of member.

Pin joints on the other hand do not transfer the moment as they are hinged. They rotate and therefore moment will not be transferred but load can. Moment is applied on a distance. Because of the pin joint, the moment will not be passed to other member. Pin joints transfers the loads or main force i.e. shear force and it is transferred from joint to joint and finally the force is transferred to the main support.

II. TECHNICAL DESCRIPTION

Suppose there are two supports and three members and there is a load acting at top, the load transferred in x and y directions. As the support is vertical, the reaction at support is also vertical. Reaction, as in on applying a load , the Newton's third law says that every action has equal and opposite reaction. Therefore the action can be at any angle and the reaction can be inclined also but component to be considered is vertical.

In practical case the reaction can be in any direction but it should withstand with the support. The supports can be of two types i.e. hinged support and roller support. The roller support gives vertical restriction but not the horizontal restriction and does not restrict moment whereas hinged support restricts both vertical and horizontal displacement. Hinged support is fixed therefore both horizontal and vertical reactions occur. Considering the example of temperature variation, due to which the steel which is a ductile material tries to expand and if we restrict the truss from both sides, the internal stresses will be generated, which will be bear by members therefore wasting member's energy. To prevent structure from this, we use rollers so that it can expand from one side keeping the other end fixed and hence providing the stability.

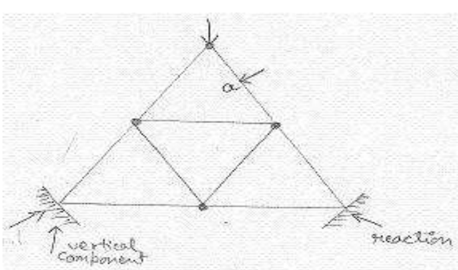

Figure 5

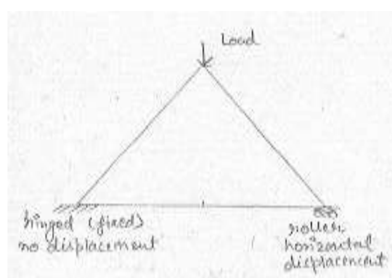

Figure 6

The member in Figure 5 at point a if experiences a load, it will deflect from original position due to which the joint component may fail. Therefore to sustain this effect, the focus should be at the quality of member and in trusses we don't depend on qualities of member as we transfer the load from pin to pin joint.

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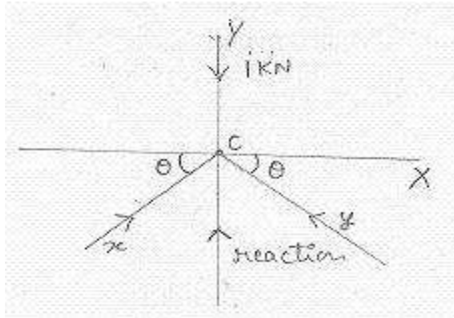

Figure 7

III. LOAD DISTRIBUTION AND ANGLE CALCULATION

To calculate the reaction force or angle, consider the Figure 7.Considering the load coming from Y plane is 1KN and we need to calculate the x and y component corresponding to the reaction. Calculating ∑X and ∑Y at equilibrium, we get corresponding to X, both angles are equal to θ. Solving further we get:

$- y \cos\theta + x \cos\theta = 0$ (i)

Component corresponding to θ is cosθ and the other component is sinθ. Corresponding to Y, we get:

$+x \sin\theta + y \sin\theta = 0$ (ii)

Equations i and ii have three unknown values therefore at least one component should be known or assumed where x and y are force component.

Arches: Any parabolic or circular structure is called an Arch. If any arch has three hinges as shown in Figure 8 with one hinge at top, is called as three hinge arch. And if two hinges then it is a two hinge arch. Arches do not allow moment to transfer from one member to another. Arch has a curved shape so that if a load is applied, it can at most go flat. We can use hinge both sides instead of roller at one side as in case of trusses because the variation can be handled by arches members linked through hinges. They can bend if there is any variation. There is only vertical displacement. Arches are also use to transfer the load at the end of supports which are grounded.

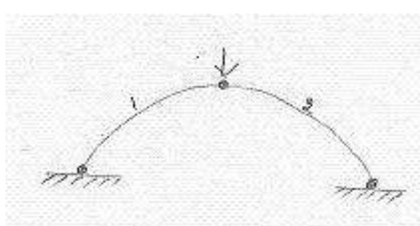

Figure 8

IV. CHOICE OF COMPONENT

Arches can be used for larger area and small material and trusses need large material and it is bulkier. For long span length there will be more vertical deflection in truss whereas the arch bridge withstand the deflection.Deflection in truss means sway. As the load is transferred from joint to joint and if load is more focused on centre and sway occurs, then structure may fail. So the truss is not for long span. Arches do not have internal stresses and it is already compressed. Arches are costly and need maintenance very frequently.

Structure Efficiency: In long-span structures, the weight of the structure itself dominates the design. Therefore component types associated with longer-span structures weigh less per foot of span and are said to be more structurally efficient.

$$structural\ efficiency = \frac{load\ supported}{weight\ of\ structure}$$

Criteria for Structure Selection: Eiffel tower is the structure that uses both arches and truss components of structure building. The original height is 324 meters as on. The scale is opted for building up this structure is 1m=0.006m.

V. MEASUREMENTS AND SCALING

At base	Original	Considered
Interior	72.24m	0.51m
Exterior	124.90m	0.71m

Table 1

The interior is considered as base only and only exterior dimensions (width) are considered at height H, H1, H2 and H3 (**Figure 9**).

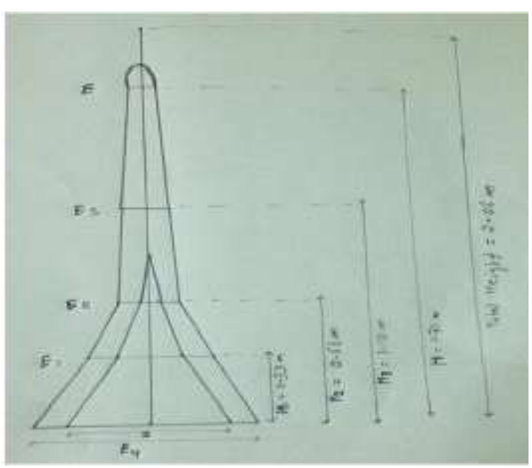

Figure 9

Height	Original	Considered
H1	57.63m	0.33m
H2	115.73m	0.66m
H3	207.56m	1.18m
H	300m	1.71m

Table 2

Exterior	Original	Considered	Height
E1	70.69m	0.4m	At height H1
E2	40.96m	0.23m	At height H2
E3	28m	0.16m	At height H3
E	18.65m	0.1m	At height H

Table 3

Material Used: 1670 Straws, cello tape, white tape, wooden sticks for base and plaster of paris for holding the base on ply board.

VI. MAKING OF STRUCTURE

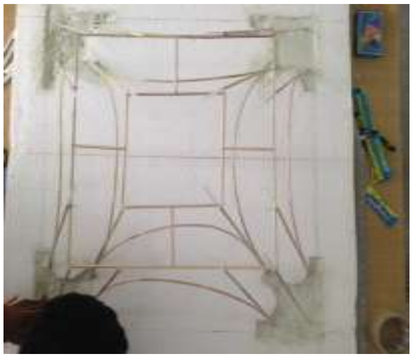

Figure 10. Top view of base foundation using plaster of paris

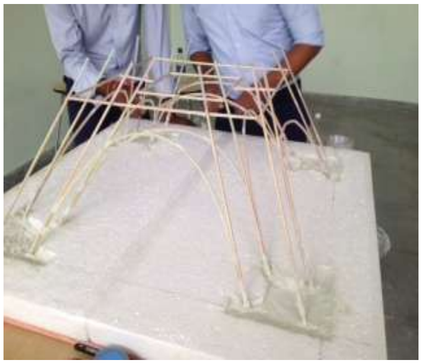

Figure 11.a. Side view of structure

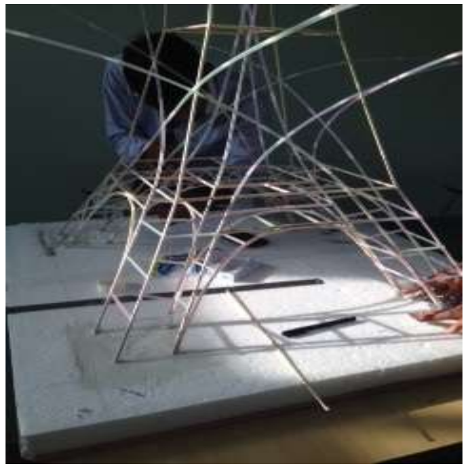

Figure 11.b. Side view of structure

Figure 12. Final view of structure

REFERENCES

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[2]http://www.steelconstruction.info/Trusses