ANALYSIS AND DESIGN OF DEPLOYABLE BRIDGE BASED ON ORIGAMI SKILL

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***Abstract*— At the time of disasters like earthquake, flood and tsunami the road and bridges are the lifelines for rescue works. If the bridges are badly damaged or any of their span has been collapsed than the instant requirement will be generated to built the bridge. This requirement can be fulfilled by mobile bridge which can be transported to the site and can fill the gap. In this research we are analyzing the deployable type mobile bridge which can be folded and transported anywhere. We designed it for single way two lanes with IRC class A loading. 10m and 15m span is taken for analysis with different stage of opening for self weight and for full live load. All analysis has been carried out on STAAD PRO software. The bridge is designed for three different materials which are titanium, steel and aluminum. Different geometric angle for X members are used to determine most effective geometry. After analysis we can conclude that the 15m span with 45 degree is the most efficient in terms of deflection and titanium alloy is the most economical material for the use.**

Index Terms—Deployable Bridge, X members, mobile type, IRC class A loading

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INTRODUCTION:-

There are many types of disasters such as Earthquakes; Floods & Tsunamis may generate on earth. The life line structures like road and bridges must survive through the disasters. Bridge and culverts may get damaged and cannot be repair and rebuilt instantly and due to this the affected area becomes isolated. So to overcome this deployable type bridge can be used. This type of bridges can be loaded on truck with different type of spans and can be transported anywhere. There are many type of geometry possible but for longer and heavy duty span the scissor type X elements are generally used. These elements also provided with different geometric angles. Analysis is carried out for span 10m and 15m. This scissor type bridge provides several advantages (1) fewer members used for construction so deployment and storage will be quick. (2) Transportation and assembling and disassembling will be easy. (3) Deployment performance will be higher because this type deploy and store by control forces. Material play an important role in any structure here we taken three materials for bridge which are aluminum titanium and steel. Here are through this research we are determining the most economical material, appropriate sizes of members and most effective angle of X members for different span by structural design. Following figure 1 and figure 2 explains about this kind of mobile bridge can be transported and erected at the any location by deploying it and after use again we can folded it.

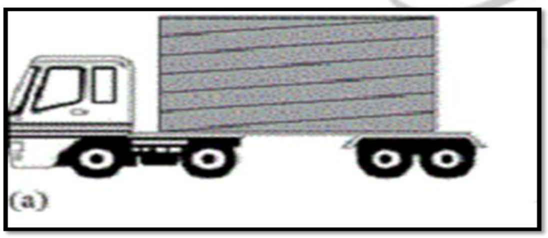

Figure 1: Shows the transporting vehicle for bridge.

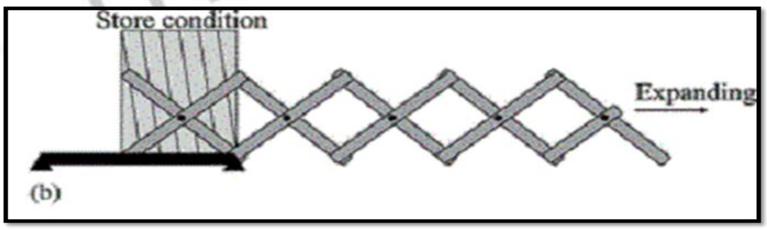

Figure 2: shows the store condition when bridge is not erected and when fully erected

PAST RESEARHCH WORK:-

[1]Rahula and Kaushik Kumarb have done research on design and optimization of portable foot bridge in 2013. In this paper the author develops the portable foot bridge using ANSYS with different types of material such as structural steel, titanium alloy and aluminum alloy with different cross section. The design is carried out for Foot Bridge only with span of 1.5mt and width of 0.5m. The loading given is of 1000kg and check for deflection was carried out for different spans. [2]Ichiro Ario , Masatoshi Nakazawa , Yoshikazu Tanaka , Izumi Tanikura and Syuichi Ono have done research on Design and Optimizat ion of Portable Foot Bridge in 2013. In this paper the author explains about beam model with the clamped supports. The concept of foldable structure of origami

skill with optimization.Model and prototype was carried out on foot bridge, use of bow mechanism to reduce the deflection. Cables are used to maintain the bow mechanism.3D-FEM analysis of model is carried and compared with the prototype.

Deflection of prototype and model was checked. [3]Authors J. Aversenga and J. F. Dubéa have worked on Design, analysis and self stress setting of a lightweight deployable tensegrity modular structure in 2012. In this paper they have shown Tensegrity systems, made of struts and cables in a self stress state, lightweight, visually transparent and deployable. They have considered a beam connected with 4 bars, 12 cables in 2 horizontal and diagonal element in upper and lower nodes for geometry h = 1.30 m, b = 80 cm, L = 12 m. setting of geometry is carried out deployment and active cable setting. The proposed solution for supporting a 12 m footbridge on a width of 1 m is a tensegrity beam weighting 440 kg. This is a linear weight of 37 kg/m. The author concluded that the system can be transported and deployed easily. [4]Author D.M. Jade and G.R. Patil had worked on light weight scissor deployable structure in 2015. They used scissor members with different span and for different angles of 30°, 45° and 60°. They used [5]STAAD PRO software for analysis and design and used Indian standard angle sections for design.

METHODOLOGY:-

Here we have performed analysis for 10m and 15m span of bridge. At the time of deployment our bridge will be in cantilever stage until it riche to other end. So analysis is also done for different deployment stage of ¼ cantilever span, ½ cantilever span, ¾ cantilever span, full cantilever span and for simply supported with [6]IRC class A loading as shown in figure 3. Than they are also design for modified geometry of 30°, 45° and 60° angles of X members. In next stage they are checked for different material properties of members made up of steel, Aluminum alloy and of titanium. Their design is performed in STAAD PRO with [7]IS 800.

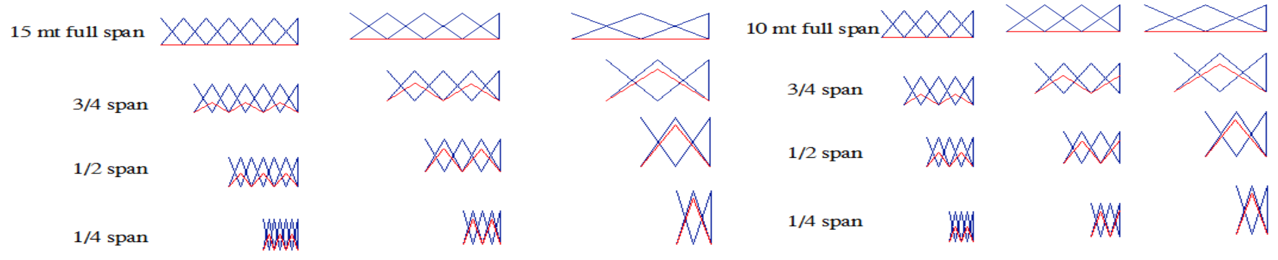

Figure 3: Different geometric angles with different stage of opening for 10m and 15m span

MODELING:-

In this research, 108 models as per above mentioned difference have been prepared in STAAD PRO. Following figure 4 shows the rendered view of model.

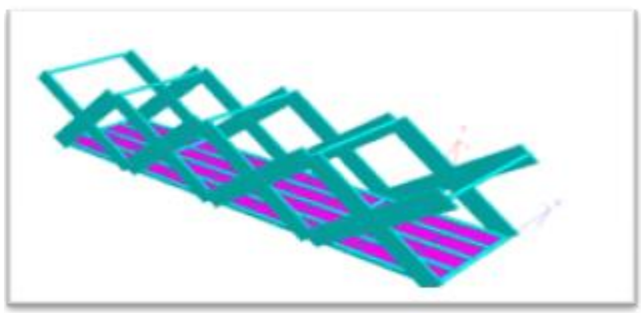

Figure 4: Rendered view of STAAD model.

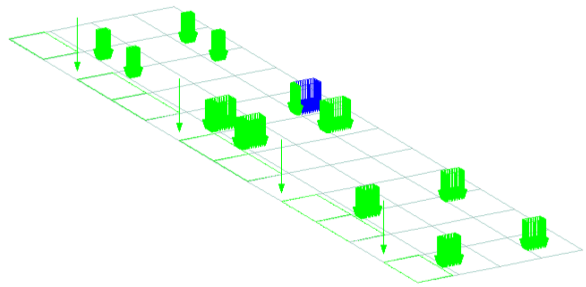

Figure 5: Deck loading as per IRC class A

Deck load as per IRC class A has been generated in software by bridge deck program. Figure 5 shows the deck loading as per IRC class A. Width of bridge is kept 3.8m and height of bridge is kept 4.1m. Steel plate of 15mm thickness is provided as deck. Under the deck the grid of rectangular hollow sections are provided to transfer the bridge deck live load to supportive pin members. These pin members are made up of solid material because they performed two task in structure, first they support deck plates and members and second they act as pin on which X members can rotate and bridge can be closed and open. These members are also provided at top for connection and bracing purpose as shown in figure 4. Two types of supports are provided in bridge, the fixe support at bottom which acts as main anchor support for bridge and above that sliding support provided which hold the upper limb of scissor X members. Following loads and load combinations have been taken as per [8]IS 875 part 5.

1. DL (dead load) includes self weight of structural members	6. 1.5(DL + IRC)
2. IRC class A X +ve (IRC live load)	7. 1.5(DL + IRC)

Following table show the member sizes and standard sections used in structure. Table 1 indicates member data of 10m span and table 2 indicates member data of 15m span.

Table 1: Member properties for 15m span

Material	Angle	Main cross member (m)	Plate thickness (m)	Square hollow section used in deck supporting grid (mm)	Circular section used (m)
Steel	30	0.85X0.09	0.015	220X220X8 38X38X4	0.15,0.21
	45	0.8X0.08	0.015	180X180X8 38X38X4	0.15,0.18
	60	0.62X0.08	0.015	220X220X5 38X38X4	0.15,0.18
Aluminum Alloy	30	0.85X0.09	0.015	220X220X8 38X38X4	0.15,0.21
	45	0.7X0.08	0.015	180X180X8 38X38X4	0.15,0.18
	60	0.62X0.08	0.015	180X180X8 38X38X4	0.15,0.18
Titanium Alloy	30	0.85X0.09	0.015	220X220X8 38X38X4	0.15,0.21
	45	0.55X0.08	0.015	180X180X8 38X38X4	0.15,0.18
	60	0.55X0.08	0.015	180X180X8 38X38X4	0.15,0.18

Table 2: Member properties for 10m span

Material	Angle	Main cross member (M)	Plate thickness (M)	Square hollow section used (mm)	Circular section used (M)
Steel	30	0.85X0.09	0.015	220X220X8 38X38X4	0.15,0.21
	45	0.6X0.08	0.015	180X180X8 38X38X4	0.15,0.18
	60	0.4X0.06	0.015	180X180X8 38X38X4	0.15,0.18
Aluminum Alloy	30	0.95X0.09	0.015	220X220X8 38X38X4	0.15,0.21
	45	0.8X0.08	0.015	180X180X8 38X38X4	0.15,0.18
	60	0.4X0.06	0.015	180X180X8 38X38X4	0.15,0.18
Titanium Alloy	30	0.80X0.08	0.015	220X220X8 38X38X4	0.15,0.21
	45	0.43X0.08	0.015	180X180X8 38X38X4	0.15,0.18
	60	0.3X0.08	0.015	150X150X8 38X38X4	0.15,0.18

RESULTS:-

In Analysis of bridge models in STAAD PRO, observations of deflection of span in different loading condition and for different degree of scissor members are tabulated below.

Table 3: 30° (10m) span deflection comparison

Span	Simply Supported (IRC)	Simply Supported	Full cantilever	¾ cantilever	½ cantilever	¼ cantilever
Steel	30.944	4.716	13.033	9.482	3.99	1.066
Aluminum Alloy	75.31	4.655	11.338	7.73	3.175	0.859
Titanium Alloy	48.519	4.695	13.859	10.825	4.58	1.213

Table 4: 45° (10m) span deflection comparison

span	Simply supported (IRC)	Simply supported	Full cantilever	¾ cantilever	½ cantilever	¼ cantilever
Steel	30.826	2.587	15.571	13.048	7.934	1.960
Aluminum Alloy	78.658	2.243	12.134	10.519	4.558	1.093
Titanium Alloy	54.775	3.249	17.160	15.727	9.258	2.294

Table 5: 60° (10m) span deflection comparison

span	Simply supported (IRC)	Simply supported	Full cantilever	¾ cantilever	½ cantilever	¼ cantilever
Steel	5.695	2.35	27.73	40.06	19.224	4.945
Aluminum Alloy	10.715	2.629	28.701	42.97	20.525	5.277
Titanium Alloy	10.983	2.848	29.184	46.23	21.94	5.636

Table 6: 30° (15m) span deflection comparison

span	Simply supported (IRC)	Simply supported	Full cantilever	¾ cantilever	½ cantilever	¼ cantilever
Steel	53.427	6.83	17.23	13.141	5.88	1.56
Aluminum Alloy	94.316	6.498	17.198	13.311	6.224	1.62
Titanium Alloy	77.931	6.602	16.829	13.032	5.835	1.832

Table 7: 45° (15m) span deflection comparison

span	Simply supported (IRC)	Simply supported	Full cantilever	¾ cantilever	½ cantilever	¼ cantilever
Steel	21.044	2.972	26.346	20.136	13.277	3.278
Aluminum Alloy	57.127	3.002	40.185	34.938	17.321	4.22
Titanium Alloy	40.779	3.913	48.154	45.7	28.22	6.81

Table 8: 60° (15m) span deflection comparison

span	Simply supported (IRC)	Simply supported	Full cantilever	¾ cantilever	½ cantilever	¼ cantilever
Steel	15.481	2.49	33.175	78.141	53.751	6.151
Aluminum Alloy	42.129	2.837	44.032	95.93	69.341	7.433
Titanium Alloy	28.071	3.05	46.217	96.56	75.853	8.661

Table 9: (15m) span total quantity consumption

Material	Angle	Quantity of material consumed
Steel	30°	(6.77m^3) 53198Kg
	45°	(7.81m^3) 61340Kg
	60°	(8.05m^3) 63269Kg
Aluminum Alloy	30°	(6.78m^3) 18045Kg
	45°	(7.07m^3) 18817Kg
	60°	(7.86m^3) 20912Kg
Titanium Alloy	30°	(6.77m^3) 53198Kg
	45°	(5.96m^3) 26398Kg
	60°	(7.29m^3) 28200Kg

Table 10: (10m) span total quantity consumption

Material	Angle	Quantity of material consumed
Steel	30°	(5.40m^3) 42446Kg
	45°	(4.28m^3) 33640Kg
	60°	(3.39m^3) 26642Kg
Aluminum Alloy	30°	(5.87m^3) 15620Kg
	45°	(5.34m^3) 14218Kg
	60°	(3.22m^3) 8568Kg
Titanium Alloy	30°	(4.76m^3) 21073Kg
	45°	(3.015m^3) 13347 Kg
	60°	(3.04m^3) 13475Kg

CONCLUSSION:-

We concluded following points from above mentioned results

1) From the above mentioned results in table 9 and in table 10, titanium alloy among those three materials is the least consume material because it shows properties of high strength & light weight for 45° angle in 10m as well as in 15m span.
2) As the angle of scissor member increases, the dead weight of structure is also increased. Due to this the self weight of structure will also increase which results in higher deflection. We can observe this conclusion in above tables.
3) For simply supported span with IRC loading, as the angle of scissor member increases the amount of deflection will reduce.
4) By observing member sizes from table 1 and 2 we can conclude that as the member angle decreases the sizes of members are also reduced.

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[7] IS 800 : 2007 Code of practice for structural steel design published by Bureau of India Standards

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