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ANALYSIS OF LIGHT WEIGHT SCISSOR DEPLOYABLE STRUCTURES WITH DIFFERENT SPAN AND ANGLE OF SCISSOR-LIKE-ELEMENTS

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Abstract: Light weight Scissor Deployable Structure is a mechanism that is expanded from enclosing a small area or volume to enclose a large area or volume. The scissor deployable structure consists of two girdle beams having width 0.50 m and height are maintained by Scissor- Like-Elements flats size 100mm X 20 mm with angle 30°, 45° and 60°. The Scissor- Like-Elements flats and 4 Indian Standard Angle 100 mm X 75 mm X 10 mm is connected with High Tensile Friction Grip (HTFG) bolts to frame light weight Scissor Deployable Structure. The girdle beam cross Scissor- Like-Elements connected with ISRO 25. The light weight scissor deployable structure (bridge) is analyzed using STAAD.Pro V8i. In light weight scissor deployable structures 3 dimensional model of Scissor Bridge is developed that carries the moving load, that moving load is uniformly distributed over a bridge width 2.80 m, Span 7.0 m and 8.0 m. The analysis is carried out solely based on the static load expected. The result shows that Span 7.0 m and 8.0m Carries maximum load 42 KN and 35 KN respectively with angle of Scissor- Like-Elements 30° and optimum number of Scissor- Like-Elements are 16.

Keywords: Deployable Structures, Girdle Beam Element, Scissor- Like- Element (SLE), Flats Scissor- Like-Elements and Structural Optimization.

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INTRODUCTION

Deployable structures have their members connected in the factory, so that they satisfy a set of pre-assigned geometrical constraints. Erection is then operated by simply articulating the various components of the structure. Other advantages are the ease of transportation and storage, the minimum skill requirements for erection, dismantling and relocation, and the competitive overall cost. Bridge for use after earthquake and other emergency situations, temporary protective covers in remote construction sites or for curing of concrete in cold environments, domes for sport facilities, exhibition structures or shelters for travelling theatres. Deployable structures are of even greater interest in the aerospace industry, where severe constraints apply to both payload capacity of space ships and to building time in space.

Two types of deployable structures have been designed and constructed in the past.

(i) Structures that is stress-free in the folded configuration, during deployment, and in the deployed configuration. Need to be stabilized by external locking devices An innovative geometric design methodology allows for structures that exhibit a stable and stress-free state in both the initial and the final configuration. However, geometric compatibility requirements cause the development of strains and stresses during the deployment procedure. The structural behavior of the structures during that phase is highly nonlinear; hence the analysis presents difficulties for the structural engineer.

(ii) Second order theory structural analysis of frames with analytical methods. However, an analytical approach is already too complicated for plane structures with simple geometry and few degrees of freedom, and it is practically impossible to use it for these deployable space structures with their non-regular geometric configuration.

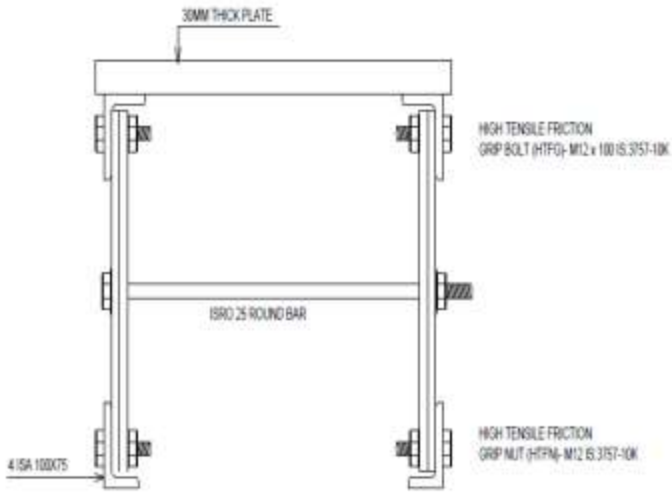

Figure 1: Transitional Scissor Hinge Structures.

RESPONSE OF DEPLOYABLE SCISSOR BRIDGE STRUCTURES DURING DEPLOYMENT STAGE

The structural behaviour of deployable structures during deployment is of great interest due to its highly nonlinear nature. Therefore, both a qualitative understanding of the behavior and a quantitative evaluation of stresses occurring during deployment constitute an integral part of the design of deployable structures. The nature of the strains and stresses develop in the members of the structure during deployment defines the type of kinematic assumptions that have to be made for this problem. These strains and stresses result from compatibility requirements between the members of inner and outer SLEs. Furthermore, a small deformation has to take place before the structure can carry loads. The deployed configuration was used as initial state for the analysis, i.e. dismantling was simulated instead of deployment.

Nonlinear beam elements i.e. Girdle Beam have been used to model inner SLEs, while outer SLEs that are only subjected to axial stresses were represented by truss elements. After introducing auxiliary coordinate systems, the master node/slave node technique was used to model the pivotal connections.

PARAMETERS AFFECTING THE STRUCTURAL BEHAVIOR DURING DEPLOYAMENT STAGE

The behavior of deployable structures during the deployment procedure. The next point of interest for the analyst, and especially for the designer is to obtain information about how several parameters affect the response of scissor bridge. Optimize the design process by taking full advantage of the features of deployable structures and by minimizing their limitations.

Parameters investigated here are the geometry of the Girdle Beam structure, the cross section of inner and outer SLEs, Properties of Angle section used in Girdle beam (ISA), Plate size and thickness, angle of SLE, and the length to stiffness ratio of the members.

Choosing a large cross-section of Angle section and Flats SLE in order to be on the safe side when loading the structure in the deployed configuration increases the stiffness of the structure and therefore the stresses that develop during deployment.

RESULT AND DISCUSSION

In deployable structures, Two Girdle Beam is spacing at 2.80 m c/c and Scissor Bridge having span 6.0 m, 7.0 m and 8.0 m over the Girdle beam a 30 mm thick plate are attached to a Beam element having 10 nodes for Finite Element Analysis. The overall Plate size is 6.0 m X 3.0 m X 30 mm, 7.0 m X 3.0 m X 30 mm and 8.0 m X 3.0 m X 30 mm.

TABLE NO. 1: PERMISSIBLE DEFLECTION OF SCISSOR BRIDGE 7.0 M SPAN

ISA	ANGLE	Number of SLE units (n)	Depth of Girdle Beam (T)	Safe Load (W)	Ixx (M^3)	Iyy (M^3)	Self Weight of Girdle Beam (Kg)	Stress (σ_{max}) N/mm^2	Permissible Deflection (δ_{max}) mm
100 X 75	30°	10	43.416	21	4.388264	343.2619	612.9607	7.15098	0.841
	30°	12	36.680	27	2.614059	238.377	612.9607	11.12714	1.548
	30°	14	31.868	34	1.688534	175.1347	612.9607	16.92056	2.710
	30°	16	28.260	42	1.156733	134.088	612.9607	25.12115	4.537
100 X 75	45°	10	73.010	13	7.825436	515.0171	668.9505	5.647714	0.395
	45°	12	61.342	17	4.652358	357.6514	668.9505	7.895014	0.657
	45°	14	53.007	23	3.001592	262.7649	668.9505	11.26244	1.084
	45°	16	46.757	26	2.055103	201.1799	668.9505	14.75001	1.610
100 X 75	60°	10	124.240	8	21.14745	1029.721	795.2	4.60337	0.189
	60°	12	104.033	10	12.5191	715.0846	795.2	5.839243	0.286
	60°	14	89.600	12	8.051182	525.3689	795.2	7.24816	0.413
	60°	16	78.775	14	5.499692	402.2361	795.2	8.859254	0.574

The Scissor are developed with 4 ISA-100 X 75 X 10 mm and Scissor-Like-Element of Flat 100 mm X 20 mm and Length of Flat SLE depends on angle of SLE units i.e. 30° , 45° and 60° are connected using HTFG Bolts. The Light weight Scissor deployable Bridge are Analyzed using STAAD.Pro V8i the optimization are carry out for design of deployable bridges.

TABLE NO. 2: PERMISSIBLE DEFLECTION OF SCISSOR BRIDGE 8.0 M SPAN

ISA	ANGLE	Number of SLE units (n)	Depth of Girdle Beam (T)	Safe Load (W)	Ixx (M^4)	Iyy (M^4)	Self Weight of Girdle Beam (Kg)	Stress (σ_{max}) N/mm^2	Permissible Deflection (δ_{max}) mm
100 X 75	30°	10	83.831	18	4.384	343.26	664.97	11.24	0.894
	30°	12	70.360	22	2.619	238.37	664.97	15.39	1.459
	30°	14	60.737	28	1.684	175.13	664.97	21.30	2.338
	30°	16	53.520	35	1.133	134.08	664.97	29.33	3.654
100 X 75	45°	10	102.010	11	7.826	515.01	720.95	8.34	0.545
	45°	12	85.508	21	4.658	357.65	720.95	12.126	0.945
	45°	14	73.721	17	3.0012	262.79	720.95	13.988	1.263
	45°	16	64.881	23	2.053	201.17	720.95	18.591	1.906
100 X 75	60°	10	143.00	7	21.145	1029.72	847.2	6.145	0.289
	60°	12	119.67	8	12.511	715.08	847.2	7.655	0.426
	60°	14	103.000	10	8.0512	525.39	847.2	9.343	0.604
	60°	16	90.500	14	5.492	402.26	847.2	11.523	0.849

TABLE NO. 3: PERCENTAGE INCREASE IN DEFLECTION OF DIFFERENT INDIAN STANDARD ANGLE SECTION

ANGLE OF FLAT SLE	ISA (mm X mm)	Span of Scissor Bridge	
		% increase in deflection 7.0 m	% increase in deflection 8.0 m
30°	100 X 75	10.43	11.092
45°	100 X 75	40.918	49.893
60°	100 X 75	46.053	56.206

TABLE NO. 4: MAXIMUM SAFE LOAD 7.0 M SPAN ISA 100 X 75

ANGLE OF SLE	Number of SLE units (n)	MAXIMUM DEFLECATION mm	MAXIMUM AXIAL FORCES Fx kN	SAFE LOAD	Depth of whole System T=2t= 2a sinθ	% INCREASE IN DEFLECTION
30	10	0.541	34.43	21 KN	40.416	0.000
30	12	0.604	42.754	27 KN	33.680	10.430
30	14	0.649	51.416	34 KN	28.868	6.934
30	16	0.706	58.78	42 KN	25.260	8.074
45	10	0.501	22.513	13 KN	70.010	-40.918
45	12	0.585	29.08	17 KN	58.342	14.359
45	14	0.658	36.257	23 KN	50.007	11.094
45	16	0.666	41.075	26 KN	43.757	1.201
60	10	0.456	17.328	8 KN	121.240	-46.053
60	12	0.531	19.271	10 KN	101.033	14.124
60	14	0.543	23.396	12 KN	86.600	2.210
60	16	0.56	27.544	14 KN	75.775	3.036

TABLE NO. 5: MAXIMUM SAFE LOAD 8.0 M SPAN ISA 100 X 75

ANGLE OF SLE	Number of SLE units (n)	MAXIMUM DEFLECATION mm	MAXIMUM AXIAL FORCES Fx kN	SAFE LOAD	Depth of whole System T=2t= 2a sinθ	% INCREASE IN DEFLECTION
30	10	0.505	38.709	18 KN	46.189	0.000
30	12	0.568	49.704	22 KN	38.491	11.092
30	14	0.616	59.525	28 KN	32.992	7.792
30	16	0.679	68.681	35 KN	28.868	9.278
45	10	0.469	25.968	11 KN	80.012	-44.776
45	12	0.936	32.597	21 KN	66.677	49.893
45	14	0.574	40.418	17 KN	57.151	-63.066
45	16	0.667	47.5	23 KN	50.007	13.943
60	10	0.427	19.538	7 KN	138.560	-56.206
60	12	0.486	21.949	8 KN	115.467	12.140
60	14	0.513	26.716	10 KN	98.971	5.263
60	16	0.615	31.75	14 KN	86.600	16.585

CONCLUSION

As angle of Flat SLE increases from 30°, 45° and 60° the safe load carrying capacity decreases. In optimization of scissor deployable structures Maximum Nos. of SLE that result into maximum deflection. Optimize the structures with optimum Nos. of Flat SLE and minimum angle of SLE so that structures have minimum deflection and maximum load carrying capacity. Angle of Flat SLE 30° for span 6.0 m percentage increase in deflection up to 66% where as the span increases from 7.0 m to 9.0 m the percentage deflection within range from 16.2% to 13.6%. for angle of SLE as 45° the deflection is 15.4% and increases up to 56.2%. When compare Angle of Flat SLE 60° with 30° and 45° the percentage increase in deflection for span 6.0 m to 9.0 m are constant in range of 49.4% to 52.2%

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