JES Journal of Engineering Sciences

Vol 11, Issue 7, July/2020
ISSN NO:0377-9254

EXPERIMENTAL ANALYSIS OF COMPLETED STATE AND CONSTRUCTION STAGE OF SUSPENSION BRIDGE BY MIDAS CIVIL

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Abstract:
Suspension bridges are categorized as long span structures. It comprises longitudinal deck (main griders) supported by hangers suspended from cables. The cables are connected to anchors at each end. In order to study the effects of various loads and load combination the bridges are modelled as two-dimensional analytical models but for more detailed analysis 3D modelling is required. The proposed suspension bridge analysis is classified into construction stage and also completed state inspection and analysed with Modelling, Integrated Design and Analysing Software (MIDAS) The completed state analysis is performed to check the behaviour of the completed bridge. At this stage, the structure is in balance under self-weight, and the deflection due to the self-weight has already occurred. The self-weight loading in the initial equilibrium state will also be added to the total loading for the completed state analysis. Suspension bridges exhibit significant non-linear behaviour during the construction stages. But it can be assumed that the bridge behaves linearly for additional loads in the completed state analysis. This linearized analytical procedure to convert section forces to geometrics stiffness is referred to as the linearized finite displacement method. This procedure is adopted because a solution can be found with relative ease within acceptable error limits in the completed state analysis. Construction stage analysis is performed to check the structural stability and.The effect of large displacements cannot be ignored during the construction stage analysis .The construction stage analysis is performed in a backward sequence from the state equilibrium as defined by the initial equilibrium state analysis

Key words: construction stage analysis, Software (MIDAS), Suspension bridge

1.0 INTRODUCTION

Suspension bridges catch all people's creativity. We look like ethereal giants stretching over opposite shore with their massive towers, sleek cords and vast distances. They are often short who stocky, who tend to defend and expand their territory. At other times, they are so long and slim they appear delicate and quick to pass. Regardless of their external appearance, people respond to them and recall how they feel at first. Suspension bridges are ideal for longer spans, and thus this is the main use for such construction, as cables are constructed using high strength steels loaded under direct tension as the main load carrying components. Today, the suspension bridge is more suitable for very long-span bridges and in turn represents 20 or so bridges across the world's longest length. Cables, vehicles with a frame on the roof, or a rising of the rocker, towers and anchorages form a suspension bridge. The function of a suspension bridge is that, by hanging the suspenders and transfer the load by direct force of tension to the supporting tower, the parabolized main cabling suspended from the tops of the two towers supports the transport deck that exists on the stifling girder.

Suspension bridges:

A bridge is concrete structures, which are intended to cross over a physical obstruction without blocking the path down, such as a water body, valley or road. The first bridges manufactured were probably layers of cut wooden logs and finally stones, and were arranged with a simple support and cross-section.

Roman Bridges:

Ancient Romans construct Roman bridges. They are the first major and robust bridges. A stone designed Roman bridges and the arch as a fundamental structure. The most widely used concrete was probably the first to be used for bridges by the Romans. The Roman brides are characterized by the following characteristics:

- Many have a width of over 5 meters.
- Gently sloping for most of them.
- There's a lot of work rustic.

Damage due to inertia loads on bridges

The Avenue Over bridge in the Moor house was one of the few bridges in Christchurch that were seriously weakened in construction by seismic instability. The bridge was constructed in 1964 to have a considerably lower lateral load than existing standard seismic designs deemed required. The 11 stretch piers and abutments have incorporated ports. Bodies 4 and 7 are semi-boats with an extension joint down the middle of the bridge into three different integrational systems. At Pier 4 there are connection bars across the joint, but at Pier 7 there are none.

Figure: Damage to western half-pier column at pier 7

2.0 LITERATURE REVIEW

Suspension bridges are the most desirable and important structures with a variety of technological, economical and esthetic benefits. The basic drawback in suspension bridges can be perceived to be improved deformability. Thanks to their comparatively thin and lightweight suspension bridges, both are vulnerable to traffic loads and wind. There have been structural problems in the past for such suspension bridges.

S. Ponnuswamy [1] A suspension bridge is essentially a lightweight structure and additional stiffening steps have to be built into the design of most situations. Rigidity is accomplished by the ramping of the bridge over highway or highway bridges using diagonal or zigzag suspenders or hybrid systems.

Ni Ni Moe Kyaw [2] There is absolutely no stiffening rod in this bridge and any load is shifted to the main wiring. The iconic Londoner Tower Bridge also reveals the possibility of locking up the central cables on two stout chains, united by powerful bonds, there are two external spans.

N. Krishna Raju [3] The research is intended to satisfy the knowledge of the suspension bridge anchorage system and to be able to investigate the reactions at an extreme wind level. Suspension bridges around the world are widely constructed and used. The most realistic type

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ISSN NO:0377-9254

of bridge is one which can be used for an extensive time when topography forbids or where traffic becomes unsafe in order to install temporary or permanent central supports.

3.0 MODELLING OF BRIDGE

The beam designs are primarily highway bridges. These may be single or several lengths, short distances or lengthy distances. Suspension bridges may be listed as structures over a prolonged period of time. Suspension bridges consist of a length deck (main girders) supported by cable hangers. Each end of the cables is anchored. Bridges are designed as two-dimensional structural models to test the effects of various loads and load configurations, but 3D modeling is required for comprehensive research and measurement The proposed bridge is developed and evaluated and constructed with the assistance of the Government of India Bridge Regulations, Modeling, Applied Design and Analysis Tools (MIDAS). As general, linear responses, moving load answers and other design considerations, the study on structural answers to bridges is essential. The design of a suspension bridge is broken down into a finished state study and review of the construction process.

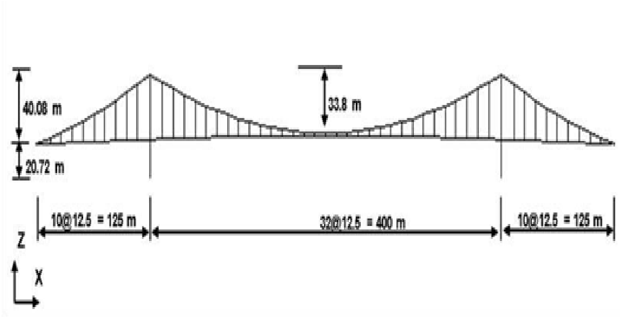

Figure: Bridge model

Model Using Midas Software:

Midas Civil is state-of-the-art architecture technology, which sets a new standard for construction or civil structures. It features a highly user-friendly interface and a perfect architecture approach for construction processes or time-sensitive properties. The technologically sophisticated simulation and analysis method helps engineers to face specific problems and inefficiencies in the scientific field of finite elements.

Material Properties

- Input material properties for cable, hanger, deck (main girder) and pylon.
- Properties/ Material
- Name>Cable
- Type>User Defined
- Modulus of Elasticity (2.0e+7)
- Weight Density (8.267)

Table I. Material Properties

Classification	**Cable**	**Hanger**	**Deck**	**Pylon**
Type	User defined	User defined	User defined	User defined
Modulus of Elasticity	2.0×10^7	1.4×10^7	2.1×10^7	2.1×10^7
Poisson's Ratio	0.3	0.3	0.3	0.3
Weight Density	8.267	7.85	0.00	7.85

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ISSN NO:0377-9254

For section properties, note that D=0.23m is used for graphical representation only, and the numerical properties in Section Properties (ie, A=0.04178) are used for analysis.

Initial Equilibrium State Analysis

In the completed state analysis of the suspension bridge, the deflections due to self-weight have already occurred, and the structure has come to an equilibrium state. Using the Suspension Bridge Wizard function, the coordinates of the cables and the initial tension forces within the cables and hangers and the forces in the pylons can be calculated automatically. The initial equilibrium state is determined by inputting the basic dimensions of cable sag, hanger spacing and the self-weight applied to each hanger.

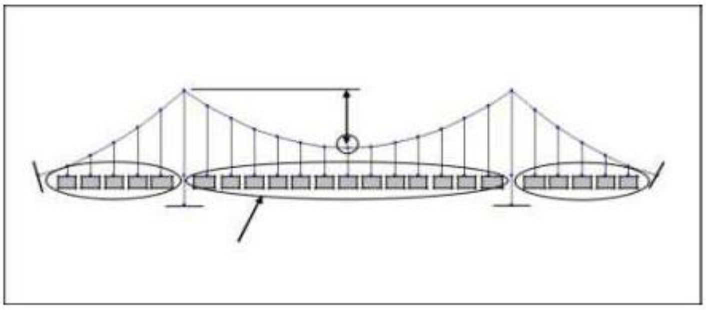

Figure: 2-dimensional basic shape for suspension bridge

To obtain the initial tension forces and basic shape, input appropriate data into Suspension Bridge Wizard. The program automatically calculates the self-weight of the cables. Only the self-weight of the Deck needs to be entered. As explained earlier, the geometric shape of the suspension bridge, especially the cable coordinates cannot be arbitrarily determined by the designer

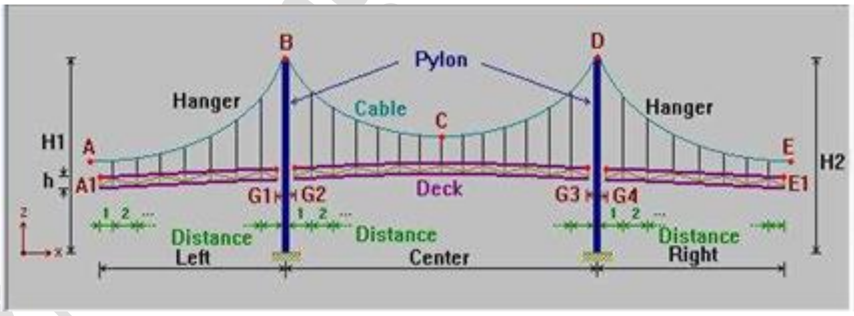

Figure: Suspension Bridge Wizard Input Window

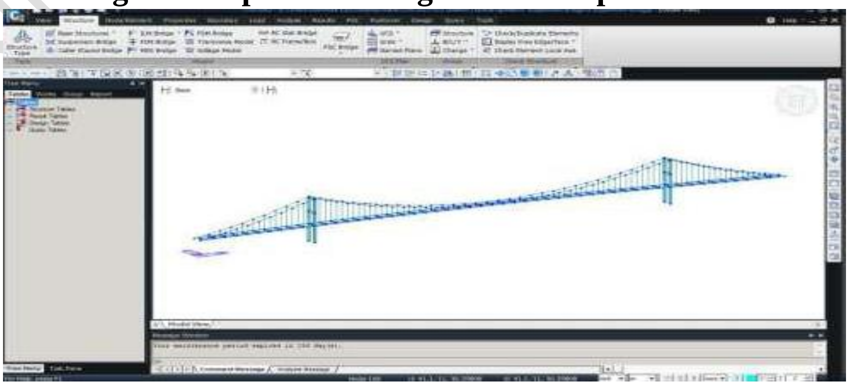

Figure: Initial equilibrium state analysis using Suspension Bridge Wizard

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ISSN NO:0377-9254

the 3D shape generated by the Suspension Bridge Wizard function. The main cables and hangers are generated as cable elements, and the deck and pylons are generated as beam elements

4.0 RESULTS

In the formulation of geometric steadiness in completed linear analysis of structure, initial factor forces are considered. When large scale analysis is carried out, these results are overlooked.

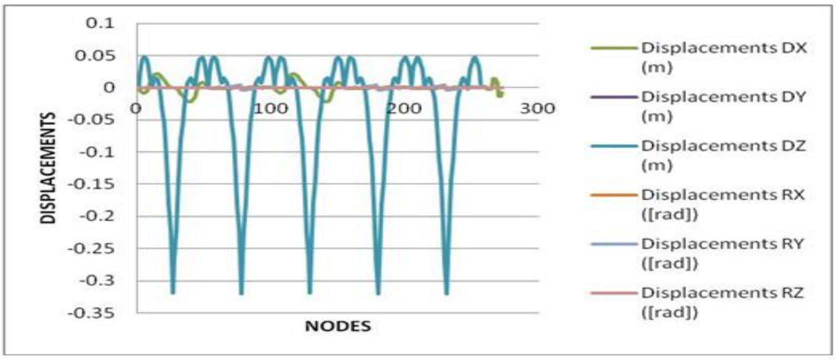
Table: Initial forces

Model View / Initial Element Force

Type	Elem	Axial-i (tonf)	Shear(y)-i (tonf)	Shear(z)-i (tonf)	Torsion-i (tonf*m)	Moment(y)-i	Moment(z)-i	Axial-j (tonf)	Shear(y)-j (tonf)	Shear(z)-j	Torsion-j (tonf*m)	Moment(y)-j (tonf*m)	Moment(z)-j (tonf*m)
Beam	203	-1.1845e	-2.0409e-	-2.6469e+0	-6.0611e-0	-8.6872e-0	-4.7380e-00	2.5370e-00	-2.0409e-	2.6469e+	-6.0611e-0	8.6588e-011	-2.1859e-006
Beam	204	-1.1563e	-2.0415e-	-2.6469e+0	-5.0406e-0	-0.0000e+	-2.2145e-00	2.2551e-00	-2.0415e-	2.6469e+	-5.0406e-0	1.5993e-007	3.3817e-007
Beam	205	-1.1281e	-2.0429e-	-2.6469e+0	-4.0612e-0	-0.0000e+	3.1001e-00	1.9732e-00	-2.0429e-	2.6469e+	-4.0612e-0	1.5977e-007	2.8645e-006
Beam	206	-1.0999e	-2.0409e-	-2.6469e+0	-3.1026e-0	-0.0000e+	2.8393e-00	1.6914e-00	-2.0409e-	2.6469e+	-3.1026e-0	1.6014e-007	5.3911e-006
Beam	207	-1.0716e	-2.0401e-	-2.6469e+0	-2.1338e-0	-0.0000e+	5.3677e-00	1.4095e-00	-2.0401e-	2.6469e+	-2.1338e-0	1.5976e-007	7.9185e-006
Beam	208	-1.0434e	-2.0426e-	-2.6469e+0	-1.1557e-0	-0.0000e+	7.8949e-00	1.1276e-00	-2.0426e-	2.6469e+	-1.1557e-0	1.5989e-007	1.0449e-005
Beam	209	-1.0152e	-2.0383e-	-2.6469e+0	-1.8643e-0	-0.0000e+	1.0428e-00	8.4571e-00	-2.0383e-	2.6469e+	-1.8643e-0	1.5994e-007	1.2977e-005
Beam	210	-9.8702e	-2.0454e-	-2.6469e+0	7.6556e-0	-0.0000e+	1.2957e-00	5.6381e-00	-2.0454e-	2.6469e+	7.6556e-0	1.5999e-007	1.5514e-005
Beam	211	-9.5881e	-2.0363e-	-2.6469e+0	1.6525e-0	-0.0000e+	1.5498e-00	2.8191e-00	-2.0363e-	2.6469e+	1.6525e-0	1.5982e-007	1.8044e-005
Beam	212	-9.3060e	-2.0439e-	-2.6469e+0	2.2228e-0	-0.0000e+	1.8037e-00	0.0000e+00	-2.0439e-	2.6469e+	2.2228e-0	0.0000e+000	2.0592e-005
Beam	213	-0.0000e	-9.1018e-	-2.6469e+0	-1.9544e-0	-0.0000e+	-3.4039e-00	8.7420e-00	-9.1019e-	2.6469e+	-1.9544e-0	0.0000e+000	-3.2901e-006
Beam	214	2.8193e-	-9.3610e-	-2.6469e+0	-1.8689e-0	1.5998e-0	-3.3248e-00	8.4599e-00	-9.3610e-	2.6469e+	-1.8689e-0	0.0000e+000	-3.2077e-006
Beam	215	5.6386e-	-8.9260e-	-2.6469e+0	-1.7477e-0	1.5984e-0	-3.2450e-00	8.1778e-00	-8.9260e-	2.6469e+	-1.7477e-0	0.0000e+000	-3.1334e-006
Beam	216	8.4579e-	-9.0467e-	-2.6469e+0	-1.6193e-0	1.5993e-0	-3.1675e-00	7.8958e-00	-9.0467e-	2.6469e+	-1.6193e-0	0.0000e+000	-3.0544e-006
Beam	217	1.1277e-	-9.0938e-	-2.6469e+0	-1.4896e-0	1.5988e-0	-3.0879e-00	7.6137e-00	-9.0938e-	2.6469e+	-1.4896e-0	0.0000e+000	-2.9742e-006
Beam	218	1.4097e-	-8.9905e-	-2.6469e+0	-1.3598e-0	1.6006e-0	-3.0061e-00	7.3316e-00	-8.9905e-	2.6469e+	-1.3598e-0	0.0000e+000	-2.8937e-006
Beam	219	1.6916e-	-8.8680e-	-2.6469e+0	-1.2304e-0	1.5984e-0	-2.9235e-00	7.0496e-00	-8.8680e-	2.6469e+	-1.2304e-0	0.0000e+000	-2.8127e-006
Beam	220	1.9735e-	-8.5289e-	-2.6469e+0	-1.1015e-0	1.5996e-0	-2.8398e-00	6.7675e-00	-8.5289e-	2.6469e+	-1.1015e-0	0.0000e+000	-2.7332e-006
Beam	221	2.2565e-	-8.2719e-	-2.6469e+0	-9.7211e-0	1.5997e-0	-2.7571e-00	6.4855e-00	-8.2719e-	2.6469e+	-9.7211e-0	0.0000e+000	-2.6537e-006
Beam	222	2.5374e-	-7.9466e-	-2.6469e+0	-8.4284e-0	1.6005e-0	-2.6759e-00	6.2034e-00	-7.9466e-	2.6469e+	-8.4284e-0	0.0000e+000	-2.5765e-006
Beam	223	2.8194e-	-7.8773e-	-2.6469e+0	-7.1322e-0	1.5988e-0	-2.5980e-00	5.9213e-00	-7.8773e-	2.6469e+	-7.1322e-0	0.0000e+000	-2.4996e-006
Beam	224	3.1013e-	-6.6349e-	-2.6469e+0	-5.8396e-0	1.6002e-0	-2.5170e-00	5.6393e-00	-6.6349e-	2.6469e+	-5.8396e-0	0.0000e+000	-2.4341e-006
Beam	225	3.3832e-	-5.7931e-	-2.6469e+0	-4.5433e-0	1.5998e-0	-2.4442e-00	5.3672e-00	-5.7931e-	2.6469e+	-4.5433e-0	0.0000e+000	-2.3718e-006
Beam	226	3.6651e-	-4.8737e-	-2.6469e+0	-3.2481e-0	1.5974e-0	-2.3795e-00	5.0751e-00	-4.8737e-	2.6469e+	-3.2481e-0	0.0000e+000	-2.3186e-006
Beam	227	3.9470e-	9.1159e-0	-2.6469e+0	-2.1508e-0	1.6004e-0	-2.2685e-00	4.7930e-00	9.1159e-0	2.6469e+	-2.1508e-0	0.0000e+000	-2.3825e-006
Beam	228	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Static Analysis Results:

- Result / deformations/ deformed shape
- Load Cases / Combinations >ST: LC1
- Components>DXYZ
- Type of Display>Un deformed (on) ; Legend (on)
- Review deformed shapes for load cases 2 & 3 using the same procedure. Review displacements in a tabular format at the loading locations. Results /Result Tables / Displacements
- Records Activation Dialog>Node or Element>210,223,231 Load case /Combination> LC1, LC2, LC3 (on)



Graph: Displacements due to load case

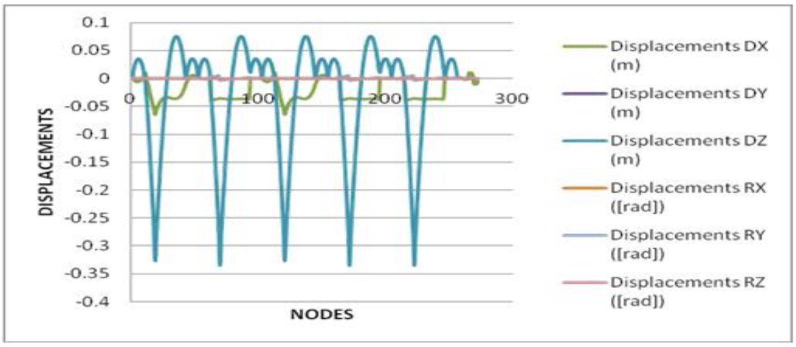
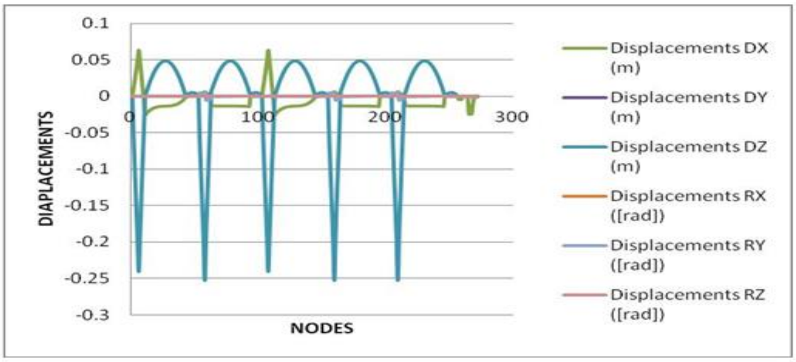


Figure: Displacements due to load case 2



Graph: Displacements due to load case 3

Review bending moments

Review bending moments in the deck.
Results / forces/beam diagrams
Load Cases/Combinations>ST: LC1 ; Components>My
Display Options>5 Points ; Line Fill
Type of Display>Contour (on) ; Legend (on)

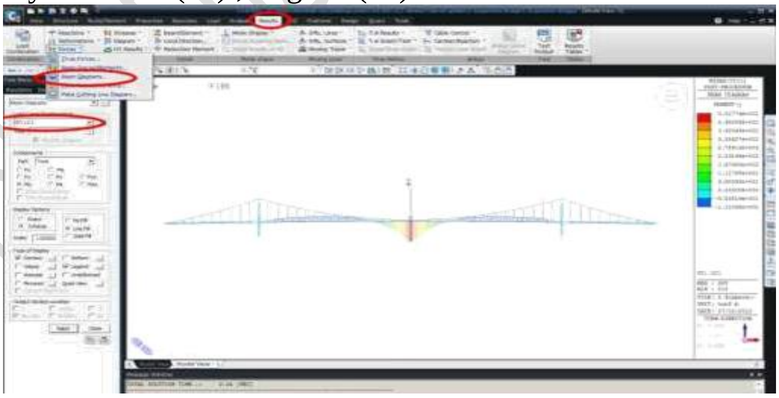


Figure: Bending moment diagram for Deck (LC1)

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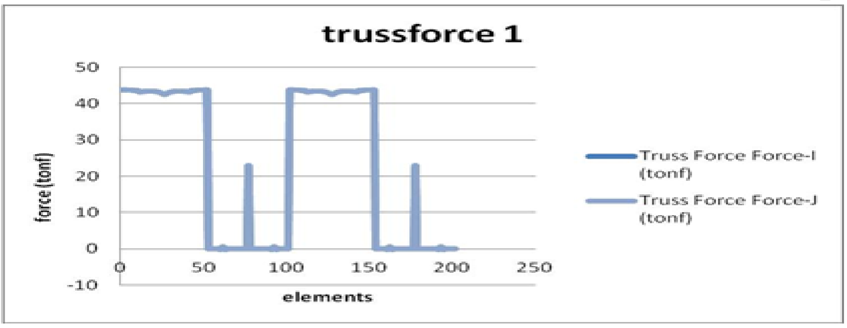
ISSN NO:0377-9254

Figure: Max tension forces in the cables (LC1)



Graph: Truss force1

Graph: Truss force2

Graph: Truss force3

The above output of axial forces shows the additional axial force in the cables. At the initial equilibrium state, tension forces due to the self-weight have already occurred. Therefore, the total member forces in the cables and hangers then become the summation of the above axial forces and the Initial Force for Geometric Stiffness introduced during pre-processing

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Construction Stage Analysis:

Stage / step graph history is for center span sag. For each construction stage there is a function value which is reduced to 0 in last stage. The following are the function values for the each construction stages from the stage/ step history graph.

Stage	Function value
C_S 7	5
C_S 6	-1
C_S 5	-1.5
C_S 4	-0.98
C_S 3	-0.9
C_S 2	-0.02
C_S 1	0
C_S 0	0

CONCLUSION:

- Initial element forces in formulation of geometric rigidity in a complete linear state analysis are taken into account. This data is ignored if large displacement analysis is carried out, only small displacement analysis are carried out. Coming to results of completed state analysis which is also known as static analysis results. The displacements and member forces for the three static load cases i.e., LC1, LC2, LC3.
- The displacements in three static load cases Dy (m), Rx (rad), Rz (rad) are zero. When in load case 1 displacements are Dx (m) maximum 0.0021 and minimum -0.0021, Dz (m) maximum 0.04 and minimum -0.021, Ry (rad) maximum 0.004 and minimum -0.004.
- When in load case 2 displacements are Dx (m) maximum 0.010 and minimum -0.06, Dz (m) maximum 0.072 and minimum -0.335, Ry (rad) maximum 0.004 and minimum -0.004.
- When in load case 3 displacements are Dx (m) maximum 0.062 and minimum -0.024, Dz (m) maximum 0.046 and minimum -0.253, Ry (rad) maximum 0.004 and minimum -0.004.
- Axial forces in the main cables are force i and force j where force i = force j; Truss force of LC1 maximum is 43.869 and minimum is -0.0005 in tonf. Truss force of LC2 maximum is 32.010 and minimum is -0.0007 in tonf. Truss force of LC3 maximum is 23.008 and minimum is -0.00001 in tonf.

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