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Behavior Of Concrete Helicoid Stair Under Mixed Loadings And Restrained Boundary Condition

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ABSTRACT

*The paper presents an analysis of helicoid stairs with different loadings with boundary restrained conditions. The helicoids stair was analyzed by Finite Element Method with a 90-degree helix angle, six curved elements,11 nodal points having a maximum of 72 degrees of freedom. The helicoid structure was discretized for 150 mm slab thickness with four different types of loadings as Gravity load,*uniformly distributed load over an entire span length,* uniformly distributed load over an entire bottom half length * uniformly distributed load over an Entire top half-length. An isoparametric curved beam element used in the analysis is capable of modeling the curvature not only in the plan but also in elevation and producing the stress distribution along the centerline of curved length. All displacements in U, V, and W directions were .shown graphically along with the global directions. All shear stress resultants as Fx, Fxy, and Fxz were represented graphically. Inplane moments as Mxy, Mxz, and TOR were also shown graphically. All the salient values were also shown in a tabular form.*

KEYWORDS: *Degree Of Freedom, Helicoid stair, Helix Angle, Isoparametric Element, Semi loof Beam*

INTRODUCTION

Structural members are designed not only for safety but also for the economy. These two aspects can only be gained through exact parameters like stress distribution, inplane moments, and displacements. are predicted for different loading patterns, and typical boundary restrained conditions. For simple determinate structures, the stress distribution can be found by well known analytical methods, but an analysis of curved structures with different boundary conditions and loading patterns creates complications due to the interaction of in-plane and bending stresses. It is therefore required to adopt various numerical methods to obtain exact solutions to such complicated problems within engineering accuracy. Finite. Element Method has gained popularity in analyzing the completed structures due to the availability of fast running computers. The Semi Loof Beam Element is probably the efficient mapping tool to find the solutions of highly curved structures. Accurate results can be predicted for nontrivial geometric and loading configurations with relatively coarse mesh. The rigid body nodes of translations and rotations are satisfied while selecting few elements to produce acceptable results. The basic uncondensed nodal configurations are shown in Figure 1.

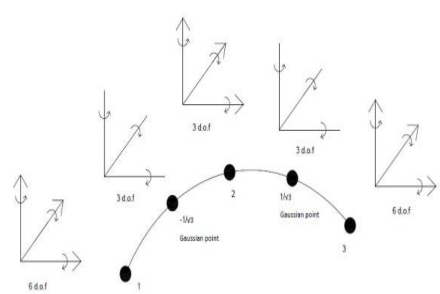

Fig-1, Nodal configuration for curved beam element

The helical staircase is a curved structure in plan and elevation both. The construction of stairs requires less space and material as compared with conventional stairs. But due to complications in analysis, the construction of such stairs are restricted to selected buildings. An attempt has been made to analyze the helicoid staircase with a helix angle of 90 degrees, floor height between the floor as 3.2 m, waist slab thickness = 150 mm. In addition to the above data,

Additional following parameters were also taken into account.

* Inner radius : 500 mm
* Outer radius : 1500 mm
* Width of staircase : 1000 mm
* End supports : Restrained
* Unit Wt of concrete :24 Kn/m^3
* Number of Element : 06
* Number of nodal points : 11
* Total degree of freedom : 72

The selected staircase was analyzed for four different loading conditions mentioned below

(1) Gravity load only

(2) U DL: 5 Kn/m over an entire length of the curve

(3) UDL Over bottom half length: Element 1 to 3

(4) UDL Over top half length: Element 4 to 6

After analyzing the selected helicoids staircase for all above loads, the results thus obtained I terms of three displacements "U, "V, "W "was represented graphically as well as in tabular form Variation of force resultants as " Fx, "Fxy, "Fxz " were also plotted and shown, i.e., tabular form. Similarly, Moment resultants as "Mxy, "Mxz. " "TOR "was also shown graphically as well as in tabular form.

METHODOLOGY

Using Finite Element Method with Semiloof Beam Element of condensed 21 degree of freedom. , helicoid stair of helix 90 degree angle ,with restrained supports was analysed Four loading conditions ,as mentioned above, were taken to study the behavior of this curved structure Additional required parameters considered were mentioned below

* E : 0.12 x10^5 N/mm^2
* G : 0.5217 x 10^4 N/mm^2
* Area =A : 1.5 x 10^5 mm^2
* Iyy : 28.125 x 10^7 mm^7
* Izz : 1.25 x 10^10 mm^4
* Ip : 10,125 x10^5 mm^4
* Ɛ : Poissons Ratio : 0.15

The displacements in U, V, W directions were shown in global direction; shear stress resultants Fx, Fxy, Fxz, and moment resultants Mxy, Mxz, Tor, were predicted at each Gaussian integration points and shown graphically. The results thus obtained were presented in a tabular form showing the salient values The (+)) indicates the tension and (-) sign indicate compression Gaussian integration points are at $\xi = \pm 1/\sqrt{2}$ The results were obtained for all four types of loads. The displacements, shear resultants, and moment resultants thus calculated were superimposed to study the effect of different loads for each parameter.

OBSERVATION

All the results thus obtained for restrained boundary conditions and four loading patterns were shown as per the details mentioned below.

For all four loading patterns, the displacements in the "U" direction were shown in Fig No 2.

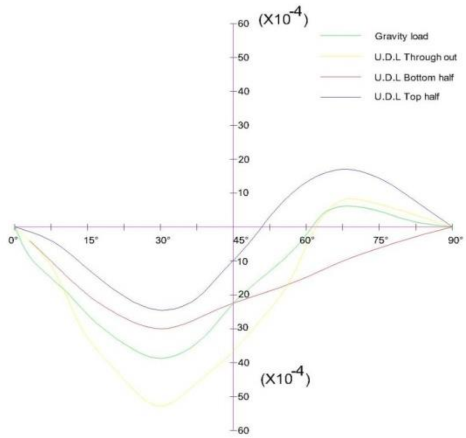

FIG.-2, U Displacement in mm

For all four loading patterns, the displacements in the "V" direction were shown in Fig No 3.

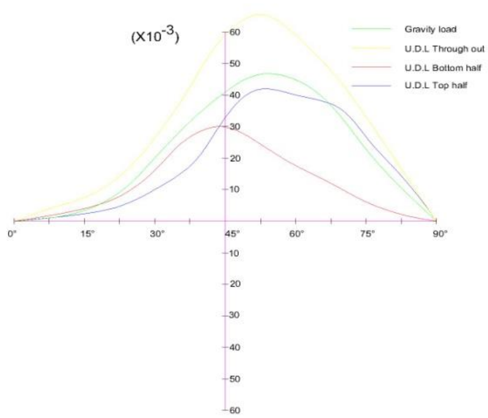

FIG.-3, V Displacement in mm

For all four loading patterns, the displacements in the "W" direction were shown in Fig No 4.

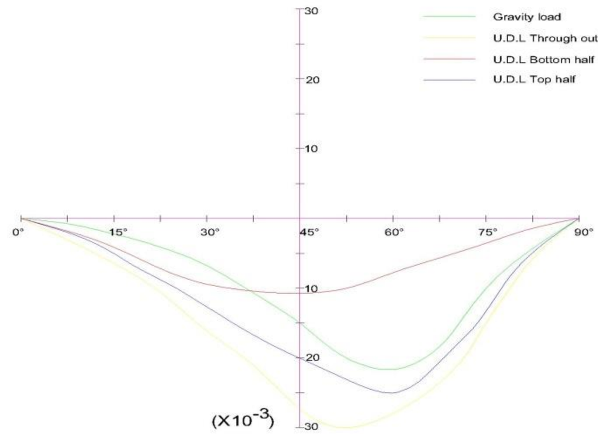

FIG.-4, W Displacement in mm

For all four loading pattern, force in the "Fx" direction were shown in Fig No 5.

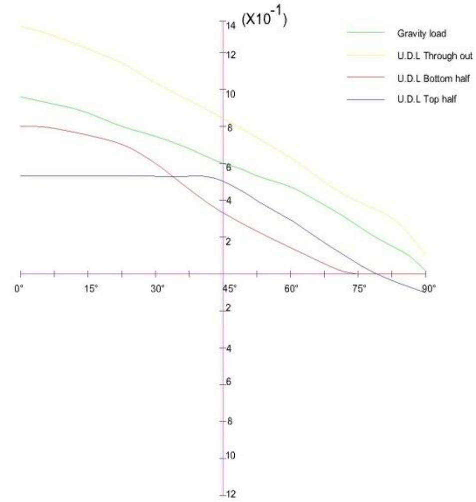

FIG.-5, Fx Force Resultant in Kn

For all four loading patterns, the force "Fxy" direction is shown in Fig No 6.

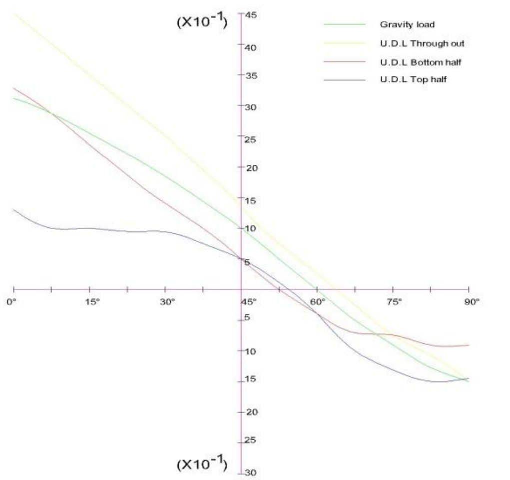

FIG.-6, Fxy Force Resultant in Kn

For all four loading pattern ,the force "Fxy" direction were shown in Fig No 7.

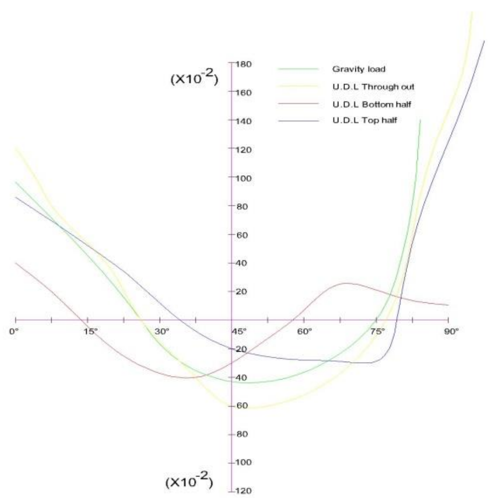

FIG.-7 Force Resultant in Kn

For all four loading patterns, the Moment" Mxy" direction as shown in Fig No 8.

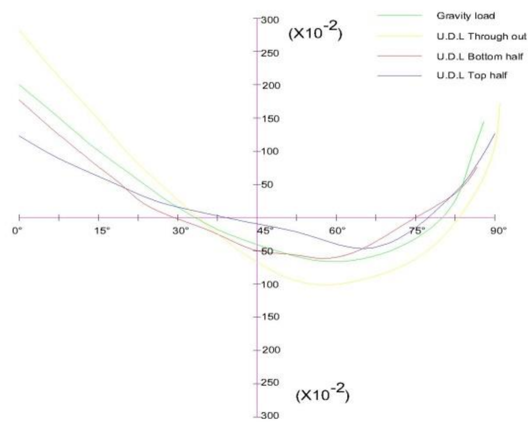

FIG.-8 Mxy Moment Resultant in Knm

For all four loading patterns, the Moment "Mxz direction as shown in Fig No 9.

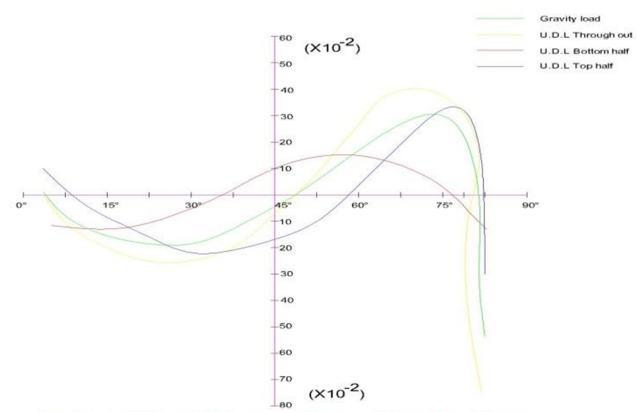

FIG.-9 Mxz Moment Resultant in Knm

For all four loading pattern, the Moment "Tor" direction as shown in Fig No 10.

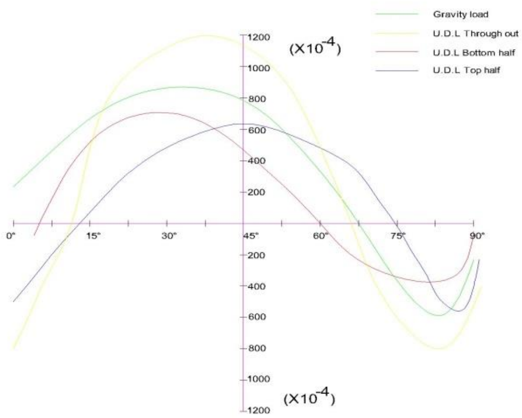

FIG.-10 "TOR" Moment resistance in Knm

The salient values of displacements, force resultants, and moment resultants were shown in Figures No 11,12 and 13, respectively. Maximum values of displacements in U, V, W in mm were shown in Table No 1. . The force resultants as Fx, Fxy, Fxz in Kn were shown in Table No 2 Similarly, moment resultants as Mxy M xz and Tor in Kn M were shown in Table No 3.

TABLE NO 1 SHOWING DISPLACEMENTS IN MM

Type Of Loads	U	V	W
Gravity Load	0.38 x 10^-2	-0.047	-0.0218
UDL Throughout	0.52 x 10^-2	- 0.066	-0.030
UDL Bottom Half	0.29 x 10^-2	-0.026	-0.0113
UDL Top Half	0.23 x 10^-2	-0.045	-0.025

TABLE NO 2 SHOWING FORCE RESULTANTS IN KN

Type Of Loads	Fx	Fxy	Fxz
Gravity Load	0.95	3.2	1.55
UDL Throughout	1.38	4.5	2.2
UDL Bottom Half	0.8	3.2	0.4-
UDL Top Half	0.52	1.5	2.0

TABLE NO 3 SHOWING MOMENT RESULTANT IN KN M

Type Of Loads	Mxy	Mxz	Tor
Gravity Load	2.0	0.65	0.09
UDL Throughout	2.7	0.78	0.12
UDL Bottom Half	1.75	0.15	0.07
UDL Top Half	1.25	0.35	0.06

CONCLUSION

- **S**emi Loof Beam Element is capable of producing accurate results within the required degree of accuracy.
- The magnitude of all types of displacements is maximum near the center of the span.
- A helicoid staircase is a highly curved structure; still, it is concluded that if both the supports are restrained, torsion is minimum.
- The displacements in the "U" direction behave like a sine curve, and maximum values for all loads are near the center of the span.
- The displacements in the "V" and "W" directions behave like a parabolic curve, and maximum values for all loads are near the center of the span.

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