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Finite Element Analysis of Concrete Gravity Dam by Using STAAD-PRO

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Abstract-Gravity dams are solid concrete structures that maintain their stability against design loads from the geometric shape, mass and strength of the concrete. The purposes of dam construction may include navigation, flood damage reduction, hydroelectric power generation, fish and wildlife enhancement, water quality, water supply. The design and evaluation of concrete gravity dam for earthquake loading must be based on appropriate criteria that reflect both the desired level of safety and the choice of the design and evaluation procedures. The Dam discussed in this paper is of the height 110m for which Equivalent static analysis and dynamic analysis by using time history method is carried out. Most of the organizations analyze the dams by elastic method which gives very rough results. Here Finite Element Approach is used to analyze the dam which is proved to be the realistic for such structures. A comparison is done between the equivalent static approach of seismic analysis with dynamic analysis by using time history. The dynamic behavior is studied by using Time History of actual earthquake of koyna (Maharashtra , India) and the proportioning is done to satisfy the stress limits.

Keywords: Gravity Dam, Finite element analysis, Dynamic analysis, Stress Contours, Staad-pro

1. Introduction Any structure that is constructed will undergo many forces such as wind, seismic, self-weight or forces like ice/snow etc. Among these, seismic forces are natural and as we know earthquake is a natural calamity and is so unpredictable.in order to prevent the structure from being collapse, itȏs very important to adopt earthquake resistant design philosophy while designing the structure. Waves which arises during Seismic event carries very massive speed and when it struck with any structure it travels through foundation to the top roof resulting In-elastic deformation. there may be the possibility of collapse of whole structure or probably it will survive depending upon the design adopted but surely the structure will have some major repairing and strengthening works which will be costly. Sometimes damages caused by earthquake vibrations are very high that goes beyond repair works. Generally hydraulic structures like concrete gravity dam, canals and RCC multi-storeyed structures are sufficiently stiff and ductile. These structures undergo large deformations in its inelastic region. Concrete gravity dam is a massive structure having many forces acting on it. Itȏs very important for the dam to survive against seismic vibrations. This paper is mainly focused on behaviour of concrete gravity dam with nonlinear characteristics using seismic time history analysis. In order to study the precise behaviour of structures, seismic time history or response spectrum plays an important role. These analyses methods can be adopted to study the structures having single degree of system or multi degree of freedom system possessing non-linear characteristics. Time history performs analysis which is based on Time-acceleration as an input data which is basically an already experienced acceleration w.r.t time by the ground during seismic event. Time history analysis provides the most probable shapes and directions of structure which is its dynamic structural response under loading which varies as according to specified time-acceleration function. One can predict either the structure will survive or not against these seismic vibrations by using time history analysis results. Mainly structures consists of stiffness and damping as a nonlinear parameter. Damping mostly encountered in dynamic problems related with structural control, aerodynamics and offshore hydraulic structures. Most hydraulic structures undergoes yielding under seismic vibrations. Damping or inertia, displacement and acceleration are non-linear parameters which provides the non-linear characteristics to the structure. The design lateral force shall be considered in each of two orthogonal horizontal directions of the structure. For structures which have the lateral force resisting elements in the two orthogonal directions, the design lateral force shall be considered along one direction at a time, and not in both directions simultaneously.

It is known that for most world tectonic regions the ground motion can act along any horizontal direction, therefore, this implies the existence of a possible different direction of seismic incidence that would lead to an increase of structural response. Critical angles are earthquake incidence angles, producing critical responses.

In this study, a four storey reinforced concrete building with moment resisting frame, of different shapes i.e., L shaped and T shaped are analysed by Time history method of Dynamic analysis of Earthquake. A set of values from 0 to 90 degrees, with an increment of 10 degrees has been used of excitation of seismic force. The details of the study and its result are described briefly in the following section of the paper.

2. Salient features of the concrete gravity dam

Concrete gravity dam is a solid structure which is made up of concrete or masonry. It acts as a water retaining structure and holds a large amount of water by creating a reservoir on its upstream side. Thatȏs why gravity dam is constructed across a river for retaining of water. The cross section of the gravity dam is approximately triangular in shape and having an apex at top and maximum width at bottom. There are various forces acting on the gravity dam mainly hydrostatic pressure, silt pressure, wave pressure, ice pressure, wind forces, self-weight of the dam, uplift pressure and seismic forces etc. The section of the dam is designed in such a way that it would resist all these forces acting on it from various directions under the effect of its own self weight. Gravity dams are also called as solid gravity dams because they are rigid as well as solids and no bending stresses are induced at any point on a dam structure. They are generally straight in plan .the upstream face is vertical and slope of downstream face is 0.7:1.For construction, they need good foundations and topography to perform better throughout in its lifetime.

3. About the software: STAAD or (STAAD.Pro) is a structural analysis and design computer program originally developed by Research Engineers International in Yorba Linda, CA. In late 2005, Research Engineer International was bought by Bentley Systems. An older version called Staad-III for windows is used by Iowa State University for educational purposes for civil and structural engineers. The commercial version STAAD.Pro is one of the most widely used structural analysis and design software. It can also make use of various forms of dynamic analysis from modal extraction to time history and response spectrum analysis.

4. Finite Element Modeling Of The Dam

The dam body is modeled in STAADpro using the SOLID isoparametric finite elements with eight nodes. Each node has three translational degrees of freedom. The stiffness matrix of the solid element is evaluated by numerical integration with eight Gauss ï Legendre points. The dam is analyzed for several basic loads and load combinations possibly met with during its service. These are enlisted in table 1 below. The stresses induced are checked for all the combinations and the dimensions are so framed that the factor of safety mentioned above is maintained. The base of the dam is to rest on rock and the extra excavation is to be filled with concrete of same strength, the foundation rock of approximately equal to the height of dam is modeled around and below the foundation level. The Youngôs modulus for concrete is used as 2.26 x 104 N/mm2 and density 25 kN/m3. For the foundation rock these properties were 1.0 x 104 N/mm2 and 28.8 kN/m3 respectively. Poissons ratio for concrete is 0.17 whereas for rock it is 0.16.

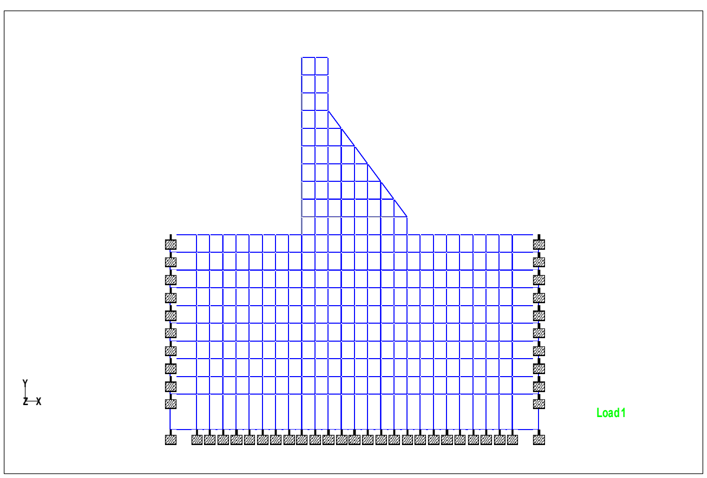

Figure1: Finite element modeling of the dam

3. Methodology

The present study undertaken deals with time history method of dynamic analysis. Time history is available only for X direction, so in order to apply forces in different angles, the structure has to be rotated with incidence angle from 0 to 90 degrees, with an increment of 10 degrees and column forces have been investigated in all cases. Further in order to find the accurate angle the interval of one degree is used. The columns have been divided into three main categories, including corner, side and internal (middle) columns and the results are compared.

5. Results and Discussion

L Structure
Time History Method
Table No. 2 a: L Structure Corner Column C1

ANGLE	SHEAR +	SHEAR-	My	Mz
0	801.92	84.815	21.504	55.231
10	795.013	85.818	23.669	54.576
20	797.32	89.046	25.986	53.626
30	797.182	89.178	28.989	51.013
40	792.962	85.526	32.348	47.029
50	785.236	78.43	35.064	43.416
60	775.381	68.971	36.741	39.392
70	766.641	58.363	37.406	35.164
80	767.044	50.154	37.533	31.432
90	767.718	51.439	37.503	30.473

Table No. 2 B: L Structure Side Column C2

ANGLE	SHEAR+	SHEAR-	My	Mz
0	1310	0.368	31.504	73.704
10	1310	12.056	33.026	73.078
20	1310	22.846	36.369	71.051
30	1310	34.259	40.321	67.534
40	1280	48.991	45.78	63.734
50	1270	62.034	50.429	60.893
60	1250	70.969	53.461	57.792
70	1230	75.751	54.905	54.522
80	1220	77.855	55.406	51.125
90	1220	78.475	55.534	47.688

Table No. 3 A: T STRUCTURE CORNER COLUMN C1

ANGLE	SHEAR +	SHEAR -	My	Mz
0	829.71	82.065	22.566	57.626
10	835.165	86.819	29.23	58.209
20	838.397	89.92	30.789	58.316
30	837.921	89.94	29.809	56.242
40	832.946	85.891	31.184	52.047
50	824.182	78.061	33.713	47.933
60	813.394	67.761	35.118	43.486
70	802.318	56.619	35.601	37.49
80	793.625	48.747	35.636	32.68
90	793.329	47.977	35.642	29.684

Table No. 3 B: T STRUCTURE SIDE COLUMN C2

ANGLE	SHEAR +	SHEAR -	My	Mz
0	1190	1.867	38.995	57.565
10	1200	4.822	41.139	55.915
20	1210	9.708	43.441	53.08
30	1220	13.961	45.522	49.326
40	1240	18.59	47.341	43.493
50	1250	23.441	48.86	36.874
60	1260	26.778	51.633	31.11
70	1260	45.764	52.922	22.902
80	1260	66.789	53.463	12.035
90	1260	76.961	53.786	1.918

Table No. 3 C: T STRUCTURE MIDDLE COLUMN C3

ANGLE	SHEAR +	SHEAR -	My	Mz
0	1750	41.067	11.624	82.225
10	1760	44.919	20.746	81.602
20	1760	47.484	36.544	76.412
30	1760	48.001	45.387	69.215
40	1760	46.215	45.081	61.679
50	1750	42.619	40.42	52.241
60	1750	38.043	44.936	41.363
70	1740	33.137	46.523	33.602
80	1740	30.411	46.586	27.988
90	1740	2.204	46.186	22.409

L Structure
Time History Method
Column C1 (Corner Column)

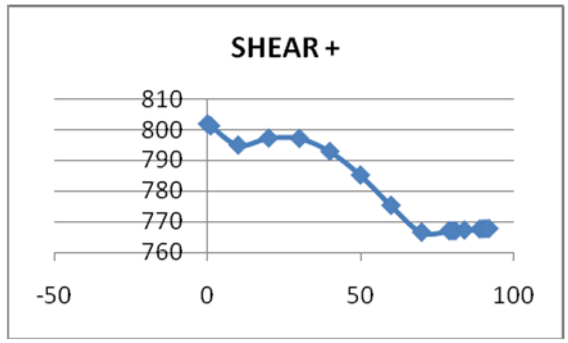

Figure No. 3 a: Graph of Fx v/s Angle of Rotation in degrees

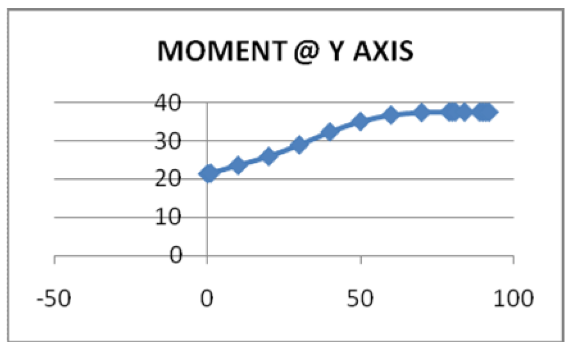

Figure No. 3 b: Graph of My v/s Angle of Rotation in degrees

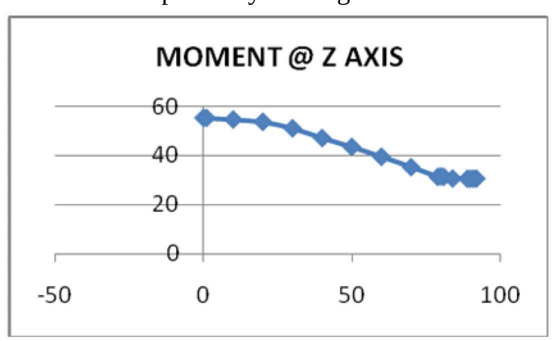

Figure No. 3 c: Graph of Mz v/s Angle of Rotation in degrees

T Structure
Time History Method
Column C1 (Corner Column)

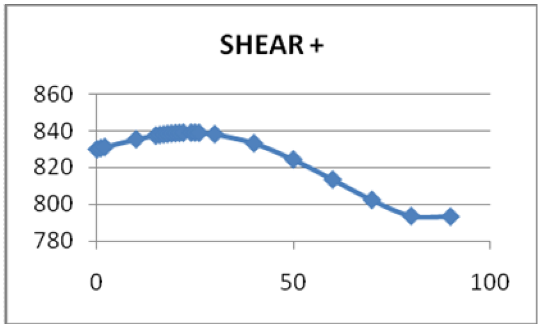

Figure No. 4 a: Graph of Fx v/s Angle of Rotation in degrees

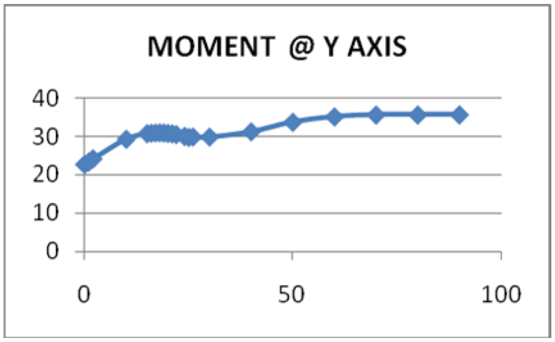

Figure No. 4 b: Graph of My v/s Angle of Rotation in degrees

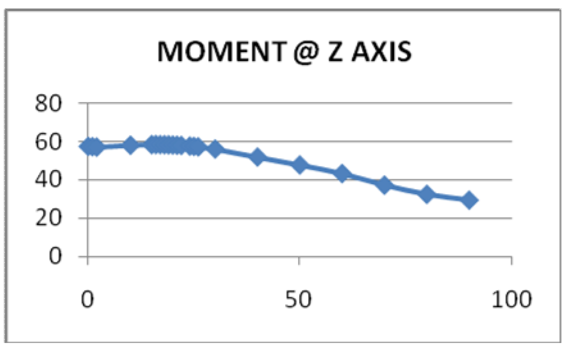

Figure No. 4 c: Graph of Mz v/s Angle of Rotation in degrees

L Structure
Time History Method
Column C2 (Side Column)

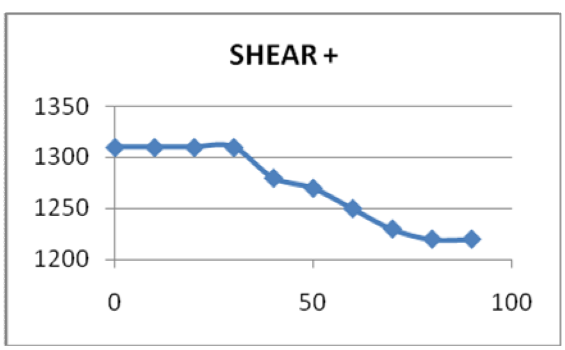

Figure No. 5 a: Graph of Fx v/s Angle of Rotation in degrees

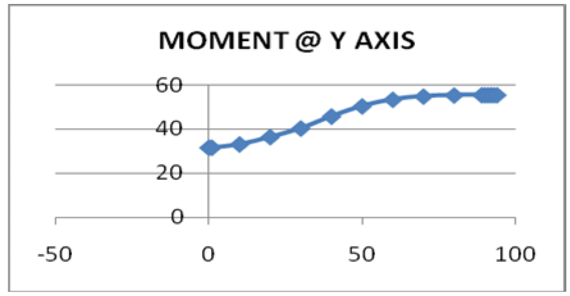

Figure No. 5 b: Graph of My v/s Angle of Rotation in degrees

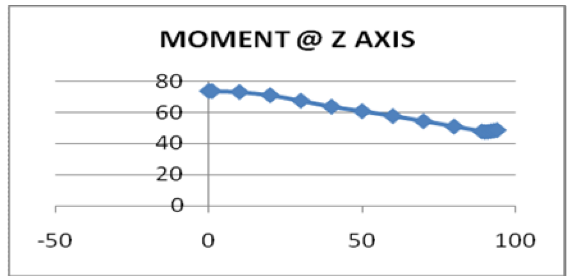

Figure No. 5 c: Graph of Mz v/s Angle of Rotation in degrees

T Structure
Time History Method
Column C2 (Side Column)

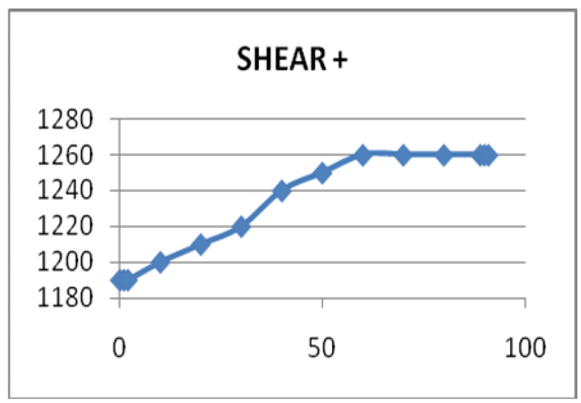

Figure No. 6 a: Graph of Fx v/s Angle of Rotation in degrees

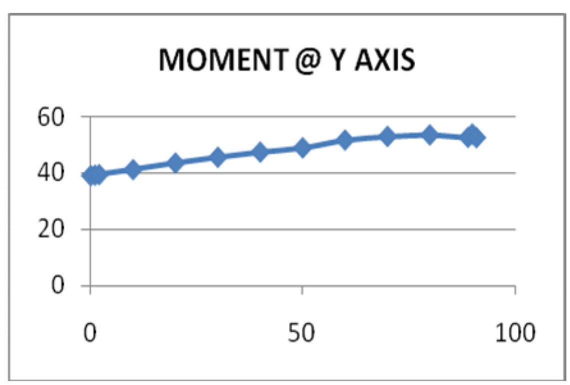

Figure No. 6 b: Graph of My v/s Angle of Rotation in degrees

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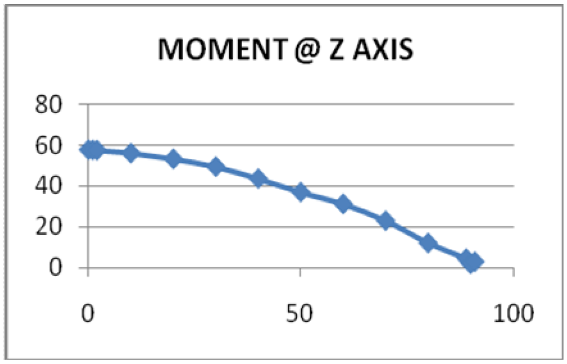

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igure No. 6 c: Graph of Mz v/s Angle of Rotation in degrees

L Structure
Time History Method
Column C3 (Middle Column)

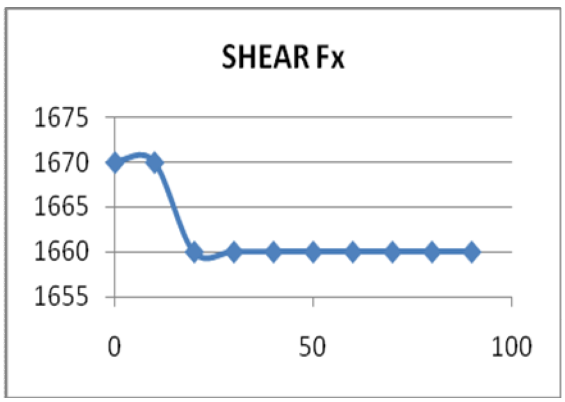

Figure No. 7 a: Graph of Fx v/s Angle of Rotation in degrees

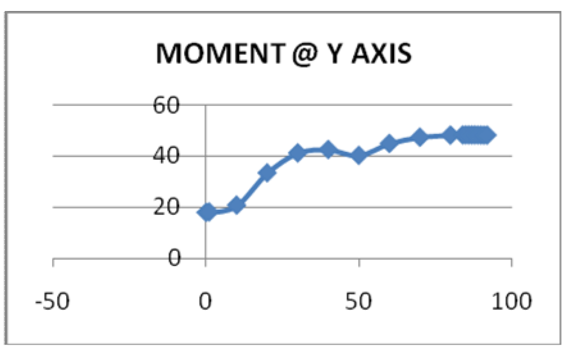

Figure No. 7 b: Graph of My v/s Angle of Rotation in degrees

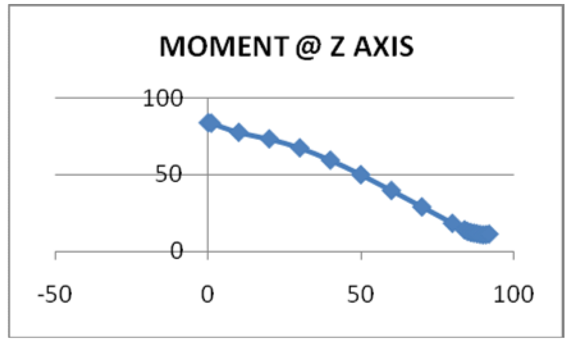

Figure No. 7 c: Graph of Mz v/s Angle of Rotation in degrees

T Structure
Time History Method
Column C3 (Middle Column)

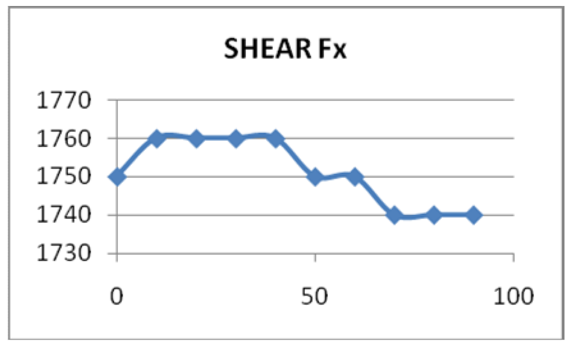

Figure No. 8 a: Graph of Fx v/s Angle of Rotation in degrees

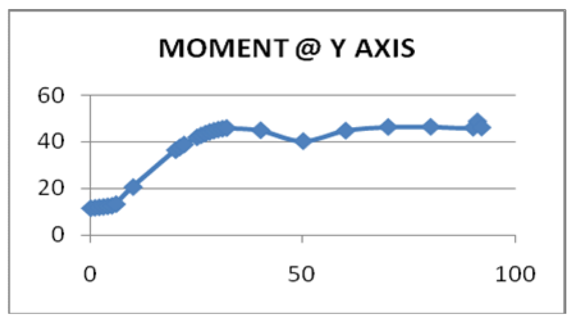

Figure No. 8 b: Graph of My v/s Angle of Rotation in degrees

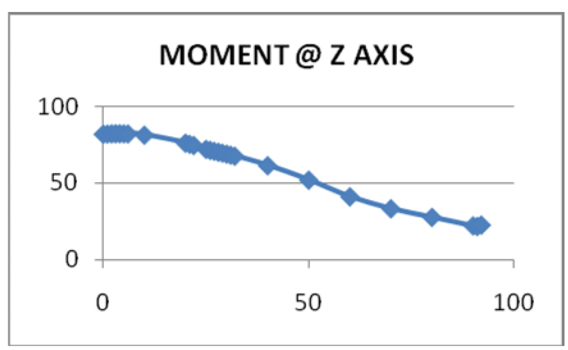

Figure No. 8 c: Graph of Mz v/s Angle of Rotation in degrees

CONCLUSION

For Corner Column C1: The shear force in X direction i.e. Fx is decreasing throughout from 0 to 90 degrees, it has maximum value at 0 degree for L structure whereas T structure also shows parabolic decreasing curve for Fx and attains maximum value at 20 degrees. Moment about Y axis for corner column C1 of L structure attains maximum value at 80 degrees and Moment about Z axis attains maximum at 0 degrees whereas T structure attains maximum value at 90 degrees for My and for Mz at 20 degrees.

For Side Column C2: Shear force Fx is constant from 0 to 30 degrees and then it decreases till 90 degrees for L structure whereas for T structure the curve is continuously increasing i.e. minimum value at 0 degree and maximum at 90 degrees.

L and T structure both attains maximum My at 90 degrees and Mz at 0 degrees.

For Middle Column C3: For L structure the shear force Fx at start increases slowly and shows a steep slope and from 20 degrees onwards it is constant throughout. T structure shows a different nature as shown in figure No. 8a.

Value of My i.e Moment about Y axis is maximum at 90 degrees for L structure and 80 degrees for T shaped structure.

Value of Mzi.e Moment about Z axis is maximum at 0 degrees for L and T shaped structure.

From the above graphs and conclusions it can be concluded that T shaped structure has to resist more shear force than L shaped structure.

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