Design of Overhead Tank with Carbon Fibre/Fiber Rebar as Reinforcement and Time History Analysis using STAAD-Pro software.

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Research Article

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Abstract

The Construction and Design industry is always trying to find new and better technologies, ways, materials and equipment. One such technology/material is the using Carbon Fibre/fiber as Reinforcement for design the structure which is a new material in this industry that brings alternative for steel in the designing of the structure and offers design opportunities to enhance the performance of the structure with encouraging innovation. The use of this material in designing of the structure reflects economical.

Most of the studies showed that the need of water and storage of water in tanks is essential and increasing now days all over the world. For that demands, we designs the huge storage water tanks structures. Designing the huge storage water tanks by traditional/conventional/regular way has limits, but it should not been limited to a certain extent structural point of view. Efficient overhead water tanks would not be possible with a traditional/conventional/regular approach. Storage tanks are different structure by their special architectural features and configurations. Materials having high strength and innovative structural systems are needed to be developed to resist the challenges created by construction the huge storages of water tanks in regions of highly dense populated area.

In present work, design of the overhead tank using carbon fibre/fiber as reinforcement, has been checked against the several loads, time history analysis and the maximum considered level criteria by performing the linear and nonlinear procedures with the help of STAAD-Pro software. In further work, the performance of overhead tank using carbon fibre/fiber as reinforcement will be checked at the several loads, time history analysis and the maximum considered level criteria.

1. Introduction

In conventional method of designing overhead water tank structure with time history analysis limiting at the certain extents, so considering the need of the water reservoirs we should thing beyond the limits. Considering the factors like “value of the design base shear is dependent on height (period), type, location, and importance of the structure as well as on the nature of foundation soil” we need to design the structure. Steel is used for the reinforced the structure, which counter balance the tensile force generated in different type of the structures. We need to high reinforcement for the huge water tanks while designing and counter the forces comes across, it is practically to much uneconomical. The new material comes in to the picture which is 3 to 5 times stronger. Also have more times of stronger materials than steel stands out in various forces/loads like earthquake, seismic and wind etc.

1.1. Overhead Water Tank:

Overhead Water Storage Tank is usual Water storage tank as its name stands for itself these tanks are placed over the head that is built on a certain height. The tank may be built of any material but the idea is to achieve maximum efficiency by placing a tank in some elevated distance. The water from the ground level is filled inside the tank through pumping. It is achieved with the high power motor pumps that send the water to storage with high pressure. These Tanks can be anywhere above a Town or even within your house where it is built on the rooftop. The main purpose is to achieve an even distribution and it maintains constant pressure and flows, at the time of discharge when the water comes down from a certain height it has a sufficient increase in pressure that makes it serves at a constant rate in almost every outlet.

1.2. Carbon Fibre/fiber Reinforcement/Rebars:

Carbon Fibre/fiber composite reinforcement/rebars has high strength, moderate modulus of elasticity, small deformation, pre-manufactured composite carbon/resin rods. Carbon Fibre/fiber Rebars is used as internal or external reinforcement providing additional strength and stiffness to concrete and masonry structural elements. Carbon Fibre/fiber Rebars rods can be effectively anchored into adjacent members, non-corrosive, light-weight, high-strength, fatigue resistance and non-magnetic, low impact on member appearance and aesthetically pleasing, increasing in-plane or out- of-plane bending capacity of masonry wall, effective topside reinforcing product for slabs and beams, suitable for special engineering structures, structural reinforcement and so on.

Table 1
Carbon Fibre/fiber Rebars Details

Item	Value
Diameter(mm)	6 ~ 30
Density(g/cm3)	1.5 ~ 1.7
Tensile Strength (MPa)	1500 ~ 2800
E-modulus(GPa)	130 ~ 200

1.3. Steel Reinforcement/Rebars:

In structural/construction engineering, steel reinforcement are steel bars that are provided in combination with plain cement concrete to make it reinforced concrete. Hence these structures form steel reinforced cement concrete structure (R.C.C). Steel reinforcement is commonly called as rebars.

Table 2
Steel Rebars Details

Item	Value
Diameter(mm)	6 ~ 50
Density(g/cm3)	7.75 ~ 8.05
Tensile Strength (MPa)	200 ~ 550
E-modulus(GPa)	190 ~ 215

1.4. Aim and Objective:

The aim of the Dissertation is to design the overhead tank using carbon fibre/fiber as reinforcement and time history analysis to improve the structural performance and cost effectiveness.

The Dissertation work is being carried out to achieve the following objectives:

1. Whether to check can design the Overhead Tank Using Carbon Fibre/Fiber as Reinforcement.

2. To do the Time History Analysis.

3. Whether it is possible the go for reinforcement details to check practical approach, it is economical or not through respective software.

4. To check the performance of the structure.

2. Problem Statement And Methodology

2.1. Problem statement:

The current IS codes do not properly address use of carbon fibre/fiber as a reinforcement. These codes primarily assess life safety and are intended to control damage under every condition, but the actual reliability of these codes is not known. So we need improved design procedures that result in better performance, durable and sustainable. Design the structures like overhead tank using carbon fibre/fiber as reinforced material can help us to achieve these goals. Such an approach provides the freedom to develop tools and methods to evaluate the entire life cycle of the building processes, from the business dealings, to procurement, through construction and the evaluation of results. However, no previous research was conducted about performance based approach for seismic design of tall building diaphragms. Hence, this study was developed to study the design of Overhead Tank using Carbon Fibre/Fiber as Reinforcement and do Time History Analysis watch the effect.

2.2. Significance of choosing the problem:

Previously no work executed in India, investigations results out that our IS codes are not compile with design the structures using Carbon fibre/fiber as reinforcement. The performance based design approach is not proposed as an immediate substitute for design to traditional codes. Recent trends show that the number of structures are being designed and constructed using carbon fibre/fiber as reinforcement outside to India. Demand of water and water storages is increasing day by day as city becomes dense. So there urges a need for more skilled engineers equipped with better tools to evaluate and guarantee the safety and performance of such structures.. Using of carbon fibre/fiber used as reinforcing material gives the opportunity to clearly define the levels of hazard to be designed against, with the corresponding performance, durable and sustainable efficient, and the cost efficient process.

2.3. Relevance to Construction Industries:

The new ideas and use of materials in the design and completion of structure have given a great challenge to the construction industries in terms of meeting the social needs. Using carbon fibre/fiber as reinforcement is a concept that produces a structure with high level of performance, durabile and sustainabile. Overhead tank using carbon fibre/fiber as reinforcement allows industry to design solutions to achieve the requirements and helps to boost the productivity. Achieving a quality product within a budget and planned schedule is the goal of all owners in the architecture, engineering and construction industry.

2.4. Methodology:

The overall methodology consisted of designing the overhead tank using carbon fibre/fiber and time history analysis. Carbon fibre/fiber is newly invented material which is going to experimentally use as reinforcement material. Perform the time history analysis and study results. The complete analysis and design of the overhead tank using carbon fibre/fiber as a reinforcement and time history analysis was done using the STAAD-Pro software. The method used for the analysis and design of the structure are discussed below.

2.5. Time History Analysis:

Time History analysis provides nonlinear evaluation of dynamic structural response under loading which may be varied according to the specified time function. This type of analysis provides the exact response of a structure as a function of time which is determined using a step-by-step numerical integration of the equation of motion. The peak response can be obtained from the maximum value of the response-history plot.

Procedure for Time History Analysis:

- Open the STAAD-Pro software location where the STAAD-Pro is placed in windows.

- Find EQDATA.TXT exel file.
- Copy this file and paste in your work space.
- Then open work space model.
- After that next step is to define the Time History. For that Go to Load&Cases > Time History.
- New pop up window come.
- Add Integration Time Step as 0.001 > Type as 1 > From External File > File Name.
- Add or Paste file name as EQDATA.TXT (file name) > Add.
- Define Param (Paramameter) > Damping as 0.05 > Arrival Time as 1, 2, 3, 4, 5, 6. > Add.

3. Methodology Adopted

3.1. General:

The total analysis work has been carried out in STAAD-Pro Software to design and check the overhead tank using carbon fibre/fiber as reinforcement and doing time history analysis.

3.2. Modeling Work:

In this present study, overhead water tank of total height 20m, Carbon- Fibre/fiber Reinforced Cement-Concrete. The modeling work is done in STAAD-Pro softwere. The structure is situated in Seismic Zone I with the following seismic, sectional and material properties. The model consists of various elements such as beams, columns, slabs, shear walls for checking the performance against the acceptance criteria.

Table 3
Seismic, Sectional and Material Properties of Structure

Seismic Zone	**I**
Soil Type	II
Importance Factor	1
Total Height	20 m
Lower Beam Size	230 mm x 690 mm
Upper Beam Size	230 mm x 350 mm
Bracing Size	230 mm x 300 mm
Column Size	350 mm x 350 mm
Top Slab	120 mm Thick
Shear Wall	150 mm Thick
Bottom Slab	300 mm Thick
Concrete	M30
Rebar	CFR1600

Load Definitions:

Dead Load (DL)	
Self-Weight	
Load of beam B1	= 0.23m × 0.30m × 25kN/m^3 = 1.725 kN
Load of beam B2	= 0.23m × 0.35m × 25 kN/m^3 = 2.013 kN
Load of beam B3	= 0.23m × 0.69m × 25 kN/m^3 = 3.968 kN
Load of Slab S1	= 0.120m × 25 kN/m^3 = 3 kN/m
Load of Slab S2	= 0.3m × 25 kN/m^3 = 7.5 kN/m
Load of Shear Wall W2	= 0.15m × 25 kN/m^3
Parapet Wall Load	= 3 kN/m
Live Load (LL)	
Floor Load	= 5kN/m
Hydrostatic Pressure (HP)	
Hydrostatic Pressure	= 1000 x 9.81 x 5 ($\rho g h$) = 49.05 kN/m^2
Wind Load (WL) (IS 875 (part 3))	
Basic Wind Speed (Vb) Risk Coefficient Factor(k1) Terrain and Height Factor (k2) Topography Factor (k3)	= 39 m/s [Fig. 1] = 1.0 (Table 1) = 1 for height 10m 1.05 for height 12m 1.05 for height 15m 1.07 for height 19m = 1

Dead Load (DL)	
Design Wind Speed (Vz) (IS 875:Part III, Cl – 6.3)	Vz = Vb × k1 × k2 × k3
V_{10}	= 39 × 1 × 1 × 1 = 39 m/s
V_{12}	= 39 × 1 × 1.05 × 1 = 40.95 m/s
V_{15}	= 39 × 1 × 1.05 × 1 = 40.95 m/s
V_{19}	= 39 × 1 × 1.07 × 1 = 41.73 m/s
Design Wind Pressure (Pz) (IS 875:Part III, Cl – 7.2)	= 0.6 × $(Vz)^2$
V_{10}	= 0.6 × $(39)^2$ = 912.6 N/m^2 = 0.9126 kN/m^2
V_{12}	= 0.6 × $(40.95)^2$ = 1006.14 N/m^2 = 1 kN/m^2
V_{15}	= 0.6 × $(40.95)^2$ = 1006.14 N/m^2 = 1 kN/m^2
V_{19}	= 0.6 × $(41.73)^2$ = 1039.99 N/m^2 = 1.039 kN/m^2

Load Combination Cases:

Combination Case 1:
= 1.5 (DL + LL)
Combination Case 2:
= 1.2 (DL + LL + WLx)
Combination Case 3:
= 1.2 (DL + LL + WLz)
Combination Case 4:
= 1.2 (DL + LL) – 1.2 (WLx)
Combination Case 5:
= 1.2 (DL + LL) – 1.2(WLz)
Combination Case 6:
= 1.2 (DL + LL + Seismic (THA))
Combination Case 7:
= 1.2 (DL + LL) – 1.2 (Seismic (THA))
Combination Case 8:
= 1.5 (DL + WLx)
Combination Case 9:
= 1.5 (DL + WLz)
Combination Case 10:
= 1.5 (DL) – 1.5 (WLx)
Combination Case 11:
= 1.5 (DL) – 1.5 (WLz)
Combination Case 12:
= 1.5 (DL) + 1.5 (Seismic (THA))
Combination Case 13:
= 1.5 (DL) – 1.5 (Seismic (THA))
Combination Case 14:
= 0.9 (DL) + 1.5 (Seismic (THA))
Combination Case 15:

Combination Case 1:
= 0.9 (DL) – 1.5 (Seismic (THA))

4. Result And Discussion

4.1 Modal Period And Frequency:

Table 4.1
Modal Period and Frequency

CASE	MODE	FREQUENCY (CYCLE/SEC)	PERIOD (SEC)
MODAL	1	0.854	1.17042
MODAL	2	0.855	1.16945
MODAL	3	1.217	0.82163
MODAL	4	5.435	0.18400
MODAL	5	5.444	0.18367
MODAL	6	5.599	0.17860
MODAL	7	5.681	0.17601
MODAL	8	6.343	0.15765
MODAL	9	7.937	0.12600
MODAL	10	7.939	0.12596
MODAL	11	9.517	0.10508

4.2 Max Base Shear:

Table 4.2
Max Base Shear

	X - direction	Y - direction	Z - direction
MAXIMUM BASE SHEAR (kN)	-84.07	0.015	0.057
TIME (Sec)	6.50	7.96	16.74

Time Step Used In Time History Analysis = 0.00139 Seconds

Number of Modes Whose Contribution Is Considered = 6.

4.3 Time vs. Displacement Graph:

Time vs. Acceleration Graph:

4.3 Comparison between steel rebar and carbon fibre/fiber rebar reinforcements provided by STAAD-Pro for similar structure. (Only reinforcement comparison).

BEAM

Table 4.3
Beam Comparison

STEEL REBARS	CARBON FIBRE/ FIBER REBARS
Ast Required	Ast Required
160 ~ 490 sq. mm	30 ~ 90 sq. mm

COLUMN

Table 4.4
Column Comparison

STEEL REBARS	CARBON FIBRE/ FIBER REBARS
Ast Required	Ast Required
2800 ~ 3000 sq. mm	900 ~ 1000 sq. mm

REINFORCEMENT IN KG

Table 4.5
Weight Comparison

STEEL REBARS	CARBON FIBRE/ FIBER REBARS
Material Weight	Material Weight
140000 ~ 170000 Kg	25000 ~ 30000 Kg

COST

Table 4.6
Cost Comparison

STEEL REBARS	CARBON FIBRE/ FIBER REBARS
₹ (Rs) 60 ~ ₹ (Rs) 90 per Kg	₹ (Rs) 20 ~ ₹ (Rs) 50 per Kg
₹ (Rs) 84,00,000 (84Lakh) ~ ₹ (Rs) 1,53,00,000 (1.53Cr)	₹ (Rs) 5,00,000 (5Lakh) ~ ₹ (Rs) 15,00,000 (15Lakh)

5. Conclusion

1. The base reaction result's conclude that the base reaction increase with the time in sec from the time history plot we can see that the base reaction is max at 6.50 Sec with 84.07 kN in x-direction (negative indicate opposite in direction).

2. 6 number of mode shapes considered, after that frequency and time period 11 values are obtained.

3. These values of variation of base shear in X, Y and Z direction with respect to time history analysis is due to el-centro earthquake ground motion.

4. Variation of story drift in X, Y and Z direction with respect to time history analysis also plotted. Maximum story drift in X direction is 2.67mm and in Z direction 3.14mm.

5. Design of overhead tank is safe from the software design with respect to load applied.

6. Design of overhead water tank is tedious method.

7. Limit state method was found to be most economical for design of overhead water tank as the quality of **carbon fibre/fiber** and **concrete** needed is less as compare to working stress method.

8. Reduction in cost of construction.

9. Reduction in total load on structure. Structure, light weight in nature.

10. Reduction in CO_2 due to reduction in concrete.

11. Reduction in sizes of beam, column, slab, foundation.

Declarations

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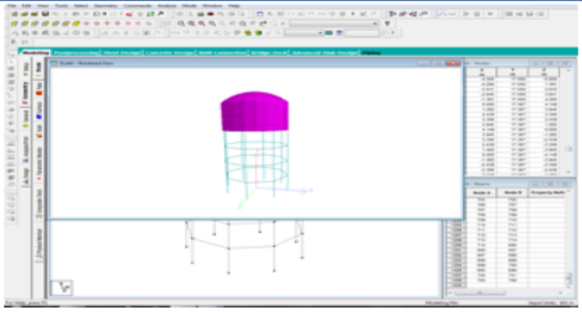
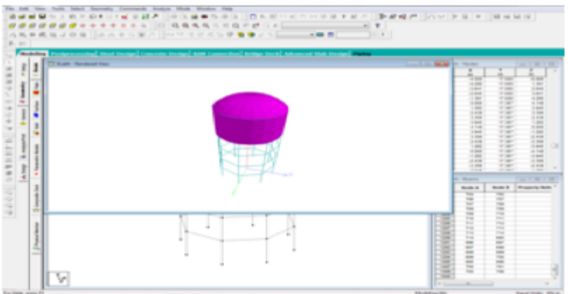
Figures



(a)



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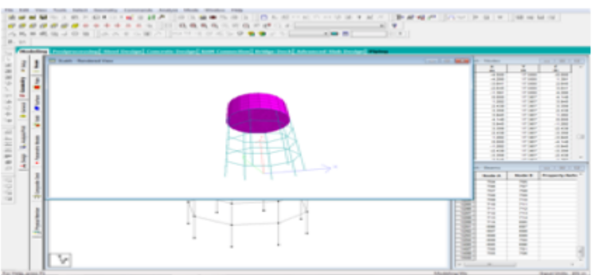

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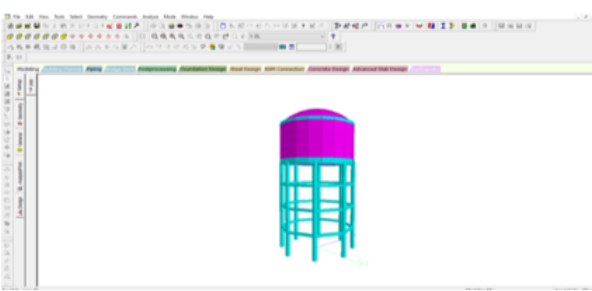


(d)

Figure 1

Figure 3.1 (a) (b) (c) (d): Plan and 3D View of Overhead Tank.

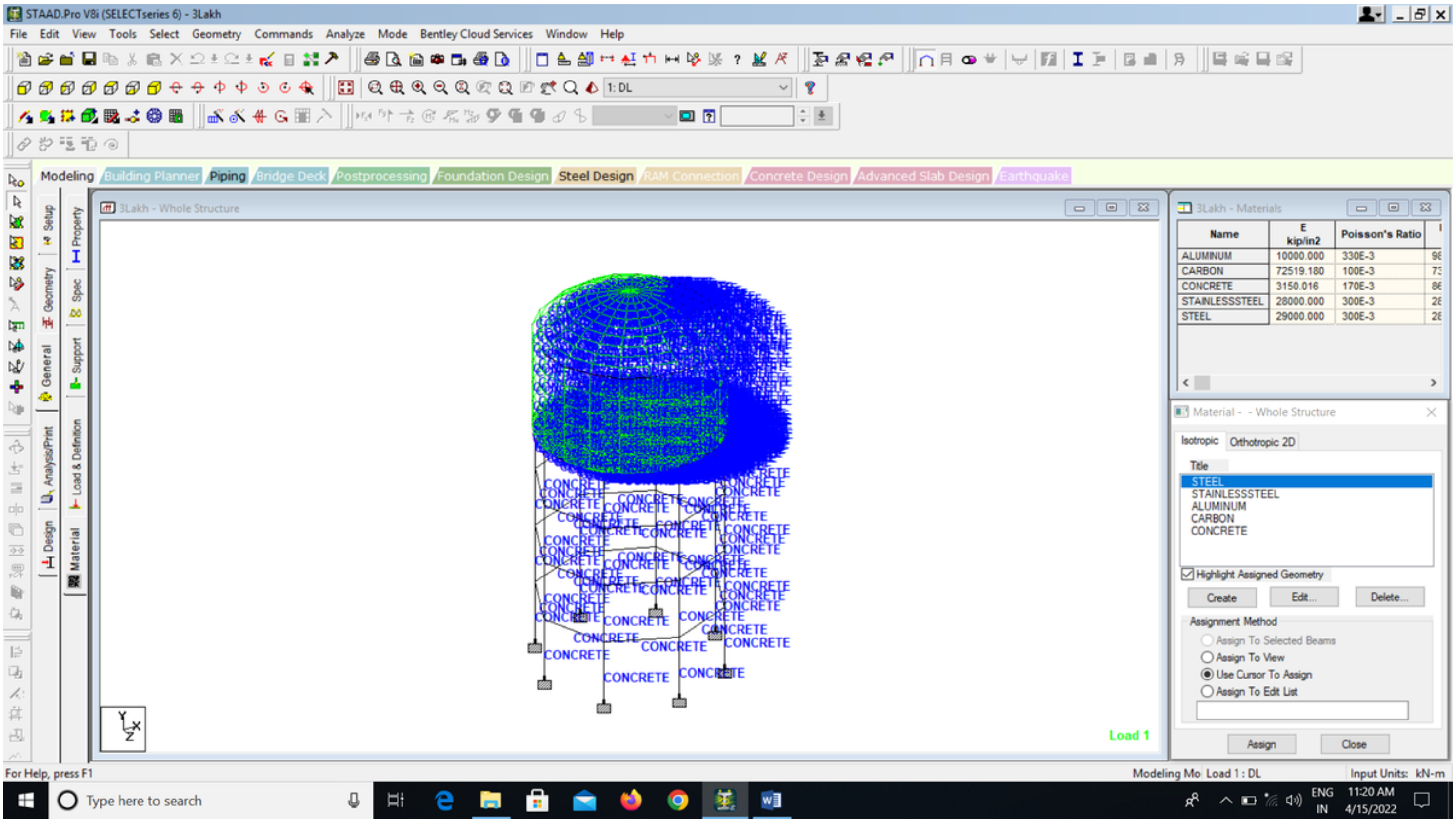
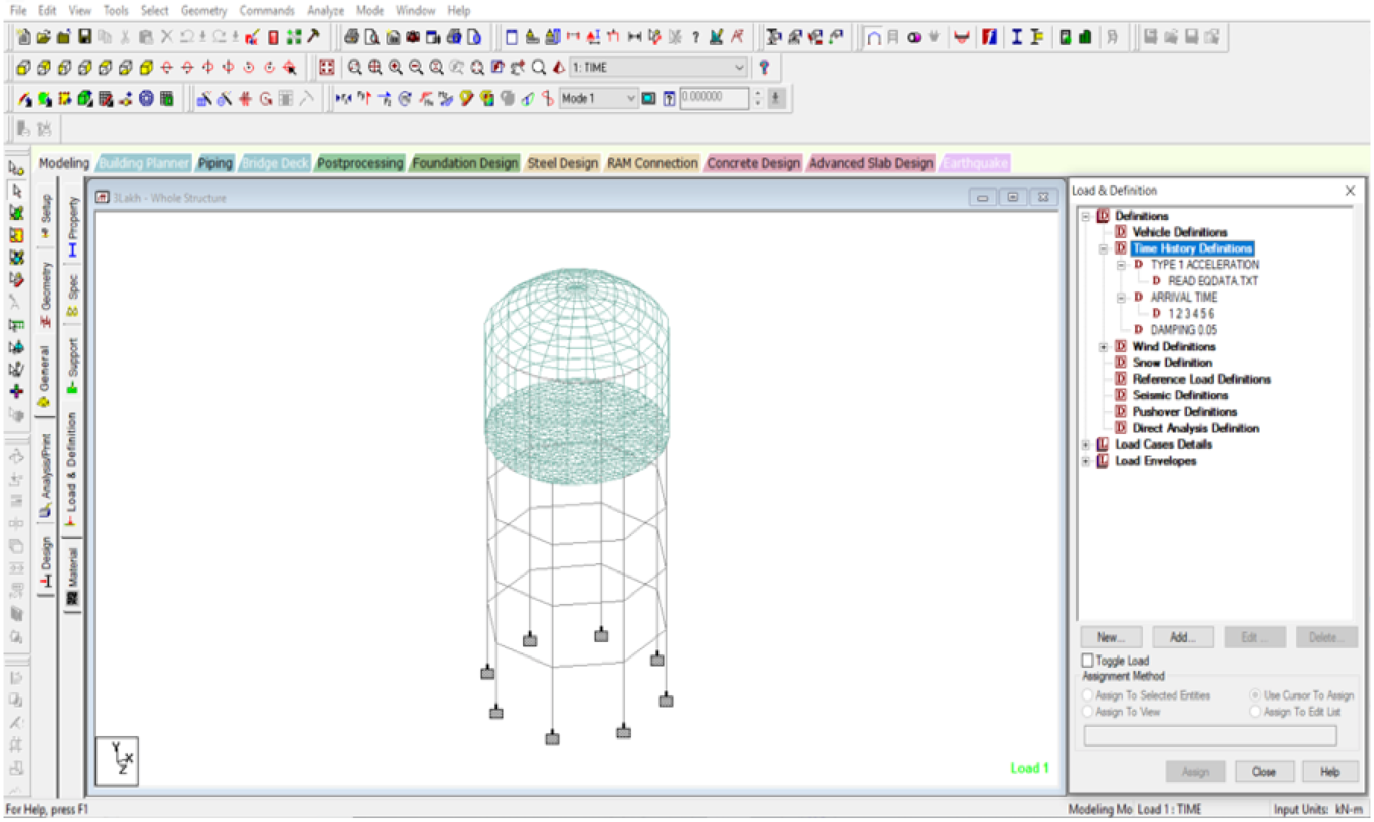


Figure 2

Figure 3.2: Defining the Material



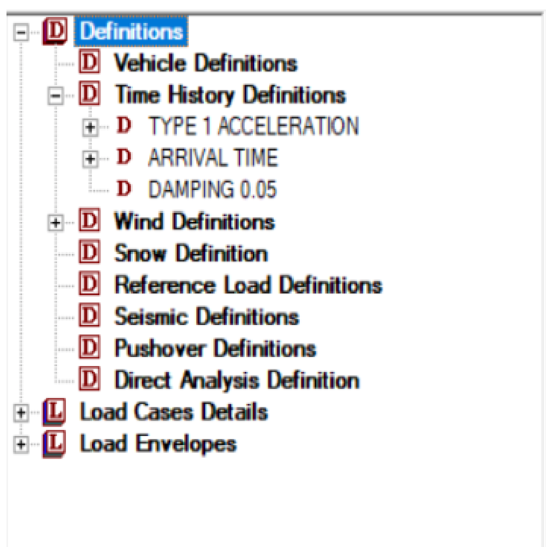


Figure 3

Figure 3.3: Defining Time History Analysis

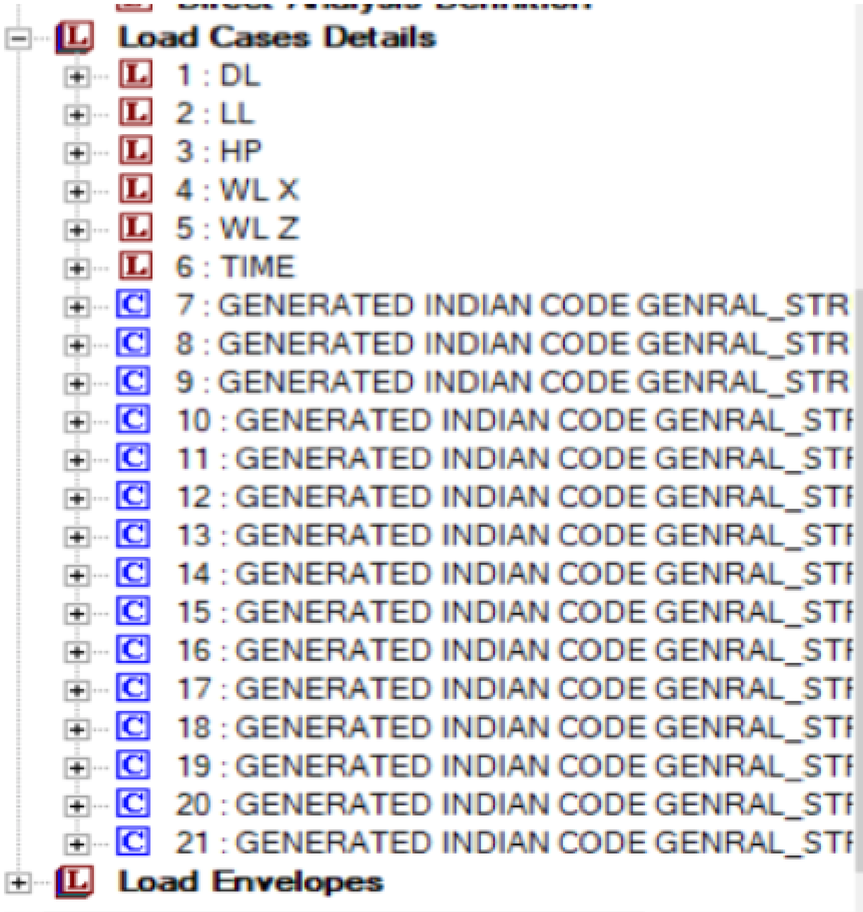


Figure 4

Figure 3.4: Defining Load Cases

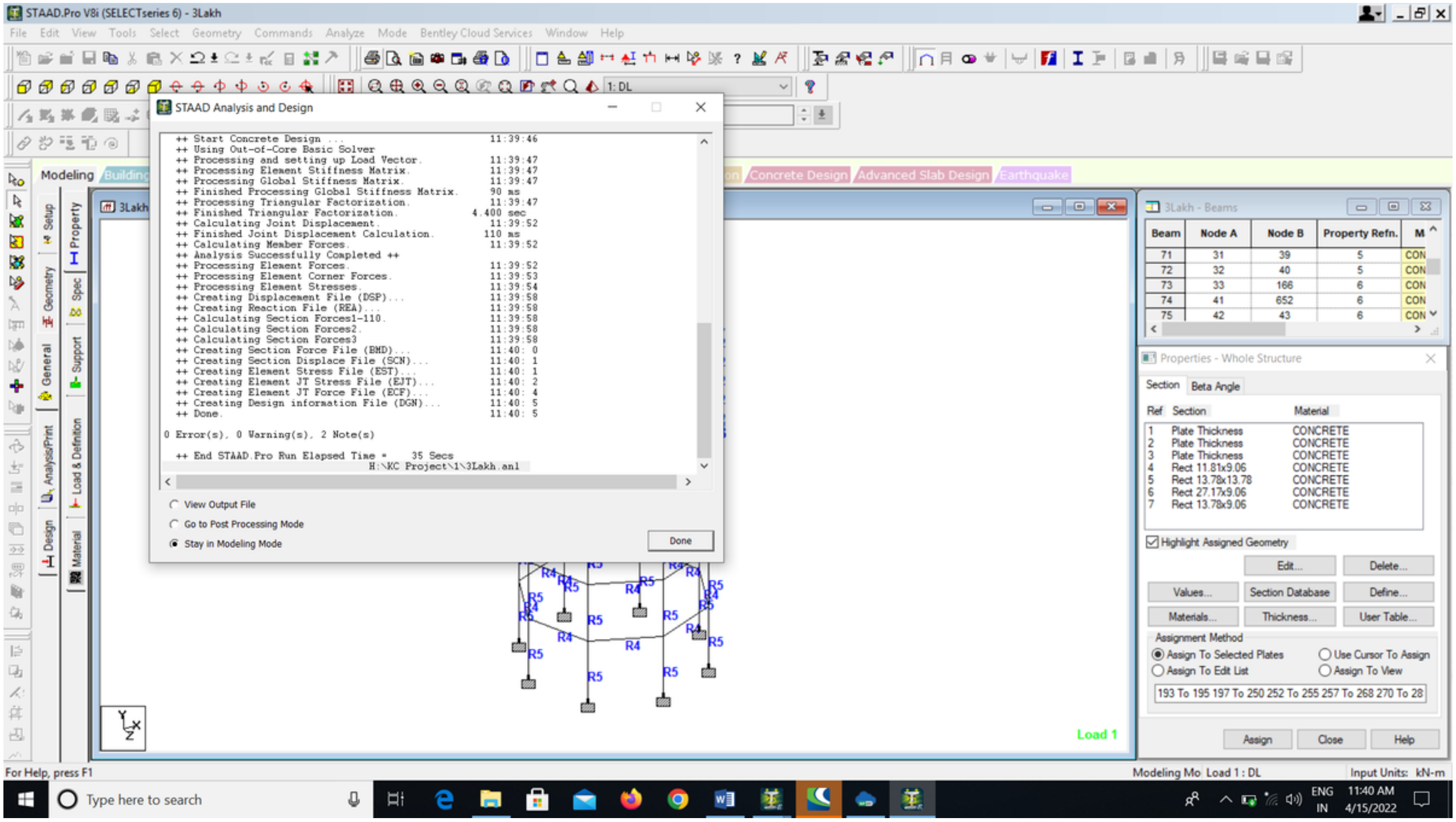
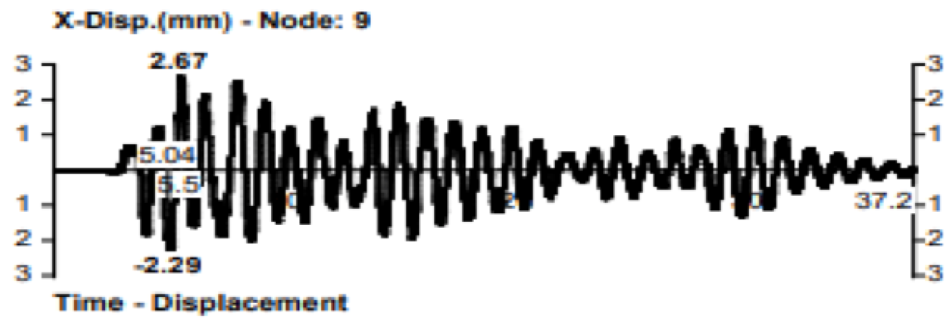


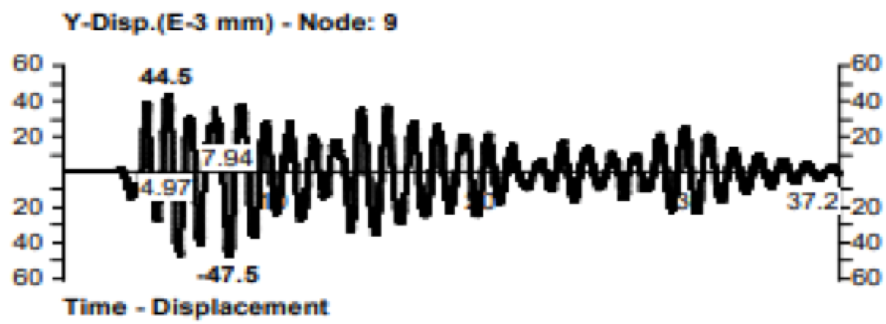
Figure 5

Figure 3.5: Perform (Run) Analysis



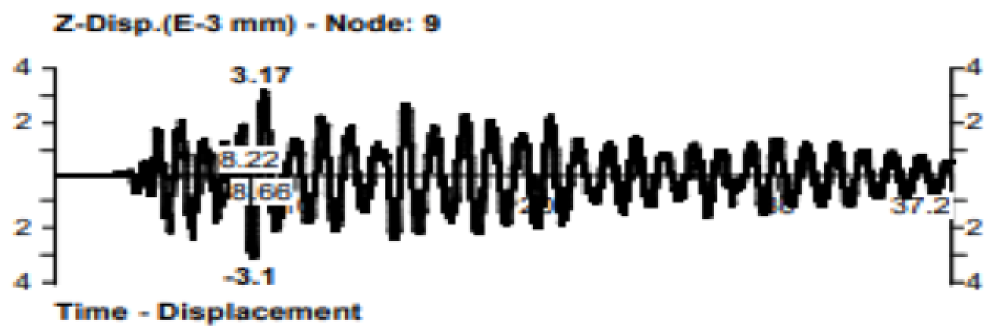
X

(a) X - Direction



y

(b) Y - Direction

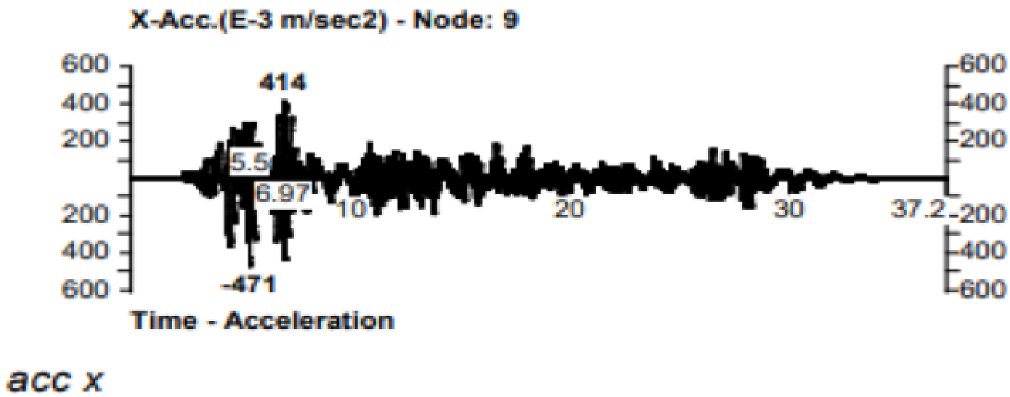


z

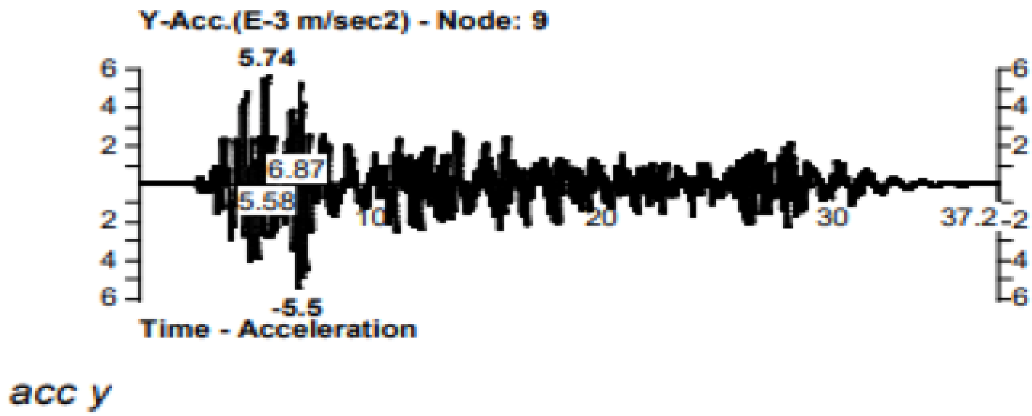
(c) Z - Direction

Figure 6

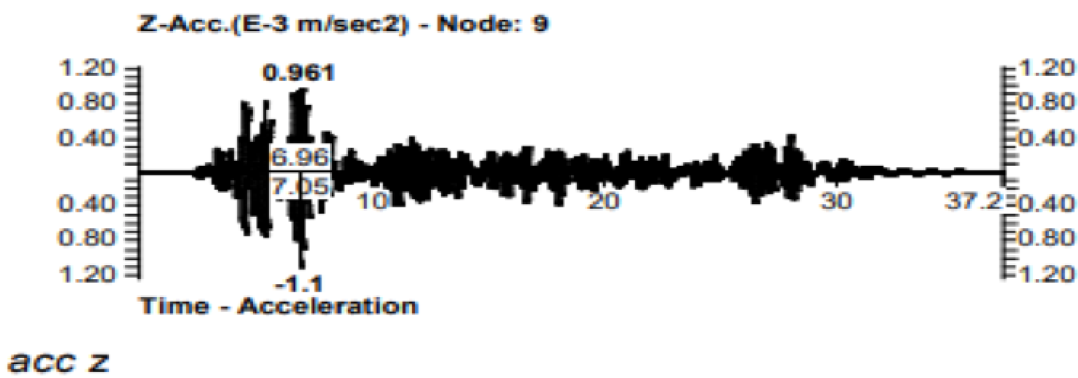
Figure 4.1 (a) (b) (c) Time vs. Displacement.



(a) X - Direction



(b) Y - Direction



(c) Z - Direction

Figure 7

Figure 4.2 (a) (b) (c) Time vs. Acceleration.