# Hydrodynamic Analysis & Design of Elevated Service Reservior Using Composite Column

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***Abstract-*** *This paper present the comparative equivalent static and time history analysis of elevated encased composite column water tank is during earthquake. The RCC column staging of elevated water tank can be replace by a encases composite column staging water tank, because the RCC water tank developed the cracks during earthquake, result in loss of their of strength and stiffness, so increase performance of elevated water tank during earthquake to study the behavior of composite elevated water tank. Therefore the parametric studies on mathematical model of six water tank are creating in ETABS software. These are both tank has been create models in an ETABS for a different height from ground level. The Indian draft code part II of IS 1893:2002*

*Which has provision of elevated water tank. The equivalent analysis with regards time periods, base shear, and storey stiffness displacement against height and storey drift.*

***Keywords***- Pushover, ETABS, Performance Point, Non-linear

## I. INTRODUCTION

### 1.1 Introduction to project work

The significant social and economic impacts of recent earthquakes affecting urban areas have resulted in an increased awareness of the potential seismic hazard and the corresponding vulnerability of the existing elevated storage water tank required for estimating seismic risk. Greater effort has been made to estimate and mitigate the risks associated with these potential losses. In order to successfully mitigate potential losses and to aid in post-disaster decision-making processes, the expected damage and the associated loss in urban areas caused by earthquakes should be estimated with an acceptable degree of certainty. Seismic loss assessment depends on the comprehensive nature of estimating vulnerability. The determination of vulnerability measure requires the assessment of the seismic performances of elevated water tank typically constructed in an urban region when subjected to a series of earthquakes, taking into account the particular response characteristics of each structural type. The fragility study generally focuses on the generic types of construction because of the enormity of the problem. Hence, simplified structural models with random properties to account for the uncertainties in the structural parameters are used for all representative structure types.

### 1.2 Alternative construction Techniques-

There are various techniques are used for the fulfillment of demand of construction industry. Some of them are popular due to availability of men, material & money, some of them are popular due to their practicality of design.

There are mainly three types of Construction techniques used for the high rise buildings construction and these are:

- RCC Construction
- Steel Structures
- Composite or hybrid Construction

### 1.3 Composite construction

Now a day’s composite is famous one in foreign countries due to their suitability in construction, also it overcomes the disadvantages of RCC & Steel construction which make the composite or hybrid beneficial for high rise construction though the composite resist lateral forces more effectively compared to the RCC & steel.

In composite structure the advantage of bonding property of steel and concrete is taken in to consideration so that they will act as a single unit under loading. These essentially different materials are completely compatible and complementary to each other; they have almost the same thermal expansion; they have an ideal combination of strengths with the concrete efficient in compression and the steel in tension; concrete also gives corrosion protection and thermal insulation to the steel at elevated temperatures and additionally can restrain slender steel sections from local or lateral-torsional buckling. In conventional composite construction, concrete rests over steel beam and under loading conditions these two component acts independently and a relative slip occurs at the interface of concrete slab and steel beam, which can be eliminated by providing appropriate connection between them. So that steel beam and slab act as composite beam and gives behavior same as that of Tee beam. In steel concrete composite sections both steel and concrete resists external loads together and helps to limit sway of the building frame. It should be added that the combination of concrete cores, steel frame and composite floor construction has become the standard construction method for multi-story commercial buildings in several countries. The main reason for this preference is that the sections and members are best suited to resist repeated earthquake loadings, which require a high amount of resistance and ductility.

**1.3.1 Composite Frame Element**

A composite member is constructed by combining concrete member and steel member so that they act as a single unit. As we know that concrete is strong in compression and weak in tension on the other side steel is strong in tension and weak in compression. The strength of concrete in compression is complemented by strength of steel tension which results in an efficient section. By the concept of this composite member the concrete and steel are utilized in well-organized manner.

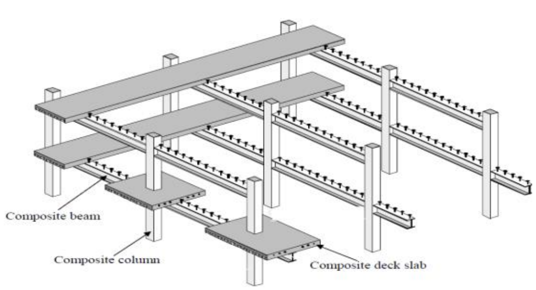



Fig no.1: Composite Frame

**Composite Element-**

The primary structural components used in composite construction consist of the following elements.

a) Composite Slab
b) Composite Beam
c) Composite Column
d) Shear Connector

## II. METHODOLOGY

To perform the proposed project work it is necessary to adopt the proper methodology, which can helpful to meet requirement of proposed objective of this work in all respect. It also provides the base and gives the strong support for this work. It contains theoretical concepts, design philosophy & analysis of members etc.

**Adaptability of computer programs**

It is well known fact the distribution of mass and rigidity is one of the major considerations in the seismic design of moderate to high rise buildings. Invariably these factors introduce coupling effects and non-linearity in the system; hence it is imperative to use non-linear static analysis approach by using specialized programs viz.SAP2000, STAADPRO2005, ETAB, IDARC, NISA-CIVIL, etc., for cost-effective seismic evaluation and retrofitting of buildings.

**2.1 Methods of Analysis**

**Seismic Analysis**

Seismic analysis is a subset of structural analysis and is the calculation of the response of a building (or non-building) structure to earthquakes. It is part of the process of structural design, earthquake engineering or structural assessment and retrofit (see structural engineering) in regions where earthquakes are prevalent.

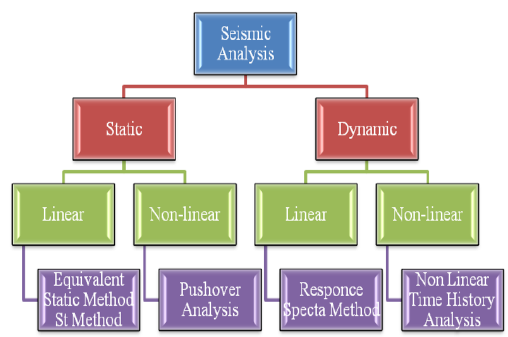


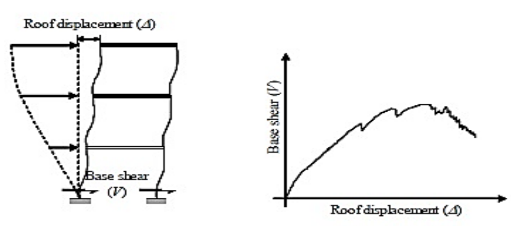

Fig No.2 Tree Diagram of Seismic Analysis

**2.2 Pushover analysis (Non-Linear Static Analysis)**

This is the important chapter in this project work considering meeting the requirement of proposed objective. This chapter gives the information regarding pushover analysis which is going to be performing using ETABs. It describes the concept of pushover analysis which is helpful in understanding the phenomena of building performance during its performance.

- Pushover analysis is a static, nonlinear procedure using simplified nonlinear technique to estimate seismic structural deformations.

- It is an incremental static analysis used to determine the force-displacement relationship, or the capacity curve, for a structure or structural element.
- The intensity of the lateral load is slowly increased and the sequence of cracks, yielding, plastic hinge formation, and failure of various structural components is recorded.
- The process continues until the design satisfies pre-established performance criteria. The performance criteria for pushover analysis are generally established as the desired state of the building given roof-top or spectral displacement amplitude.
- Pushover analysis is a simplified nonlinear analysis whose central focus is generation of the pushover curve or capacity curve.
- This represents the lateral displacement as a function of force applied to the structure.
- This capacity curve is representation of the structures ability to resist the seismic demand.
- To generate the capacity curve, the structure is pushed in a representative lateral load pattern which is applied monotonically while the gravity loads are in place.
- For a given structure and ground motion, the displacement demand is an estimate of maximum expected response of building during ground motion. Once capacity curve and demand displacement are defined, a performance point can be determined.
- The analysis techniques are recommended by FEMA-356 and a main component of the Spectrum Capacity Analysis method (ATC-40)




a) Building model b) Pushover curve

A predefined lateral load pattern as shown in fig. which is distributed along the building height is then applied. The lateral forces are increased until some members yield.

The structural model is modified to account for the reduced stiffness of yielded members and lateral forces are again increased until additional members yield. The process is continued until a control displacement at the top of building reaches a certain level of deformation or structure becomes unstable.

**2.2.1 Purpose**

The purpose of pushover analysis is to evaluate the expected performance of structural systems by estimating performance of a structural system by estimating its strength and deformation demands in design earthquakes by means of static inelastic analysis, and comparing these demands to available capacities at the performance levels of interest. The evaluation is based on an assessment of important performance parameters.

**2.2.2 Necessity**

The existing building can become seismically deficient, since seismic design code requirements are constantly upgraded and advancement in engineering knowledge. Further, Indian buildings built over past two decades are seismically deficient because of lack of awareness regarding seismic behavior of structures. The widespread damage especially to RC buildings during earthquakes exposed the construction practices being adopted around the world, and generated a great demand for seismic evaluation of existing building.

**2.2.3 Description**

The nonlinear static pushover procedure was originally formulated and suggested by two agencies namely, Federal Emergency Management Agency (FEMA) and Applied Technical Council (ATC), under their seismic rehabilitation programs and guidelines. This is included in the documents, FEMA356 and ATC40.

**a) FEMA356**

The primary purpose of FEMA356 document is to provide technically sound and nationally acceptable guidelines for the seismic rehabilitation of buildings. The guidelines for the seismic rehabilitation of buildings are intended to serve as a ready tool for design professionals for carrying out the design and analysis of buildings, a reference document for building regulatory officials, and a foundation for the future development and implementation of building code provisions and standards.

**b) ATC40**

Seismic evaluation and retrofit of concrete buildings commonly referred to as ATC40 was developed by the Applied Technology Council (ATC) with funding from the California Safety Commission. Although the procedures recommended in this document are for concrete buildings, they are applicable to most building types.

ATC40 recommends the following steps for the entire process of evaluation and retrofit:

1. Initiation of a project: determine the primary goal and potential scope of the project.
2. Selection of qualified professionals: select engineering professionals with a demonstrated experience in the analysis, design and retrofit of buildings in seismically hazardous regions. Experience with PBSE and nonlinear procedures are also needed.
3. Performance objective: choose a performance objective from the options provided for a specific level of seismic hazard.
4. Review of building conditions: perform a site visit and review drawings.
5. Alternatives for mitigation: check to see if the nonlinear procedure is appropriate or relevant for the building under consideration.
6. Peer review and approval process: check with building officials and consider other quality control measures appropriate to seismic evaluation and retrofit.
7. Detailed investigations: perform a nonlinear static analysis if appropriate.
8. Seismic capacity: determine the inelastic capacity curve also known to pushover curve, covert to capacity spectrum.
9. Seismic hazard: obtain a site specific response spectrum for the chosen hazard level and convert to spectral ordinates format.
10. Verify performance: obtain performance point as the intersection of the capacity spectrum and the reduced seismic demand in spectral ordinates (ADRS) format. Check all primary and secondary elements against acceptability limits based on the global performance goal.

**2.3 Design Parameters**

1. Total load
2. Base shear
3. Storey displacement
4. Storey drift
5. Pushover curve

**2.4 DETAILS OF PROJECT WORK**

For the study, elevated service reservoir analyzed with different staging heights are considered; each water tank is modelled as Reinforced cement concrete, Concrete filled tube and Encased Composite Column water tank.

The models which are used in this report is 12m staging height from the ground level. The above models are analyzed for static and Time History records of earthquake such as Kobe, Bhuj. The comparative static analysis of both tank for hard soil and seismic zone V.

**Future scope**

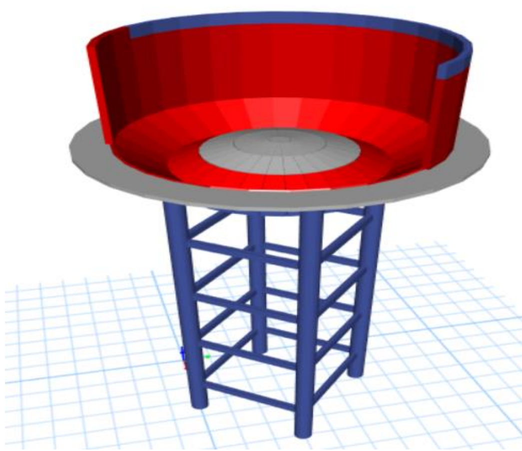
Try to suggest the suitability of composite structure as compared to RCC & steel structures. The project work helps to understand the different parameters of pushover analysis of composite, RCC & steel structure respectively. Further extension of work gives the capacity based design concept which is measure parameter of strong column & weak beam theory.

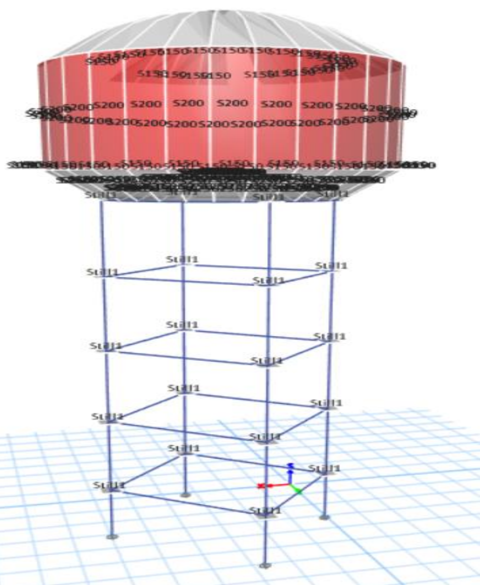
**Geometric & material properties**

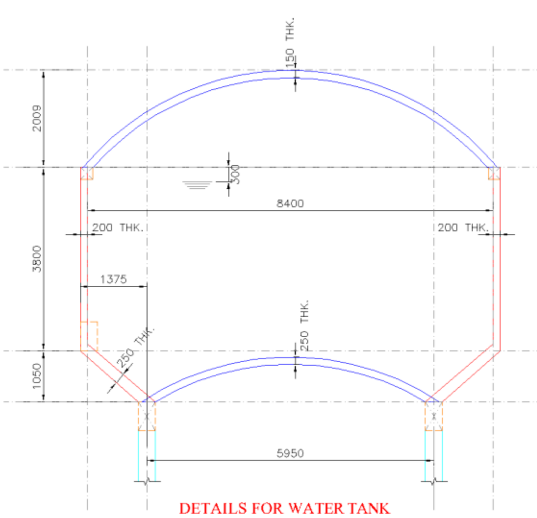
**Table no. 1**

| Description | RCC structure | Composite structure |
|---|---|---|
| Plan dimension | 5.95m X 5.95m | 5.95m X 5.95m |
| Total height | 19m | 19m |
| Depth of footing | 2m | 2m |
| Size of beam | 200mm X 300mm<br>200mm X 450mm<br>200mm X 600mm | 200mm X 300mm<br>200mm X 450mm<br>200mm X 600mm |
| Size of column | RCC 600mm Dia | CFT 450mm Dia<br>CIS 450X450 mm |
| Slab thickness | 200mm<br>150mm | 200mm<br>150mm |
| Bottom slab thickness | 250mm | 250mm |
| Side wall thickness | 200mm | 200mm |
| Dead load | Self weight | Self weight |
| Live load | 1.5KN/m2 | 1.5KN/m2 |
| Hydrodynamic load (Max. at Bottom) | 45KN/m2 | 45KN/m2 |
| Seismic zone | IV | IV |
| Soil condition | Medium | Medium |
| Response reduction factor | 5 | 5 |
| Importance factor | 1.5 | 1.5 |
| Zone factor | 0.24 | 0.24 |
| Grade of concrete | M30 | M30 |
| Grade of steel | Fe500 | Fe500 |
| Damping ratio | 5% | 5% |

**Geometrical Details of water tank**





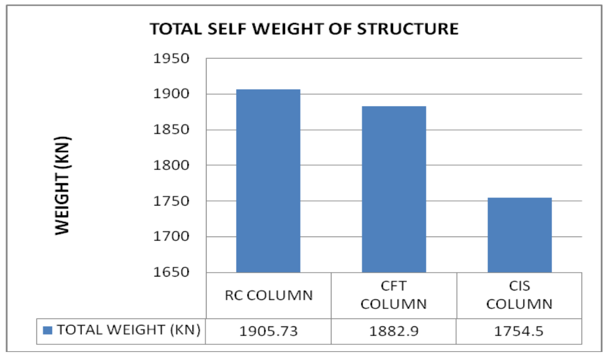



### 2.4.1 Dead load

It is the total dead load of frame. Results show that the total load of CFT is maximum as compare to the steel-concrete composite frame which is given in table no. 2

Table No. 2 : Dead Load

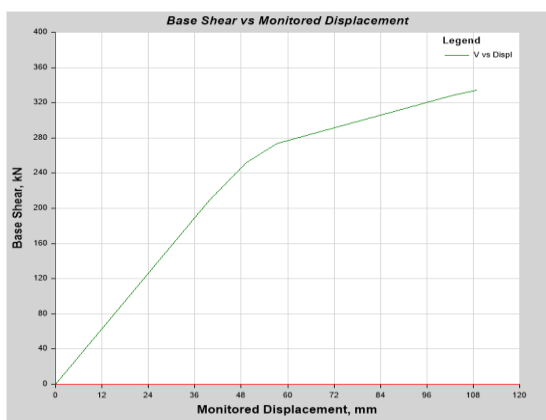
| SR. NO | STRUCTURE WITH COLUMN PROFILE | TOTAL WEIGHT (KN) |
|---|---|---|
| 1 | RC COLUMN | 1905.73 |
| 2 | CFT COLUMN | 1882.9 |
| 3 | CIS COLUMN | 1754.5 |




Graph No. 1

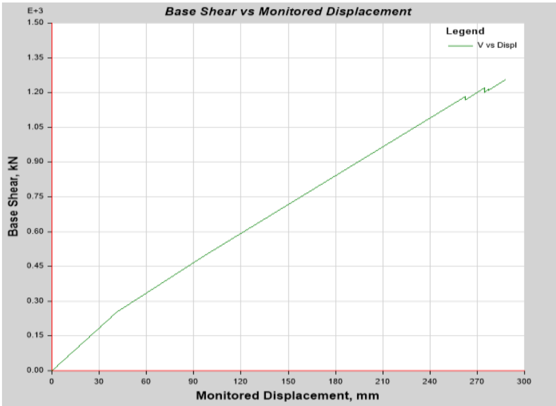
### 2.4.2 Base Shear Vs Displacement (Pushover Curve)

#### 2.4.2.1 Pushover Curve for RCC Column frame



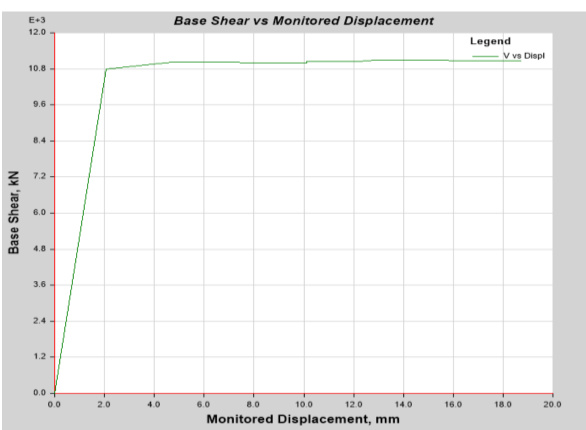

| Monitored Displ | Base Force |
|---|---|
| mm | kN |
| 0 | 0 |
| 39.829 | 209.2952 |
| 49.428 | 251.6613 |
| 57.338 | 273.446 |
| 102.311 | 328.2001 |
| 102.316 | 328.1117 |
| 103.722 | 329.4988 |

**2.4.2.2 Pushover Curve for CFT Column frame**




| Monitored Displ | Base Force |
|---|---|
| mm | kN |
| 0 | 0 |
| 41.21 | 252.0322 |
| 96.795 | 496.9031 |
| 185.264 | 864.3959 |
| 262.371 | 1183.0866 |
| 262.376 | 1169.044 |
| 274.376 | 1220.4333 |
| 274.381 | 1207.9776 |
| 274.386 | 1201.919 |
| 277.253 | 1215.6298 |
| 277.258 | 1209.4689 |
| 288.015 | 1255.5691 |

**2.4.2.2 Pushover Curve for CIS Column frame**




| Monitored Displ | Base Force |
|---|---|
| mm | kN |
| 0 | 0 |
| 2.077 | 10781.1164 |
| 4.71 | 11018.4987 |
| 10.109 | 10992.0893 |

| Monitored Displ | Base Force |
|---|---|
| mm | kN |
| 10.127 | 11050.2177 |
| 12.196 | 11039.6676 |
| 12.889 | 11097.9638 |
| 18.725 | 11065.5532 |

## III. RESULTS AND CONCLUSION

Inelastic/pushover analysis of both RCC & Composite frame is carried out using ETAB. The outcome from the analysis is described with respective to various parameters in this chapter and comparative analysis is done with RCC frame. The results from above analysis shows that in case of dead load and in case of pushover curve displacement of RCC frame is lesser as compared to composite section.

Hence we can conclude that the RCC are more preferable than composite sections.

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