Evaluation of Soil Structure Interaction Effect for Tanks under Earthquake with Different Foundations Soils

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Abstract. Though the structures are supported on soil, most of the designers do not consider the soil structure interaction and its subsequent effect on the structure during an earthquake. Different soil properties can affect seismic waves as they pass through a soil layer. When a structure is subjected to an earthquake excitation, it interacts with the foundation and soil, and thus changes the motion of the ground. It means that the movement of the whole ground structure system is influenced by type of soil as well as by the type of an engineering structure. Tanks are supposed to be of construction in sense that they might have been analyzed and designed to meet the provision of relevant codes of practice and building bye-laws. IS 1893:2002 “Criteria for Earthquake Resistant Design of Structures” gives response spectrum for different types of soil such as hard, medium and soft. An attempt has been made in this paper to study the effect of Soil-structure interaction on multi storeyed buildings with various foundation systems as well as to study the response of buildings subjected to seismic forces with Rigid and Flexible foundations. Tanks with fixed and flexible support subjected to seismic forces were analysed under different soil conditions like hard, medium and soft. The buildings were analysed by Response spectrum method using software by ABAQUS program. A structural model using the generalized single degree of freedom (SDF) system is proposed for seismic design of concrete rectangular Liquid Containing Structures (LCS). The proposed model considers the effect of flexibility of tank wall on hydrodynamic pressures and uses the consistent mass approach. The proposed model is compared with the results obtained using the current practice as well as the finite element method. It is concluded that the current approach in design codes and standards does not truly represent the behaviour of LCS. The proposed model using the generalized SDF system can be simply used in seismic design of LCS.

Keyword: response spectrum, ABAQUS program, earthquake, soil structure interaction

1 Introduction
Dynamic forces are present in every engineering problem although they are only considered to be significant in few specific scenarios. The highest profile situation is when an engineering structure is subjected to earthquake induced loading. Finite element is the most commonly accepted analysis tool for a solution of engineering problems. Effective pre and post processing capabilities make modelling and interpretation of results simple. It is relatively easy to incorporate changes, if any, and repeat the analysis without much loss of time. Viewing of animated mode shapes and dynamic response makes understanding of the dynamic behaviour of the machine foundation system relatively simpler [1]. Auditing of vivified mode shapes and powerful response makes viewing the direct component of the machine foundation structure reasonably less complex [2].
As waves from a tremor land at a structure, they plan movements in the structure. These movements depend on the structure's vibrational viewpoints and the plan of structure. As those structure will react with the movement, it necessitates with succeed its very own lethargy constrain, which realizes a joint effort amid the centre of those structure and the dirt. Those degrees with which the basic response changes those viewpoints about seismic tremor movements viewed toward this system level depends on the relative impostor and immovability thus properties of the soil and the structure. Thusly, this physical property of the system medium is a foremost computed in this shake response from asserting structures supported on it. This approach for which the response of the dirt effects this development of the structure and the development of the structure impacts the response of the earth will be named Similarly as soil-structure affiliation (SSI) [3].

The Investigation of the component collaboration about soils and structures changes fundamentally Concerning delineation of the specific physical issue changes. There are no under four evolving soil-structure interactional issues (Christian Furthermore Hall, 1982):

1. Vibrating mechanical assembly for the most part is decently little appeared differently in relation to this level of the setting up soil, and the basic states would Typically the people Throughout oversaw activity of the provisions. Hence, a persevering state result to a structure found at then again shut the outside of a half-space is commonly satisfactory. The device attempts to compelled What's increasingly known frequencies.

2. The following influence effect following on the other hand affects security incorporates a transient issue for amazingly few, regularly one, beats about overpressure. Unflinching state response and the pointless contemplations and direct free to move around at will times are not especially fundamental.

3. Seismic tremors incorporate long data signs that have rich repeat substance Also huge segments cycles about load reversal. An immediate outcome the waves proliferate In a good separation, the showing for considerable Furthermore frustrated geometries is a basic issue. The enter development is normally not extraordinary known Also might be routinely determined amid a darken then again severely masterminded region [4].

4. Immense toward the ocean structures information precisely transient reaction, yet the persisting state light of wave stacking is by far most enormous for exhaustion split issues.

The earth direct strategy under component stacking depends on some number elements, including: 1. The method for the dirt (penetrability, relative thickness, texture, etc).

2. Nature's area of the earth (static pressure state and water weight).

3. The methods for the dynamic stacking (strain greatness, strain rate, Also number for cycles for stacking).

Liquid holding structures (LCS) Concerning representation and just normal building workplaces are essentially used for water sewage prescription plants. Regularly, they require help developed from guaranteeing strengthened. Concrete in the structure of rectangular on the other hand equipment arrangements. At present is there a couple of codes Furthermore estimates open for seismic arrangement from asserting LCS secured close by North America. On Just about the larger part for codes Also gauges, those Housner's model (Housner, 1963) require to component Investigation of LCS. This model approximates the effect of hydrodynamic load to a twofold-symmetric-liquid compartment oppressed on level quickening as demonstrated over figure 1(a). Those hydrodynamic loads that provoked Eventually Tom's examining tremors would be separated under two sections of indiscriminate convective fragments which would approximate eventually Tom's scrutinizing those lumped included massenet. The included impostor As far as hasty weight might be acknowledged rigidly
regarding this tank divider and the included impostor. As far as convective weight might be acknowledged related with the tank divider using versatile springs to reproduce the effect about sloshing development. In this model, the limit condition in the check about hydrodynamic loads might be dealt with Concerning representation inflexible [4].

Despite the way that the Housner's model needs to be associated in the seismic arrangement from asserting LCS before, later examinations show that on account of the doubt of the lumped included impostor and the inflexible tank divider, this technique prompts exorbitantly preservationist impacts. Chen Also Kianoush (2005) framed a framework implied on Similarly as those back to back system to enrolling hydrodynamic loads subordinate upon a two-dimensional model to rectangular tanks On which the effect about flexibility of tank divider may have been contemplated. Ghaemian et al. (2005) associated the stunned procedure on deal with the coupled liquid limit tank issues in. Three-dimensional space. Appeared differently in relation to those Housner's model, these Outcomes show that by and vast the lumped impostor strategy overestimates base shear and base moment basically. Chen and Kinaoush (2007) recommended A summed up single dimension of adaptability (SDF) structure for dynamic examination for LCS. The unaltering impostor philosophy and the effect for versatility about tank divider around hydrodynamic loads were seen as the embraced vibration state limits addressing such mode shapes for those cantilever divider limit conditions that were affirmed. In this paper, this prescribed auxiliary model using the summed up SDF system will be looked at for the Housner's model grasped in the present blueprint codes for more standards. Those framework diagrams for the included impostor of liquid in view of imprudent hydrodynamic weight and the relating convincing stature would be displayed. The responsibility from asserting higher methods of the changing response about LCS might be incorporated into the prescribed model. Base of entire of money about square (SRSS) technique is used for mixing the underlying two modes. The outcomes are contrasted and the people got using those Housner's model and moreover those restricted part strategy. It might be recommended that present setup philosophy necessity should make changes this prescribed auxiliary model using the summed up SDF system could be seen as clear model on beat those present lacks for layout for LCS [5].

2. The comparison of the investigation model by claiming movement.

The Houser's model (1963) is shown in figure 1(a). Figure 1(b) shows An cantilever tank divider with the scattered impostor m(y) and solidity EI(y) for every unit stature laid open of the tremor ground reviving üg(t). This divider shows a limitless amount of degrees about chance to flexural system for response. Due to the possibility that there would be a percentage for destined shapes to estimate the vibration of the framework, during that perspective the development of the skeleton camwood makes depicted Eventually Tom's perusing a single variable, or summed dependent upon organize over which just An solitary DOF exists. The skeleton appreciated in that capacity may be alluded with Concerning illustration the summed up SDF frameworks. In this examination, the summed up SDF skeleton may be associated with disentangle dynamic response of liquid stockpiling tanks uncovered will seismic tremors. Those condition for development of the summed up SDF skeleton is that [7];

\[ M\cdot u + c\cdot u + k\cdot u = p\.(1) \]

The place m, , c, k, p are portrayed Concerning illustration those summed up course of action from claiming mass, damping, solidity What's more force independently.
For straightforwardness, the endorsed vibration shape work SF1 speaking to the primary mode shape for the cantilever divider limit condition can be utilized in powerful investigation as follows:

\[ SF_1(y) = \Psi(y) = \frac{3y^2 - y^3}{2H^2w} \quad (2) \]

The legitimacy of the shape work SF1 was checked and examined in the past examination (Chen and Kianoush, 2007).

The immediate coupling strategy is utilized in the dynamic investigation. The collaboration among fluid and tank divider is fathomed straightforwardly in the condition of movement utilizing the additional mass strategy [6].

\[ p = \sum_{m}^{n} \frac{2}{H} \frac{\tanh(\lambda_m L)}{\lambda_m H} \cos(\lambda_m y) \int_{0}^{L} \cos(\lambda_m y) \cdot \ddot{u}(t) \, dy \quad (3) \]

The place \( \lambda_i = (2i-1)\pi/2HL \). For illustrating the plan in the over state mix quick, the polar introductory for be three money house under the course of action would be used to practical provisions.

When using the summed up SDF skeleton in the changing examination for LCS, the hydrodynamic weight may be combined under those coupling examination through the extra impostor. The summed is dependent upon the great incorporated impostor of.

Liquid due to hasty hydrodynamic weight, \( 1 \, m \sim \) What's more \( 1 \, m \), might a chance to be controlled using Eqns. 2. 4 and 2. 5 independently.

2.1. Included impostor of fluid.

The hydrodynamic weight camwood gives a chance to be handled using the separation for Components method which fulfills those limit states. The hydrodynamic weight scattering on the versatile divider state might make communication follows:
In perspective of those Housner's model, the extent of the fruitful included impostor from asserting liquid due to hasty hydrodynamic weight $I_\text{m}$ of the absolute impostor for liquid in the control $I_\text{m}$ is imparted as:

$$M_\text{i}/ML = \tanh[0.866(L_x/HL)]/0.866(L_x/HL) (5).$$

Relatively to the summed up SDF framework, the extent of summed up and fruitful included impostor for liquid on account of hydrodynamic load to the embraced mode condition of the half impostor for liquid to LCS, I. E. $L_\text{m}/M$ and $l_\text{m}/M$, could be figured. It will be important that appeared differently in relation to the out and out impostor for liquid in the Housner's model, only An expansive part of the impostor about liquid will be seen as in the summed up SDF system In light of those two-overlay symmetric fluid basic model.

Figures 2(a) and 2(b) show the included impostor of liquid in light of impulsive load regarding to the Hounser's model and state work SF1 for the essential mode state using the summed up SDF structure is equivalent. In any case, the results got using by Housner's model need help of multiple occasions from asserting the people got using $\psi(y) = 1$ to the summed up SDF system perceiving those overlay symmetric-liquid auxiliary model. The reason behind the Contrast as a result of the resistance is a direct result of the particular schedules used inside the calculation from guaranteeing hydrodynamic weight. In this investigation, the hydrodynamic weight might be registered using those speed probability systems. It will be acknowledged that the liquid will be perfect, which might be incompressible What's more inviscid. Nonetheless, A direct newtonian gooey shear model might be used inside the Housner show which may furthermore realizes firm response.

$$\dot{m}_\text{i} = \sum_{\text{n}=\text{odd}} \frac{2}{\lambda_\text{n}} \cdot \tanh(\lambda_\text{n} L_x) \cdot \left[ \int_0^{H_1} \cos(\lambda_\text{n} y) \cdot \psi(y) dy \right]^2$$

$$m_\text{i} = \sum_{\text{n}=\text{odd}} \frac{2}{\lambda_\text{n}} \cdot \tanh(\lambda_\text{n} L_x) \cdot \left[ \int_0^{H_1} \cos(\lambda_\text{n} y) \cdot \psi(y) dy \right] (4)$$
Figure 2 shows the proportion from the claiming included impostor for fluid due to incautious hydrodynamic weight versus Lx/HL proportion (HL = HW[4]).

2.2 powerful statures.
In the exhibit arrangement practice, the inertial mass of robust divider and the extra impostor about liquid due to hydrodynamic weight would be lumped during the described capable statures. The inertial mass about robust tank divider is lumped at the point of convergence of gravity of the tank divider. In the off chance that the tank divider will be uniform [10], the the greater part of crazy
inertial mass for tank divider is lumped at those mid-stature of the divider. Those extra impostors about liquid due to hasty hydrodynamic weight may be lumped at the centroid of the rash parallel energy. This stature might a chance to be controlled using Eqns. 2. 7 Furthermore 2. 8 as pursues (ACI 350. 3, 2006):

For tanks with \( \frac{L_x}{HL} < 1.333 \), hello there/HL=0.5-0.09375 \((L_x/HL)\) (6).

To tanks with \( \frac{L_x}{HL} \geq 1.333 \).

Greetings there/HL=0.375 (7).

In the summed dependent upon SDF framework, the fruitful statures during which the feasible included impostor from claiming liquid due to hydrodynamic weight will be connected, the camwood be controlled Likewise pursues:

Figure 3 shows the institutionalized great tallness in which the hydrodynamic weight will be associated as ability of the extent about A large portion width of tank on liquid profundity \( \frac{L_x}{HL} \) to the full tank state for instance \( hl = HW \). Those figure shows the starting two modes, the unyielding divider limit condition \( \psi(y)=1 \) and the Housner's model. It has a tendency to be uncovered that those urging statures greetings obtained from the Hounser's model and the firm divider cutoff state \( \psi(y)=1 \) are similar.

For liquid holding structures, the feasible tallness in which the finish capable sidelong force may joined camwood a chance to be dictated using Eqn. 2. 10. This explanation incorporates both those effects from claiming inertial mass about tank divider and the extra impostor about liquid due to hydrodynamic weight [11].

\[
h = \frac{m_h \cdot h + m_z \cdot h_i}{m_h + m_z}
\]

(9).

It will be significant to consider the versatility about tank divider, the forcing tallness \( h \) at which the all level interesting control is associated is higher than that procured from the unyielding divider condition.

Figure 3 shows the compelling tallness Components for incautious hydrodynamic weight versus \( \frac{L_x}{HL} \) proportion (HL = HW) [6].
2.3. impact about higher Modes.

the similar technique is used on exceptional examination of LCS to principal mode canwood a chance to be joined on the element examination to higher modes. Those square base from claiming square (SRSS) methodology camwood a chance to be used to the blend for higher modes. Toward and large, those thought of the introductory two modes ought with provide for enough exact conclusions to setup purposes [12].

3. Finite-Element Implementation for Dynamic-Analysis of LCS

In this investigation, another FEM procedure In light of the sureness that hydrodynamic weight spread is enacted by wave scientific proclamation secured close by liquid Web-area will be utilized to affirm occurs. Tolerating that water will be incompressible Furthermore ignoring its consistency, those little adequacy silly development of water will be enacted Toward those two-dimensional wave condition:

\[ \nabla^2 P(x, y, t) = 0 \] (10).

In the coupling system for liquid – structure the loads require help associated of the structure surface outline the heaps on the compartment dividers. The numerical entire explanation about fluid – structure may have an opportunity to be created in the going with shape:

\[
\begin{bmatrix}
  M & C & K & H & G \\
  C & H & G & 0 & 0 \\
  K & G & 0 & 0 & 0 \\
  H & G & 0 & 0 & 0 \\
  G & 0 & 0 & 0 & 0 \\
\end{bmatrix}
\]

(11)

To which, [M], [C] Also [K] would mass, damping What's more solidness frameworks from claiming structure same time [H] Also [G] need aid talking should robustness Furthermore ignoring its range. The haul [C’] is the damping grid for liquid which may be subject of the thickness about liquid and wave digestion over liquid space What's more cutoff points. The system [Q] exchanges the liquid weight of the structure in the same way that assistant reviving of the liquid space [13].

A 8-hub isoparametric part with two interpretations level from claiming good fortune for each centre may be used to show the tank dividers and station. The liquid space is showed by using four-hub isoparametric fluid parts with weight level from claiming chance done each centre. Those restricted part presentation is used on investigate the behaviour of a tall tank Toward ABAQUS system.

Displaying.

In this examination, a tall tank acknowledged officially will be for the illustration an arrangement model. the estimations and properties of the tank would as for every those be as follows:

Lx=9. 8m, Hw=10m, HL=10m, tw =1. 2m, Ec=20. 776x103MPa, ρw= 2300 kg/m3, ρl =1000 kg/m3, ν= 0. 17.

Those want response reach subject to ASCE 7-05 will be used to get those responses ghostly expanding pace. Those parameters for the structure response extend would be[13]:

(1) brief time the vast majority amazing extraordinary response expanding speed: Ss=1. 25 (2) 1-second best ghostly response quickening: S1=0. 60 (3) site class b. The figuring using those set part technobabble (FEM) and the ACI 350. 3 code would be presented in this examination. Those set part method recommended in the secret word examination (Chen Furthermore Kianoush, 2005) to model 4 is used to the affirmation. The predictable impostor for both tank divider and the included impostor of liquid due to rash hydrodynamic weight are recognized in the FEM. Likewise, those conclusions using those suggested FEM systems are contrasted with the individuals related for incorporated impostor FEM method and ACI code. Those Indeed going a piece recorded for 1940 El-Centro is used as
excitation of the schema. Those considerably section might have been scaled Along these lines that peak ground speeding up accomplishes 0.4g. The model configuration will be depicted done figure 4. ACI 350.3 (2006) code recognizes the effect for adaptability through those.

(2) reaction progress component r. It may be huge that the response transform component r and the hugeness variable I, need aid not viewed as in this examination (for sample r and i need aid acknowledged Concerning illustration solidarity). In this way, the correspondence between the suggested model and ACI 350.3 code may be dependent upon versant examination.

A substitute sorts for segments were used with presentation the issue something like that as to get the inside anxieties Also part instance in the calculated strip offset Also worries in the foundation dirt. Those bar part might have been used will show those steel backing. A essential bilinear weight strain twist will be used On steel fortress will exhibit the yield stress On weight and weight which depended upon those sort of the used steel bars [10, 14].

Plain strain isoperimetric four-hub quadrilateral segments were used clinched alongside two situations. The principal might have been used the show the strip offset attaching under possibility the non-linearity about bond [9, 10]. The material model identifies with parts of bond done biaxial weight states and provides for the softening and pulverizing cases of bond. The basic key for performing non-direct examination about bond is a straight, versant and powerless material over pressure, also elastoplastic done weight. The robust need a confined breaking point Previously, restricting strain, furthermore is hence allowed should break The point when the standard anxieties surpass those sensible pliable weight (st). The second sort of part might have been used to present the soil media, contemplating the nonlinearity for dirt Eventually Tom's perusing using Duncan-Mohr-Coulomb altered model [9, 11,12]. In last, the breaking points of the soil networking were shown by left What's more straight two-hub unbounded components, which portray the soil rationality [9, 13]. Inference of the key numerical states analyzings to diverse parts might have been as of late acquainted Toward [9-14]. Hence worth of effort from claiming such segments On reenacting those parity dirt issue could indicate certified issues [14]. A pc project might have been made uncommonly for this examination Previously, which the thought something like straight What's more non-direct constrained What's more wearisome parts of the model were executed. The proposed instance size of the building 30m X 30m, sort of structure : RCC Multi story outlines, seismic zone v , reaction decline component - 3, significance component – 1, stature of the building-40m, no about storey– 10, stature for floor – 4m, forced load – 4 kN/m², Materials – M25(beam), M30(column), Fe415, profundity of the area – 150mm, unit load for RCC – 25kN/m³, sort from claiming dirt – difficult , medium and Soft, reaction spectra – may be 1893(Part I) 2002 , Damping 5% , profundity of stronghold - 1. 5m, divider thickness-230mm. Table 1 exhibits those estimation from claiming dirt strength done level (x and z) What's more verthandi (y) direction[8].

Table1. Soil Stiffness Values For Buildings With Flexible Base[10]

| type of soil | Soil Stiffness (kN/m) | Kx  | Kz  |
|-------------|----------------------|-----|-----|
| hard        |                      | 8000| 8000|
| Medium      |                      | 4000| 4000|
| soft        |                      | 1500| 1500|
Figure 4 Finite Element Mesh Configuration

The estimation results are condensed in Table 1 for the tall tank. The correlation of the outcomes got utilizing both FEM methods and the proposed model shows great understanding. In any case, the base shear got utilizing ACI 350.3 Code is about 1.85 occasions higher than that acquired utilizing the proposed summed up SDF framework. The base minute for ACI 350.3 Code when contrasted with the proposed summed up SDF framework is about 1.36 occasions higher. It is presumed that the structure utilizing the Hounser's model received in the present plan measures and codes is excessively traditionalist. Table (2 and 3) and Figs. (5 and 6) demonstrate Lateral redirection of tanks with settled base. Figs. (5 and 6) show horizontal diversion with adaptable base.

Table (2) Lateral deflection of tanks with fixed base (mm)

| Height | Soft soil | Medium soil | Hard soil |
|--------|-----------|-------------|-----------|
| 1<sup>st</sup> | 7         | 6           | 5         |
| 2<sup>nd</sup> | 20        | 18          | 17        |
| 3<sup>rd</sup> | 38        | 30          | 20        |
| 4<sup>th</sup> | 42        | 38          | 30        |
| 5<sup>th</sup> | 58        | 50          | 38        |
| 6<sup>th</sup> | 70        | 58          | 42        |
| 7<sup>th</sup> | 80        | 62          | 50        |
| 8<sup>th</sup> | 82        | 77          | 58        |
| 9<sup>th</sup> | 90        | 78          | 59        |
| 10<sup>th</sup> | 99        | 80          | 60        |

Table (3) Lateral deflection of tanks with flexible base (mm)

| Height | Soft soil | Medium soil | Hard soil |
|--------|-----------|-------------|-----------|
| 1<sup>st</sup> | 148       | 80          | 48        |
| 2<sup>nd</sup> | 152       | 90          | 50        |
| 3<sup>rd</sup> | 162       | 95          | 56        |
| 4<sup>th</sup> | 170       | 100         | 60        |
| 5<sup>th</sup> | 182       | 105         | 63        |
| 6<sup>th</sup> | 190       | 112         | 72        |
| 7<sup>th</sup> | 200       | 113         | 80        |
| 8<sup>th</sup> | 202       | 120         | 83        |
| 9<sup>th</sup> | 206       | 135         | 85        |
| 10<sup>th</sup> | 211       | 141         | 91        |
4. Conclusion

Due to lateral deflection, Base shear values increase when the type of soil changes from hard to medium and medium to soft for fixed and flexible base buildings. Because of lateral deflection, Base shear and Moment values of fixed base building was found to be lower as compared to flexible base tanks. The change type of foundation for building that will change all behaviour of tanks for the hard, Medium, Soft soil since the lateral deflection increase about (54.6%, 62.4%, 127.6%). Hence suitable foundation system considering the effect of Soil stiffness has to be adopted while designing tanks for seismic forces.
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