IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
IJARSCT
Impact Factor 6.252
Volume 2, Issue 1, July 2022

Study on Soil Structure Interaction for Earth Retaining Structure

Sabyath Shetty and Shashwathi S Shetty
Department of Civil Engineering
N.M.A.M. Institute of Technology, Nitte, Karnataka, India
shettysabyath@nitte.edu.in and shashwathishetty99@gmail.com

Abstract: *Earth retaining structures have suffered damages under past earthquakes. Usually, the analyses do not consider the retained soil interaction with the structure, which takes place during dynamic conditions. The objective of this study is to perform an engineering assessment of soil-structure interaction (SSI) features of selected earth retaining walls. This report mainly deals with the seismic analysis of earth retaining structure using ETABS software under the effect of soil structure interaction. A proper understanding of the soil-structure interaction plays a key role in the efficient design of geotechnical structures. This general report of Soil-Structure Interaction and Retaining Walls summarizes with both dynamic and static loading analysis condition.*

Keywords Earth Retaining Structure, Soil Structure Interaction, ETABS

I. INTRODUCTION

General 1.1

Soil structure interaction consists of the interaction between soil (ground) and a structure built upon it. It is primarily an exchange of mutual stress, whereby the movement of the ground-structure system is influenced by both the type of ground and the type of structure. This is especially applicable to areas of seismic activity. Various combinations of soil and structure can either amplify or diminish movement and subsequent damage. A building on stiff ground rather than deformable ground will tend to suffer greater damage. A second interaction effect, tied to mechanical properties of soil, is the sinking of foundations, worsened by a seismic event. This phenomenon is called soil liquefaction.

Most of the civil engineering structures involve some type of structural element with direct contact with ground. When the external forces, such as earthquakes, act on these systems, neither the structural displacements nor the ground displacements, are independent of each other. The process in which the response of the soil influences the motion of the structure and the motion of the structure influences the response of the soil is termed as soil-structure interaction (SSI).

Based on conventional theories it has been said that the soil structure interaction has effects that are beneficial for the structural response. Most of the design codes for structures recommends neglecting the effect of SSI in the seismic analysis of the structure. This recommendation is because of the false myth that the SSI brings good response of the structure and hence have chances to increase the safety margins. More flexible structural design can be obtained if we consider the effects of soil structure interaction. This helps in increasing the natural period of the structure. This provides an improved structure when compared to a corresponding rigid structure. Incorporation of SSI effects on the structural design helps in increasing the damping ratio of the structure. This study is limited or neglected for conservative design procedures. The SSI analysis is very complicated in nature. The neglection will reduce the complexity in the analysis of the structures. This means that the myth put forward that the SSI effects are good for structures is not true. In fact, SSI can bring detrimental effects to structures. Neglecting SSI effect can bring unsafe design of the superstructure and the substructure.

The effects of the SSI are more focused on its detrimental effects. As mentioned, even if studies have told that the design based on soil structure interaction increases the time period, increase in time period is not always a beneficial factor. There is elongation of seismic waves when it is on a site of soft soil sediments. This results in the increase of the natural period hence leading to resonance. This happens with a long period vibration. If the natural period increases, the demand for ductility also increases. This may result in permanent deformation and soil failure that will further worsen the structural seismic response. A structure under the action of seismic force (seismic excitation), there is interaction between the soil and foundation which brings changes in the ground motion.

The Structures that are built to retaining soil, clay, gravel, stones etc through its weight or flexural ability are called earth retaining structures. There are different types of earth retaining structures such as gravity retaining structures, cantilever retaining structures etc all of them performs the same function using different behavior towards detainment. Earth retaining structures sometimes also called retaining walls plays a vital role in field of Structural engineering, Geo-technical Engineering, Transportation engineering, water resources engineering and many other fields of civil engineering.

The study of soil-structure interaction (SSI) is related to the field of earthquake engineering. It is very important to note that the structural response is mainly due to the soil-structure interaction forces that brings an impact on the structure. This is a form of seismic excitation. A committee of engineering research deals with the study of soil-structure interaction only when these forces bring an appreciable effect on the basement motion when we are comparing it with the free-field ground motion. The free-field ground motion can be defined as the motion recorded on the surface of the soil, without the involvement of the structure. The structural response to an earthquake is highly dependent on the interactions between three linked systems, namely:

- The structure
- The Foundation
- The underlying soil

The soil-structure interaction analysis is the method of evaluating the collective response of the three linked systems mentioned above for a specified ground motion. The soil-structure interaction can be defined as the process in which the response from the soil influences the motion of the structure and the motion of the given structure affects the response from the soil. This is a phenomenon in which the structural displacements and the ground displacements are independent to each other. Soil-structure force are mainly interaction forces that can occur for every structure. But these are not able to change the soil motion in all conditions.

A structure, when analysed by considering its foundation to be rigid, is said to have no soil-structure interaction effects. Now, this case is considered even if the interaction force impacts the foundation. The influence on the soil motion by the interaction forces will depend upon:

- The magnitude of the force
- The flexibility of the soil foundation

The base mat acceleration and the inertia of the structure can be used to estimate the value of interaction forces. The heavier the structure the more is the soil-structure interaction effects for a particular soil site and for a given free-field seismic excitation. Most of the civil structure, whether it is lying on the hard or effects are more dealt with heavy structures that includes hydraulic structures like dams, nuclear power plants (NPP) reactor buildings. We can conclude that the soil interaction in earthquake engineering study was mainly developed and applied for these fields of construction industry. Another condition considered the soil-structure interaction effects are the soil flexibility. Softer is the soil, more is the chances for the occurrence of SSI effects. This is for a given structure and a site that have a free -field seismic excitation. The product of mass density of the soil and the square of shear wave velocity will give the soil shear module**.** In practice, the mass density of the soil will vary around 2,0 t/m3. Hence the main characteristic of soil stiffness can be considered to be the shear wave velocity(V_S)

If Vs< 300m/s then the soil is considered to be soft

If Vs> 800m/s then the soil is considered to be hard.

If Vs > 1100m/s the soil is considered to be rigid.

Based on conventional theories it has been said that the soil structure interaction has effects that are beneficial for the structural response. Most of the design codes for structures recommends neglecting the effect of SSI in the seismic analysis of the structure. This recommendation is because of the false myth that the SSI brings good response of the structure and hence have chances to increase the safety margins. More flexible structural design can be obtained if we consider the effects of soil structure interaction. This helps in increasing the natural period of the structure. This provides an improved structure when compared to a corresponding rigid structure. Incorporation of SSI effects on the structural design helps in increasing the damping ratio of the structure. This study is limited or neglected for

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

Volume 2, Issue 1, July 2022

Impact Factor 6.252

conservative design procedures. The SSI analysis is very complicated in nature. The neglection will reduce the complexity in the analysis of the structures. This means that the myth put forward that the SSI effects are good for structures is not true. In fact, SSI can bring detrimental effects to structures. Neglecting SSI effect can bring unsafe design of the superstructure and the substructure.

The effects of the SSI are more focused on its detrimental effects. As mentioned, even if studies have told that the design based on soil structure interaction increases the time period, increase in time period is not always a beneficial factor. There is elongation of seismic waves when it is on a site of soft soil sediments. This results in the increase of the natural period hence leading to resonance. This happens with a long period vibration. If the natural period increases, the demand for ductility also increases. This may result in permanent deformation and soil failure that will further worsen the structural seismic response. A structure under the action of seismic force (seismic excitation), there is interaction between the soil and foundation which brings changes in the ground motion. The soil structure interaction can have two types of phenomena or effects (As per FEMA P-750, NEHRP). They are:

- Kinematic Interaction
- Inertial Interaction
- Soil Foundation flexibility effects

Kinematic Interaction

The soil displacement caused by the earthquake ground motion is called as the free-field motion. This free field motion is not followed by the foundation that is located on the soil. The kinematic interaction is caused by the inability of the foundation to sink with the free field motion of the ground.

Inertial Interaction

The additional deformation caused in the soil due to the transmission of inertial force to the soil by the superstructure is called as the inertial interaction. When the ground shaking is of low level, the kinematic effect of SSI is more prominent. This results in the lengthening of period and there is increase in the radiation damping. When stronger shaking commences, the radiation damping is limited by the soil modulus degradation in the near field and the soil pile gaping. At this situation, the inertial damping is more prominent. This will hence cause excessive displacements near the ground surface. This will bring damage of the pile foundations. The study and researchers from the past and recent earthquakes show that the overall response of the structure is affected by the:

- Response from the foundation
- Response from the soil

The SSI have become great cause in the collapse of large structures when subjected to earthquake. These include the Hanshin Expressway, in 1995 due to the Kobe earthquake. Following are the factors to which the above-mentioned effects are related to:

Stiffness and Damping of the foundation

- When a vibrating structure develops inertia force it give rise to moments, torsion and base shear. These are the forces that brings displacements and rotation in the interface between the soil and the foundation. The formed displacement and the rotation are a result of flexibility lying in the soil and the foundation. This flexibility is the basic reason for whole structural stability. The displacements created results in energy dissipation. This affects the overall system damping. As all these effects are more rooted with the structural inertia it is called as the inertial interaction effects. **Variations Existing Between the Free-field motions and the foundation input motions** These motions can differ because of the: Kinematic Interaction
- Relative displacements between the foundation and free field
- The foundation motions are created by the stiff foundation elements that are placed either above or below the ground surface. This is done to have deviation from the free field motion, in the absence of structure and the foundation inertia forms the kinematic Interaction.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Impact Factor 6.252
Volume 2, Issue 1, July 2022

Foundation Deformation

The forces and the displacements applied on the foundation elements by the superstructure or the soil medium results in the flexural, axial and shear deformations. These parameters are the demands for which the components of the foundation must be designed. These effects are more significant in the case of foundation like rafts and piles.

Gurupura Bridge

The Gurupura bridge built over river Phalguni on NH-169 was 170-metre-long and 5.10 metre-wide connecting Kulshekara and Moodbidri built in 1923. Chunks of cement from under the bridge are falling into the river, and corroded rods are a common sight on the bridge. To make things worse, the motorable side of the bridge was also deteriorating. The surface of the bridge was worn out, and was safe for commuting.

Fig 1.1- Arial View of the Old Gurupura Bridge

The bridge could be maintained by carrying out general maintenance, and they didn't consider giving the bridge a facelift. The existing bridge cannot be widened as it is made of steel and dates back to almost a century ago. Hence constructing a new bridge was necessary.

Fig 1.2- Deterioting state of Old Gurupura Bridge

The new bridge was built parallel to the existing one. The new bridge across River Phalguni at Gurupura on NH 169 was inaugurated on 12th June 2020.Gurupura bridge, built at a cost of Rs 39.42 crore, is 175 meters long and 16 metres wide. Footpath of 2.5 metre width has been provided with a connecting road that is 11 meters wide.

IJARSCT
ISSN (Online) 2581-9429
Impact Factor 6.252
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Volume 2, Issue 1, July 2022

Fig 1.3- New Gurupura Bridge

II. LITERATURE REVIEW

1) H.H. Vaziri: "An efficient three-dimensional soil-structure interaction model for' analysis of earth retaining structures"

The solution procedure involves combining the stiffness matrix of the wall and soil system and computing the displacements from a knowledge of the stress changes due to excavation. An interative approach is adopted to apply the correcting forces at locations that reach active or passive states, thus resulting in correct displacements for plastic conditions that cannot be accounted for by the Mindlin's elastic solutions. The model is shown to provide matching results against a finiteelement model under plane-strain conditions. Application of the proposed model within the context of a practical project has demonstrated its role both as a predictive tool and as a theoretical model for performing sensitivity analysis and establishing practical guidelines to control magnitude and mode of wall deflections, which are important design considerations in excavations close to movement-sensitive structures.

2) Amin Rahmani, Mahdi Taiebat n, et.al "Evaluation of substructuring method for seismic soil-structure interaction analysis of bridges"

This paper evaluates the commonly used substructuring method for analysis of bridge systems where the bridge is divided into two sub-systems: the bridge superstructure and the substructure including the pile foundations, abutments, and soil. Modeling of the soil-structure interaction (SSI) in the system is simplified by replacing the pile foundations, abutments, and soil with sets of independent equivalent linear springs and dashpots at the base of the superstructure. The main objective of the paper is to examine how well the substructuring method simulates the seismic response of a bridge system. The baseline data required for the evaluation process is derived from analyzing a fully-coupled continuum bridge model, already validated for the instrumented two-span Meloland Road Overpass. The same bridge system is also simulated using the sub structuring method. The results from both approaches are compared, and it is shown that the differences between them can be significant. The sub structuring method consistently overestimates the pier base shear forces and bending moments and the pier top deflections. Moreover, the spectral response of the bridge structure is mis predicted. The analyses are repeated for a three-span bridge system subjected to several ground motions, leading to a similar observation as before. Hence, the current state of practice for simulating seismic SSI in bridges using the substructure model is shown to be too simplified to capture the major mechanisms involved in SSI.

3) Vishwajit Anand, S.R. Satish Kumar, "Seismic Soil-structure Interaction: A State of the Art Review"

The process of soil response influencing motion of the structure and vice-versa is termed as soil-structure interaction (SSI). SSI has been traditionally considered to be beneficial to seismic response of a structure. It has been suggested that ignoring SSI in design practice leads to a conservative design Though advances have been made in developing methods to solve an SSI problem, incorporating SSI in design practice has been a rarity. The present paper attempts to summarize various approaches to include SSI in analysis of structures and guidelines outlined in prominent seismic codes. The significance of such a study lies in the need for selection of appropriate approach. A review of contemporary research in field of SSI is also presented at the end. Contemporary research in field of SSI focus on either exploring its effects on certain structural type or finding rationale behind its effects on a general structural configuration. Parameters of interest include seismic vulnerability, seismic fragility, inelastic displacement ratio, strength reduction factor, ductility demand and modal characteristics. There have been recent attempts to study SSI effects on structures equipped with earthquake resistant systems such as tuned mass dampers and seismic base isolators. Another field of study which is gaining popularity is SSSI and associated phenomena of structural pounding.

4) Aditya Parihar, et.al "Effects of Wall-Soil-Structure Interaction on Seismic Response of Retaining Wall"
In this work emphasis has been made on the modeling of interface between structure and soil and the difference in displacement and stress response presented with their evaluated using finite element analysis and presented for static and seismic conditions. The problem has been analyzed using ANSYS.While modeling the retaining wall in continuum with backfill and foundation soil, the elements constituting the wall and soil are connected through same node. This prevents relative motion between wall and soil boundary, thereby the deflection and stresses are same at the corresponding points.The displacement response of retaining wall significantly changes with the introduction of interface. When interface movement is allowed the retaining wall move in outward direction which is the realistic situation.

5) Shin-Tower Wang "Application of Soil-Structure Interaction (SSI) in The Analysis of Flexible Retaining Walls"
In this paper is to model the structural elements in terms of overall behavior and to use nonlinear p-y curves for modeling the passive resistance of soils due to lateral deformation of embedded wall sections.p-y curve method Engineers can receive the information, such as the maximum bending moment, maximum shear, and the deflection profile, easily for the final design.This paper discusses the modifications of p-y curves that are needed to take into account the configuration of the wall system (group effects), the unsymmetrical driving forces in the backfill side, the soil resistance in the penetration side, and the long-term effect from the sustained loads.The results show that the p-y Curve method for design of anchored sheet-pile wall is rational and can also be adaptable for seismic conditions. It provides a reliable way to aid the designer in obtaining a more refined evaluation of the actual performance of anchored retaining walls, especially for the cases with seismic loading**.**

6) Bougherra, S. and Belgasmia, M. "Effect of soil structure interaction on the response of R.C building to seismic loads, a case study"
In this paper, an investigation about the dynamic response of a reinforced concrete structure subjected to seismic loads and designed by assuming the base coupled with discrete spring and dashpot elements, was carried out. The behaviour of the soil is accounted for by simple mechanical elements such as springs and dashpots. Different configurations was taken into account by connecting several springs and dashpots.Introducing SSI by adding springs and dashpots in a 3D model has an effect on the behaviour of the high-rise building, for a soft soil the building tend to have a lower capacity and collapses quickly than a building with a fixed base. Neglecting the effect of SSI affects the structural behaviour in an unconservative way. It is more relevant to introduce this effect and to do some changes in structural modelisation by incorporating the stiffness and the damping parameters of the soil.

III. OBJECTIVES

- To understand the behavior of Earth Retaining structure under the effect of soil structure interaction.
- To propose a soil structure interaction model by performing dynamic analysis.
- To determine the mode shape with respect to ground motion configuration.
- To conduct response spectrum analysis of existing retaining wall for different seismic zone.

IV. METHODOLOGY

The practical implication of analysis of the soil structure interaction of static and dynamic loading condition is to simulate staged construction in preference to the gravity turn-on procedure for static analysis because static stresses can have a significant effect on the computed dynamic response of the retaining structure. Soil-structure interaction can significantly affect the response of soil and the soil-supported or soil-supporting structure to an external load. Response spectrum analysis procedures provide rational means to model construction sequence and to allow for relative movements between distinctly different materials or surfaces. The analyses results presented in this paper demonstrate this facility using ETABS. Also, with the help of Winkler model some assumptions are made for the modelling of foundation such as deformation of foundation occur at loaded region only, soil medium is closely spaced, discrete and linearly elastic springs.

To collect the detail of retaining wall

↓

Modelling of the Retaining wall using ETABS Software.

↓

To analyse the structure for seismicloading using ETABS software.

↓

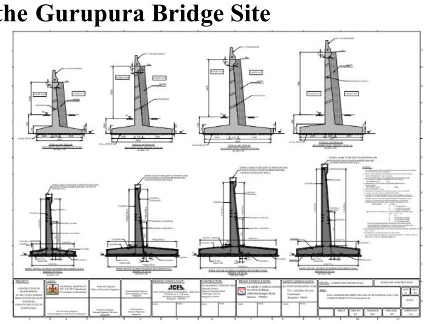
To conduct Response spectrum analysis of the retaining wall under different seismic zone.

V. WORK CARRIED OUT

Literature study is carried out
Learning of ETABS Software
Experimental Test Conducted
Modelling of Retaining Wall Structure using ETABS Software.
Modal Analysis is carried out for the Retaining Wall.
Response Spectrum Analysis for the Retaining Wall
What is E-tabs?

ETABS is an engineering software product that caters to multi-story building analysis and design. Modeling tools and templates, code-based load prescriptions, analysis methods and solution techniques, all coordinate with the grid-like geometry unique to this class of structure.

5.1 Design of the Retaining Wall of the Gurupura Bridge Site



5.1 Design of Retaining Wall

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
IJARSCT
Impact Factor 6.252
Volume 2, Issue 1, July 2022

5.2 Modelling of the Retaining Wall in ETABS Software

Dimensions:

- Top width of stem = 0.3m
- Thickness of base slab = 0.5m
- Bottom stem thickness = 1m
- Width of base slab = 7.1m
- Height of stem = 9m
- Width of toe slab = 2.9m
- Heel projection = 3.2

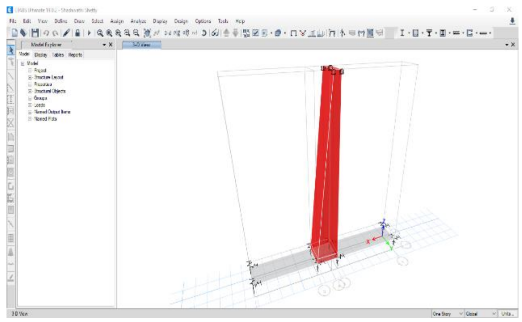


Fig 5.2- 3D View of Retaining Wall

5.3 Model Analysis

Modal Analysis considering the effect of higher modes on the structural performance. It is the combination of the responses of each mode with a constant lateral load pattern. The total response is determined from the response of each mode by a certain rule. Since the higher modes are taken into consideration, the modal analysis has a superior accuracy and fits the actual solution better. The response spectrum analysis (RSA) is introduced in this thesis which is shown to be equivalent to the modal pushover analysis for elastic systems. The advantage of modal pushover analysis lies in its accuracy and simplicity for nonlinear analysis.

To calculate the response of RC retaining wall and to characterize the displacement pattern due to free vibration responses modal analysis is carried out. The inelastic response spectrum analysis is regarded as an effective method for predicting seismic forces and deformation demands, which approximately accounts for the redistribution of internal forces that occurs when the structure is subjected to inertia forces that can no longer be resisted within the elastic range of structural behavior.

5.4 Mode Shape

A mode shape is the deformation that the component would show when vibrating at the natural frequency. It describes the deformation that the component would show when vibrating at the natural frequency.

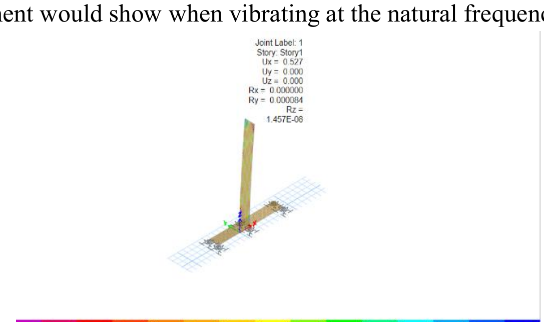


Fig 5.3- 1st Mode Shape

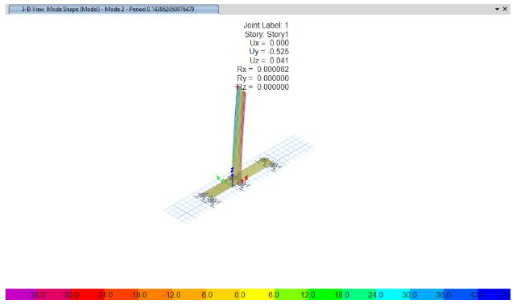


Fig 5.4- 2nd Mode Shape

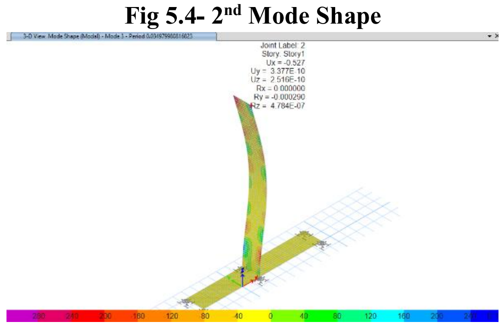


Fig 5.5- 3rd Mode Shape

5.5 Test Conducted

- Water content test IS 2720: Part-2
- Specific gravity testIS-2720-Part-3/section-1-1980 (Reaffirmed-2002)
- Standard proctor compaction: IS 2720-Part VII- 1980 (Reaffirmed-2011)
- Direct Shear test IS 2720-PART-13-1986

Water Content Test IS 2720: Part-2

The water content may be an extremely important index used for establishing the relationship between the way a soil behaves and its properties. The consistency of a fine-grained soil largely depends on its water content. The water content is also used in expressing the phase relationships of air, water, and solids in a given volume of soil.

Equipment Required: Drying oven, Balance, Moisture can, Gloves, Spatula.

Test Procedure:

1. Record the moisture can and lid number. Determine and record the mass of an empty, clean, and dry moisture can with its lid (MC)
2. Place the moist soil in the moisture can and secure the lid. Determine and record the mass of the moisture can (now containing the moist soil) with the lid (MCMS).
3. Remove the lid and place the moisture can (containing the moist soil) in the drying oven that is set at 105 °C. Leave it in the oven overnight.
4. Remove the moisture can. Carefully but securely, replace the lid on the moisture can using gloves, and allow it to cool to room temperature. Determine and record the mass of the moisture can and lid (containing the dry soil) (MCDS).
5. Empty the moisture can and clean the can and lid.

Water Content Test Data:

Table 5.1- Water Content Test

CONTAINER	A	B
Wt of container(W1) gm	68	66
Wt of wet sample (W2) gm	143	147
Wt of dry soil+ container (W3) gm	133	137
Wt of water (W2- W3)	10	10
Wt of dry soil (W3 -W1)	65	71

Result:
The water content of soil = 18.58%

Specific gravity testIS-2720-Part-3/section-1-1980 (Reaffirmed-2002)
The specific gravity of a soil is the ratio of the mass of a given volume of the material at a stated temperature to the mass of an equal volume of de-aired or gas-free distilled water at a stated temperature. The specific gravity of a soil is used in the phase relationship of air, water, and solids in a given volume of the soil.

Equipment Required:
1. Specific gravity- glass bottle of 50 ml capacity with a fitted glass stopper
2. Stopper - glass with small hole through centre to permit emission of air and water
3. Balance - 0.001 g sensitivity
4. Oven - capable of 1100
5. Thermometer
6. Funnel
7. Sand bath for heating

Procedure
1. First weigh 'W1' the specific gravity bottle.
2. Transfer the oven dried soil sample to the specific gravity bottle (about 50gm when the 250ml volumetric flask is used, about10-20gm when 50cc stoppered bottle is used or 100gm when 500ml pycnometer is used).
3. Weigh the bottle 'W2' again with the soil.
4. Add distilled water to fill the bottle to fill about three fourths.
5. Remove the entrapped air either by subjecting the contents to a partial vacuum or by boiling gently in a sand - bath till the air bubbles cease to appear while occasionally rolling the bottle to assist in removal of air.
6. Then cool to room temperature and fill the bottle with distilled water up to the mark and clean and dry the outside surface with a clean, dry cloth and note down the temperature.
7. Determine the weight of the bottle with water and soil, W3.
8. Then remove the soil and water from the bottle and clean it.
9. Again weigh 'W4' after filling with distilled water up to the mark and drying outside.
10. From data obtained determine specific gravity of the soil.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Impact Factor 6.252
Volume 2, Issue 1, July 2022

Fig 5.6- Specific Gravity Test

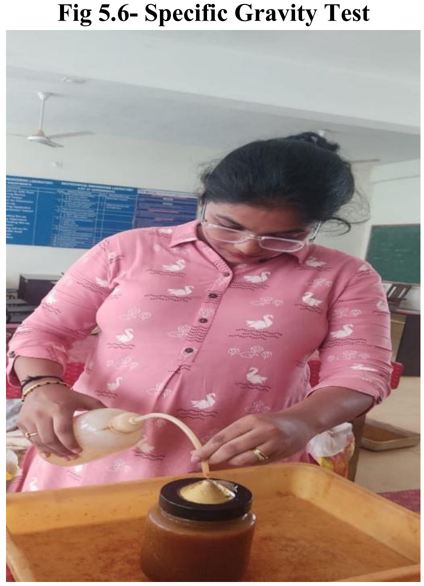


Fig 5.7- Specific Gravity Test Conduction

Specific Gravity Test Data:

Table 5.2- Specific Gravity Test

TRAIL	1	2
EMPTY WT OF THE PYCNOMETER(W1)	570	570
WT OF THE SOIL SAMPLE + PYCNOMETER(W2)	780	793
WT OF THE SOIL+PYCNOMETER+WATER(W3)	1584	1592
WT OF WATER+PYCNOMETER(W4)	1404	1401
SPECIFIC GRAVITY	2.76	2.79

Result:

The Specific Gravity of soil sample = 2.78

Standard Proctor Compaction: IS 2720-Part VII- 1980 (Reaffirmed-2011)

In geotechnical engineering, soil compaction is the process in which a stress applied to a soil causes densification as air is displaced from the pores between the soil grains. It is an instantaneous process and always takes place in partially saturated soil (three phase system). The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density.

Apparatus Required:

1. Proctor mould
2. Rammer
3. Sample extruder
4. spoon
5. trowel and spatula
6. A balance of 15 kg capacity
7. Sensitive balance
8. Straight edge
9. Graduated cylinder& Moisture tins

Procedure:

1. Take a representative oven-dried sample, approximately 5 kg in the given pan. Thoroughly mix the sample with sufficient water to dampen it with approximate water content of 4-6 %.
2. Weigh the proctor mould without base plate and collar. Fix the collar and base plate.
3. Place the soil in the Proctor mould and compact it in 3 layers giving 25 blows per layer with the 2.5 kg rammer falling through. The blows shall be distributed uniformly over the surface of each layer.
4. Remove the collar; trim the compacted soil even with the top of mould using a straight edge and weigh.
5. Divide the weight of the compacted specimen by 944 cc and record the result as the bulk density ρbulk.
6. Remove the sample from mould and slice vertically through and obtain a small sample for water content.
7. Thoroughly break up the remainder of the material until it will pass a no.4 sieve as judged by the eye. Add water in sufficient amounts to increase the moisture content of the soil sample by one or two percentage points and repeat the above procedure each increment of water added. Continue this series of determination until there is either a decrease or no change in the wet unit weight of the compacted soil.

Fig 5.8- Apparatus Used in Standard Proctor Compaction Test

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
IJARSCT
Impact Factor 6.252
Volume 2, Issue 1, July 2022

Fig 5.9- Test Conduction of Standard Proctor Compaction Test

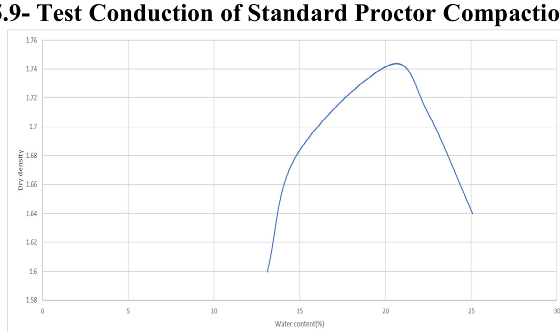


Fig 5.10- Graphical Representation of Standard Proctor Compaction Test

Standard Proctor Compaction Data:

Table 5.3- Standard Proctor Compaction

Determination no	1	2	3	4	5
Weight of cylinder + compacted soil	6543	6654	6708	6715	6670
Weight of compacted soil	1893	2004	2065	2058	2020
Average moisture content	14.802	18.57	20.29	22.47	25.09
Wet density	1.92	2.04	2.10	2.09	2.05
Dry density	1.67	1.72	1.73	1.68	1.63
Container no	23	12	6	15	27
Weight of container + wet soil	88.342	98.230	109.82	101.710	108.640
Weight of container + dry soil	86.048	95.061	103.00	95.00	101.00
Weight of container	70.550	78.000	69.40	65.15	70.55

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

Impact Factor 6.252

Volume 2, Issue 1, July 2022

Weight of water	2.294	3.169	6.820	6.710	7.640
Weight of dry soil	15.498	17.061	33.60	29.85	30.45
Percentage of water content	14.802	18.57	18.61	18.68	25.09

Result:
Maximum Dry density of soil=1.68g/cc

Direct Shear test IS 2720-PART-13-1986
Determination of shear strength parameters of a silty or sandy soil at known density and moisture content. As per IS: 2720(Part 13)-1986- Methods of test for soils: Direct shear test.

Apparatus Required:
1. Shear box
2. Box container
3. Porous stone and grid plate
4. Tamper, Balance, Sieve (4.75 mm)
5. Loading frame, Proving ring, Dial gauge

Procedure:
1. Shear box dimensions is measured, the box is set up by fixing its upper part to the lower part with clamping screws, and then a porous stone is placed at the base.
2. For undrained tests, a serrated grid plate is placed on the porous stone with the serrations at right angle to the direction of shear. For drained tests, a perforated grid is used over the porous stone.
3. An initial amount of soil is weighed in a pan. The soil is placed into the shear box in three layers and for each layer is compacted with a tamper. The upper grid plate, porous stone and loading pad is placed in sequence on the soil specimen.
4. The pan is weighed again and the mass of soil used is computed.
5. The box is placed inside its container and is mounted on the loading frame. Upper half of the box is brought in contact with the horizontal proving ring assembly. The container is filled with water if soil is to be saturated.
6. The clamping screws is removed from the box, and set vertical displacement gauge and proving ring gauge to zero.
7. The vertical normal stress is set to a predetermined value. For drained tests, the soil is allowed to consolidate fully under this normal load. (Avoid this step for undrained tests.)
8. The motor is started with a selected speed and shear load is applied at a constant rate of strain. Readings of the gauges are taken until the horizontal shear load peaks and then falls, or the horizontal displacement reaches 20% of the specimen length.
9. The moisture content of the specimen is determined after the test. The test is repeated on identical specimens under different normal stress values.

Fig 5.11- Direct Shear test Process

Fig 5.12- Direct Shear test Equipment

Result:

Shear strength parameter for soil used in this test are
Cohesion c =12.65kN/m^2
Angle of internal friction Φ=40.23

VI. RETAINING WALL STRUCTURE

Retaining wall is a structure that are designed and constructed to withstand lateral pressure of soil or hold back soil materials. The lateral pressure could be also due to earth filling, liquid pressure, sand, and other granular materials behind the retaining wall structure. There are various types of retaining wall structures which are used for numerous goals.

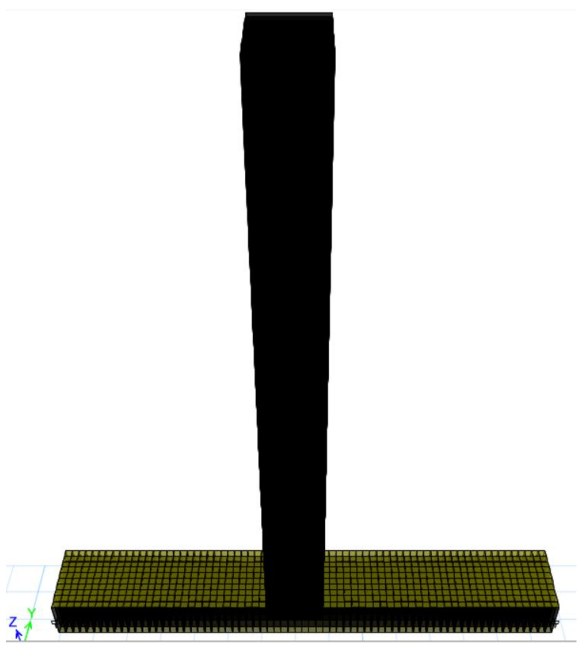


Fig-6.1 3D View of Retaining Wall

6.1 Specification of Structure

- Top width of stem = 0.3m
- Thickness of base slab = 0.7m
- Bottom stem thickness = 1m
- Width of base slab = 7.1m
- Height of stem = 8.15m
- Width of toe slab = 2.9m
- Heel projection = 3.2m
- Seismic Zone – III
- Seismic Zone Factor (Z) - 0.16
- Importance Factor (I) – 1
- Response Reduction Factor (R) – 5
- Function Damping Ratio– 5%

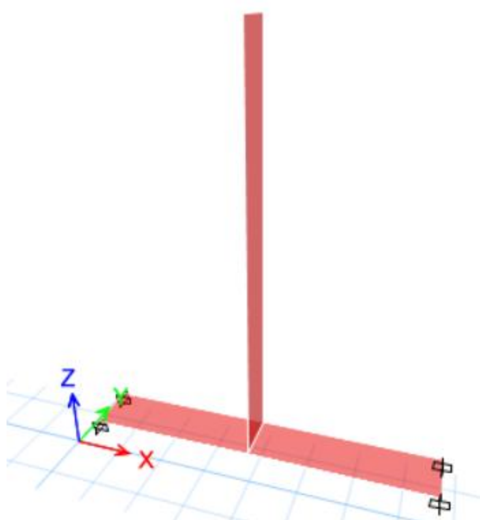


Fig-6.2 3D Frame Element of Retaining Wall

6.2 Modelling Approach

The general finite element package ETABS has been used for analyses. A three-dimensional model of each structure has been created to undertake equivalent static analysis called as response spectrum analysis. This approach permits the multiple modes of response of a building to be taken into account. The response of a structure can be defined as a combination of many modes due to harmonic excitation. For each mode a response is read from the design spectrum, based on modal frequency and the modal mass and they are then combined to provide an estimate of the total response of the structure. Base on the winkler's method it is assumed that the foundation model consists of closely spaced independent linear springs. If such a foundation is subjected to a partially distributed surface loading q, the springs will not be affected beyond the loaded region in such case an actual foundation is observed to have the surface deformation. The load deflection equation can be written as p = kw. The value of stiffness k=7702.9KN/m.

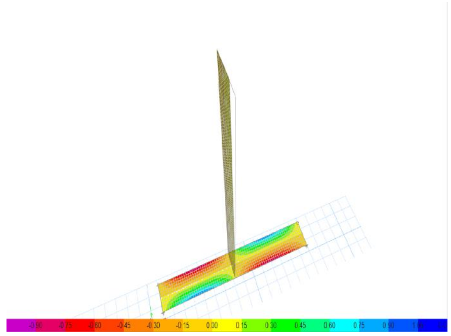


Fig-6.3 1st Mode Shape without SSI of Static Analysis

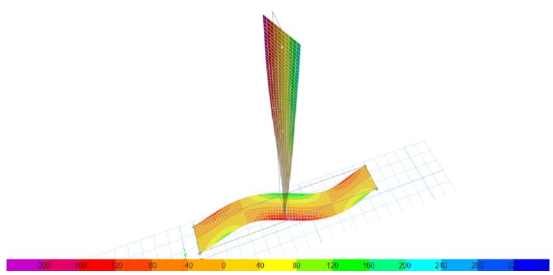


Fig-6.4 Final Mode Shape without SSI of Static Analysis

Table 6.1- Base Shear without SSI of Static Analysis

Output Case	Case Type	FX kN	FZ kN	MX kN-m	MY kN-m	MZ kN-m
Dead	LinStatic	0	269.42	134.71	-1093.65	0
Live	LinStatic	117.68	-103.41	-51.70	-422.30	-58.84
RSx	LinRespSpec	4.40	0.11	0.05	28.39	2.20
RSy	LinRespSpec	4.40	0.11	0.05	28.39	2.20
RS 1	Combination	148.09	199.39	99.69	-1774.81	-67.17
RS 1	Combination	134.35	199.02	99.51	-1863.44	-74.04
RS 2	Combination	148.09	199.3	99.69	-1774.81	-67.17
RS 2	Combination	134.35	199.02	99.51	-1863.44	-74.04

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
IJARSCT
Impact Factor 6.252
Volume 2, Issue 1, July 2022

Table 6.2 - Modal Periods and Frequencies without SSI of Static Analysis

Case	Mode	Period sec	Frequency cyc/sec	CircFreq rad/sec	Eigenvalue rad2/sec2
Modal	1	0.21	4.766	29.947	896.8219
Modal	2	0.193	5.181	32.5556	1059.8693
Modal	3	0.056	17.993	113.0532	12781.0288
Modal	4	0.032	31.316	196.7673	38717.3838
Modal	5	0.029	33.998	213.6142	45631.0268
Modal	6	0.018	57.03	358.3298	128400.2505
Modal	7	0.011	93.356	586.5753	344070.5621
Modal	8	0.011	93.636	588.3308	346133.1213
Modal	9	0.009	111.786	702.3731	493327.9384
Modal	10	0.008	132.377	831.7499	691807.8786
Modal	11	0.007	148.026	930.0747	865038.8712
Modal	12	0.007	153.393	963.7957	928902.0902

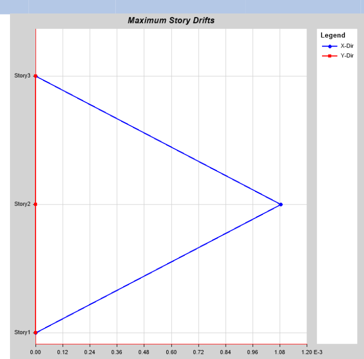


Fig-6.5 Maximum Drift without SSI of Static Analysis

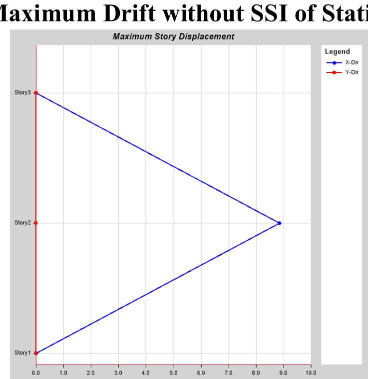


Fig-6.6 Maximum Displacement without SSI of Static Analysis

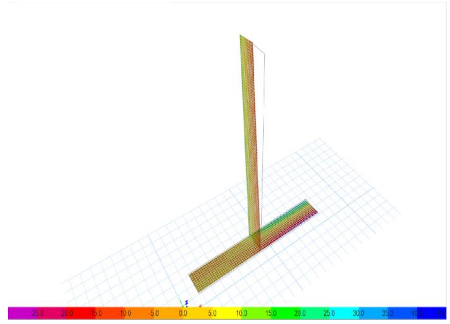


Fig-6.7 1st Mode Shape with SSI of Static Analysis

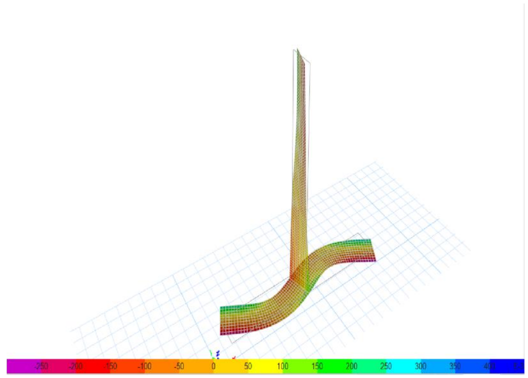


Fig-6.8 Final Mode Shape with SSI of Static Analysis

Table 6.3- Base Shear with SSI of Static Analysis

Output Case	Case Type	FX kN	FZ kN	MX kN-m	MY kN-m	MZ kN-m
Dead	LinStatic	0	269.42	134.71	-1093.6	0
Live	LinStatic	117.68	-103.41	-51.7062	-422.30	-58.84
RSx	LinRespSpec	7.65	0	0	32.81	3.82
RSy	LinRespSpec	7.65	0	0	32.8186	3.82
RS 1	Combination	153.16	199.20	99.60	-1767.95	-64.64
RS 1	Combination	129.28	199.20	99.68	-1870.34	-76.55
RS 2	Combination	153.16	199.20	99.68	-1767.95	-64.64
RS 2	Combination	129.24	199.20	99.68	-1870.34	-76.58

IJARSCT
ISSN (Online) 2581-9429
IJARSCT
Impact Factor 6.252
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Volume 2, Issue 1, July 2022

Table 6.4 - Modal Periods and Frequencies with SSI of Static Analysis

Case	Mode	Period sec	Frequency cyc/sec	CircFreq rad/sec	Eigenvalue rad2/sec2
Modal	1	1.777	0.563	3.53	12.49
Modal	2	0.33	3.028	19.02	362.06
Modal	3	0.105	9.527	59.86	3583.56
Modal	4	0.102	9.794	61.53	3787.07
Modal	5	0.09	11.127	69.91	4888.23
Modal	6	0.03	33.081	207.85	43202.5059
Modal	7	0.028	35.75	224.62	50455.8958
Modal	8	0.017	59.957	376.71	141917.6363
Modal	9	0.01	95.475	599.88	359863.6675
Modal	10	0.01	96.13	604.00	364818.6553
Modal	11	0.009	111.884	702.98	494189.4098
Modal	12	0.006	161.323	1013.61	1027423.841

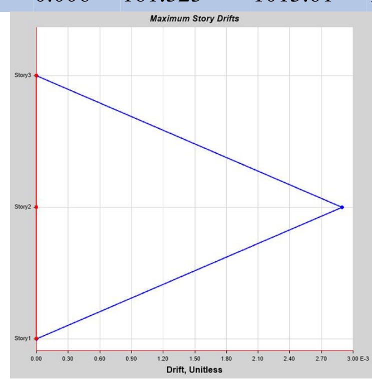


Fig-6.9 Maximum Drift with SSI of Static Analysis

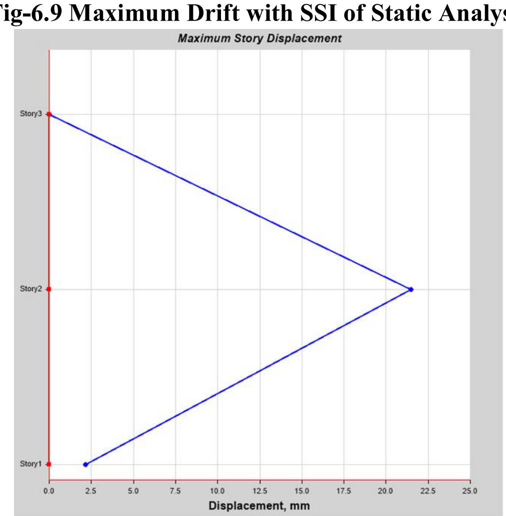


Fig-6.10 Maximum Displacement with SSI of Static Analysis

6.3 Response Spectrum Analysis

Response spectrum analysis is a method to estimate the structural response to short, nondeterministic, transient dynamic events. Examples of such events are earthquakes and shocks. The response spectrum method is based on a special type of mode superposition. The idea is to provide an input that gives a limit to how much an eigenmode having a certain natural frequency and damping can be excited by an event of this type. A response spectrum is a function of frequency or period, showing the peak response of a simple harmonic oscillator that is subjected to a transient event. The response spectrum is a function of the natural frequency of the oscillator and of its damping. Thus, it is not a direct representation of the frequency content of the excitation force but it is due to external agencies such as seismic effects and wind force impacting on the structure.

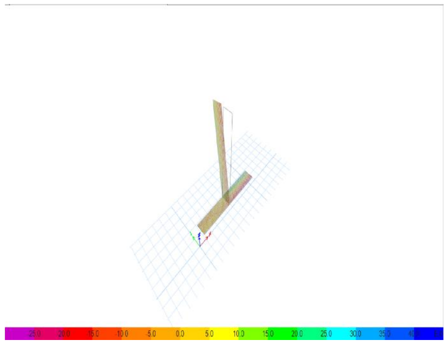


Fig-6.11 1st Mode Shape without SSI of Dynamic Analysis

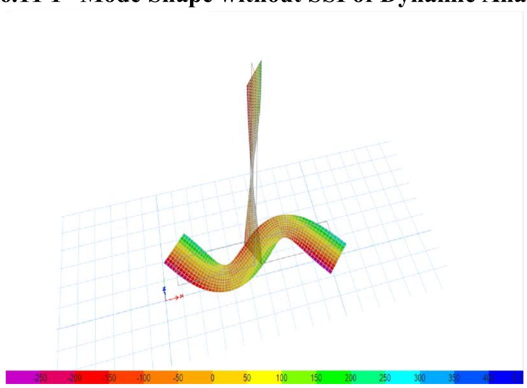


Fig-6.12 Final Mode Shape without SSI of Dynamic Analysis

Output Case	Case Type	FX kN	FY kN	FZ kN	MX kN-m	MY kN-m	MZ kN-m
Dead	LinStatic	0	0	269.42	134.71	-1093.65	0
Live	LinStatic	117.686	0	-103.41	-51.70	-422.39	-58.84

Table 6.5 - Base Reactions without SSI of Dynamic Analysis

Table 6.6 Modal Periods and Frequencies without SSI of Dynamic Analysis

Case	Mode	Period sec	Frequency cyc/sec	CircFreq rad/sec	Eigenvalue rad2/sec2
Modal	1	1.777	0.563	3.55	12.49
Modal	2	0.33	3.028	19.01	362.06
Modal	3	0.105	9.527	59.89	3583.56
Modal	4	0.102	9.794	61.52	3787.07
Modal	5	0.09	11.127	69.99	4888.23

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
IJARSCT
Impact Factor 6.252
Volume 2, Issue 1, July 2022

Case	Mode	Period sec	Frequency cyc/sec	CircFreq rad/sec	Eigenvalue rad2/sec2
Modal	6	0.03	33.081	207.81	43202.50
Modal	7	0.028	35.75	224.69	50455.89
Modal	8	0.017	59.957	376.76	141917.63
Modal	9	0.01	95.475	599.84	359863.65
Modal	10	0.01	96.13	604.22	364818.63
Modal	11	0.009	111.884	702.91	494189.48
Modal	12	0.006	161.323	1013.62	1027423.81

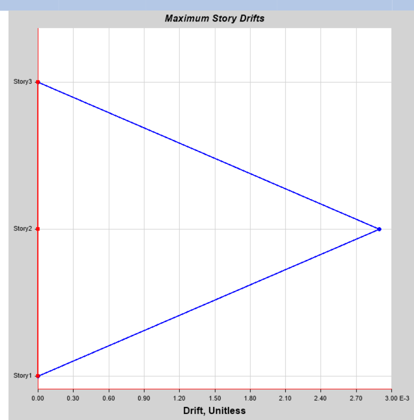


Fig-6.13 Maximum Drift without SSI of Dynamic Analysis

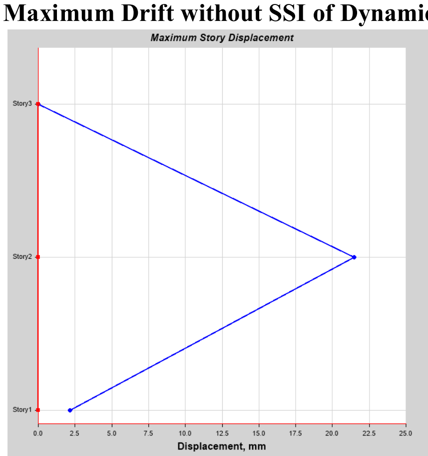


Fig-6.14 Maximum Displacement without SSI of Dynamic Analysis

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
Impact Factor 6.252
Volume 2, Issue 1, July 2022

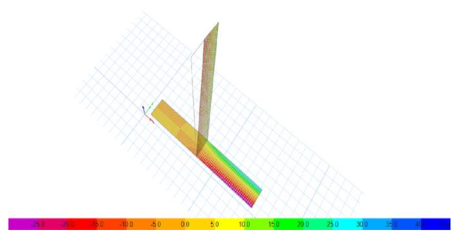


Fig-6.15 1st Mode Shape with SSI of Dynamic Analysis

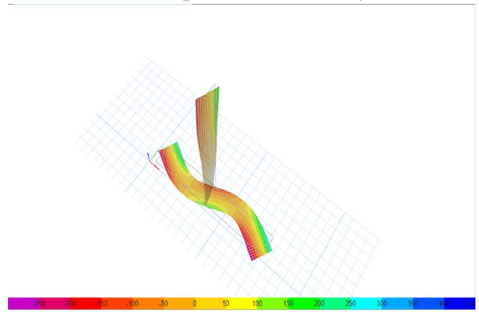


Fig-6.16 Final Mode Shape with SSI of Dynamic Analysis

Table 6.7 - Base Reactions with SSI of Dynamic Analysis

Output Case	Case Type	FX kN	FZ kN	MX kN-m	MY kN-m	MZ kN-m
Dead	LinStatic	0	269.44	134.71	-1093.62	0
Live	LinStatic	117.66	-103.45	-51.70	-422.39	-58.83
RSx	LinRespSpec	7.37	0	0	32.86	3.89
RSy	LinRespSpec	7.67	0	0	32.86	3.89
RS 1	Combination	153.13	199.26	99.60	-1767.98	-64.67
RS 1	Combination	129.28	199.26	99.60	-1870.39	-76.55
RS 2	Combination	153.13	199.26	99.60	-1767.98	-64.67
RS 2	Combination	129.28	199.26	99.60	-1870.89	-76.55

Table 6.8 - Modal Periods and Frequencies with SSI of Dynamic Analysis

Case	Mode	Period sec	Frequency cyc/sec	CircFreq rad/sec	Eigenvalue rad2/sec2
Modal	1	1.777	0.563	3.5355	12.4999
Modal	2	0.33	3.028	19.0281	362.068
Modal	3	0.105	9.527	59.8629	3583.5644
Modal	4	0.102	9.794	61.5392	3787.0786
Modal	5	0.09	11.127	69.9159	4888.2358
Modal	6	0.03	33.081	207.8521	43202.5059

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
IJARSCT
Impact Factor 6.252
Volume 2, Issue 1, July 2022

Case	Mode	Period sec	Frequency cyc/sec	CircFreq rad/sec	Eigenvalue rad2/sec2
Modal	7	0.028	35.75	224.6239	50455.8958
Modal	8	0.017	59.957	376.7196	141917.6363
Modal	9	0.01	95.475	599.8864	359863.6675
Modal	10	0.01	96.13	604.0022	364818.6553
Modal	11	0.009	111.884	702.9861	494189.4098
Modal	12	0.006	161.323	1013.6192	1027423.841

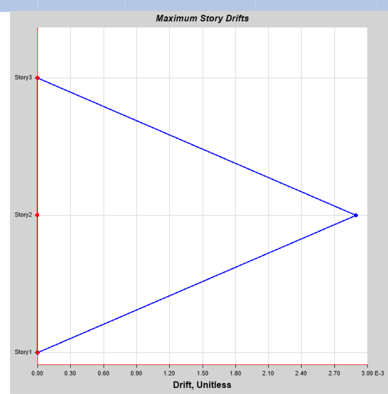


Fig-6.17 Maximum Drift with SSI of Dynamic Analysis

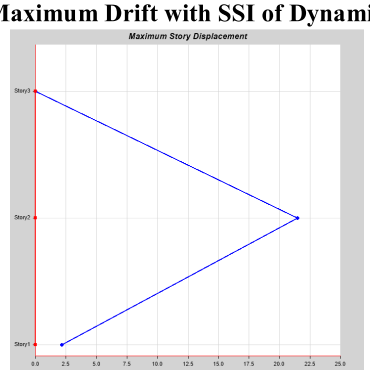


Fig-6.18 Maximum Displacement with SSI of Dynamic Analysis

Table 6.9 – Static Analysis

	Deflection (mm)	Shear Force (kN)	Bending Moment (kN-m)
Without SSI	8.841	951.11	507.957
With SSI	21.457	1035.488	511.435

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

IJARSCT
Impact Factor 6.252

Volume 2, Issue 1, July 2022

Table 6.10 – Dynamic Analysis

	Deflection (mm)	Shear Force (kN)	Bending Moment (kN-m)
Without SSI	11.208	1171.732	650.522
With SSI	27.676	1299.944	661.885

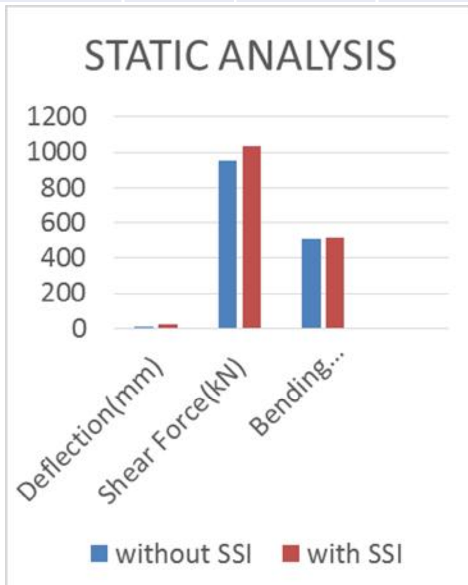


Fig-6.19 Static Analysis of Deflection, Shear Force and Bending Moment

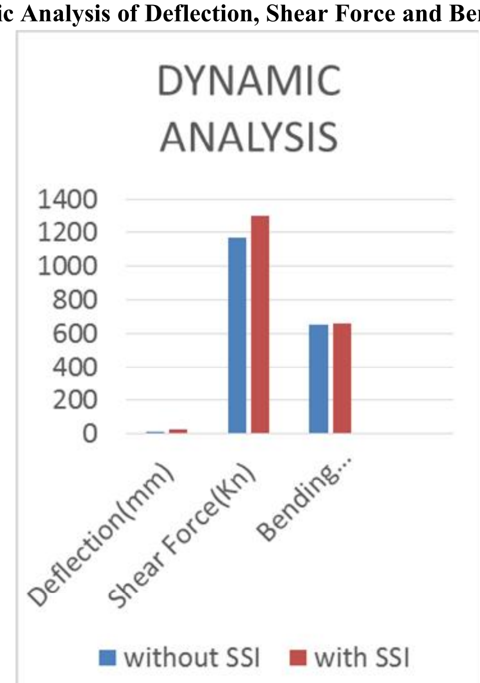


Fig-6.20 Dynamic Analysis of Deflection, Shear Force and Bending Moment

Table 6.11 Bhuj Eathquake

	Deflection (mm)	Shear Force (kN)	Bending Moment (kN-m)
With SSI	93.98	3707.28	1820

Table 6.12 Utter Kashi Eathquake

	Deflection (mm)	Shear Force (kN)	Bending Moment (kN-m)
With SSI	122.76	4127.86	2577

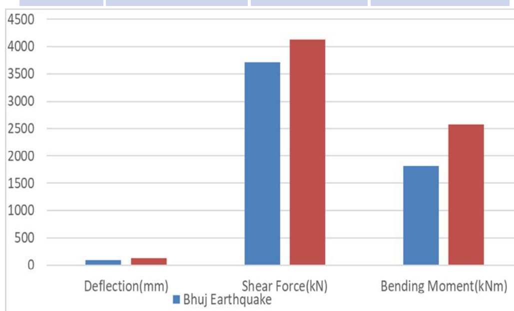


Fig-6.21 Bhuj Earthquake and Utter Kashi Earthquake

VII. CONCLUSION

- The usage of two - dimensional numerical simulations have an effect on the wall-retained soil structure interface and the relative peak of the structure at the static and dynamic loading condition.
- The deformation pattern with the soil structure interaction of both static and dynamic analysis shows almost similar in lateral displacement of retaining wall. These displacements represent the relative lateral displacements of the wall with respect to the ground.
- The peak responses and the corresponding natural period maximum at the top most shell level with the effect of soil structure interaction which is significant on the structural response of the retaining wall.
- The peak responses depend on the soil condition, foundation stiffness and mass of the retaining wall with soil structure interaction. Also, with the application of loading condition the amplitude of vibration varies.
- The dynamic analysis with and without soil structure interaction shows 59.50% variation in deflection, 9.86% variation in the shear force and 1.74%variation in the in the bending moment.
- The static analysis with the presence and absence of soil structure interaction shows 58.79% variation in the deflection, 8.148% variation in the shear force and 1.48%variation in the in the bending moment.

VIII. REFERENCES

[1]. S. P. G. Madubhushi et al.,2006, "Seismic response of flexible cantilever retaining walls with dry backfill", Geomechanics and Geoengineering: An International Journal Vol. 1; pp 275—289

[2]. Tufan Cakir.,2013, "Evaluation of the effect of earthquake frequency content on seismic behavior of cantilever retaining wall including soil–structure interaction", Soil Dynamics and Earthquake Engineering 45, pp 96–111

[3]. Ashok K. Chugh et al.,2017, "Soil Structure Interactions of Retaining Walls", ResearchGate, DOI: 10.1061/9780784479742.036

[4]. George Papazafeiropoulos et al.,2009, “Retaining wall-soil-structure interaction effects due to seismic excitation Earthquake Geotechnical Engineering Satellite Conference XVIIth International Conference on Soil Mechanics & Geotechnical Engineering.

[5]. Tufan Cakir et al.,2020, “An Overview to the Dynamic Behaviour of the Inverted T Type Cantilever Retaining Wall Taking into Account Soil Structure Interaction Phenomenon”, Sigma Journal of Engineering and Natural Sciences 2019 3rd International Conference on Advanced Engineering Technologies, pp 37-50.

[6]. Lou Menglina, et.al.,2011, “Structure–soil–structure interaction: Literature review”, Soil Dynamics and Earthquake Engineering 31; pp 1724–1731

[7]. George Gazetas,1991, “Foundation Vibrations”,H.Y Fang(ed), Foundation Engineering hand book; Springer Science; pp 1 – 41.

[8]. George Gazetas,1991, “Formulas and Charts for Impedances of Surface and Embedded Foundations” J. Geotech. Engrg. 1991.117, pp 1363-1381.

[9]. S. Ramamrutham.,1974, “Design of Reinforced Concrete Structures”, Dhanpat Rai &Sons, Delhi-Jullundur.