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Analysis of Geofoam Backfill Retaining Wall

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Abstract. Expanded Polystyrene (EPS) geofoams are used widely in civil engineering projects as it has light weight and low density. The present study is to analyze the lateral pressures and surface settlements in the retaining walls using EPS geofoam as an inclusion in the backfill. Retaining wall with the height of 6m is designed and modelled using PLAXIS. Geofoam is included as backfill in various orientations such as upper triangular pattern, lower triangular pattern, and the rectangular pattern. Optimum orientation with regard to low lateral pressures and low vertical settlements is found. Using Plaxis 2D Software, seismic analysis is also performed the present model. Bhuj earthquake data is used as the input parameter for examining the seismic behavior. The variation of lateral pressures at the top, middle and the bottom of the wall with respect to time is plotted and the peak values are compared. These values are compared with Mononobe-Okabe method pressures. From the study, it is observed that the geofoam reduces lateral thrust by about 50% in both static as well as seismic conditions.

Keywords: Conventional retaining wall, EPS Geofoam, Orientation, Seismic analysis.

1 Introduction

Retaining walls are structures used to retain any fill material vertically. These retaining walls are generally designed by using Rankine and Coulomb equations. In the conventional retaining walls, when the height of the wall increases, the design concrete section becomes too large leading to huge cost. In order to economize the cost, various methods improvements are applied. Some of them include, retaining wall with geogrid, geocells geonets and geofoam materials. Geofoam inclusion retaining structures are becoming prominent now-a-days.

In the present study, geofoam is used to restrain the lateral pressures which are present in the retaining wall. The orientation of geofoam is placed in different forms to analyze the behavior of retaining wall. In past many scripts there is no description about orientation of geofoams application. The present work is done by numerical analysis using geotechnical software PLAXIS 2D. In this by numerical model's lateral pressures and settlements are examined.

Numerous research [1–8] have been done on geofoam retaining walls. Using experimental step-up, Abdelsalam and Azzam [1] assessed the soil-geofoam interface parameters for numerical modelling. The study also analyzed at the use of geofoam in yielding walls, and it determined the minimal thickness of geofoam for the optimum lateral pressures. Elragi [3] provided a thorough explanation of the technical uses and features of geofoam. In order to examine the lateral loads on the retaining walls, geofoam thickness and density parametric tests were carried out by various researchers ([4], [6]). The lateral pressures on the retaining wall were examined by Khan and Meguid [4] with various angles of internal friction angle values of backfill and also with different geofoam material densities.

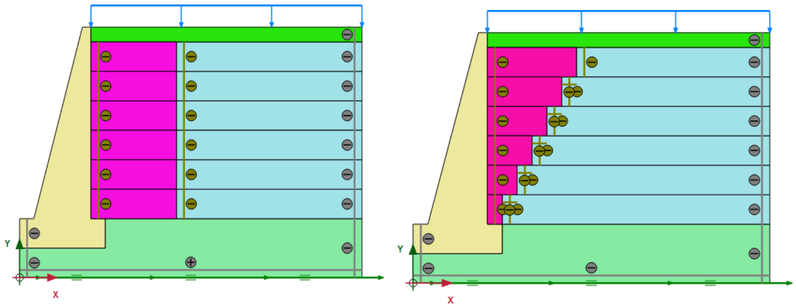
Literature had studied the geofoam in various structures using numerical modelling. Zarnani and Bathurst [9, 10] studied on the non-yielding walls. The seismic behaviour of the retaining wall with geofoam inclusion was also studied [2, 9, 10]. The numerical model was simulated and verified by Zarani and Bathurst [9] using data from an shaking table. Zarani and Bathurst [10] conducted parametric studies the geofoam's stiffness, thickness, and wall height. Using a laboratory scale physical model, Dasaka et al. [2] assessed the performance of the geofoam inclusion retaining wall under seismic and surcharge loads.

In the all above studies, the geofoam was placed in the form of rectangular size. The main objective of the study is to place the geofoam in various orientations As the lateral pressures and lateral thrusts were reduced in an upper triangular pattern compared to other orientations, the static studies were conducted before for the same model using Geofoam as a retaining wall. Seismic analysis was used in the current study to examine the retaining wall's acceleration, frequency, and lateral pressures following the installation of the geofoam.

2 Numerical Modeling:

In the present study, the retaining wall is designed in at-rest condition. A conventional retaining wall was designed with the conventional equations and standard stability checks. The same section was simulated in a finite element software (PLAXIS 2D). A plain strain model of retaining wall was simulated. The model was analysed for static and seismic loading. To study the condition of retaining wall the seismic analysis is done by numerical modeling in plaxis 2D program.

Retaining wall of height, 8.5 m (including pavement and foundation soil) was modelled. EPS Geofoam was included in the backfill behind the retaining wall. Foundation soil is upto 2 m height, the effective depth of the retaining wall is 6 m, pavement thickness is about 0.5 m, the width of the total retaining wall is 15 m, height of the geofoam is 6 m and width 3 m from the foundation soil. Surcharge load is applied on the pavement of 36 kPa which suffice the liveloads and extra dead loads incurred on the surface of the backfill.
Seismic analysis was carried out in the model. The Bhuj earthquake data is considered for the analysis in standard in Strong Motion CD-ROM. The earthquake displacement are given at the bottom of the model as shown in the Figure 1. The geofoam was placed in different orientations, i.e. rectangular pattern (Fig. 1(a)) and upper traiangular pattern (Fig. 1(b)). Free-field and Compliant base boundary conditions were taken into consideration for the earthquake loading. Properties of all the materials are given in Table 1.



(a) (b)

Fig. 1. Retaining wall models in seismic analysis arranging Geofoam in (a) Rectangular pat- tern (b) Upper triangular pattern.

Table 1. Material Properties of soil

Properties	Backfill Material	Foundation soil	Geofoam	Concrete	Pavement
Material Type	Mohr coulomb	Mohr coulomb	Linear elastic	Linear elas- tic	Mohr coulomb
Density (kN/m^3)	17	22	1.8	24	20
Elastic modulus (MPa)	30	1000	10	30,000	60
Poisson's ratio (ν)	0.35	0.35	0.1	0.15	0.35
Cohesion (kPa)	1	50	-	-	20
Angle of shearing resistance (φ)	35	35	-	-	35

2.1 Generalization of Upper triangular pattern and rectangular pattern

To generalize the results of upper-triangular pattern (Fig. 2) and rectangular pattern (Fig. 3), numerical study was extended for various heights of the retaining walls (i.e., 4 m, 6 m, 8 m, and 10 m) . Half of the height is deemed to be the width of the geofoam in every case. The wall's height is normalized by dividing the wall's depth (z) by its overall height (H). There was a finding that all wall heights taken into consideration had similar normalized lateral pressure patterns. Hence, the results obtained can be applied in design of retaining wall of any height. Lateral pressures can be obtained by multiplying σ_{xx} by the wall's height and the backfill material's unit weight. Figure 7 displays the lateral pressures for the geofoam rectangles at various wall heights. The normalized lateral pressures were noted to be highest in the wall height of 4m. As the height of the wall increases, the normalized lateral pressures converges to a single value. Lateral stresses were measured for the walls' varied wall heights and the upper triangular design (Fig. 7). The lateral pressures are increase with decreasing retaining wall height and vice versa. Therefore, when using an upper triangular pattern, it is best to build the retaining wall higher in the normalized lateral pressures, σ^*_{xx} is the lateral pressures against the wall, is the backfill's unit weight, and H is the wall's overall height, i.e. $\sigma^*_{xx} = \sigma_{xx}/\ \gamma H$.

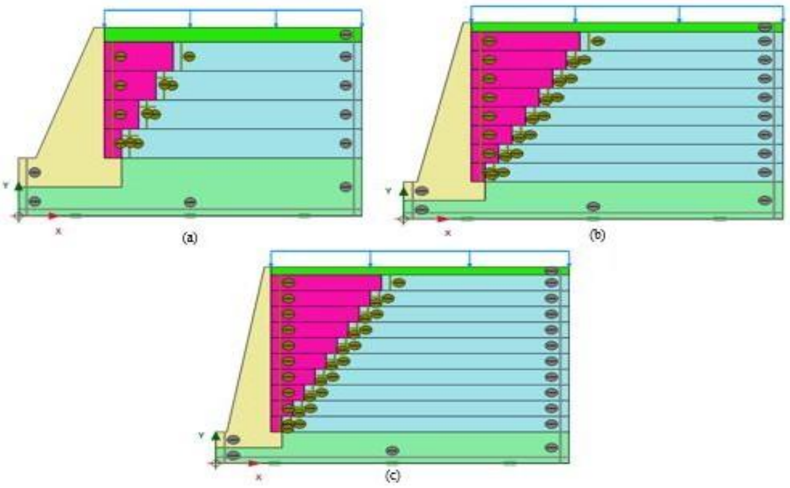


Fig. 2. Different wall heights of retaining wall in Upper triangular pattern
(a) 4 m (b) 8 m (c) 10 m walls

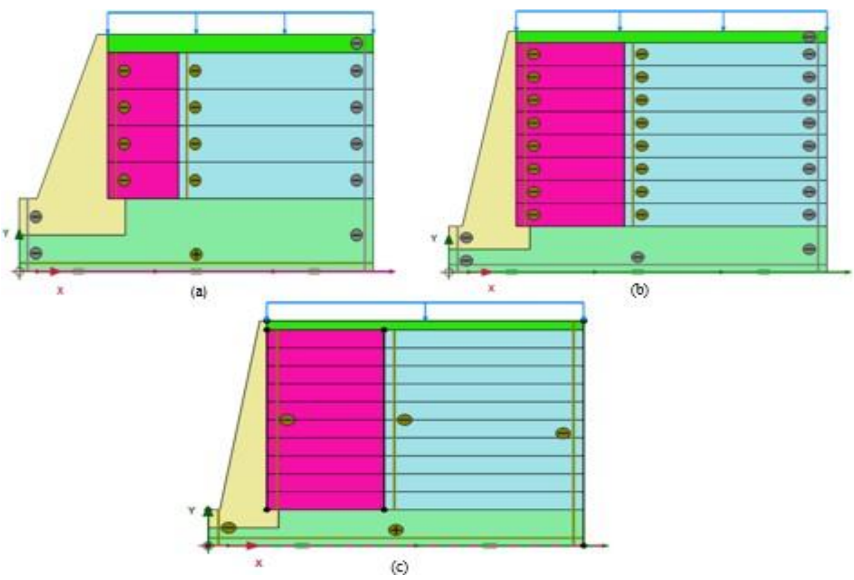


Fig. 3. Different wall heights of retaining wall in Rectangular pattern
(a) 4 m (b) 8 m (c) 10 m walls

3 Results and Discussions:

3.1 Seismic analysis of Upper triangular pattern

Generally in retaining walls lateral pressures are more to reduce the lateral pressures in the retaining wall Geofoam is used in Figure 4. It shows that the lateral pressures a reduced after placing geofoam behind the retaining wall the values were compared with the at rest condition (k_0) and active pressure (k_a) the lateral pressures are less compared to at rest condition and active pressure the latter pressures are decreased after placing Geo foam in upper triangular pattern in the retaining wall even in the season condition.

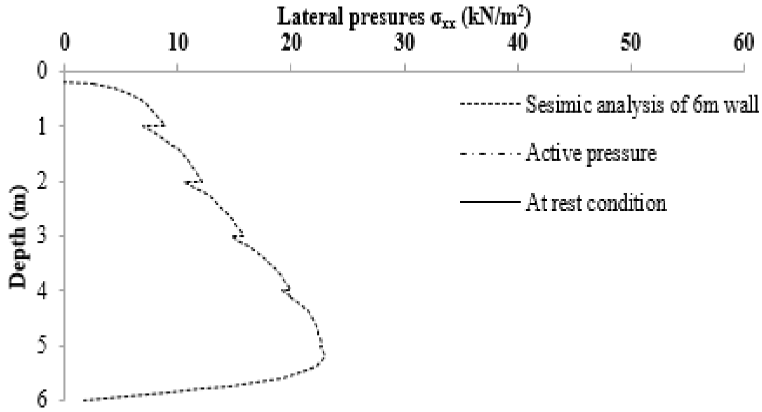


Fig. 4. Lateral Pressures of Upper triangular shape in Seismic Condition

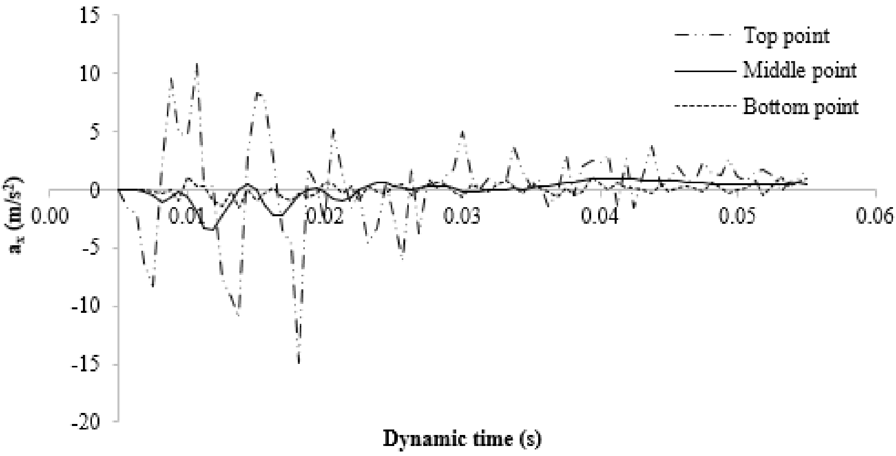


Fig. 5. Variation of acceleration in dynamic time at upper triangle shape in seismic condition

As the retaining wall's height increases, accelerations at the top of the wall increase; as the height gradually decreases, accelerations become minor as shown in Figure 5. Due to the earthquake the various in acceleration are present near the wall when geofoam is places in upper triangular pattern.

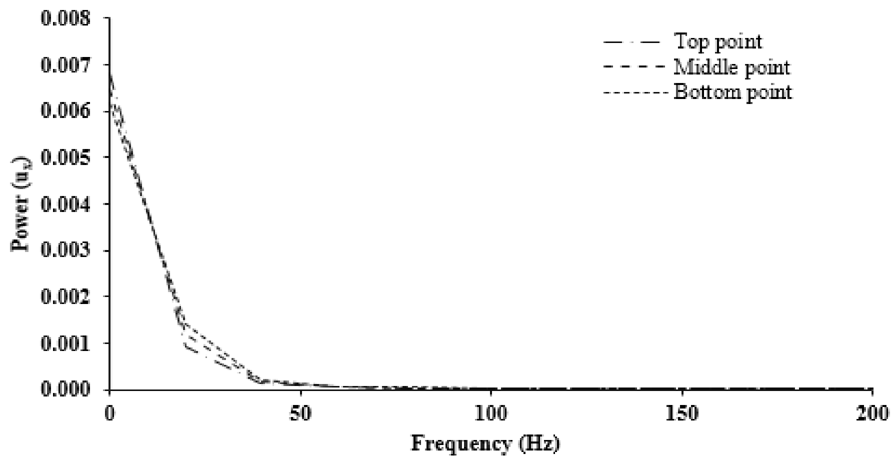


Fig. 6. Frequency representation of upper triangular pattern

In the upper triangular pattern the frequency of the retaining wall is approximately same, more number of frequencies are at the top point of the retaining wall as we go to the bottom point of the retining wall frequency is also same at all the points Frequency vs Power u_x (spectrum) shown in the fig 6.

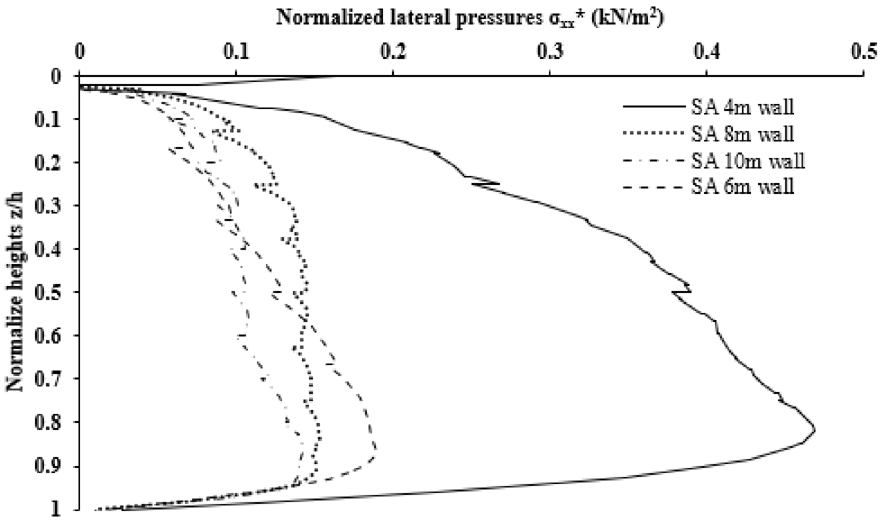


Fig. 7. Different heights of Upper triangular pattern in seismic analysis

Seismic analysis is done for upper triangular pattern, the wall heights are normalize z/h in comparing different wall height as the wall heights decreases the lateral pressure increases, if the wall is increases gradually with the height the laterl pressures decreases as shown in the fig 7.

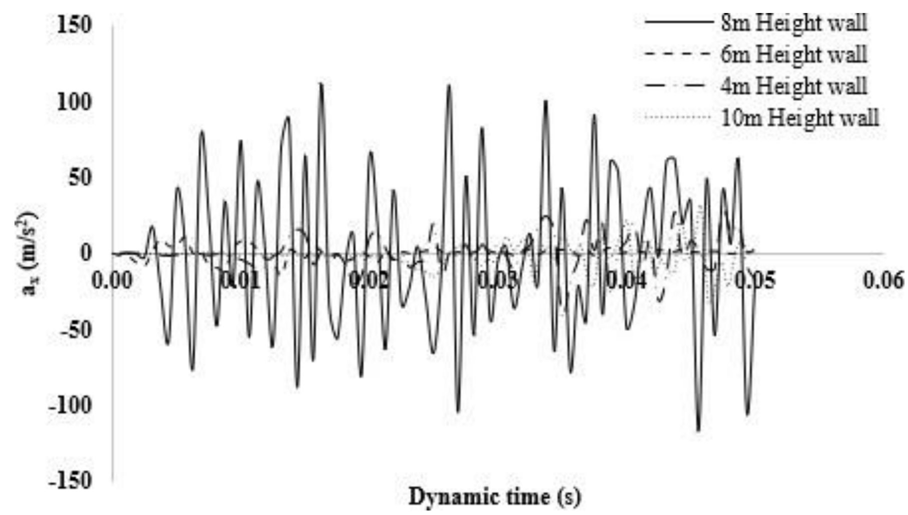


Fig. 8. Variation of acceleration in dynamic time at different heights of upper triangular pattern

Acceleration are compared in retaining wall by placing geofoam in upper triangular pattern as the wall height increases the acceleration is also increasing gradually at the height of 10m we have more number of acceleration compared to the another wall heights as shown in the fig 8.

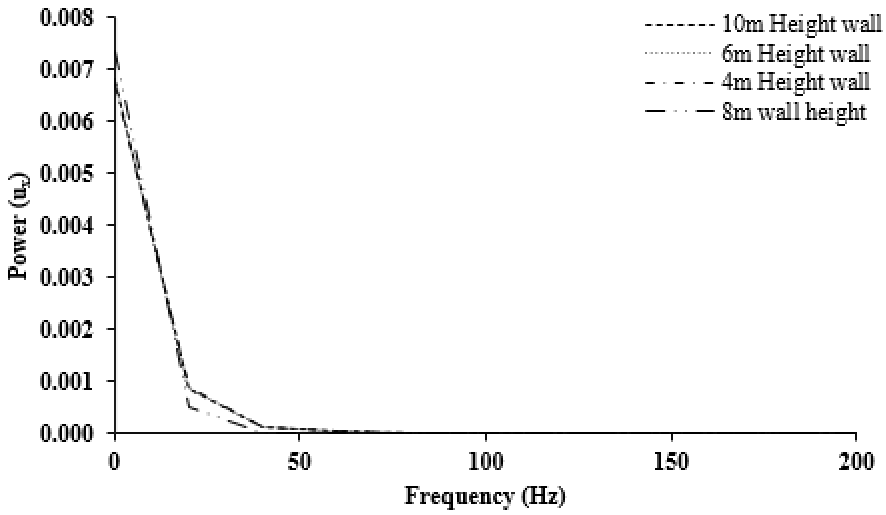


Fig. 9. Frequency representation of upper triangular pattern at different wall heights

In the fig 9, the frequency of the retaining wall of various wall heights are compared as the wall height incereses the frequency of the retaining wall is approximately same for all the wall heights like 4m, 6m, 8m, and 10m walls in upper triangular pattern

3.2 Seismic analysis of rectangular pattern

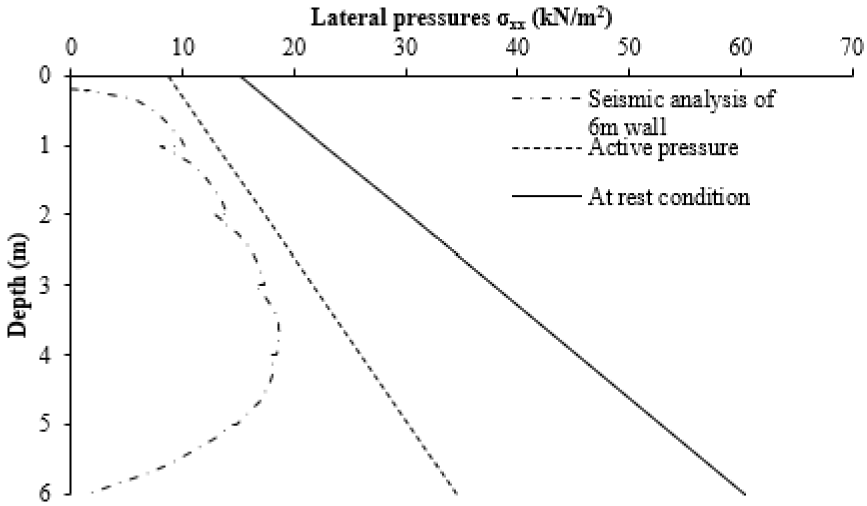


Fig. 10. Lateral pressures of rectangular shape in seismic condition

Fig 10, it shows that the lateral pressures a reduced after placing geofome behind the retaining wall the values were compared with the at rest condition (k0) and active pressure (ka) the lateral pressures are less compared to at rest condition and active pressure the latter pressures are decreased after placing Geo foam in upper triangular pattern in the retaining wall.

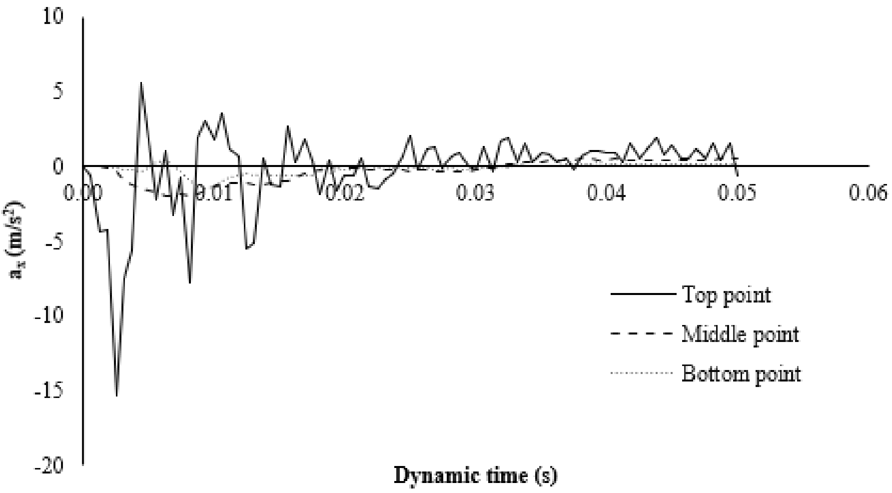


Fig. 11. Variation of acceleration in dynamic time at Rectangular 6m wall

As the retaining wall height increases, accelerations at the top of the wall increase; as the height gradually decreases, accelerations become minor as shown in Fig 11. Due to the earthquake the various in acceleration are present near the wall when geofoam is places in rectangular pattern.

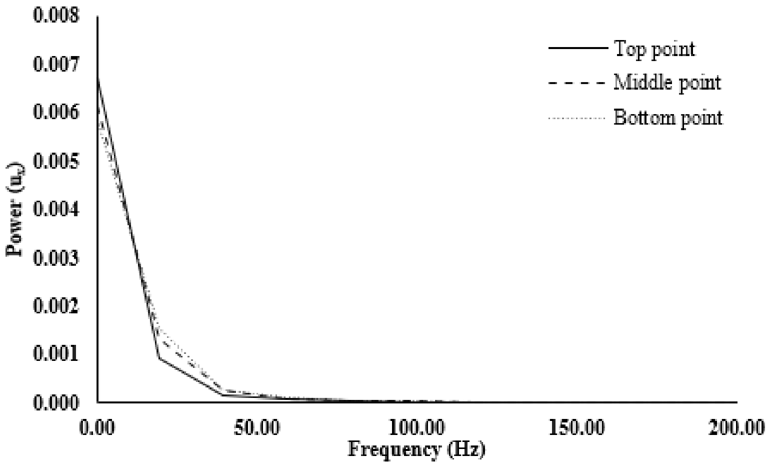


Fig. 12. Frequency representation of rectangular pattern

In fig. 12, the frequency of the retaining wall is approximately same, more number of frequencies are at the top point of the retaining wall as we go to the bottom point of the retining wall frequency is also same at all the points in rectangular pattern.

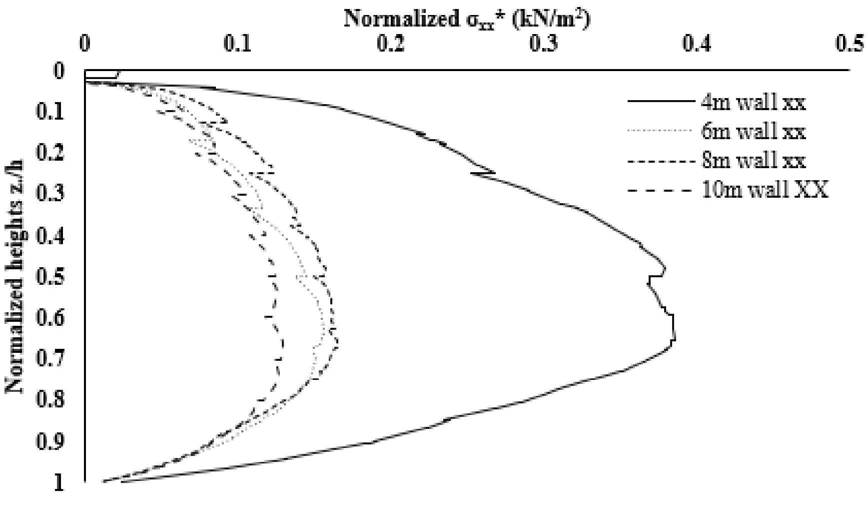


Fig. 13. Different heights of rectangular pattern of seismic analysis

Seismic analysis is done for rectangular pattern, the wall heights are normalize z/h in com paring different wall height as the wall heights decreases the lateral pressure increases, if the wall is increases gradually with the height the laterl pressures decreases as shown in Figure 13.

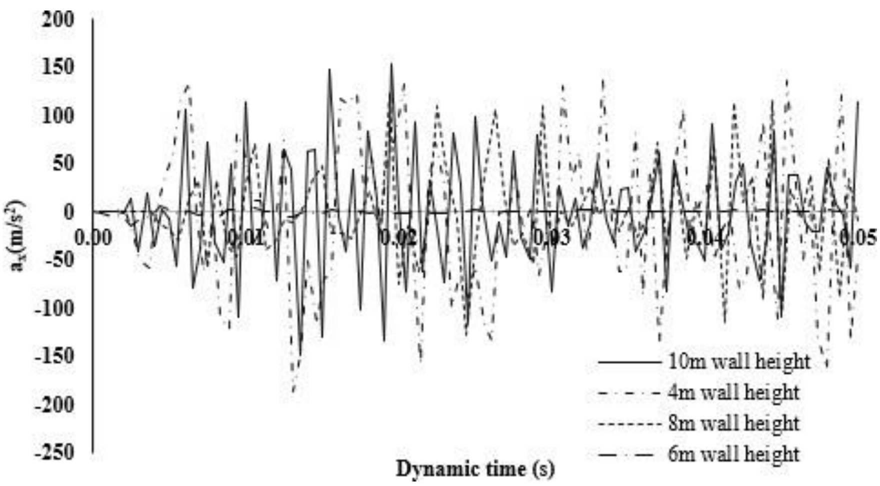


Fig. 14. Variation of acceleration in dynamic time at different heights of rectangular pattern

Acceleration are compared in retaining wall by placing geofoam in rectangular pattern as the wall height increases the acceleration is also increasing gradually at the height of 10 m we have more number of acceleration compared to the another wall heights, less number of acclerations are in 6 m wall as shown in Figure 14.

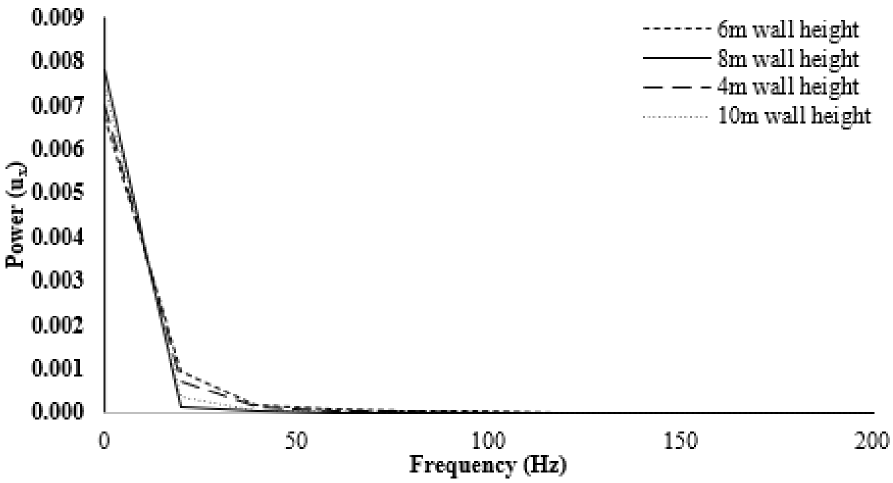


Fig. 15. Frequency representation of rectangular pattern at different wall heights

In Fig. 15, the frequency of the retaining wall of various wall heights are compared as the wall height incereses the frequency of the retaining wall is approximately same for all the wall heights like 4 m, 6 m, 8 m, and 10 m walls in rectangular pattern.

4 Conclusion:

In this present study, the effect of various orientations of geofoam behavior in seicimic anyalsis was studied using numerical analysis. The lateral pressures, frequency and acceleration were examined. The normalized graphs proposed can be used for the design of various heights of the walls. Following conclusions were drawn from the study.

1. As the height of the wall increses in both upper triangular pattern and rectangular pattern lateral pressures decreases gradually upto 63% after inclusion of geofoam in seismic analysis.
2. Acceleration after earthquake date incited in analysis, acceleration in the retaining wall gradually increasing as the height increases.
3. In both the upper and rectangular pattern, the frequency are almost same in various retaining wall heights of 4 m, 6 m, 8 m and 10 m.

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