Nonlinear Analysis of Retaining Wall For Different Soil Condition

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Abstract- *These Structural dynamic deals with method to determine the stresses and displacement of structure subjected to dynamic loads .the dimension of structure are finite. This leads to a finite domain for soil which can be modeled similarly to the structure the total discretized system, consisting of the structure and soil, can be analyzed straight forwardly. 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. Hence, the modern seismic design codes, such as Standard Specifications for Concrete Structures: Seismic Performance Verification JSCE 2005 stipulate that the response analysis should be conducted by taking into consideration a whole structural system including superstructure, foundation and ground. In this study nonlinear analysis of retaining wall is studied including soil structure interaction for various types of walls for silty soil, clay soil and sandy soil.*

Keywords- Dynamic Analysis, Soil Conditions, soil-structure interaction, ANSYS.

I. INTRODUCTION

1.1 Parametric Details

The analysis of a rigid wall with reinforced backfill is carried out by considering the different parameters which are discussed below. Wall geometry: (height of wall and Roadway width) the rigid wall with reinforced backfill technology is suitable particularly for the construction of flyover approach roads and road construction in hilly areas. Hence, height of wall always varying. The width of roadway of 12 m is considered in the present investigation as per IRC: 6 as referred in references.

- **Backfill soil**: As reported in the literature, granular soils are preferred for the construction for reinforced earth walls. They have the advantage of free drainage and also because of higher frictional resistance at the interface of soil and reinforcement; there is no slippage of reinforcement. In the present investigation three types of backfill soils having soil modulus 1.00E+04, 5.00E+04, 1.00E+05 (kPa) as reported in literatures as granular soils are selected for investigation.
- **Soil in foundation strata**: The soil in foundation strata covers large variations from soft and stiff clay to moderate and compact granular formation. Hence, seven types of soils are considered having soil modulus 1.00E+01 to 1.00E+07 (kPa) as reported in literatures.
- **Steel reinforcement**: The reinforcement considered in the analysis is galvanized iron strips of 40 mm wide and cross sectional area of 100 mm2 placed at 500 mm vertical spacing. The elastic properties of reinforcement assumed in the analysis are: modulus of elasticity (*E*) 200 GPa, and Poison’s ratio (*m*) 0.30

1.2 Typical Cross Section

The typical cross section of a rigid wall with a reinforced backfill and underlying foundation strata is shown in Fig. 1.1, in which ‘*b*’ denotes the roadway width, and ‘*H*’ denotes the wall height. The underlying foundation strata are assumed to be a semi-infinite soil formation.

1.3.1 Soil In The Backfill

Three types of soils are considered in the backfill. The engineering properties of these three types of backfill material are presented in Table

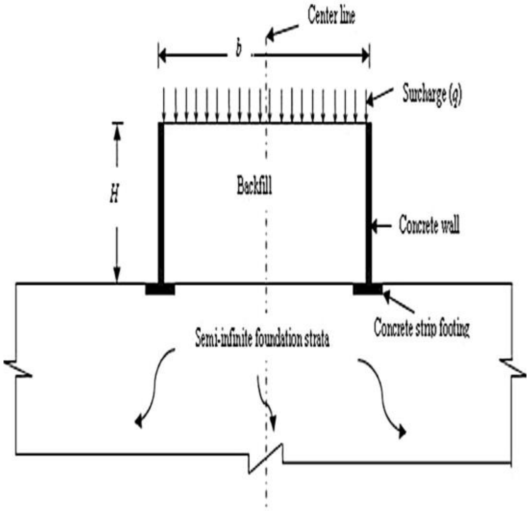
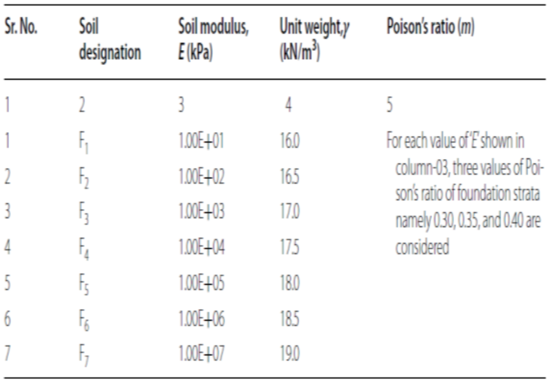


Fig 1 Typical cross-section of a rigid wall with reinforced backfill

2. The infinite domain of the foundation strata is curtailed vertically at a depth ‘*D*’, and the boundary so formed is assumed to be restrained horizontally as well as vertically.
3. The infinite lateral boundary of the foundation strata on the left is curtailed at a distance‘*L’,* and resulting boundary is assumed to be restrained in horizontal direction.



Sr. No.	Soil designation	Soil modulus, *E* (kPa)	Unit weight,γ (kN/m³)	Poison's ratio (*m*)
1	2	3	4	5
1	F_1	1.00E+01	16.0	For each value of '*E*' shown in column-03, three values of Poi-son's ratio of foundation strata namely 0.30, 0.35, and 0.40 are considered
2	F_2	1.00E+02	16.5	
3	F_3	1.00E+03	17.0	
4	F_4	1.00E+04	17.5	
5	F_5	1.00E+05	18.0	
6	F_6	1.00E+06	18.5	
7	F_7	1.00E+07	19.0	

Table 1.2 The engineering properties of the soils constituting foundation strata

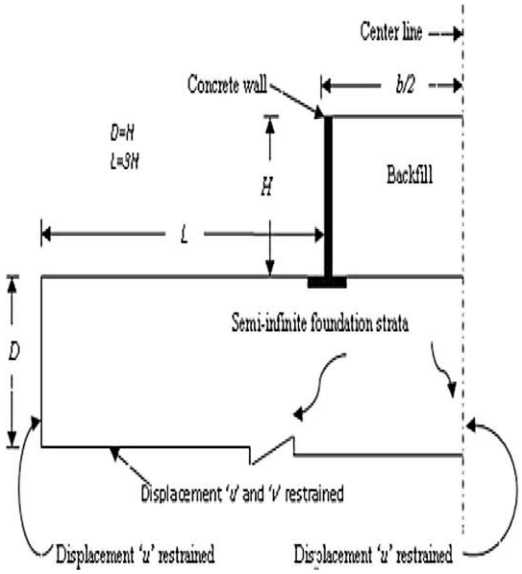


Fig 2 The details of symmetrical section considered in the analysis

The half section as shown in Fig. 2 is considered for discretization. The coordinate system, dimensions, nodal point locations and loading are as shown in Fig. 3. The section is idealized through square elements of size 0.5 m by 0.5 m. The backfill and foundation soil have been discredited using two dimensional (2D) four nodded isoperimetric plane strain quadrilateral element as shown in Fig. 4a. Every element is defined by four nodal points having two degrees of freedom at each node, i.e. translation in *X* and *Y* directions. A unit thickness is assumed for the element. The material properties as a input for this element, for isotropic elastic case, are soil modulus ‘*E*’, Poison’s ratio ‘*m*’ and soil density ‘_’.The reinforcing elements have been modeled as line element as shown in Fig. 4b. It is uniaxial tension/compression element with two degrees of freedom at each node (*u*iandv*i*). No bending of element is considered. The element is defined by two nodal points. The cross sectional area, and elastic material properties (*E, m*) are the input for this element. At an interface layer of soil and reinforcement, zero thickness interface element issued as shown in Fig. 4c.It is found that, the common approach of providing equally spaced truncated reinforcement with reinforcement length (*L*) to wall height (*H*) ratio, *L/H* equal to 0.7, provides a relatively efficient distribution of reinforcement force. In contrast, the approach of varying reinforcement spacing in an attempt to mimic the horizontal stress distribution

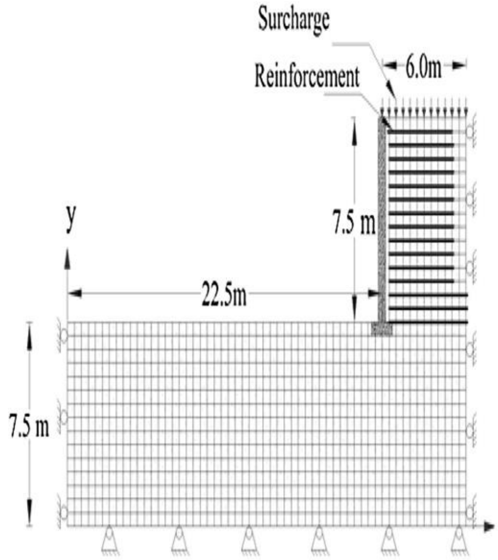
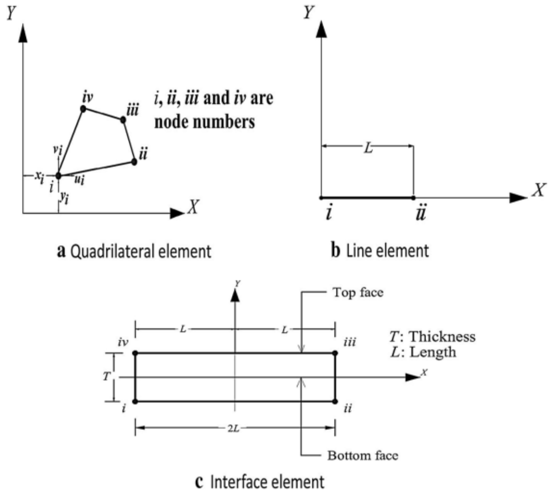


Fig 3 Typical finite element idealization of a rigid wall with a reinforced backfill



a Quadrilateral element **b** Line element

c Interface element

Fig 4 Details of a Line element, b quadrilateral element, c interface element

Proves to be less efficient and is not recommended. Varying reinforcement length, i.e. reinforcement extended to the zero force line, does not provide any significant improvement inforce distribution relative to the truncated reinforcement of L/H = 0.7. Hence, in the current investigation, the minimum ratio L/H = 0.7 is maintained [21].The investigations carried by Saran et al. [21] are based on limit equilibrium method and are focused on the estimation of earth pressure. The limitations of limit equilibrium method are also highlighted in introduction section. The present investigation is done by finite element method and is focused on serviceability aspect which is a potential area of ongoing works in case of reinforced soil walls.

1.3 STATE OF DEVELOPMENT

Abdolreza Osouli et. al. (2017) the validated methodology is then used to investigate the effects of three earthquake ground motions including Kobe, Loma Prieta, and Chi-Chi on seismic response of retaining walls. In addition, the input peak ground acceleration values are varied to consider a wide range of earthquake acceleration intensity.

B. Mendez (2015) A model built in FLAC for the analysis considers non-linear soil properties, stress-dependent soil modulus and interface elements to model soil-wall interaction. Hysteretic damping is accounted for during dynamic loading. Harmonic waves of different frequencies are used as input motion, as well as an actual earthquake record of broad frequency content to compare to analytical results. Preliminary analyses have shown that there is a noticeable difference in the predictive capacity of limit equilibrium methods for computing dynamic pressures when considering harmonic or earthquake loading. It is expected that results help to make a more insightful use of simplified methods.

Siddharth Mehta et. al. (2015) the concept of seismic analysis of reinforced earth wall along with soil structure interaction is reviewed and discussed. A systematic summary of history and status of seismic analysis of reinforced earth wall and soil structure interaction is proposed in this paper. Various methods for analysis considering different seismic parameters different soil conditions are discussed along with work in numerical modeling. Parametric studies illustrate the effects of seismic acceleration on the design of reinforced retaining wall and also the forces in the reinforcements.

Muthucumarasamy Yogendrakumar et. al. (2015) This study reported here reviews two different methods of analysis that have been used to model the response of soil under dynamic loading. The first method is an iterative equivalent linear elastic approach, and the second is an incremental elastic approach. The field test data was obtained by subjecting the instrumented wall to seismic excitations generated by buried explosives detonated with delays. Accelerations on the order of 0.08 g and duration of 0.70 s were generated in the blast scries considered for this study. The results of this study show that the incremental elastic approach used in TARA-3 gives the best prediction of dynamic wall response under blast loading.

II. PROPOSED METHOD

2.1 Material modeling

The definition of the proposed numerical model was made by using finite elements available in the ANSYS code default library. SOLID186 is a higher order 3-D 20-node solid element that exhibits quadratic displacement behavior. The element is defined by 20 nodes having three degrees of freedom per node: translations in the nodal x, y, and z directions. The element supports plasticity, hyper elasticity, creep, stress stiffening, large deflection, and large strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elastoplastic materials, and fully incompressible hyper elastic materials. The geometrical representation of is show in SOLID186

2.2 Numerical Modeling

Constitutive model of the material

Due to the complexity of concrete, the constitutive relations of it differ from the different load case. In this case, several different constitutive models of concrete were proposed. The elastoplastic constitutive model based on the increment theory is used to describe the constitutive relations of concrete. This model usesWiliam-Warnke’s five-parameter yield criterion, uniform strength criterion and associated flow criterion. Because of the special structure style of the steel-concrete composite beam to concrete-filled steel tubular column joints, the behavior differs in the different place of concrete. The concrete in the core area of concrete-filled steel tubular restrained by the steel tubular is under triaxle load cases. According to the numerical analysis and experimental results, the Han-linhai’s model is reasonable and reliable by using the confinement index to define the concrete restrained by the steel tubular. Because of the insufficient research on the dynamic property, experiments of the stress-strain hysteretic models of concrete in the core area are not reported. The skeleton curves of stress-strain hysteretic relationship of concrete under cyclic load are basically close to the stress-strain curves under monotonic load. So many researchers approximate skeleton curves of the stress-strain relationship under monotonic load as the stress-strain relationship under cyclic load. The common constitutive models is used in the composite beam. The MISO method is used to describe the stress strain relationship of concrete in the procedure of analysis, shown in Fig 3.6

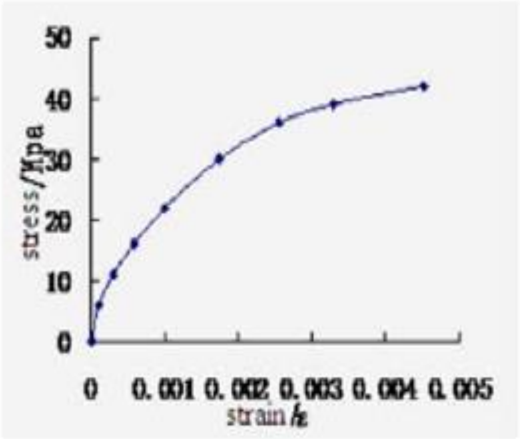
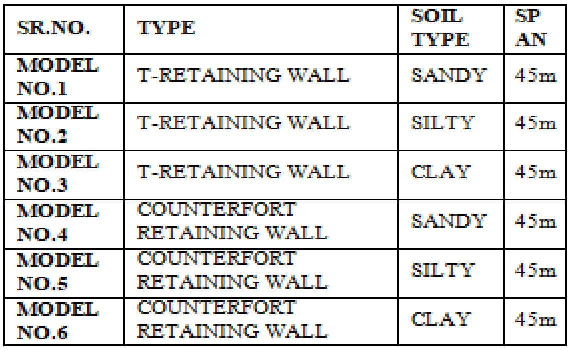


Fig 9: stress strain relationship of concrete

III. RESULT



SR.NO.	TYPE	SOIL TYPE	SP AN
MODEL NO.1	T-RETAINING WALL	SANDY	45m
MODEL NO.2	T-RETAINING WALL	SILTY	45m
MODEL NO.3	T-RETAINING WALL	CLAY	45m
MODEL NO.4	COUNTERFORT RETAINING WALL	SANDY	45m
MODEL NO.5	COUNTERFORT RETAINING WALL	SILTY	45m
MODEL NO.6	COUNTERFORT RETAINING WALL	CLAY	45m

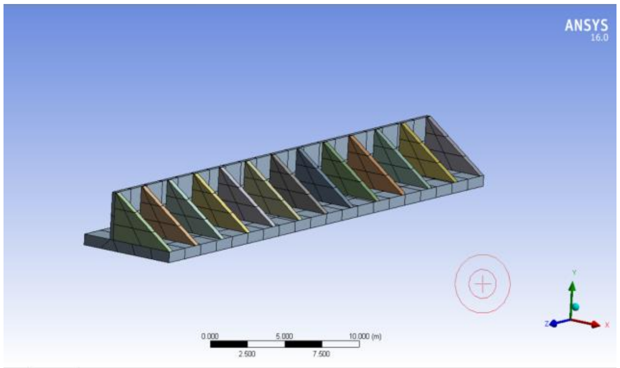


Fig 10. Modeling of Counterfort Retaining Wall

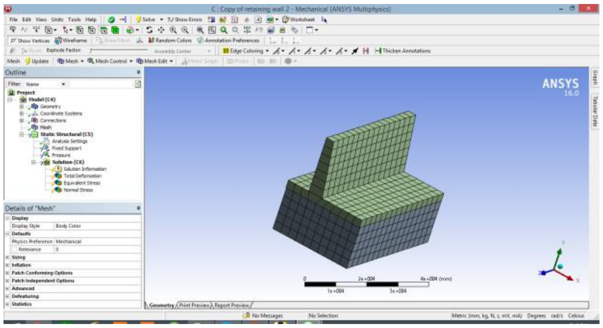
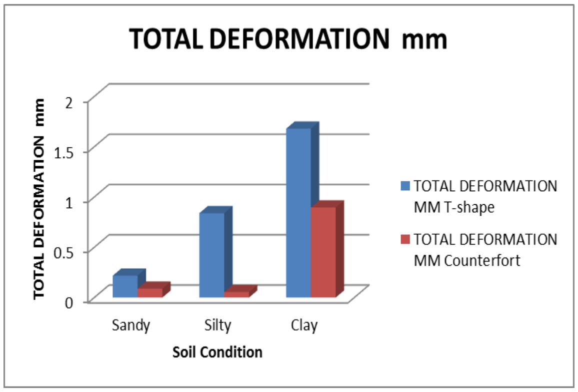


Fig 11 T Shaped Retaining Wall Modeling

3.1 Total Deformation in mm

Table 1 Total Deformation in mm

TOTAL DEFORMATION MM		
Soil type	**T-shape**	**Counterfort**
Sandy	0.21849	0.089054
Silty	0.84066	0.055595
Clay	1.68	0.896



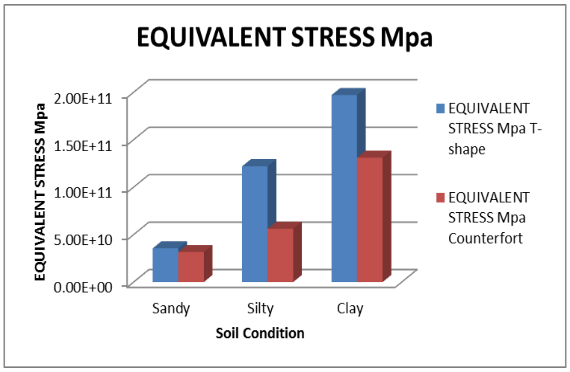
Graph 1: Total Deformations in mm

In the above graph the results of the total deformation for the T-shape and counterfort wall for the different soil conditions , as per dam type the Deformation for the counterfort retaining wall is economic than the T shape wall by 20-25% , and as per soil condition Sandy soil have less deformation than silty and clay soil for the both dams

3.2 Equivalent Stress

Table 2 Equivalent Stress

EQUIVALENT STRESS Mpa		
Soil type	**T-shape**	**Counterfort**
Sandy	3.56E+10	3.15E+10
Silty	1.22E+11	5.61E+10
Clay	1.97E+11	1.31E+11

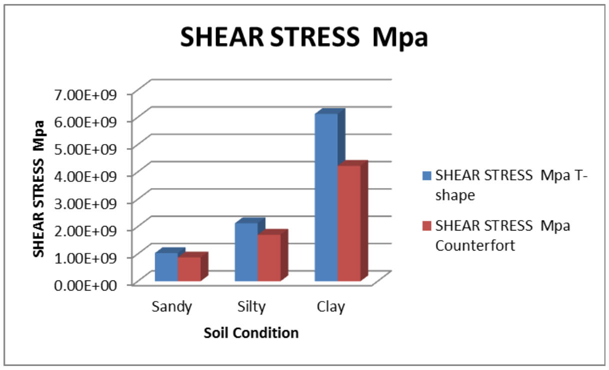


Graph 2: Equivalent Stress

3.3 Shear stress

Table 3 Shear stress

SHEAR STRESS Mpa		
Soil type	**T-shape**	**Counterfort**
Sandy	1.03E+09	8.68E+08
Silty	2.12E+09	1.70E+09
Clay	6.12E+09	4.22E+09

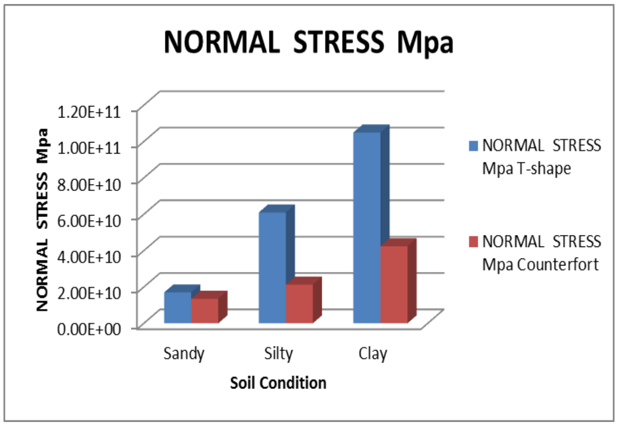


Graph 3 Shear stress

3.4 Normal stress

Table 4 Normal stress

NORMAL STRESS Mpa		
Soil type	**T-shape**	**Counterfort**
Sandy	1.70E+10	1.35E+10
Silty	6.10E+10	2.13E+10
Clay	1.05E+11	4.24E+10



Graph 4 Normal stress

3.5 Shear Strain

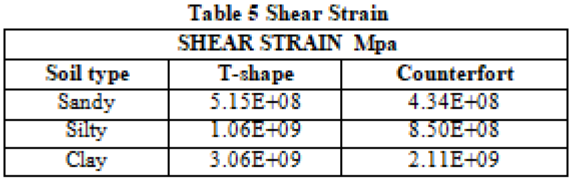
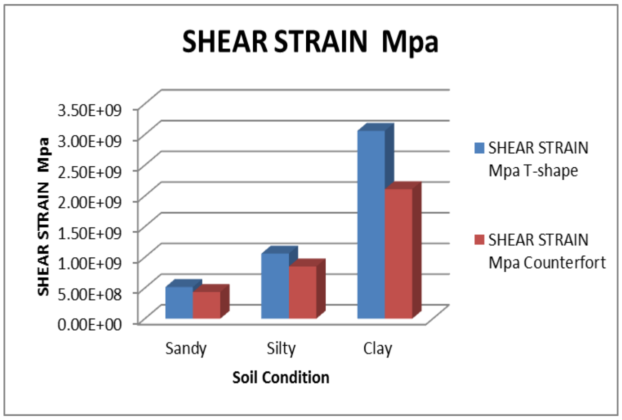


Table 5 Shear Strain

SHEAR STRAIN Mpa		
Soil type	**T-shape**	**Counterfort**
Sandy	5.15E+08	4.34E+08
Silty	1.06E+09	8.50E+08
Clay	3.06E+09	2.11E+09



Graph 5 Shear Strain

3.6 Normal Strain

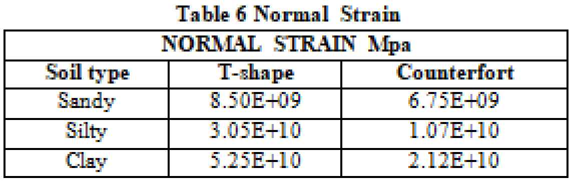
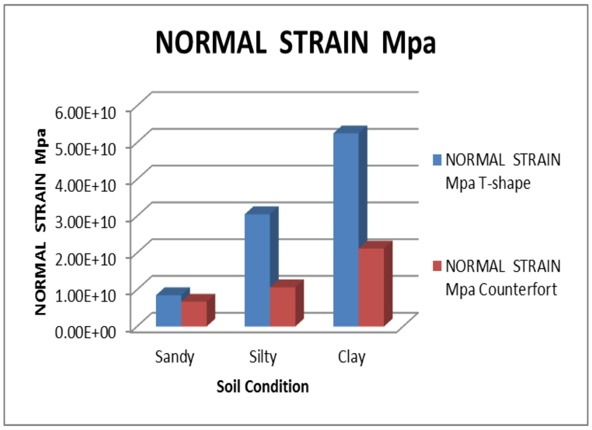


Table 6 Normal Strain

NORMAL STRAIN Mpa		
Soil type	**T-shape**	**Counterfort**
Sandy	8.50E+09	6.75E+09
Silty	3.05E+10	1.07E+10
Clay	5.25E+10	2.12E+10



Graph 6 Normal Strain

IV. CONCLUSION

It has been observed by parametric study that active earth pressure coefficient are almost identical by different methods, it can be noted from the graphical representations of the results obtained from the application of the different theories.

- It is observed that counter fort retaining wall has more capacity than T- shape retaining walls. From the following results
- The results of the total deformation for the T-shape and counterfort wall for the different soil conditions , as per dam type the Deformation for the counterfort retaining wall is economic than the T shape wall by 20-25% , and as per soil condition Sandy soil have less deformation than silty and clay soil for the both dams
- The results of the Equivalent Stress for the T-shape and counterfort wall for the different soil conditions, as per dam type the Equivalent Stress for the counterfort retaining wall is economic than the T shape wall by 15.20% , and as per soil condition Sandy soil have less Equivalent Stress than silty and clay soil for the both dams
- The results of the Shear stress for the T-shape and counterfort wall for the different soil conditions, as per dam type the Shear stress for the counterfort retaining wall is economic than the T shape wall by 25-30% , and as per soil condition Sandy soil have less Shear stress than silty and clay soil for the both dams
- The results of the Normal stress for the T-shape and counterfort wall for the different soil conditions, as per dam type the Normal stress for the counterfort retaining wall is economic than the T shape wall by 20-25% , and as per soil condition Sandy soil have

less Normal stress than silty and clay soil for the both dams

- The results of the Shear Strain for the T-shape and counterfort wall for the different soil conditions, as per dam type the Shear Strain for the counterfort retaining wall is economic than the T shape wall by 15.20%, and as per soil condition Sandy soil have less Shear Strain than silty and clay soil for the both dams
- The results of the Normal Strain for the T-shape and counterfort wall for the different soil conditions, as per dam type the Normal Strain for the counterfort retaining wall is economic than the T shape wall by 10-15% , and as per soil condition Sandy soil have less Normal Strain than silty and clay soil for the both dams

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