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ANALYTICAL METHOD FOR CHECKING STABILITY IN DEEP SOIL PILE BLOCK UNDER STATIC AND EARTHQUAKE LOADING IN A SOIL STRATA

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ABSTRACT

Geological stratification of Indian subcontinent is composed of formation of Rocky strata in the central, western and southern part of the sub-continent and a vast area beyond this upto Himalayan foot hills in the north and eastern part of the country including part of Bangladesh up to Burmese Plate on the east is deep sedimentary strata of varying depth up to 20km till it meets the top of the Indian Plate. Especially Gangetic plane of eastern India and Bangladesh is having a soft clayey strata upto 50m from ground level which is inadequately strong to bear heavy structural load more than 50metric ton/m2 coming from Nuclear Plant Buildings and Multistoried residential structures. With the use of technology for precast and cast in situ Reinforced Concrete Piles in this region of the subcontinent, the problem of low bearing capacity of founding strata was solved majorly. But designers were looking for a technology improving the strength of the soil instead of transferring the load over RCC Piles keeping the adjoining soil strata unchanged. There came this technique of deep soil-pile which is basically auguring maximum 1.0 m dia soil column up to a depth of 25-30m and mixing with cement slurry simultaneously so that a soil-cement piles of length 25-30 m with a minimum compressive strength of 2Mpa is developed in this engineered cement-soil pile (C-S Piles). A pattern of C-S pile-group is developed in both horizontal axis keeping a center to center distance of 75 cm between 2 adjacent piles center which overlaps each other by 25 cm and behaves like bonded pile block. Outer dimension of the pile block containing 36 overlapped C-S piles becomes 4.694mx 4.694m. Therefore, to make this geometry little more rhombic the engineered C-S pile block was optimized to a plan dimension of 5mx5m and the merged rhombic pile block was conceived to be a rhombus of dimension 5mx5mx25m(Fig-1&2). The other elements of the geometric model are the boundary soil which is original which encircles the C-S Pile block and transfer lateral soil pressure on the C-S Pile block in a hydraulic pressure mode.

The model is loaded with a Live Load of 60 Metric Ton/m2 as a static Load. Additionally, an earthquake load in terms of acceleration time -history is also applied at the bottom of the boundary soil using program Ansys 2021vers R1. The size of the boundary soil 50mx50mx35m was made to see that the earthquake wave doesn't travel back from the boundary.

In this paper, the author has tried to investigate how the Deep Soil pile block is transferring the imposed load to a deeper subsoil layer while interacting with the boundary soil medium which is present all around the pile block with a gradual increase of compressive strength of the C-S Pile block from 2Mpa to 15Mpa. Further this approach was modified by inserting a RCC foundation plate of plan dimension 1mx1mx0.25m over which the imposed load was placed instead placing directly over the pile block. The RCC foundation plate was planned to have a high stiffness of grade M25(cube strength 25Mpa). Pile block 5mx5mx25m is embedded in boundary soil of 50mx50mx35m.

Keywords: Geological Stratification, Deep Soil-Pile Technology, Engineered Cement-Soil Piles (C-S Piles), Load Transfer Mechanism, Earthquake Load Simulation

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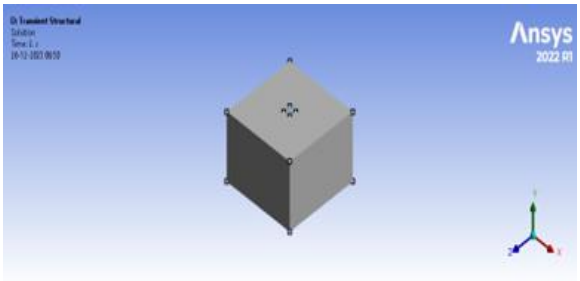

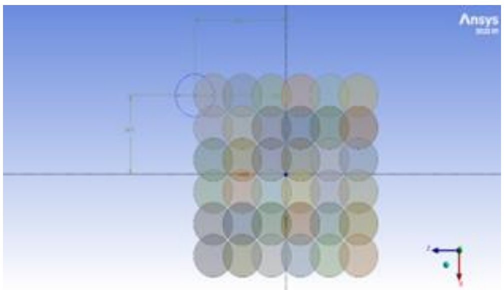

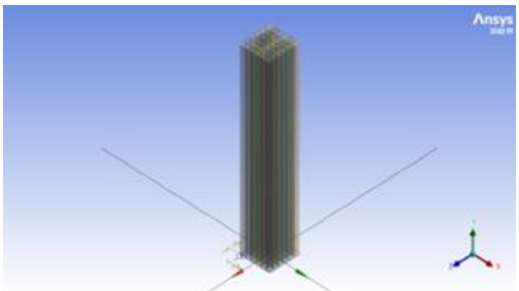

Fig-1 Engineered Cement Soil Pile Block **Fig-2** 3D view of the C-S Pile Block

2. DEVELOPMENT OF ENGINEERED CEMENT SOIL-PILE BLOCK AS A PART OF DEEP SOIL MIXING TECHNIQUE

2.1. The technique used all over the world.

For stabilization of soft grounds, in-situ deep mixing technique has been used extensively in last 20 years. It is a solidification technique in which the in-situ soft soil is mixed with a stabilizing material, in the form of slurry or powder, to produce stronger and firmer ground for foundations of structures.

Deep mixing technique, which has steadily progressed in Japan, Europe and the US, has been applied for solution of various problems in soft ground engineering. It has been applied, for instance, for prevention of sliding failure, reduction of settlement, excavation support, controlling seepage, preventing shear deformation and to mitigate liquefaction.

Mechanical soil mixing is typically performed using single or multiple shafts of augers and mixing paddles. The auger is slowly rotated into the ground, typically 10-20 rpm, and advanced at 0.5-1.5 meters per minute. As the auger advances, cement slurry is pumped through the hollow stem of the shaft(s) feeding out at the tip of the auger. Mixing paddles are arrayed along the shaft above the auger to provide mixing and blending of the slurry and soil.

The modulus of elasticity and unconfined compressive strengths are typically 1/5 to 1/10 that of normal concrete.

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Figure 3.0: Single and extruded overlapping deep mixed soil column (Massarsch and Topolnicki,2005).

2.2. Methodology of load dispersion through engineered pile block.

Imposed Load on the C-S Pile Block transfers major portion of the load first on the engineered pile group and the balance load on the boundary soil which are being resisted by the soil friction all around the pile up to its shear strength of the soil. The major portion of the load transferred through the pile then transfer the received load to soil below the pile toe which finally are born by the untreated soil.

The following equations are few available approaches which are used by various researchers.

(a) Weighted method:

$Qu = Cuc.\ \alpha + (1 - \alpha).\ Cus$ ----- (4)

where Cuc and Cus are the undrained shear strength of column and soft soil and α is replacement ratio.

(b) Brom (2000); Bouassida and Porbaha (2004) method:

$Qu = 0.7Cu_c.\ \alpha + \lambda(1 - \alpha).Cu_s$ -------(5)

where Cu_c and Cu_s Are the unconfined compression strength of the column and undrained shear strength soft soil. λ is taken 5.5, as proposed by Bergado et al. (1996).

Ultimate Bearing Capacity for a Block failure approach proposed by Topolnicki (2003)

In composite ground, stabilizing with floating deep soil mixed columns, the ultimate bearing capacity depends on types of failure. When failure is attributed to Block failure, the bearing capacity is expressed as below.

$Qu = 2Cu_p H(B+L) + (6 \text{ to } 9) Cu_s BL$ -----------(6) where,

B, L and H are the width, length and height of the Column block respectively and Cu_p Cu_s are the Shear Strength of C-SPile and Virgin soil. The factor 6 corresponds to rectangular Foundation whereas 9 corresponds to square foundation. Bergado et al., 1996 suggested not to add the 2nd part (End bearing resistance) of the equation (6) in estimating Qu.

Ultimate Bearing Capacity for a Local failure approach proposed by Broms (2000)

The bearing capacity with respect to a local failure condition along the boundary of the C-S pile group may occur due to uneven static loading condition or due to seismic loading condition mostly. In these cases, the Ultimate B.C of a local failure depends on the average shear strength Cav of the boundary soil at the boundary of the C-S pile group and is estimated as

$Qu = 5.5Cav(1+0.2B/L)$ ------------------------(7) where B and L are the two sides of a rectangular foundation. Out of these two failure modes, the least of the two Bearing Capacity calculated shall be considered for comparison with the combined effect of vertical load and moments on the foundation.

3. MATHEMATICAL MODEL AND LOADS ON THE PILE GROUP AND BOUNDARY SOIL

3.1. Mathematical Model

The C-Spile group considered in this paper is composed of 6 overlapping piles of diameter 1m each in each row of both horizontal axes .This way the above pile group is composed of total 36 overlapping piles which bears the vertical load of 60 Mt /m2 over the entire area of 5mx5m(Fig-1).Total 4 vertical faces and one bottom face of the block C-S pile group(Fig-2) is given elastic support condition which touches the unimproved boundary soil wherein appropriate soil properties were considered. This elastic support along the length of the C-S pile block in a way takes care of the spring and the damping effect of the adjoining soil elements.The C-S pile group is of size 5mx5m along both horizontal axis and25 m along vertical axis.The Boundary soil size is taken as 50mx50m along 2 horizontal axis and 35 m along vertical axis. This boundary soil is encircled by infinite soil mass along its 5 faces with the same elastic support condition on the 4verticalfaces and fixed boundary condition at the bottom face. In this paper , author has conceived of initially 5 cases of analysis of Deep soil Pile by mixing cement with soil in an increasing order of cement. And further assumed that characteristic strength of the C-S Piles are developed as 2,5,7.5,10and 15Mpa. These five cases were marked as .

Case 1. DeepSoil Pile3D (fck=2Mpa)

Case 2. DeepSoil Pile 3C (fck=5Mpa)

Case 3. DeepSoil Pile 3B (fck=10Mpa)

Case 4. DeepSoil Pile3A (fck=15Mpa)

Case 5. DeepSoil Pile 3E (fck=7.5Mpa)

Static Loading of 60Mt/m2 was placed over the entire 5mx5m C-S Pile block.

Material data of C-S Piles and Boundary Soil (Silt clay mixed with coarse sand mostly available in the subsoil of Kolkata City area upto50m) is presented in Table-1 below. Later on, based on the analysis results further 3 more cases were investigated wherein the superimposed load 60Mt/m2 in the above 3 cases were placed over a small reinforced concrete plate element of thickness 0.25m with size 1mx1m to present the actual loading condition in site thereby reducing to a great extent overstressing of the C-Spile block and boundary soil which were observed in the earlier 5 cases.

* Nu is Poisson ratio. ** Mod.ofElasticityof soil (Siltyclay mixedwith CoarseSand) =ShearModx2(1+Nu)

Model	Characteristi cComp stress ofC-S Pile fck(Pa)	Mod.Elast 5000SqRootfck (Pa) CS Pile	Nu of CS Pile	Mod.Elast Boundry Soil Clay semisolid ** (Pa)	Nu of Boundry Soil	Shear Modulus Of Soil (Pa)	Ct = Shape Constfor Square Foundation
Deep SoilPile3D	2E+06	7.07E+09	0.25	1.24E+09	0.30	4.77E+08	1.08
Deep SoilPile3C	5E+06	1.12E+10	0.25	1.24E+09	0.30	4.77E+08	1.08
Deep SoilPile3B	10E+06	1.58E+10	0.25	1.24E+09	0.30	4.77E+08	1.08
Deep SoilPile3A	15E+06	1.94E+10	0.25	1.24E+09	0.30	4.77E+08	1.08
Deep SoilPileE	7.5E+06	1.37E+10	0.25	1.24E+09	0.30	4.77E+08	1.08

Material Data for C-S Pile and Boundary Soil Table-1

We have collected the above soil data in Table-1 for the above boundary soil (SiltyClay with Coarse Sand) from geotechnical investigation report [3]to feed in the material input of Ansys work bench version 2022/R1 and further calculated the following soil parameters in the working sheet below in Table1&2.

Sample SiltyClayee-Soil element atMid height of the Pile12.5m below G.L	Vertical Stress in (Pa) on the Soil Element at the mid height of Pile block. =18*12.5(Gamma*h) Sigma-1=225Kpa	Radius of smallerMohr circle =(225-75)=150Kpa/2 =75Kpa ϕ=10.16degree L14=75/Sin10.16=425Ka L20=425-(75+75)=275Kpa Tanϕ=C/L2,where C=cohesion C(L23)=275*Tan10.16deg =49.3Kpa Say 49Kpa	LateralEarthPressure at depth 12.5m below G.L =1/3*(1800*12.5)=7500kg/m2=75 KPa Sigma-3=75Kpa	Friction Coeffecient =Tanϕ ϕ =Friction angle. Assuming ϕ=10.16deg Meu=Tan(10.16) =0.18
SiltyClayee-Soil element atthe Foot of B.soil depth 25m	At the Foot of Concrete Pile25m Sigma1=18*25=450kpa	Radius of the 2nd Bigger Mohr circle =(450-150)/2 =150Kpa ϕ=10.16 degree L22=150/0.1736=850.35kpa Say850Kpa B2=850-(2x150)=550kpa C(L24)=(550*Tan10.16)=98.6kpa Say100Kpa.	Lat EarthPressure at the foot of Concrete pile 25m below G.L =75x(25/12.5)from above Sigma3=150Kpa	Assuming ϕ=10^0 Meu=Tan(10.16) =0.18

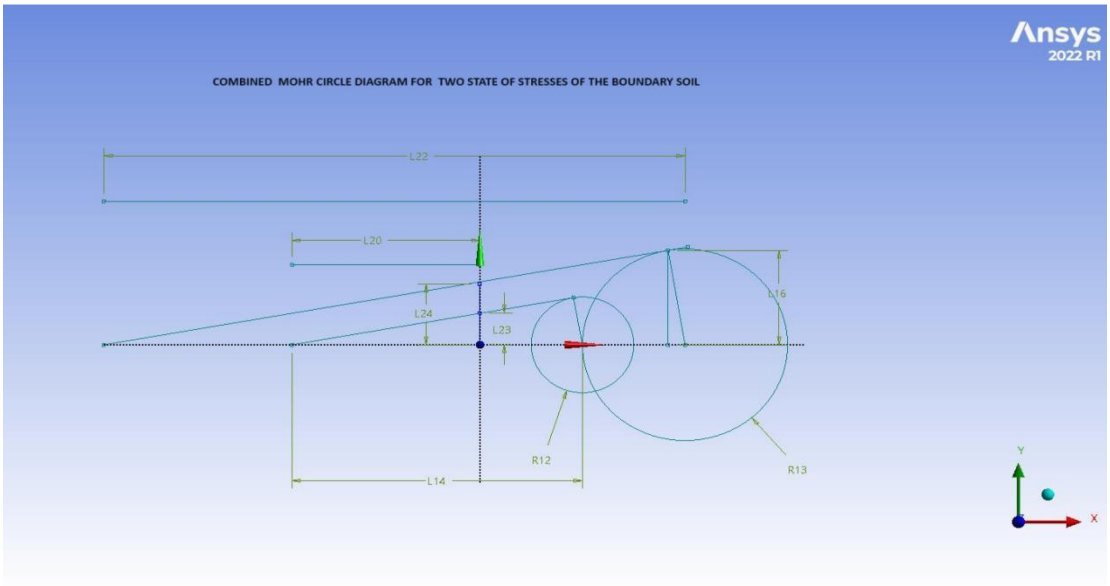
Table-2 Calculation worksheet for developing a combined Mohr Circle of stresses(Fig-4)

The Contact between C-SPile block and Virgin Soil around the pile block was considered to be frictional for which a meu value which is calculated as 0.18 and is used in Ansys wb as 0.20. The friction value will be maintained as 0.2 for for all the contact conditions.

Using Coulomb Equation, we get Shear Strength of Soil(Tao)= C+SigmaTanϕ WhereSigma=137Kpa,is mapped from the smaller Mohrcircle as xcoord of the vertical interceptof the line joining the smaller mohr circle at maxshear stress =74Kpa C=49Kpa(Cohesion) Tao= 49+137*Tan10.16 =49+25=74Kpa Ansys Input data BoundarySoil: 1.Mod of Elasticity of Soil (Average of 25readings from 2m to 50m below G.L). Esoil=1.24E+09Pa Actual site data[3]from Kolkata for Alipore site . Foundation Size=5mx5m as per model size Nu=0.30(Average poisson ratio data for soil strata upto50m) Cu $=\frac{E}{\sqrt{(1-nu^2)}}x\frac{1}{\sqrt{Area\ of\ Foundation}}$ Cu=5.8E+08N/m3 In case Foundation size=1mx1m then Cu = 1.24E+09/(Root(1-0.09)xRoot(1)) =1.3E+09N/m3	2. Ultimate Compression for the smaller Mohrcircle is equal to Max Shear Stress =74Kpa 3.Yield Compression =0.7*74=52Kpa 4.Ult Tensile strength=0.0 Similar calculation for the bigger Mohr circle C for bigger Mohr circle=100kpa Sigma=275kpa is mapped as the x coordinate of the vertical intercept CG.Tao at the Foot of C-SPile. Max Shear Stress of the combined cases Taomax=100Kpa+(275)*Tan10.16 Kpa = (100+49)Kpa=149Kpa Here the value of Sigma and Cohesion for both the above cases were taken from the respective Mohr Circles(Fig-4) . 5. **Final soil parameter for Ansyswb material input,Taoult=149kpa(maxofthetwocases),Tao(yield) =104Kpa.**

Table-3 Calculation Sheet for Soil parameter and Input data for feeding to Ansys W.B 2021/R1

In the above Table-2&3, calculation is presented to show the 2 state of stresses at rest without the effect of imposed loading in the mid depth of the C-S pile block and at the foot of the C-S Pile.Max Shear Strength in state-1 is 74kpa whereas the same at the foot of C-S Pile in state-2 was calculated as 149kpa. So for Developing Mohr circle of stresses for boundary soil we have taken the maximum of the 2 cohesion values i.e, C=100kpa and ϕ=10.16^0.Max Shear Strength was calculated as 149kpa and Yield Strength ofSoil =104Kpa.



Combined Mohr Circles for 2 state of stresses Fig-4

3.2. Various Loads applied on The pile group is as follows:

3.2.1The C-S pile block is loaded at the top with a vertical load of 60 Mt/m^2. Lateral earth pressure load is also acted from the adjoining soil mass on all the 4 faces of the C-S Pile block . In addition, a matching earthquake acceleration time history load converted from Response spectral data obtained from ASCE7-16 is also applied at the bottom of the soil boundary as

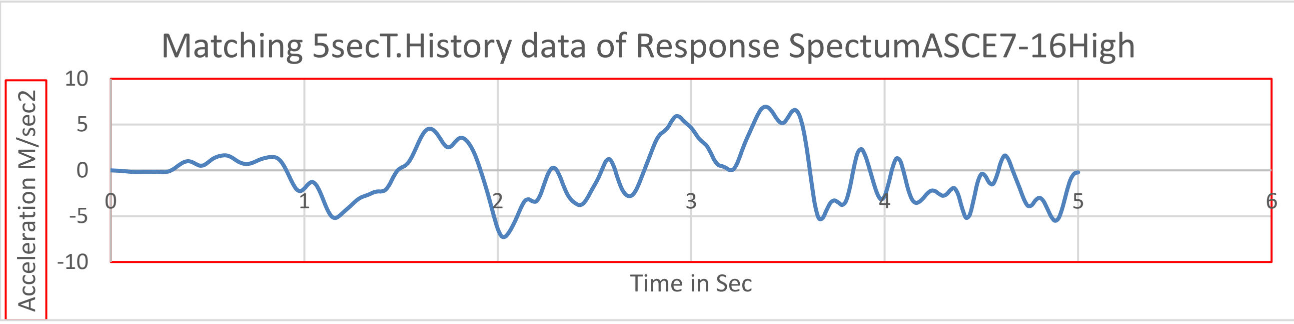


Fig-5: Matching Time History graph for 5 sec data generated out of ResponseSpectrumASCE7-16.

Base excitation as well as All bodies excitation are as per Ansys work Bench norms.

4. PARAMETRIC EVALUATION OF STRESSES IN BOTH C-S PILE AND BOUNDARY SOIL

4.1 Five parametric cases were analyzed with gradual increase of proportion of cement being mixed in the grout so that we get characteristic strength of C-S Plie as below.

Case 1 DeepSoil Pile3D(fck=2Mpa) Case 3. DeepSoil Pile 3B (fck=10Mpa)

Case 2. DeepSoil Pile 3C (fck=5Mpa) Case 4.) DeepSoil Pile3A (fck=15Mpa)

Case 5. DeepSoil Pile 3E (fck=7.5Mpa)

The mechanics working in Deep Soil Pile technique was analytically solved using Ansys work Bench 2022/R1. Here,the author wanted to investigate as to how the stresses in cement-soil mixed Column's and the virgin boundary soil vary in the above 5 cases. In this topic, Broms and Boman (1979) were the two front runner investigators who had proposed two approaches.

(a) Load is first carried by the C-S Column and when the stress in the C-S Column exceeds the yield strength then rest of the load is transferred to the virgin boundary soil.
(b) The second approach was the load will be shared by the virgin boundary soil and C-S Column based on their individual stiffness.

Here the author is examining his analysis results and coming to a conclusion about selecting the approach (either a or b) which one is closer to the analytical results. In structural mechanics theory, it is a well-established concept regarding load distribution in a structure based on stiffness of the various structural members that load is shared more by the member which has more stiffness. Similar analogy can be used in this case also that the total superimposed load 600 Kn/m2 will be shared by majorly by C-S Column up to its Characteristic strength with adequate friction developed at the interface of C-SPile and virginsoil so that the deformation in the soil is within a reasonable limit of 25mm in static case and 50mm combined with earthquake Load.Simultaneously the virgin boundary soil will resist through friction the balance load and the shear stresses in the soil at the interface shall be within maximum yield strength of soil calculated above para equal to 104kpa.

Variation of Shear stresses in Boundary soil with increasing Fck value of Pile block.

In the following few graphs,Max Shear stresses of total eight cases discussed above were plotted
against first 5 fck values and later on 3 fck values 2,5 nd 7.5Mpa .In first case, imposed Load was on total area 5mx5m.In the 2nd three cases imposed load was over 1mx1m area.

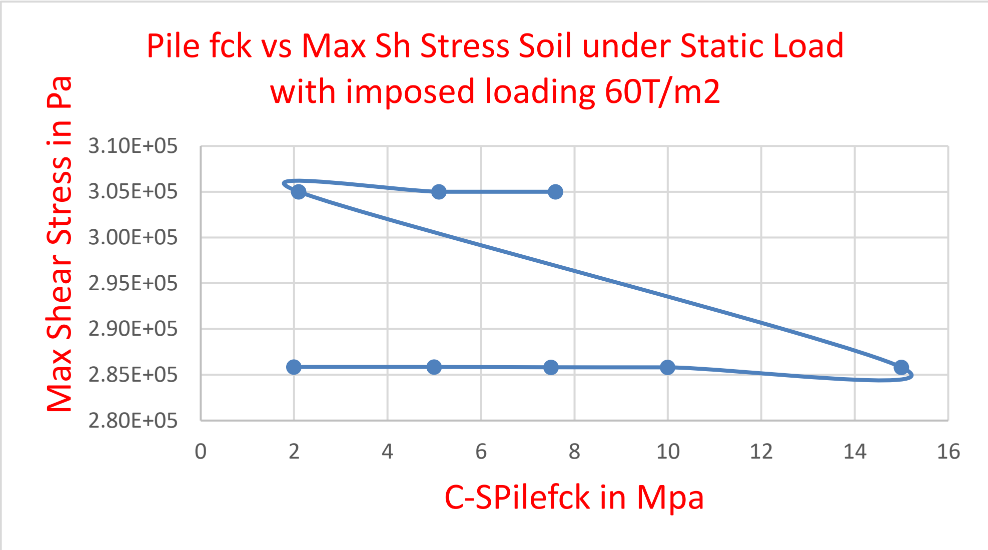


Fig-6(a)

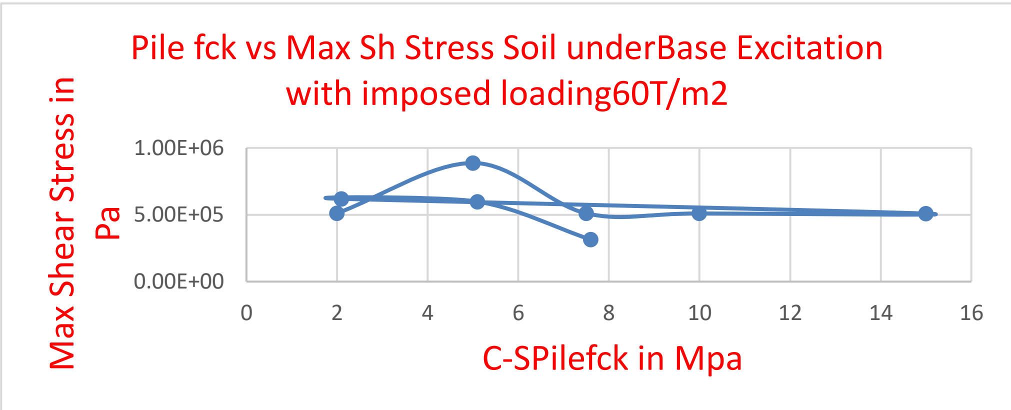


Fig-6(b)

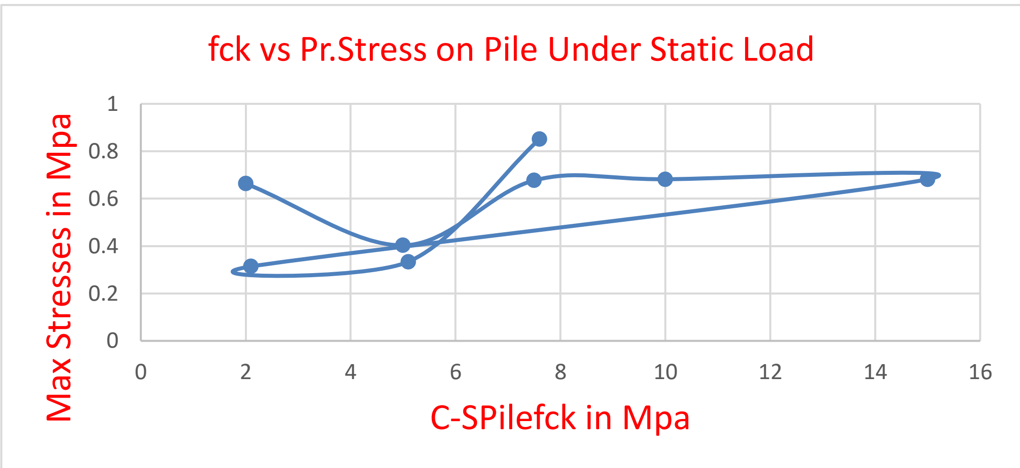


Fig-6 (c)

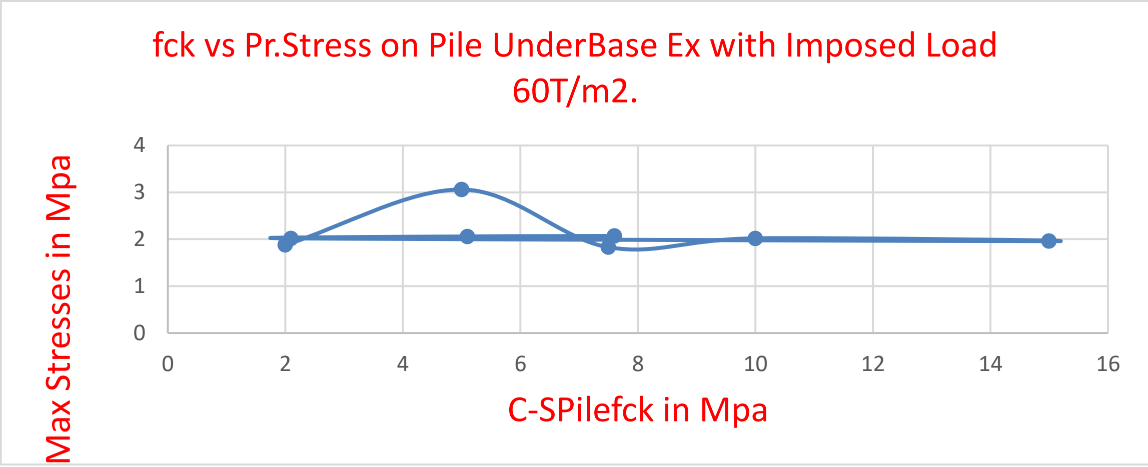


Fig-6(d)

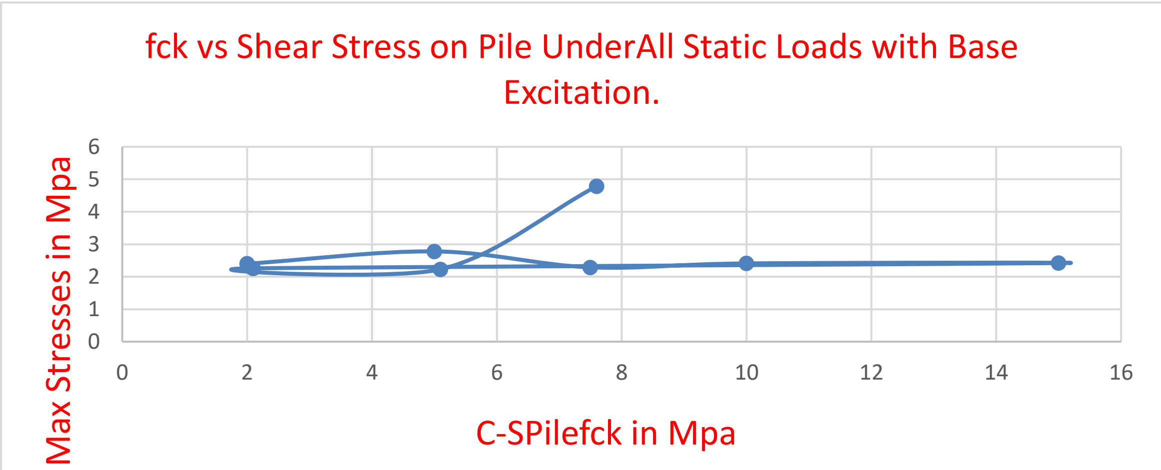


Fig- 6(e)

4.2. VARIATION OF SHEAR STRESSES IN BOUNDARY SOIL WITH INCREASING FCK VALUE OF C-SPILE BLOCK WITH SUPERIMPOSED LOAD 60MT/M2 TRANSFERRED ON A SQUARE FOUNDATION PLATE1MX1MX0.25M AND COMPARISION WITH EARLIER 5 CASES WHERE IMPOSED LOAD WAS PLACED OVER 5MX5M PILE BLOCK

Three additional cases are presented in this paper wherein the model size, material parameters of C-S Pile block and the Boundary soil were kept identical with the earlier 5 cases .Only addition was a RCC plate of size 1mx1m with thickness 0.25m in top of the C-Spile block as foundation plate to bear the superimposed load of 60Mt/m2.The contact between Pile block and the foundation plate was assumed as bonded as it will behave like an embedded Pile cap. Other contact between pile block and boundary soil was kept identical as frictional (derived equal to 0.20 in working sheets Table-2).The size of the foundation plate was kept minimum required so as to keep the pressure bulb within the pile block area 5mx5m and to take advantage of higher shear strength due to the pile block's improved compressive and shear strength capability.

This way, results from analysis of 3 additional cases were added to the earlier 5 cases to see the trend of stressing pattern.Data Sheet of C-S Pile Material 3piles of maximum compressive stresses (2,5and 7.5Mpa).Length of Pile=25m Case-1:CSPile3D4(2Mpa) Case-2: C-S Pile 3D3 (5Mpa). Case-3:C-S Pile 3D5 (7.5Mpa). Shear Strength of Soil as per Columb's Law τ =C+σ tanϕ where C= Cohesion of boundary soil. σ = Normal stress at point of max Shear Stress works out to be the same{Kpa for Boundary Soil	1.Shear Stress in Pile (2Mpa)= 2.4Mpa&2.26Mpa--Fig-6e 2. Shear Stress in Pile(5Mpa)=2.78&2.23Mpa--------Fig-6e 3. Shear Stress in Pile(7.5Mpa)=2.29&4.79Mpa-----Fig6e Here the 1 st set of values 2.4,2.78and2.29 are without RCC foundation and the 2 nd set of values are with RCC foundation.Infact not much of change noticed over the stress in piles in both cases. Now by Analysing Fig-6(a) &6(b) for max Shear stresses in Boundary soil under static Load and Static +E.Q load at base.we find 1a.ShStressinB.Soil(Pile2-7.5Mpa)=(0.286,0.305in Static) 1b.Sh Stress in B.Soil(Pile2-7.5Mpa)=(0.314-0.62in Stat+EQ) After seeing into the Stress outputs of both pile as well as boundary soil for static and static+Eqload condition for 3 cases mentioned above and by compairing similar stress outputs for the earlier 5 cases we find not much of stress reduction in boundary soil is happening by reducing the loaded area over C-S Pile block area from the point of view of more load sharing by C-S pile block.

Calculation Sheet for Shear Strength of C-S Pile Table-4.

4.3 Estimation of Block Failure and Local failure possibilities as proposed by Topolnicki (2003) and by Broms (2000).

Stability against Block Failure.

Qu = 2Cp H(B+L) + (6 to 9)Cs BL **by Topolnicki (2003)** -----------(6) where,H= Total Depth of Pile Block=25m Static Load on Plan area 5mx5m 600kn/m2 of the pile block B and L=5m Qu= Bearing Capacity of the Pile Block,Cp = Shear Strength at the Interface of Pile block and Boundary Soil.Here only one case loading (Static+ Time history earthquake Load as shown in fig-5) will be taken to check stability. Based on calculation worksheet in Table-3 Cs is taken average of of the shear strength value at depth12.5m and 25m=(74+149)/2 =112 Kpa.

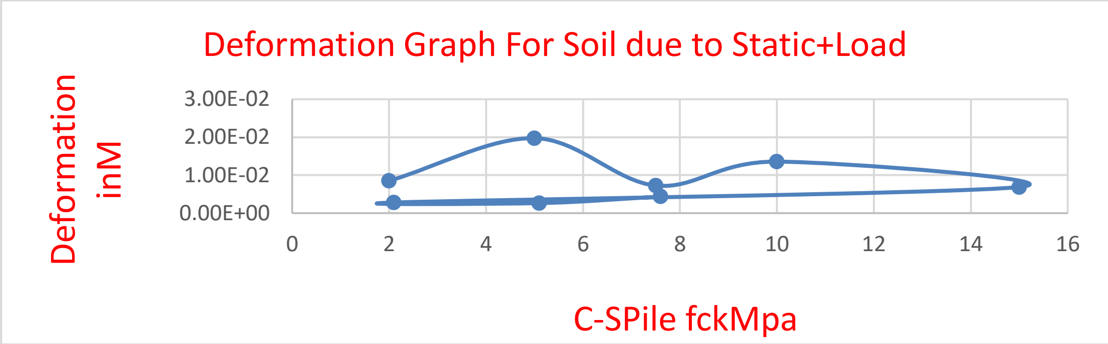
Stability against Local Failure by Broms (2000)

Qu =5.5 Cav(1+0.2B/L) **by Broms (2000)** ------------------------(7)

Deep Soil Pile -3D worksheet for calculating total Shear Strength against Block Failure due to Base Excitation			
Shear strength		Cs	Unit
at Soil boundary		112	KN/m2
TotalStatic Load on the FDN=600*5^2 + 23*(5*5)*25	29375		KN
Total Shear Resistance as per Eq (6)		87725	KN
Therefore Block failure of the C-S Pile group is not imminent			
Deep Soil Pile -3D worksheet for total Shear Strength against Local Failure			
Total shear strength		Cav	Unit
at Soil boundary	112		KN/m2
Max B.C available as per Eq(7)		739.2	KN/m2
TotalStatic Load of the Pile Block with Imposed Load		=600+575=1175	KN/m2

Therefore Local Failure is possible.

Deformation graph of all the 5Cases. Fig-7a &7b.



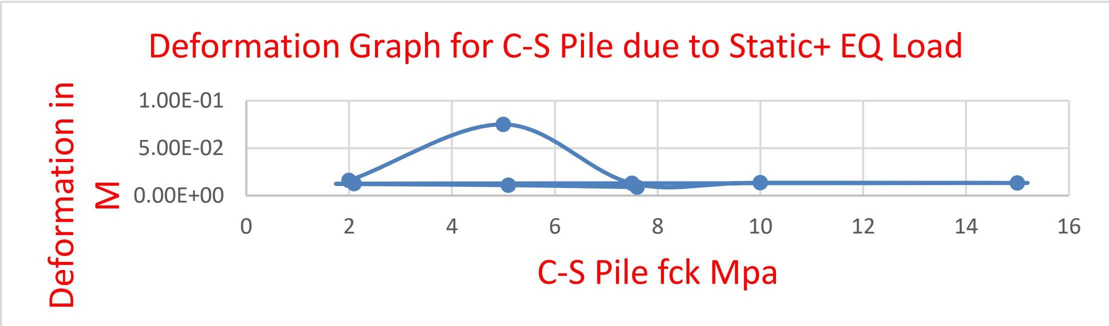


Fig-7b.

5. DISCUSSION ON THE RESULTS AND CONCLUSION

The analysis results of the 5 models DeepSoil-Pile3D,3C,3E,3B&3A for both mode of failures indicate that there is no chance of a block failure as margin of total shear strength of soil is at least 2.986 , but there will be some local failures situation due to self weight plus Imposed Loading 600Kn/m2 comes equal to 1175Kn/m2 and Static margin of Bearing capacity goes down below 1.0 due to the ratio of Bearing Capacity Available /Applied Pressure works out to 0.45<<1.0. By looking the maximum value of shear stresses of boundary soil element in fig 6 (a) for fck=2Mpa C-S Pile there are 2 values 0.305Mpa and 0.286Mpa.The high values are at the corner nodes of the Pile toes .Rest all other values at the 4 interfaces of the pile and soil are within max Shear strength of soil 149Kpa or 0.149Mpa we can mark these excesses as local failures.As far as deformation of boundary soil and C-SPile is concerned these are within limit of 25mm on account of static load and deformation due to static+earthquake load.

REFERENCES

[1] Understanding the Performance of Deep Mixed Column Improved Soils - A Review Abbey, S. & Ngambi, Mar 2015 In: International Journal of Civil Engineering & Technology (IJCIET). 6, 3, p. 97-117 20 p, ISSN 0976 – 6316(Online).

[2] Stabilization of Soft Soils with Deep Mixed Soil Columns – General Perspective, January 2013 Electronic Journal of Geotechnical Engineering ,Vol-18 By Ali Dehghanbanadaki, Kamarudin Ahmad, Nazri Ali, Mahdy Khari, Payman Alimohammadi and Nima Latifi

[3] Department of Civil Engineering, University Technology Malaysia; 81310 Johor; Malaysia.

[4] Geotechnical Investigations and Site Classification of Kolkata under workorder by department of Disaster management Govt of West Bengal India.

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