Improving the Engineering Response of Subsoil by Fibre Reinforcement Technology

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Abstract— **The main objective of the present study is to examine the properties of soil reinforced with randomly distributed fibres. It is one of the latest technologies in fibres used to improve the strength of the soil and increases the performance of pile. When pile is subjected to loading compared to unreinforced soil it was found that it is able to withstand and resist the pile. The behavior of unreinforced single laterally loaded and vertically loaded pile was studied and got settlements. The shear strength of the soil has improved and properties can be altered when it is mixed with fibres as fibre is a composite material. The main aim is to improve the performance of soil when it is mixed with fibres. This method has recently gained attention in geotechnical engineering. The paper, as a whole describes the series of models done on unreinforced soil and fibre reinforced soil using finite element analysis.**

***Keywords*— Fibre reinforcement technology; geotechnical engineering; Composite material; finite element analysis.**

I. INTRODUCTION

The soil reinforcement technique by high tensile strength materials has been widely circulated in earthwork construction. In recent years fibre reinforced soil used in geotechnical engineering is not a new technique. This technology is generally used in dam projects, road works, sanitary landfill line and many more. Fibre reinforcement is the technology which improves the soil strength and widely used in geotechnical structures. Fibre reinforced soil contains small fibres that are randomly distributed and is of different types and each of them varies in their properties. This technique can reduce the displacements and shrinkage of soils. It is one of the latest technology improves the soil strength .Today the usage of fibres in geotechnical study is the major part of study when compared to systematically reinforced soils and randomly distributed soils. It exhibits some advantages and properties. It increases the shear strength of soil and beneficial to all types of soil. It reduces the shrinkage and swell pressures of expansive soil. Fibre reinforcement helps to improve soil strength and makes stable near surface soil layers and it palliates the risk of soil liquefaction .The study presents the failure criteria of fibre reinforced sand by assuming the total combination of shear resistance of soil and reinforcement of fibres. It also improves the performance of pile. The behavior of fibre reinforced soil and unreinforced soil of single laterally loaded pile and vertically loaded pile was studied and got settlements. Soil reinforced with fibres gives the improvement in tensile strength and fracture toughness as it prevents the development of cracks and increase in self seaming ability of soils. It also improves various engineering properties. The civil engineering industry benefits a lot from the wide variety of geotechnical applications obtained due to fibre reinforced soil.

Research on different types of soil reinforcement and materials found a limited amount of information on fibre reinforced soil. Fibre reinforced soil is similar to that of unreinforced soil but when its properties are compared it gives more strength and deformation. When fibre is mixed with soil it gives a little effect on friction angle and cohesion factor acts as the main part. The increase in shear strength increases the fibre content. The effective shear stress of fibre reinforced soil specimen is higher than the unreinforced soil specimen. The strength in soil increases due to combination of increase in principal stress and decrease in higher pore pressures caused by fibres.

II. ENGINEERING PROPERTIES OF FIBRE REINFORCED SOIL

The main purpose of reinforcing soil is to improve its stability and bearing capacity and to reduce its settlements and deformation. The fibre reinforced soil is one of the most attractive and advanced techniques used in geotechnical structures. Improving the engineering properties of soils with both fibres and cement is found to be more attractive because of its combined effect of adding cement and fibre in soil. This further improves the engineering response of soil under structural loads and provides resistance to the deformation.

A. Evaluation of shear strength in fibre reinforced soil and unreinforced soil

The shear strength of fibre reinforced clay is more difficult than fibre reinforced sand because of its pore water pressure and interface shear strength. The fibre reinforced soil shows that mobilization of fibre tension requires strain level higher than that of unreinforced soil. The comparison shows that fibres may lead to shear strength even below that of unreinforced soil.

B. Predictive model of shear strength of fibre reinforced soil

Soil structure is reinforced with randomly distributed fibres which characterize the contribution of stability to fibres. This mixture is treated as homogenous and it has been qualified by friction angle and cohesion of soil.

C. Advantages and disadvantages of fibre reinforced soil

Advantages:

- It increases ductility and seismic performance.
- It provides erosion control and alleviates the development in vegetation.
- It reduces the cost of maintenance and is not affected by weather conditions.
- It helps in eliminating the shallow failure on slope face.

Disadvantages:

- It has poor resistance to moisture and has low compatibility and thermal stability.

D. Evaluation of stress-strain behaviour of fibre reinforced soil

The fibre reinforced soil provides shear strength in mobilizing the tensile forces. The development of strain levels of tensile forces may be higher compared to unreinforced soil.

III. FINITE ELEMENT MODELS

The PLAXIS 2D program includes 2D dynamics and 2D Plax flow modules which constitute a finite element package intended for the two dimensional analysis of deformation and stability in geotechnical engineering. It offers professional tools required in today's and tomorrow's world of high-tech building to analyze complex projects. Any project involves modeling of structures and interaction between structure and the soil. The number of models used in plaxis is to analyze the performance of soil. The models in this paper are designed by using plaxis 8.2 versions. It has various general features of modeling.

- Automatic mesh generation
- High-order elements
- Consolidation analysis
- Stress paths
- Calculation facilities
- Output features
- Modeling options
- Automatic load stepping
- User defined soil models
- Staged construction

Generally plaxis is made of four internal programs.

- Input
- Calculation
- Output
- Curves

The paper describes the comparison of unreinforced and fibre reinforced soil using plaxis 2D.

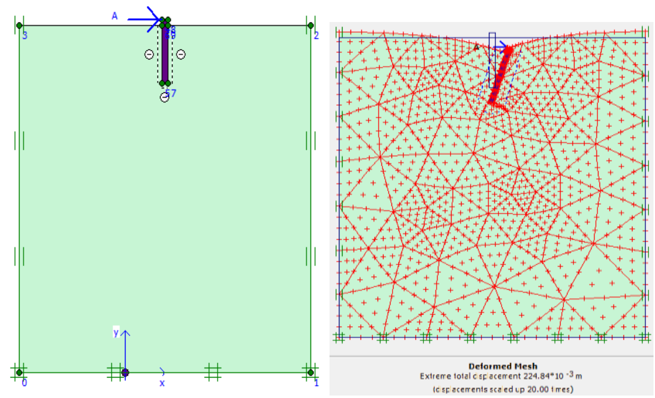

Fig.1 Input and output models of unreinforced single laterally loaded pile

Fig.1 shows that the input model is the first program in plaxis. In this model of unreinforced laterally single loaded pile the dimensions are taken as 10*15. It is a mohr-coloumb material type of model. In this model, pile is subjected to the loading of unreinforced soil as it withstands and resists the pile. The load is acted horizontally and ten nodes are used for load displacement. In order to apply finite element analysis the geometry must be added to the elements which are taken as output. The pile used in this is a linear elastic type of model and contains non-porous type of material. The pile length is taken as 10m and the model is rigid type of strength. In general here the stiffness is taken as 500 KN/m³. Finally the mesh will be generated due to load applied. When the load is applied horizontally the mesh in this fig .1shows the bending of pile and it shows it is not able to resist the pile as it is slightly bending due to lack of stiffness.

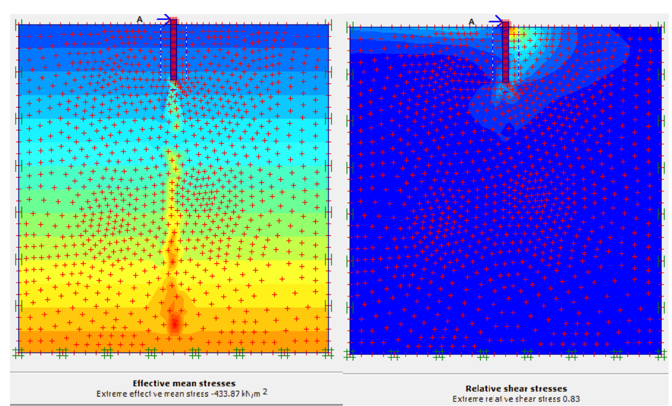

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Fig.2 Shear stress and effective mean stress of unreinforced laterally single loaded pile

The total displacement was found to be 164.82 KN/m³.The total increments in displacements was obtained to be 49.44 KN/m³.The effective stresses is evaluated to be -434.24 KN/m².These results depends on various parameters. In this the parameter 'c' is taken as 9.5 and Poisson ratio is taken to be 18.Depending on these factors these stresses are formed.

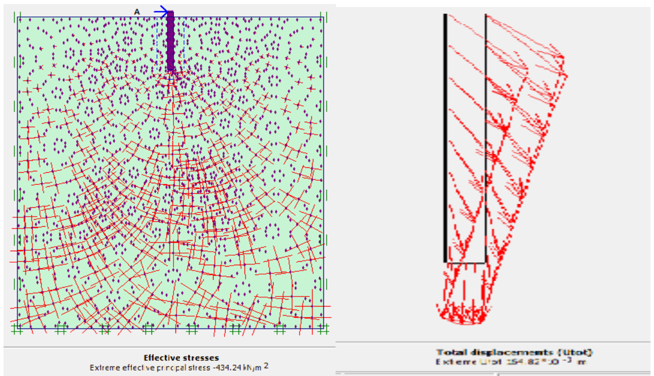

Fig.3 Total displacements and effective normal stress of unreinforced laterally single loaded pile

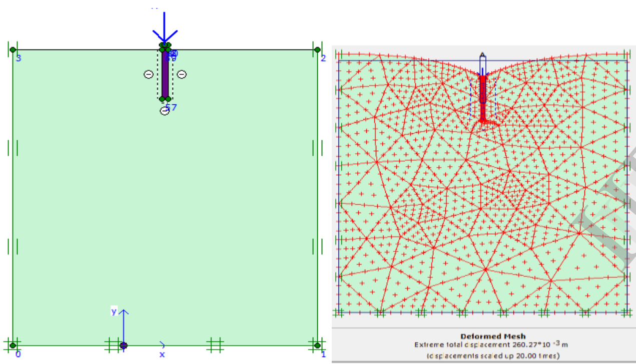

Fig.4 Input and output models of unreinforced vertically single loaded pile

The input and output model of unreinforced vertically single loaded pile is shown in fig 4. In this unreinforced soil clay material is used and pile toe material is used. Here stiffness is taken to be the same as before. When the load is applied vertically it does not change in the deformed mesh. It remains the same.

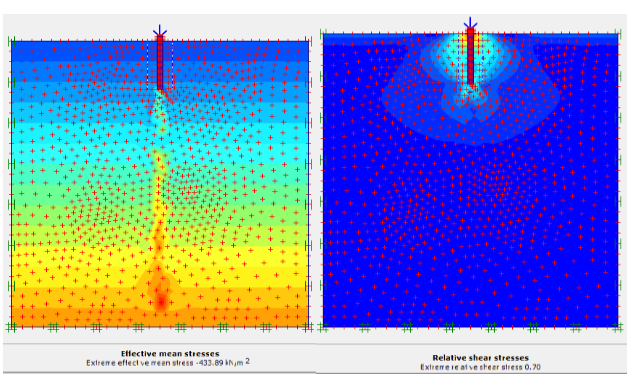

Fig.5 Effective shear stress and normal stress of unreinforced vertically single loaded pile

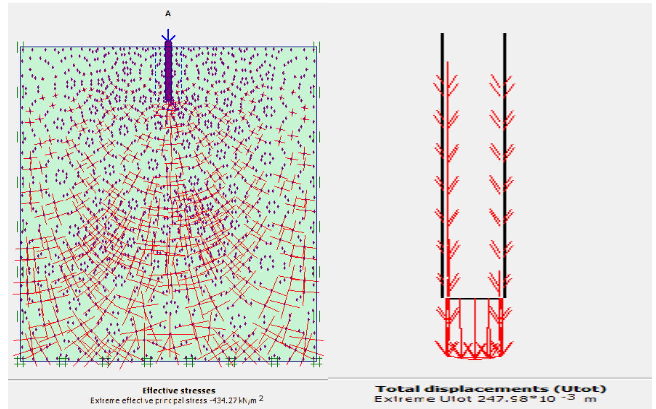

Fig.6 Total displacements model of unreinforced vertically single loaded pile

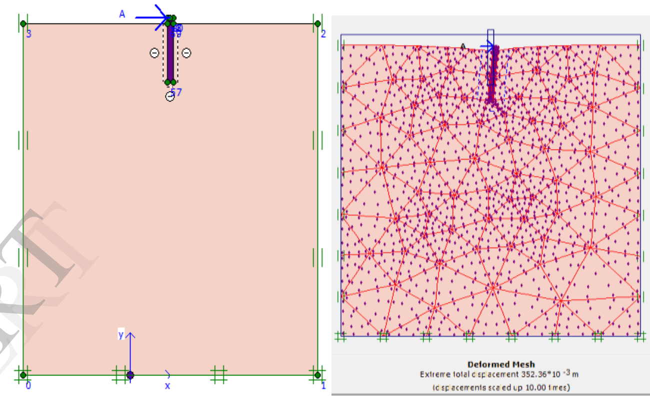

Fig. Input and output models of fibre reinforced laterally single loaded pile

In the fig.7, the behavior of fibre reinforced soil of laterally single loaded pile and its different parameters have been shown. In this model, the load acts horizontally to the pile in input geometry and after generating the mesh it shows that the load is slightly twisted due to shear strength and deformation of fibres. Here, fibre is mixed with soil to give strength and stiffness to the soil. In this fibre reinforced soil, the fibre reinforced clay is the material used. Here the stiffness used is 5000KN/m².The strength parameter 'c' is taken as 13 and ϖ is taken as 38.3. It is a rigid type of interface. The displacement and shear stresses factors are determined as it depends on these parameters.

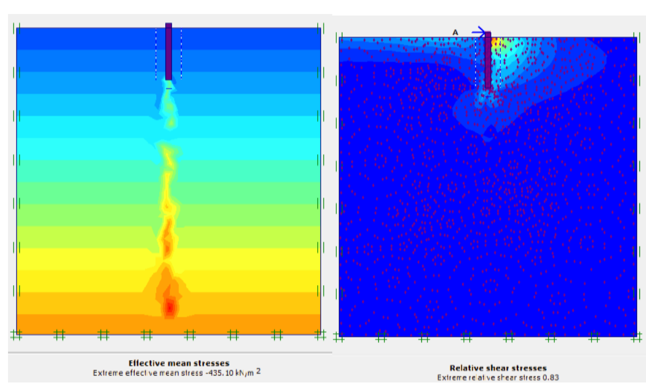

Fig.8 shear stress and normal shear stress of fibre reinforced laterally single loaded pile

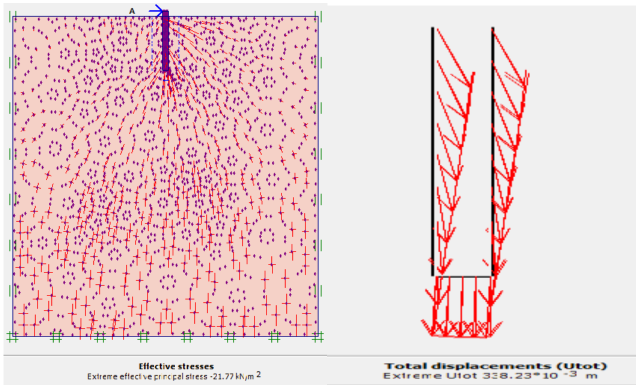

Fig.9 Total displacements and effective stresses of fibre reinforced laterally single loaded pile

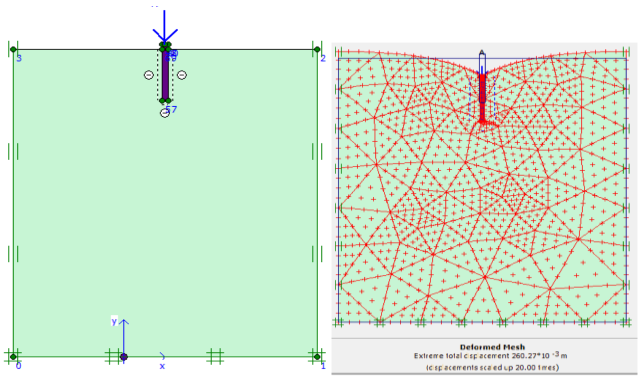

Fig.10 Input and output models of fibre reinforced vertically single loaded pile

It shows that the load is applied vertically to the pile as it remains same because fibres mixed with soil gives additional strength to the properties. It improves its stability and stiffness. It is mohr-coloumb material type of model and it behaves as a undrained model.

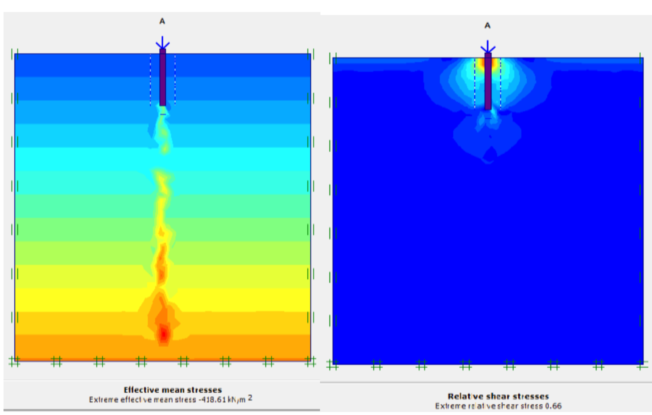

Fig.11 Shear stress and effective stress of fibre reinforced vertically single loaded pile

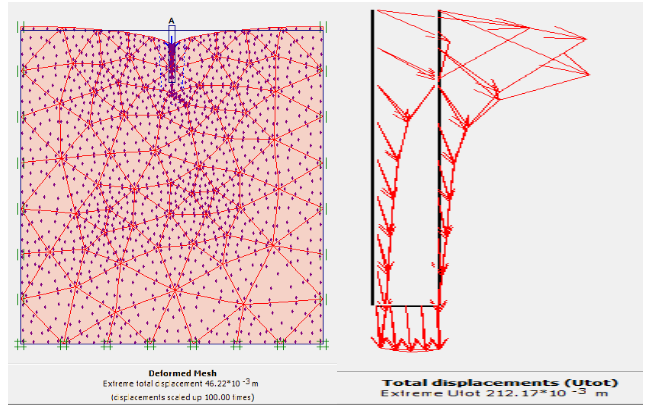

Fig.12 Total displacement of fibre reinforced vertically loaded pile

Here the total displacement was found 87.9 KN/m² and shear stress as 11.15KN/m²depending o the parameters.

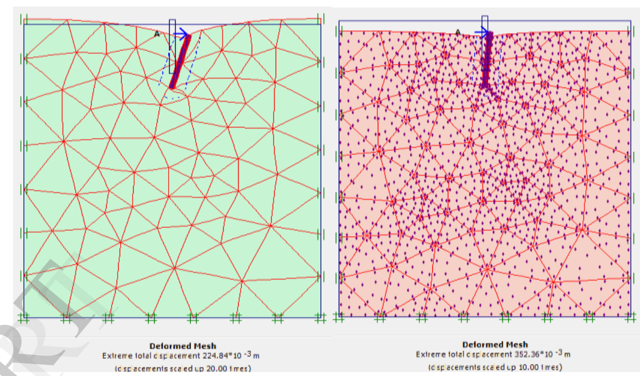

Fig.13 The differences between unreinforced laterally single loaded pile and fibre reinforced laterally single loaded pile

In the above fig.13, the difference between unreinforced and fibre reinforced laterally single loaded pile is examined. The load given is horizontally and in unreinforced the pile is bending and in fibre reinforced pile remains the same it is due to strength and stiffness.

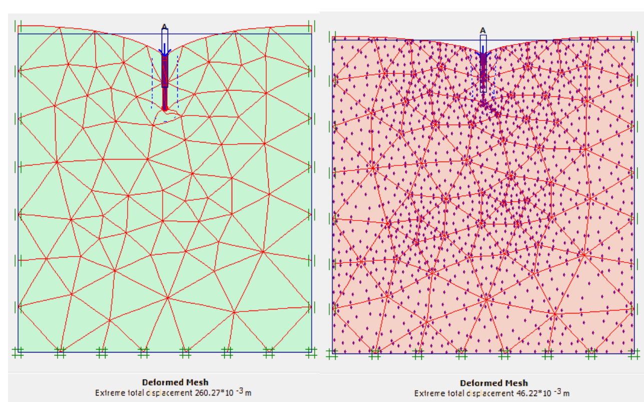

Fig.14 The differences between unreinforced vertically single loaded pile and fibre reinforced of vertically single loaded pile.

In this fig.14, it explains that load acting is vertical in both the mesh and it remains the same in both the cases as the pile load slightly twists.

The difference in parameters between the unreinforced and fibre reinforced soils taken as

TABLE.1. MATERIAL PROPERTIES OF UNREINFORCED SOIL

Parameters	name	Value	Unit
Material model	model	Mohr-coulomb	-
Type of material behaviour	type	Drained	-
Soil unit weight above phreatic level	Γunsat	12.02	KN/m³
Soil unit weight below phreatic level	Γsat	15.80	KN/m³
Youngs modulus	Eref	13000	KN/m²
Poissons ratio	µ	18	-
Cohesion(constant)	Cref	9.5	KN/m³
Dilactancy angle	ש	0.30	-

TABLE.2 MATERIAL PROPERTIES OF FIBREREINFORCED SOIL

parameters	name	Value	Unit
Material model	model	Mohr-coulomb	-
Type of material behaviour	type	Undrained	-
Soil unit weight above phreatic level	Γunsat	11.94	KN/m³
Soil unit weight below phreatic level	Γsat	15.46	KN/m³
Youngs modulus	Eref	13000	KN/m²
Poissons ratio	µ	0.30	-
Cohesion(constant)	Cref	13	KN/m³
Dilactancy angle	ש	0	-

IV CONCLUSION

The study deals with a analytical investigation of fibre reinforcement technology by using finite element analysis software.

- The behavior of pile foundation for vertical and laterally loading condition was studied.
- Fibre reinforcement was found to have significant influence in improving the properties of soil.
- The settlement was found to be reduced from 247.98x10³KN/m³ to 212.17x10³ KN/m³ of unreinforced vertically loaded pile to fibre reinforced vertically loaded pile was embedded in reinforced soil.
- When the pile was laterally loaded the lateral displacement was reduced from 164.82x10³KN/m³ of unreinforced laterally loaded pile to 87.97x10³KN/m³ of fibre reinforced laterally loaded pile.

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