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Experimental Research on Effect of Fines Content on Liquefaction Properties of Sand

S.Eswara Rao, Y.S.Prabhakar, T.Santosh Kumar, K.V.D.G.Balaji

ABSTRACT--- Liquefaction is a phenomenon mainly occurred in saturated fine grained soils under major earthquakes causes tremendous loss to infrastructure. From the literature it has been observed that liquefaction not only occurs in fine sands but also occurs in sands containing some amount of fines particles, which are of less than 75µ in size. Unfortunately there is no clear conclusions given as how effect the fines content on liquefaction resistance of sandy soils. In order to solve above mentioned problem this study was undertaken through stress-controlled cyclic triaxial tests to know the effect of fines content on liquefaction resistance of sandy soils. In this study the program of experimentation was done on base sand and sand mixed with four different combinations of fines like 10%, 20%, 30%, and 40% of fines with base sand by weight.. The main parameters changed in this work were percentage fines and shear stress ratio (CSR), where the observed parameter was amount of pore water pressure and cycle of loading..

The result showed that, rate of pore water pressure generation during cyclic loading was largely affected by limiting silt content and density index. The trend observed as amount of pore water pressure is increased more than base sand with adding of fines content up to 20%, later the trend observed as reverse. And also noticed that more CSR value increases the pore water pressure generation and decreases the cyclic resistance.

Key words - Liquefaction, Pore water pressure, Fines, Cyclic shear stress ratio (CSR), Cyclic Resistance Ratio (CRR)

I. INTRODUCTION

Liquefaction is a process in which saturated soils temporarily loses its shear strength due to rise in high pore water pressure under cyclic or dynamic loading. Sometimes it leads to catastrophic failures if it is not properly assessed. It is first observed in Niigata Earthquake of 1964 and the Alaska Earthquake of 1964 and researchers start doing research on this topic. Initially they were emphasised on clean sands and later they shifted to sand contains some amount of fines. However the results given were conflict and statements were contradictory. Keeping this in view this study has taken up to determine the effect of fines content on liquefaction resistance of sand fine mixtures.

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* Correspondence Author (s)
S.Eswara Rao, Assistant Professor, (E-mail: eswarrock36@gmail.com)
Y.S.Prabhakar, Professor,
T.Santosh Kumar, Assistant Professor,
K.V.D.G.Balaji, Professor,

II. LITERATURE REVIEW

From Literature, It has been observed that there is lot of discrepancy in concluding the effect of fines content on liquefaction properties of sand. Several authors said that liquefaction resistance of sand increases with increasing fines content. Chang et al. (1982) investigated that cyclic resistance of sandy soil drastically increases with addition of fines content up to 60% fines by weight of sand. The results observed that around half of the cyclic resistance has improved to soil when it is combined with fines up to 60%.The results are measurable and noticeable. Some authors have given vice versa behavior with addition of fines to sand. Shen et al. (1977), Tronsco and Verdugo (1985), and Vaid (1994) were reported that cyclic resistance of sand decreased to around 60% when sand is mixed with 30% fines. Erten and Maher (1994) did lot of experimentation on clean sand with different % fines and concluded that amount of generated pore water pressure was more compare to addition of fines and LFC reported by him was 30%. Dash and Sitharam (2009), Mohammad et al. (2014) were studied locally available sand in Gujarat region and marked that cyclic resistance is decreasing with addition of non plastic fines up to some value and later he seen reverse trend .i.e cyclic resistance is started increasing. Yassine et al. (2014) studied the nature of three Algerian sands through cyclic triaxial tests with focus on the effect of the fines content. And also Compared the behavior of clean and natural sand with combined mixed of sands and fines and analyzed the behavior.

EXPERIMENTAL PROGRAM

Materials Used: The sand taken to this study was locally available construction sand in surat region, Gujarat . It has a maximum grain size of 2 mm, and a minimum grain size of 0.150 mm. The specific gravity of sand was 2.65.

The fines used as fine-grained portion of locally available sand which is passing through 75µ sieve and classifies as a non-plastic silt (ML).

To know the effect and behavior of portion of fines on liquefaction properties of clean sand, the following combinations was made i.e. clean sand, sand+ 10% fines, sand+ 20% fines, sand+ 30% fines, and sand+ 40% fines by weight.

Table 1. index Properties of Sand and fines

Index properties	Sand	fines
	Values	

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Mean Grain Size D_{50} (mm)	0.8936	0.375
Coefficient of Uniformity (C_u)	4.37	7.83
Minimum Density (kN/m^3)	14.98	12.0
Maximum Density (kN/m^3)	17.30	13.3
Minimum Void Ratio (e_{min})	0.531	0.99
Maximum Void Ratio (e_{max})	0.769	1.2
Specific Gravity	2.65	2.64
Liquid Limit	-	-
Plastic Limit	-	-
PI	-	-
Free Swell Index	0	0
USCS Classification	SP	Silt

Sample Preparation: specimens used in this study were of 50 mm in diameter and 100 mm in height. The specimens were formed by dry deposition method with the help of spilt mould. While preparing specimen was compacted in 3 layers.

Saturation and Consolidation: After sample preparation, specimen was saturated by applying back pressure. Complete saturation is ensured when Skempton's pore water pressure parameter B greater than 0.95 or 95%. During this stage all samples were consolidated with cell pressure of 100kPa. The time taken for consolidation was about 4 minutes (for clean sands) and about 30 minutes (for sand+ 40% fines).

Cyclic Triaxial Testing Equipment: Testing was done by using state of the art GDS cyclic triaxial testing apparatus shown in figure 1.Appartus is fully digitalized and equipped with advanced accessories like LVDT ,load cells and transducers to measure the volume change, chamber pressure, and pore water pressure. Equipment is capable of performing both static and dynamic tests with a frequency range of 0.01–10 Hz.

Fig.1.Cyclic triaxial Test Apparatus and sample prepartion.

III. RESULTS AND DISCUSSIONS

A series of stress controlled cyclic triaxial tests were carried out for base sand and sand fine mixtures with two different CSR ratios at a constant cell pressure 100kPa.

Here the typical test results were presented on a sample with sand +10% fines at constant void ratio 0.65 and CSR 0.25 to observe the variation between different parameters like Deviator stress and cycles, Axial strain and cycles and also for excess pore water pressure and cycles of loading. The number of cycles restricted to 100 in these tests.

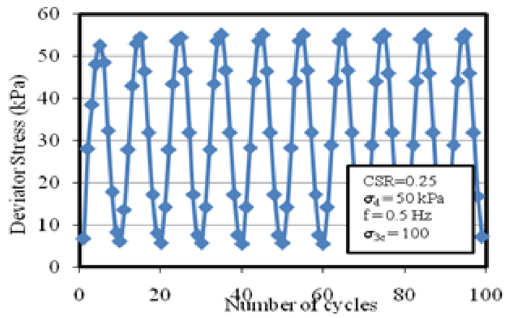

Fig. 2 Deviator stress vs cycles of loading for sand + 10% fines.

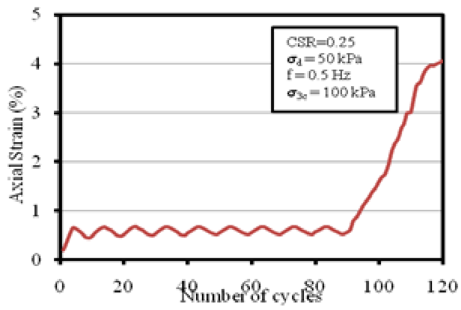

Fig. 3. Axial strain vs number of cycles for sand + 10% fines.

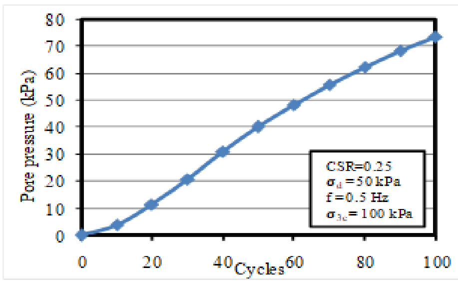

Fig. 4 Pore pressure vs cycles of loading for sand + 10% fines.

Cyclic Triaxial Test Results for Deviator Stress 50kpa: Stress controlled cyclic triaxial test were performed on sand and sand-fine mixtures with below loading conditions. The variation between pore pressure and cycles of loading was presented here,

Loading conditions: Deviator stress = 50kPa,CSR = 0.25, frequency =0.5, σ_{3c} = 100 kPa, void ratio =0.65.

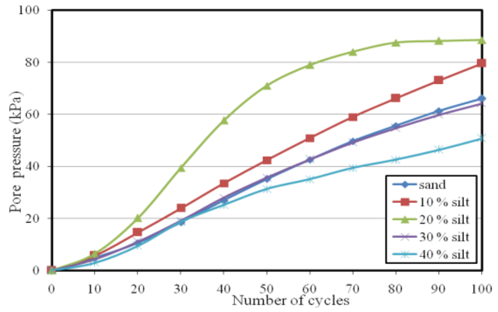

Fig. 5. Pore pressure vs cycles of loading for all sand-fines at Deviator stress of 50 kPa.

Cyclic Triaxial Test Results For Deviator Stress 60 kPa:

Laboratory Stress controlled cyclic triaxial test were conducted on sand and sand-fine mixtures with below loading conditions. The variation between pore pressure and cycles of loading was presented here,

Loading conditions: Deviator stress = 60kPa,CSR = 0.25, frequency =0.5, $\boldsymbol{\sigma}_{3c}$ = 100 kPa, void ratio =0.65.

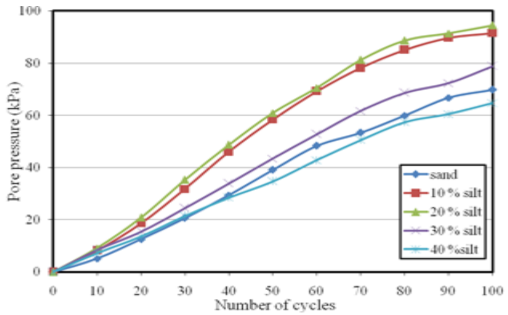

Fig.6. Pore pressure vs number of cycles for all sand-fines at Deviator stress of 60 kPa.

Final Trend of Cyclic Resistance with Addition of Fines Content:

We have seen the the individual behaviour of sand and sand- fines mixtures ,here the final trend was shown to understand the variation between pore pressure with different amount fines shown for two different CSR values of 0.25 and 0.3. The number of cycles restricted to 100.

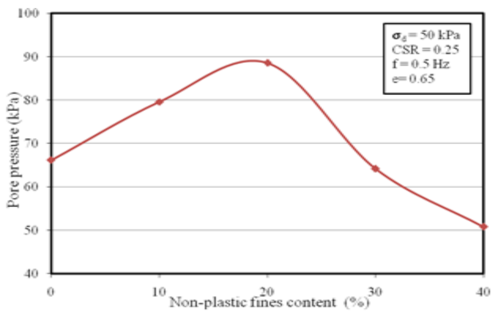

Fig.7. Pore pressure vs non -plastic fines content (%) for CSR 0.25.

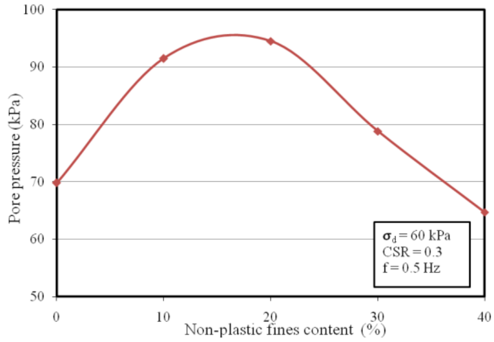

Fig.8. pore pressure vs non -plastic fines content (%) for CSR 0.3

In the above figure it is clearly observed that with addition of portion of fines the amount of pore pressure water pressure generated initially increases up to 20% and then this trend observed was reversed after 20% of fines portion i.e pore water pressure is decreases.

Cyclic resistance response is always just reverse to the pore water pressure response of the soil. CRR is defined as the cyclic stress ratio (CSR) required to causing initial stage of liquefaction in n number of cycles of loading. Here cyclic resistance is defined as cyclic stress ratio required to causing excess pore water pressure of 50 kPa in 100 numbers of cycles.

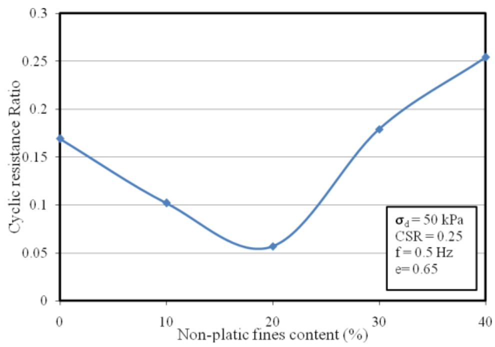

Fig.9.Variation of cyclic resistance with different %fines content at CSR 0.25.

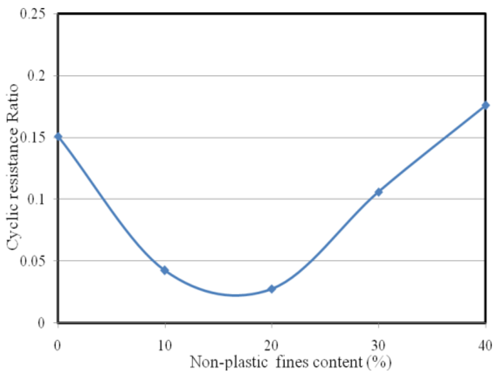

Fig.10. cyclic resistance vs different %fines content at CSR 0.3.

The behaviour of pore pressure, CRR versus % fines for Deviator stress 60 kpa is observed to be same as like for Deviator stress 50kpa.

The limiting silt content calculated for both cases is

$$LFC = \frac{G_f e_s}{G_f e_s + G_s(1+e_f)} = \frac{2.65\times0.531}{2.65\times0.531 + 2.65(1+1.2)} = \mathbf{20\%}$$

From the above calculation the limiting silt content value is 20% and it is well coincide with the trend of sand silt mixture in fines versus pore pressure generation graph.

The true justification is noticed for the above trend by calculating the relative density of sand and sand -fine combinations. It has been observed that relative density is initially lowers down up to 20% fines content,further its value increasing with addition of fines.

The relative density values are given below table

Table 2 Relative densities of sand and sand silt mixtures

Soil type	e_{max}	e_{min}	RD (%)
clean sand	0.76	0.52	56
sand + 10% fines	0.82	0.53	45.45
sand + 20% fines	0.92	0.577	26.6
sand + 30% fines	0.74	0.488	69.2
sand + 40% fines	0.70	0.433	82.99

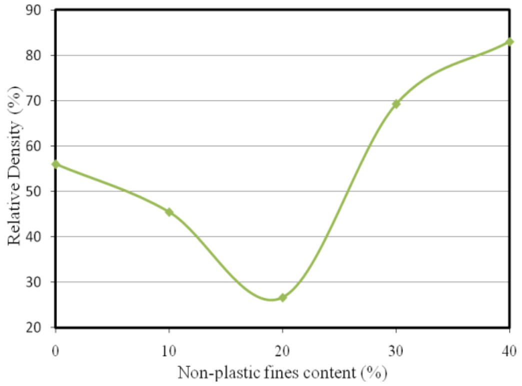

Fig.11. Relative density vs % fines content

Relative density and limiting fines content greatly influences the cyclic resiatance of sand and sand –fine mixtures and it is well observed with given trend between pore pressure and relative density.

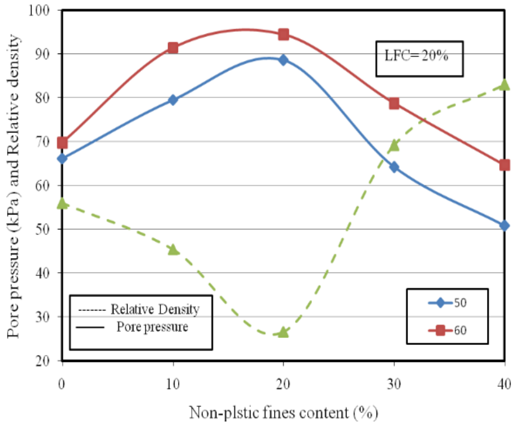

Fig. 12. Pore pressure vs relative density with % fines content

Effect of Deviator Stress on Pore Pressure Generation:

To know the effect of deviator stress on pore pressure generation ,in all cases the total number of cycles during testing was limited to 100 and two different deviator stresses i.e.50kpa and 60kpa is applied on all sand and sand-fine mixtures and the result is presented here. It has been observed that high deviator stress causes more disturbance and leads to failure than low deviator stress. So it is concluded that deviator stress is directly proportional to pore pressure generation.

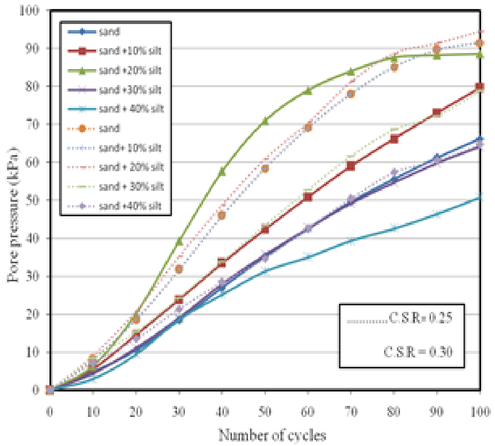

Fig.13 Pore pressure vs cycles for all sand and sand fine mixtures at two different deviator stresses.

IV. CONCLUSIONS

Based on the experimental investigation the results and observations made summarized here.

- It has been noticed that Limiting Fines content and Density index plays a Vital role in contributing the cyclic résistance of sand- fine mixtures .The limiting fines content value calculated is around 20%.
- Relative density values were observed to be increased with adding of fines content after LFC ,up to LFC the relative density value was observed to be low.
- The amount of pore pressure generation was observed initially high corresponding to 100 cycles with addition of fines up to 20%,later it starts decreasing for 30 and 40% fines. The cyclic resistance behavior is just opposite to pore pressure response.
- It also concluded that deviator stress is directly proportional to pore pressure generation.

REFERENCES

1. Chang, N. Y., Yeh, S. T., & Kaufman, L. P. (1982) Liquefaction potential of clean and silty sands. Proceedings, 3rd International Earthquake Microzonation Conference, Seattle, vol 2, 1017–1032.
2. Dash, H.K., &Sitharam, T.G. (2011) Undrained cyclic and monotonic strength of sand-silt mixtures. Journal of Geotechnical and Geoenvironmental Engineering, 29,555-570.
3. Dash, H.K., &Sitharam T.G. (2009) Undrained cyclic pore pressure response of sand–silt mixtures: effect of non-plastic fines and other parameters. Journal of Geotechnical and Geoenvironmental Engineering 27,501–17.

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4. Erten, D., &Maher, M.H. (1999) Cyclic undrained behaviour of siltysand. Soil Dynamics and Earthquake Engineering, 14,115–123.
5. Mohammad,E.K., &Md.Jahangir, A.(2014). Effect of non - plastic silt content on liquefaction behaviour of sand-silt mixture. Soil Dynamics and Earthquake Engineering, 65,142-150.
6. Seed,H.B., &Idriss,I.M. (1971) Simplified procedure for evaluating soil liquefaction potential. Journal of Geotechnical and Geoenvironmental engineering, 97, 1249 – 1273.
7. Shen, C.K., Vrymoed, J.L., and Uyeno, C.K., (1977) "The Effects of Fines on Liquefaction of Sands" Proceedings of the Ninth International Conference on Soil Mech. and Found. Eng., Tokyo, Japan, Vol. 2, pp.381-385.
8. Transco, J.H., and Verdugo, R., (1985). "Silt Content And Dynamic Behavior of Tailing Sands" Proceedings. Twelfth International Conference on Soil Mech. and Found. Eng., San Francisco, USA, pp.1311-1314.
9. Vaid, Y. P. (1994) Liquefaction of Silty Soils. Geotechnical Special Publication**,** 1 – 16.

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