STUDY OF THE USE OF FLY ASH TO PREVENT LIQUEFACTION BY USING SHAKE TABLE

BY :- PATEL DHARUV N. (120783106016)
PARAMAR HIREN N. (120783106014)
PATEL KRUNAL S. (120783106007)

GUIDED BY : Dr. Ami H. Shah
CONTENTS

- Introduction
  - History
  - Types of liquefaction
  - Occurrence
  - Reason of liquefaction
  - Effect of liquefaction
- Literature review
- Importance of project
- Objective
- Methodology
- Result and conclusion
- Reference
INTRODUCTION

- During heavy earthquakes the shaking of ground or sudden change in stress condition may cause a loss of strength or stiffness in saturated soil that result in settlement of building/structure, the failure of earth dam, landslide or other hazard. The process leading to loss of strength or stiffness of soil is called soil liquefaction.
Earthquakes accompanied with liquefaction have been observed for many years.

In back hundred and even thousand of years description of earthquake effects that are now known as a liquefaction.

1. Alaska, USA (1964)
2. Niigata, Japan (1964)
3. Loma Prieta, USA (1989)
5. Chi-Chi Earthquake, Taiwan, 1999
TYPES OF LIQUEFACTION

- **Flow liquefaction**: A 'flow failure' may initiate if the strength of the soil is reduced below the stresses required to maintain equilibrium of a slope or footing of a building for instance.

  Occurs when shear stress required for equilibrium of a soil mass (the static shear stress) is greater than the shear strength (residual strength) of the soil in its liquefied state.
Cyclic liquefaction: The term 'cyclic liquefaction' refers to the occurrence of a state of soil when large shear strains have accumulated in response to cyclic loading.

Occurs when the static shear stress is less than the shear strength of the liquefied soil.
Why does liquefaction occur

If the soil is loose and is being shaken, the particles will settle due to gravity. When the soil is saturated, the pore-water is unable to move out of the way quickly enough and more and more particles start to partially float in the water (this leads to excess pore-pressure buildup). Eventually as shaking continues, the particles float in the water temporarily as they settle downwards and reach a new densified and consolidated state.
OCCURRENCE

- In loose soil
- Moderately saturated soil
- Low-lying areas near bodies of water such as rivers, lakes, bays, and oceans.
The “liquefaction” state is reached when the effective confining stress goes down to zero (i.e., the original effective confining stress has gradually decreased and has become “excess pore-water pressure” known as $u_e$).
REASON OF LIQUEFACTION

- Heavy earthquakes
- Wave loading
- Cyclic undrained loading
- Suddenly movement of ground
EFFECT OF LIQUEFACTION

- Loss of support from liquefied foundation soil
- Ground settlement
- Loss of bearing capacity that resulting in foundation failure
- Irregular settlement of building.
- Damaging of building.
- Cracking of foundation.
- Leave structure unusable.
MAIN FACTORS THAT GOVERN LIQUEFACTION IN THE FIELD

- Earthquake intensity and duration
- Groundwater table
- Soil type
- Soil relative density $Dr$
- Particle size gradation
- Drainage conditions
- Particle shape
- Building load
FIG. EFFECT OF LIQUEFACTION
Fig. Effect of liquefaction
DURING AND AFTER THE EARTHQUACK

FIG : 1
**Sand Boils (Sand Volcanoes)**
Sand, silt and water erupts upward under pressure through cracks and flows out onto the surface. Heavy objects like cars can sink into these cracks. Sand, silt and water cover the surface.

Power poles are pulled over by their wires as they can't be supported in the liquefied ground. Underground cables are pulled apart.

**Lateral Spreading**
River banks move toward each other. Cracks open along the banks. Cracking can extend back into properties, damaging houses.

Tanks, pipes and manholes float up in the liquefied ground and break through the surface. Pipes break, water and sewage leaks into the ground.
1. Ground Improvement Techniques for Mitigation of Liquefaction Hazards

Sushma, B.V, Mumbai

Vibro Compaction works were carried out up to a depth of 10m in 3m grid spacing for each area. The crater formed during vibro compaction was filled using the sand – available material at site. For the present area, the consumption of backfill material (sand) was 10 to 14%, which clearly indicates that significant densification has taken place. Also the ground level in compacted area went below by 1m clearly showing the achieving of ground improvement. Vibro compaction is a suitable compaction technique to mitigate the liquefaction potential and can be successfully implemented. The target Relative Density of 70% was achieved using a grid spacing of 3m c/c in square pattern for the project under consideration.
2. “Ground Improvement Techniques for Liquefaction Remediation Near Existing Lifelines”

Ronald D. Andrus, Riley M. Chung

They study on five techniques for ground improvement. The five techniques are: compaction grouting, permeation grouting, jet grouting, in situ soil mixing, and drain pile. With great care and depending on their nature and condition. Permeation and jet grouting could improve soil conditions immediately adjacent to lifelines.
They studies on the liquefaction potential of gravelly soil. shear wave velocity based correlation and large Hammer Penetration Test (LPT) are employed to evaluate the liquefaction resistance of gravelly soils. They show that after experiment the Large Hammer Penetration Test and shear wave velocity methods are reasonably suitable for liquefaction assessment of gravelly soils.
“Prevention of liquefaction during earthquakes through Induced partial saturation in sands”

M. K. Yegian, Alshawabkeh and S. Gokyer

A new liquefaction mitigation measure was introduced: "Induced Partial Saturation (IPS)". This measure has a great potential to be a cost-effective and practical solution for new as well as existing structures. IPS aims to improve the resistance of liquefiable sands by introducing some amount of air/gas in the voids of the sand. The air/gas entrapped sand specimens were prepared by two techniques developed under laboratory conditions: 1) by generating oxygen and hydrogen gases through Electrolysis and 2) by assisting air entrapment in the voids by draining and reintroducing water in the fully saturated sand specimens: Drainage-Recharge (D-R).
The test results demonstrated that initial liquefaction was prevented in air/gas entrapped specimens and excess pore water pressures were reduced significantly. The results provided evidence that air/gas bubbles remain entrapped in the sand, providing evidence that Induced-Partial Saturation (IPS) holds promise for use as a sustainable liquefaction mitigation measure.
The effect of fiber surface on the controlling liquefaction and excess pore water pressure has been finding an important factor for further investigation. The fiber improve sand liquefaction resistance, drainage and sand mass lateral deformation but no effected on pore water pressure mitigation.
“A STUDY ON PROBABILISTIC EVALUATION OF SOIL LIQUEFACTION”

Y. Yao Chi* and Li Ting Ou

They present new method for evaluating annual liquefaction probability was developed based on both Davies and Berrill’s seismic energy dissipation theory and Juang et al.’s limit state methodology. The new method also involves use of the average annual liquefaction probability (AALP) of divided soil layers to represent the AALP at a site. The results of the developed method are conservatively. They show that Lunya neighbourhood has the highest AALP, and these results are similar to previous investigation results after the Chi-Chi earthquake. The developed model yields an overall prediction rate of 87% in both liquefied and non-liquefied tendency.
A liquefaction box that permitted the application of cyclic simple shear strains in large loose sand specimens using a shaking table was designed and manufactured. Fully and partially saturated sand specimens were tested under constant cyclic simple shear strains. The experimental results demonstrate that small reduction in the degree of a fully saturated specimen can lead to significant reduction in excess pore pressures generated in loose liquefaction susceptible sand, hence increases the liquefaction strength.
HOW TO REDUCE LIQUEFACTION HAZARD?

1. Avoid Liquefaction Susceptible soil
2. Built liquefaction resistance structure
3. Improve the soil
4. Providing deep foundation like piles
5. By ground water pumping
6. By injection grouting
7. By providing proper drainage of soil
8. Providing stone columns
IMPROVE THE SOIL

In this method of mitigation of soil the strength of soil is increased by compacting soil, adding different types of materials such as ground granulated blast-furnace slag and silica fume etc. We use fly ash to improve the strength of soil and reduce the effect of liquefaction.
IMPORTANCE OF PROJECT

- Fly Ash is a by-product of the combustion of pulverized coal in electric power generation plants. When the pulverized coal is ignited in the combustion chamber, the carbon and volatile materials are burned off. Environmental issues associated with disposal of fly ash. So, fly ash is easily available.
OBJECTIVE

- Focus on information about how to prevent liquefaction of soil by using fly ash to improve the strength of soil.

- To study the effect of the use of fly ash for the prevention of liquefaction.
METHODOLOGY

SAMPLE COLLECTION

DETERMINATION OF PROPERTIES OF SOIL AND FLY ASH

SAMPLE PREPARATION

EXPERIMENT SETUP PREPARATION

RESULT ANALYSIS

CONCLUSION
MATERIAL AND EQUIPMENT TO BE USE

- Soil
- Fly ash
- Shake table
- Liquefaction box
- Building model
PROPERTIES OF SOIL AND FLY ASH

- Specific gravity
- Density
- Fineness modulus of soil
- Permeability of soil
Specific gravity:

Specific Gravity is the ratio of the weight in air of a given volume of a material at a standard temperature to the weight in air of an equal volume of distilled water at the same stated temperature.

Test procedure:

- Take an empty bottle. Clean and dry the bottle.
- Determine the weight of the empty bottle $w_1$.
- Fill the sample (soil or fly ash) in the bottle. Determine the weight $w_2$.
- Add water in the bottle and remove the air bubble by shaking the bottle. Determine the weight $w_3$. 
- Remove the sample and clean the bottle.
- Fill the bottle with water and determine the weight $W_4$.
- Repeat the process three times. Take the average result of three tests.

Specific gravity = \[ \frac{(W_2-W_1)}{(W_2-W_1)-(W_3-W_4)}. \]

Result: Cohesion less soil – 2.609
Fly ash – 2.47
Density:
A material’s density is defined as its mass per unit volume.

Test procedure:
- Take a mould. Determine the volume (V) of mould by determining the inner dimension.
- Weight the empty mould. M1
- Fill the soil sample in the mould in three layer by 25 stoke of 16 mm dia. steel bar.
- Determine the weight of (soil + mould) M2
• Mass of soil = M2 - M1

• DENSITY = mass/volume = M/V

• RESULT :- Cohesion less Soil  1746.04 kg/m³
  
  fly ash  694.52 kg/m³
Permeability:

The co-efficient of permeability is equal to the rate of flow of water through a unit cross sectional area under a unit hydraulic gradient. In the constant head parameter, the head causing flow through the specimen remain constant throughout the test.

Length of soil sample (L) = 12.00 cm
Diameter of the soil sample (d) = 10.00 cm (It is remolded specimen)
Area of the soil specimen (A) = 100 cm²
Height of reservoir above the outlet of the bottom plate (h) = 150 cm
Temperature of water (T) = 30 °C
Discharge: 80 cc Time 150 sec

\[ K = \frac{QL}{Ah} \times t \]

Permeability of soil = \(5.43 \times 10^{-4}\) cm²/sec
SIEVE ANALYSIS

- There is large variation in types of soils from site to site. Accordingly, their behavior has also variation. To make understanding of soil in easy manner, their grouping has been done depending on size of soil particles. Ratios of soil of different sizes are worked out from sieve analysis and hydrometer tests. These tests are used to classify the soils. Sieving is used for gravel as well as sand size particles and sedimentation procedures are used for finer soils. For soils containing coarse and fine soil particles both, it is usual to employ both sieving and sedimentation procedures.

- F.M. OF SOIL = 2.61

- Fineness modulus of the soil is 2.61, so the soil is medium sand.
## SAMPLE PREPARATION

<table>
<thead>
<tr>
<th>SR.NO</th>
<th>% OF SAMPLE</th>
<th>SOIL</th>
<th>FLY ASH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>0</td>
<td>20 kg</td>
<td>0 kg</td>
</tr>
<tr>
<td>2.</td>
<td>5</td>
<td>19 kg</td>
<td>1 kg</td>
</tr>
<tr>
<td>3.</td>
<td>10</td>
<td>18 kg</td>
<td>2 kg</td>
</tr>
<tr>
<td>4.</td>
<td>20</td>
<td>16 kg</td>
<td>4 kg</td>
</tr>
<tr>
<td>5.</td>
<td>30</td>
<td>14 kg</td>
<td>6 kg</td>
</tr>
<tr>
<td>6.</td>
<td>40</td>
<td>12 kg</td>
<td>8 kg</td>
</tr>
</tbody>
</table>
FLY ASH

- Fly ash is one of the residues created during the combustion of coal in coal-fired power plants.
- Fine particles rise with flue gasses and are collected with filter bags or electrostatic precipitators.
- Fly ash is a waste by-product material that must be disposed of or recycled.
TYPES OF FLY ASH

CLASS C FLY ASH

- Produced from burning younger lignite and subbituminous coal
- Contains more than 20% lime
- Self-cementing properties
- Not for use in high sulfate conditions
- Primarily residential construction
- Limited to low fly ash content concrete mixes
CLASS F FLY ASH

- Produced from burning harder, older anthracite and bituminous coal.
- Contains less than 20% lime
- Requires cementing agent like PC, quick lime, hydrated lime
- Used in high sulfate exposure conditions
- Useful in high fly ash content concrete mixes
LIQUEFACTION BOX

FIG : 3
SHAKE TABLE

FIG : 4
**BUILDING MODEL**

- **Square footing**: In this type of the foundation of the building is separate for each column. Square or rectangular shaped blocks of reinforced concrete that typically support a single column or wall of a building. The allowable bearing pressure on the soil determines the size of the spread footing.
Raft foundation: Raft foundation is a thick concrete slab reinforced with steel which covers the entire contact area of the structure like a thick floor. Sometimes area covered by raft may be greater than the contact area depending on the bearing capacity of the soil underneath. The reinforcing bars runs normal to each other in both top and bottom layers of steel reinforcement. Sometimes inverted main beams and secondary beams are used to carry column loads that require thicker foundation slab considering economy of the structure. Both beams cast monolithically with raft slab.
1. Square footing

2. Raft foundation
RESULT AND CONCLUSION

To know the effect of fly ash in soil liquefaction we test and study the settlement at different % of fly ash. The % of fly ash is 0 %, 5 %, 10 %, 20 %, 30 % and 40 % of the soil.

<table>
<thead>
<tr>
<th>Mode</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel</td>
<td>11</td>
</tr>
<tr>
<td>Frequency</td>
<td>2.5</td>
</tr>
<tr>
<td>No. of cycle</td>
<td>30</td>
</tr>
</tbody>
</table>
## TEST RESULT ON LIQUEFACTION

<table>
<thead>
<tr>
<th>No.</th>
<th>% of soil</th>
<th>% of fly ash</th>
<th>Settlement in Square footing in cm</th>
<th>Settlement in Raft footing in cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>100</td>
<td>0</td>
<td>1</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>0</td>
<td>2</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>0</td>
<td>3</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>0</td>
<td>4</td>
<td>4.0</td>
</tr>
<tr>
<td>2.</td>
<td>95</td>
<td>5</td>
<td>1</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>95</td>
<td>5</td>
<td>2</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>95</td>
<td>5</td>
<td>3</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>95</td>
<td>5</td>
<td>4</td>
<td>3.4</td>
</tr>
<tr>
<td>3.</td>
<td>90</td>
<td>10</td>
<td>1</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>10</td>
<td>2</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>10</td>
<td>3</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>10</td>
<td>4</td>
<td>2.9</td>
</tr>
</tbody>
</table>
## TEST RESULT ON LIQUEFACTION

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>80</td>
<td>20</td>
<td>1</td>
<td>2.0</td>
<td>0.5</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>20</td>
<td>2</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>20</td>
<td>3</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>20</td>
<td>4</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>70</td>
<td>30</td>
<td>1</td>
<td>0.6</td>
<td>0.2</td>
</tr>
<tr>
<td>5</td>
<td>70</td>
<td>30</td>
<td>2</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>70</td>
<td>30</td>
<td>3</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>70</td>
<td>30</td>
<td>4</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>40</td>
<td>1</td>
<td>1.2</td>
<td>0.6</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>40</td>
<td>2</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>40</td>
<td>3</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>40</td>
<td>4</td>
<td>0.9</td>
<td></td>
</tr>
</tbody>
</table>
RESULT GRAPH

- Column 1
- Column 2
- Column 3
- Column 4
- Raft foundation
CONCLUSION:

In cohesion less soil liquefaction is occur during the heavy earth quake. The effect of liquefaction is create major problem. To mitigate the effect of liquefaction many method are available. We use fly ash to prevent liquefaction.fly ash is added in different percentages of total soil. 30 % of fly ash in soil is economy for prevent liquefaction effect. with increase the fly ash more than 30 % increase the rate of fly ash.
REFERENCE

1. Sushma, B.V, Mumbai
“Ground Improvement Techniques for Mitigation of Liquefaction Hazards” Journal page 5,20-23

2. „A. Murali Krishna“ M.R. Madhav
“Engineering of Ground for Liquefaction Mitigation Using Granular Columnar Inclusions: Recent Developments” ISSN 1941-7020 © 2009 Science Publications page 1, 7-8

3. Ronald D. Andrus, Riley M. Chung
“Ground Improvement Techniques for Liquefaction Remediation Near Existing Lifelines” U.S. Department of Commerce journal page 2,68,72
4. Ping-Sien Lin, Chi-Wen Chang, Wen-Jong Chang
   “Characterization of Liquefaction Resistance in Gravelly Soil Large Hammer Penetration Test and Shear Wave Velocity” Department of Civil Engineering, National Chi Nan University, Puli, Taiwan. 545 page 13-16

5. M. K. Yegian, A. Alshawabkeh and S. Gokyer
   “Prevention of liquefaction during earthquakes through Induced partial saturation in sands” Northeastern University, Boston, MA, USA page 1,4-6

   “Liquefaction Mechanisms and Mitigation-A Review”
REFERANCE

7. Y. Yao Chi* and Li Ting Ou

“A STUDY ON PROBABILISTIC EVALUATION OF SOIL LIQUEFACTION” Department of Land Management and Development Chang Jung Christian University December 2003 page 2-3, 17-18

8. E. E. Bayat, M. K. Yegian, A. Alshawabkeh

“A NEW MITIGATION TECHNIQUE FOR PREVENTING LIQUEFACTION” page 1, 4, 7,
Thank you