IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

# Effect Of Relative Density On The Liquefaction Behaviour Of Sand Using Cyclic Triaxial

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***ABSTRACT:*** Strong earthquakes cause liquefaction, which causes significant damage to buildings and infrastructure. The purpose of this study is to investigate the effects of relative density on the liquefaction behaviour of sand using cyclic triaxial testing. In order to recreate essentially undrained field circumstances during an earthquake or other cyclical load for untreated sand specimens, cyclical triaxial strength tests are carried out in an undrained environment. A measure of liquefaction is identified by how many stress cycles are required to reach a limiting strain or a 100% pore pressure. The results shows that as the relative density increases from 10% to 30%, the liquefaction resistance developed from 0 % to 7% approximately. CRR value changes means it's also increase by 0.026 to 0.143 at relative density changes from 10 to 30%. It is concluded that as increase of relative density of sand liquefaction resistance of sand also increases.

***Index Terms* - Sand, Relative Density, Liquefaction, CRR**

## I. INTRODUCTION

In saturated soils, the seismic energy causes an increase in pore water pressures and consequently the effective stresses decrease. This results in loss of shear strength of soil and soil starts to behave as a fluid. This fluid is no longer able to sustain the load of structure and the structure settles. This phenomenon is known as liquefaction. During earthquakes, major destruction of various types of structures occurs due to the creation of fissures, abnormal and/or unequal movement and loss of strength or stiffness of the ground. The loss of strength or stiffness of the ground results in the settlement of buildings, failure of earth dams, landslides and other hazards. The process by which loss of strength occurs in soil is called soil liquefaction. [1]
The phenomenon of soil liquefaction is primarily associated with medium to fine-grained saturated cohesion less soils. Examples of soil liquefaction-related damages are June 16, 1964, earthquake at Niigata, Japan, the 1964 Alaskan earthquake and also the 2001 Republic Day earthquake at Bhuj, India. Most of the destruction at port and harbour facilities during earthquakes is attributable to liquefaction. Classical examples are Kobe Port, Japan (1995 earthquake) and at Kandla Port, India (2001 earthquake). One of the first attempts to explain the liquefaction phenomenon in sandy soils was made by Casagrande (1936) and is based on the concept of critical void ratio. [1].

Following are the Consequences of liquefaction: Flow failures, Lateral spreads, Ground Oscillation, Loss of bearing strength & settlement and increased lateral pressure on retaining walls. Factors affecting the control of liquefaction: Soil type, Grain size distribution and particle shape, Earthquake intensity and duration, Ground water table, Confining pressure, Load from super structures and previous earthquake study.

Two different types of testing, namely in-situ tests and laboratory tests are used to evaluate liquefaction resistance (CRR). In-situ Tests: Standard Penetration Test (SPT), Cone Penetration Test (CPT), Shear Wave Velocity Measurements (Vs) and Beaker Penetration Test (BPT).Laboratory Tests: Cyclic Simple Shear Test and Cyclic Triaxial Test.The present study is focused on pre liquefaction behaviour of obtained sand at different relative density. For analysis of liquefaction, we conduct cyclic Triaxial test.

## II. MATERIAL

**Sand:** Sand required for the present study is collected from the Malaprabha River. Some of the laboratory tests were carried out as per IS code to determine index properties of the sand.

Table 1: Properties of sand

| Particulars | Value |
|---|---|
| Soil type | Poorly Graded Sand(SP) |
| Specific Gravity | 2.64 |
| Max. Voids Ratio | 0.613 |
| Min. Voids Ratio | 0.312 |
| Min. Dry Density | 16.12 kN/m$^3$ |
| Max. Dry Density | 19.82 kN/m$^3$ |

## III. EQUIPMENT

**Digital cyclic triaxial machine:** A cycle triaxial test utilizing the DYNATRIAX cyclic triaxial equipment can be fully controlled manually or automatically by the user using the user-friendly and comprehensive DYNATRIAX software. The compression frame, pressure systems, actuator and volume change device are all completely under the control of the software from the beginning to the end of a test, enabling it to be finished with the least amount of user involvement. Due to the software adaptability, any combination of an infinite number of stage types, such as saturation, isotropic consolidation, K0 consolidation, stress path, monotonic shear, and cyclic shear, can be used to create a custom test template. Live transducer readings and the software shows graphical test results during the test.


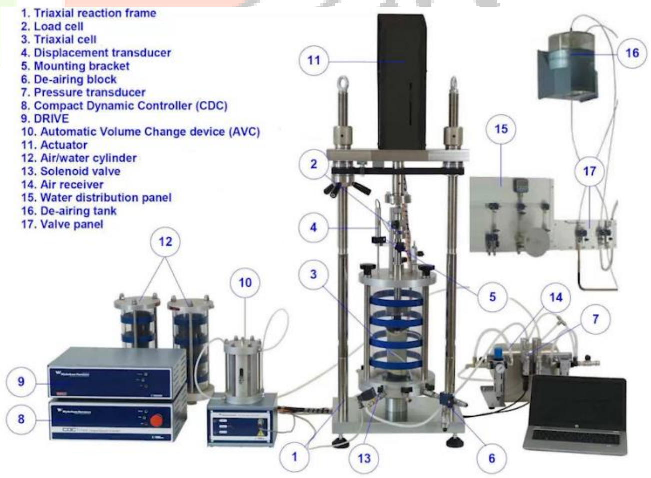


**FIGURE 1:** CYCLIC TRIAXIAL TESTING MACHINE SETUP

**FIGURE 2:** PARTS OF CYCLIC TRIAXIAL TESTING MACHINE

## IV. METHODOLOGY

Figure 3, shows the flow chart shows the methodology of present work. The Cyclic Triaxial test is most frequently used to determine the liquefaction potential of sand in either intact or reconstituted states using the load-controlled cyclic triaxial technique. To recreate essentially un-drained field conditions during an earthquake or other cyclical stress, cyclic triaxial strength tests are carried out in an un-drained environment. The number of stress cycles needed to reach a limiting strain or a 100% pore pressure.

The following procedure will followed for conducting cyclic triaxial tests: Sample preparation, test setups add in software, saturation stage, cyclic shear stage and termination of test.Some of the main phases are explained as below.

**Saturation Phase:** Initialises the saturation stage by enabling the required functions on the panel. When the saturation has started, this button is disabled. It is only available during a manual stage. Increment summary Displays the following values for the current saturation increment: Saturation increment number – the current increment or step number. Elapsed time – the amount of time that the increment has been running for, in hours, minutes and seconds B value – the pore pressure coefficient B, calculated from the live pore pressure readings during a cell pressure increment, during a backpressure increment or a cell and backpressure ramp, the value will be zero. Change in length – the amount, in millimeters, that the length of the specimen has changed during the increment, as calculated from the change in displacement measured by the displacement transducer. A positive number indicates a decrease in length; a negative number indicates an increase. Change in volume – the amount of water that has been taken up by the specimen, as measured by the volume change device, in cubic centimeters A negative number indicates that water has moved into the specimen; a positive number indicates that water has moved out. Ends the saturation stage, displays the End of stage values tab and enables you to exit the saturation panel and proceed to the next stage of the test.

**Cyclic Shear Phase:** Starts the cyclic stage by starting the actuator cycling axially and the cell pressure cycling (if applicable), opening the backpressure line (where 'Drained' is selected for the drainage method), and starting the data logging. Cyclic shear summary: Displays the following live calculated values for the stage: Elapsed time – the amount of time that the stage has been running for, in hours, minutes and seconds. Change in length – the change in specimen height, in millimeters, as measured by the displacement transducer. A positive number indicates a decrease in length; a negative number indicates an increase. Axial strain – the change in specimen height as a percentage of the specimen height at the start of the stage. Change in pore pressure – the amount of excess pore pressure that has been generated since the start of the stage, in kPa. Change in volume – the amount of water that has moved into or out of the specimen, as measured by the volume change device, in cubic centimeters A negative number indicates that water has moved into the specimen; a positive number indicates that water has moved out. Volumetric strain – the amount of water that has moved into or out of the specimen, as a percentage of the specimen volume at the start of the stage. Ends the stage by stopping the data logging, stopping the actuator and the cell pressure cycling (if applicable), and closing the backpressure line valve (where 'Drained' is selected for the drainage method).

**Termination Phase:** Once the last stage is finished, the test must be stopped. The following steps are used to finish the tests.

- Make sure that locking collar has been unlocked and is not in contact with the top beam of the compression frame.
- The actuator comes back to the loaded-zero location and the pressure is reduced to zero, when you press the unload test button.
- Close all lines and empty the triaxial cell after the test.

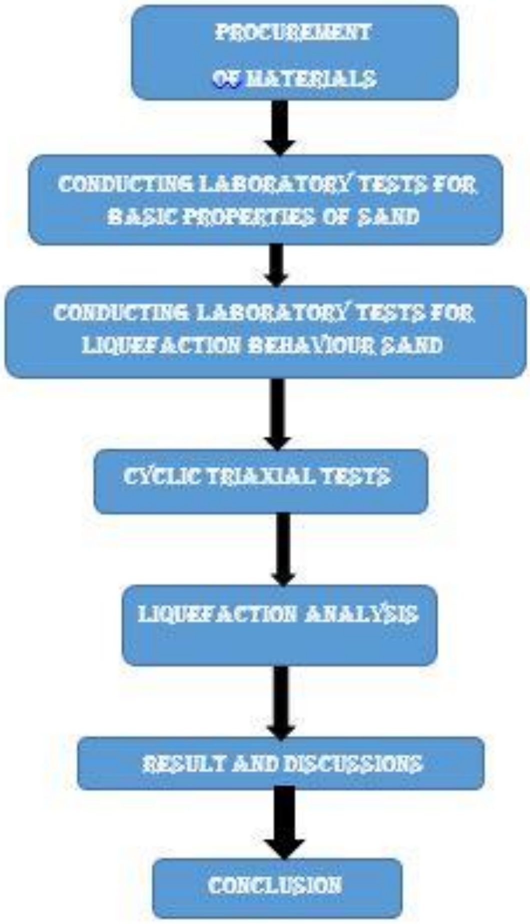


**FIGURE 3:** FLOW CHART

## V. RESULTS AND DISCUSSIONS

Figure 4 shows the how samples liquefied after cyclic shear strength tests. And also we observed the development excess pore water pressure.

**Figure 4 :** Sample before Liquefaction & Sample after Liquefaction

Samples are studied at different relative density, such as 10%, 20%, and 30%. In addition, the effects of pore water pressure development (PWP) and CRR (Cyclic Resistance Ratio) on the liquefaction behaviour of sand properties are investigated. Figure 4 below shows the variation in pore water pressure at different relative density.

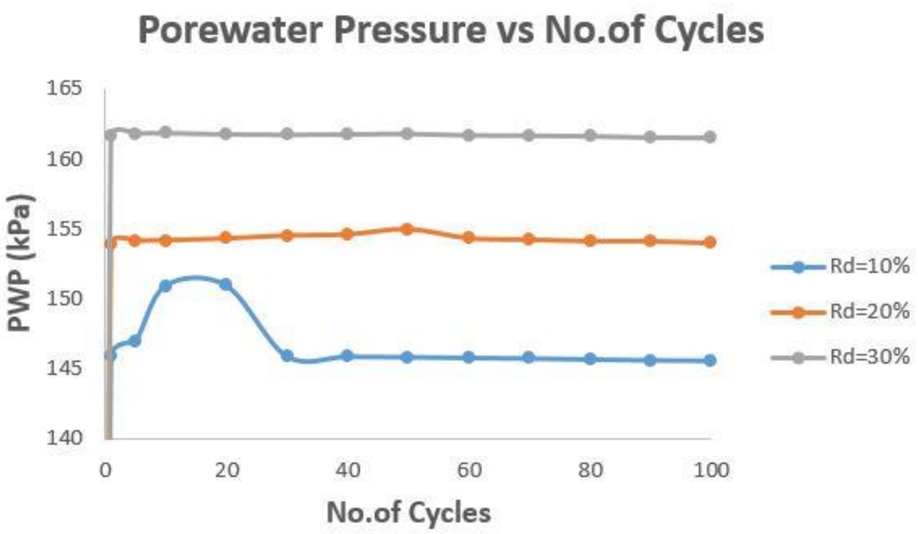


**FIGURE 4:** PORE WATER PRESSURE VARIATION WITH RESPECT NO.OF CLYCLES

The liquefaction resistance is also measured with respect to pore water pressure developed at 10% relative density. Figure 5 shows the liquefaction resistance variation:

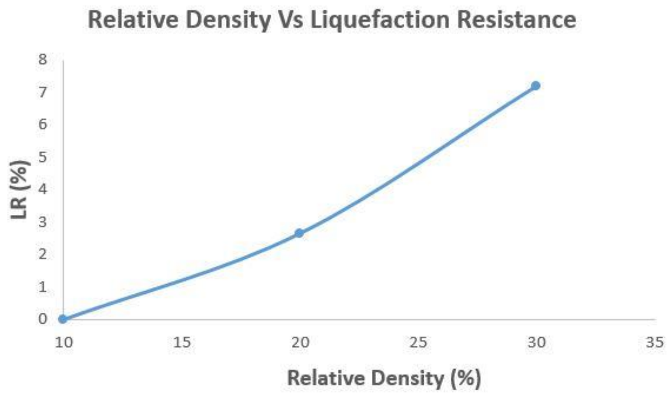


**FIGURE 5:** LIQUEFACTION RESISTANCE AT DIFFERENT RELATIVE DENSITY

Mainly the liquefaction behaviour or property measured in terms of CRR is best way to represent liquefaction resistance and their values are shown in below table and variations shown in below figure:

Formulae to calculate CRR:

Mean principle Stress, $p = \frac{\sigma_1 + 2\,\sigma_3}{3}$

Deviator Stress, $q = \sigma_1 - \sigma_3$

Cyclic Resistance Ratio, $CRR = C_r\,(\frac{1}{2} \times \frac{\sigma_d}{\sigma'_3})$

Where,σ1 = Major Principle Stress, kPa

σ3 = Minor Principle Stress (Confining Pressure), kPa

σd’ = Deviator stress, kPa

σ3' = Effective Confining Pressure, kPa

Cr = Correction Factor

Table 2: Calculation of CRR

| Rd | p(kPa) | q(kPa) | σ1'(kPa) | σ3'(kPa) | CRR |
|---|---|---|---|---|---|
| 10% | 190.85 | 3.7 | 42.39 | 38.69 | 0.026 |
| 20% | 181.33 | 7.08 | 31.1 | 24.02 | 0.08 |
| 30% | 190.36 | 12.87 | 37.13 | 24.26 | 0.143 |

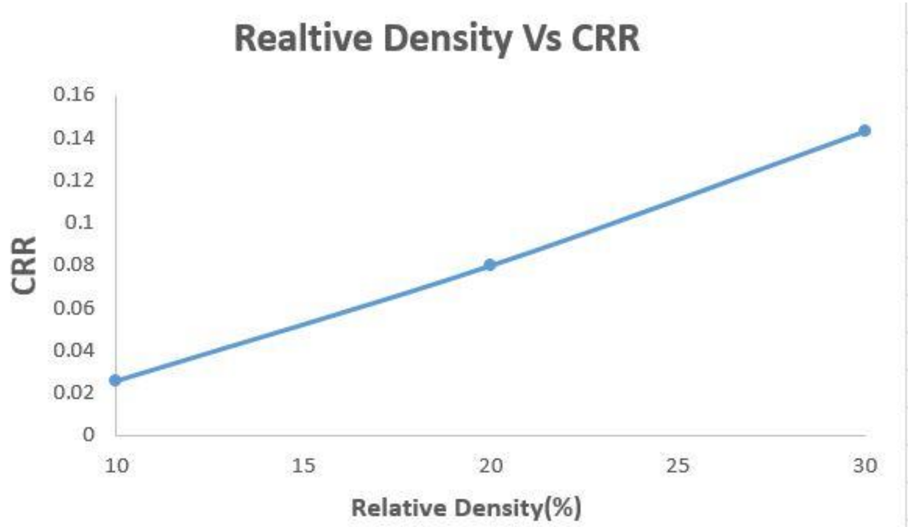


**FIGURE 6:** CYCLIC RESISTANCE RATIO AT DIFFERENT RELATIVE DENSITY

From figure 6 it's show that as increase in relative density the liquefaction resistance of sand in terms of CRR also increases, Which indicates the liquefaction occurring rate has been reduced.

## VI. CONCLUSIONS

In comparison to sand at different relative densities (i.e., 20% and 30%), pore water pressure created in river sand at 10% relative density is smaller. The pore water pressure rises as the relative density increases, indicating a gradually decreasing liquefaction occurring rate. As the relative density increases from 20% to 30%, the liquefaction resistance developed from 2.71 % to 7% approximately. CRR value changes means it's also increase by 0.026 to 0.143 at relative density changes from 10 to 30%. When liquefaction resistance is expressed in terms of CRR, it is evident that as relative density rises, so does liquefaction resistance.

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