



**ASSESSMENT OF INITIATION OF SOIL LIQUEFACTION  
INDUCED BY EARTHQUAKES :A RESEARCH**

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Abstract— Soil liquefaction is a phenomenon that occurs when saturated soil loses its strength and stiffness due to the sudden application of stress, such as an earthquake. This can lead to severe damage to infrastructure and buildings, which is why it is important to accurately assess the initiation of soil liquefaction. In recent years, laboratory testing has become an increasingly popular method for assessing soil liquefaction susceptibility. By subjecting soil samples to a series of cyclic loading tests, researchers can measure the resistance of the soil to liquefaction and estimate the likelihood of liquefaction occurring during an earthquake. This abstract presents a study on the assessment of the initiation of soil liquefaction using laboratory testing. The study involved conducting cyclic triaxial tests on soil samples collected from a liquefaction-prone area. The results of the tests were analysed to determine the soil liquefaction potential and the corresponding liquefaction resistance of the soil. The study found that the initiation of soil liquefaction could be accurately assessed using laboratory tests, and that the cyclic triaxial test was an effective method for evaluating the liquefaction potential of soils. The results of the study can be used to improve the accuracy of liquefaction hazard assessments and inform the design of earthquake-resistant infrastructure in liquefaction-prone areas.

Aim of this project is to analyze the liquefaction susceptibility of some selected sites. The selected sites of specific data related to Standard Penetration Tests data are collected for determination of liquefaction susceptibility of these sites by using LiqIT software. From these procedures, shear stresses due to earthquake or settlements of structures are evaluated using

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LiqIT software for liquefaction analysis of soils. Liquefaction, which can be defined as a loss of strength and stiffness in soils, is one of the major causes of damage to buildings and infrastructure during an earthquake. To overcome a lack of comprehensive analyses of seismically induced liquefaction. The characteristics of liquefaction and its related damage to soils and foundations during earthquakes or settlements of structures. By using LiqIT software for liquefaction data analysis, test values graphs are collected for determination of liquefaction susceptibility of these sites using LiqIT soil software.

Finally we can analyse the liquefied zones or sites with the help software, for this liquefied sites prevention methods are to be given to promote anti liquefaction. Additionally, phenomena related to damage in soils and foundations induced by liquefaction are investigated and discussed.

**Keywords**—Liquefaction, LiqIT soil software , Factor of safety

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## INTRODUCTION

Liquefaction is the phenomena when there is loss of strength in saturated and cohesion less soils because of increased pore water pressures and hence reduced effective stresses due to dynamic loading. It is a phenomenon in which the strength and stiffness of a soil is reduced by earthquake shaking or other rapid loading. Although earthquakes often triggers this increase in pore water pressure, but activities such as blasting can also cause an increase in pore water pressure. When liquefaction occurs, the strength of the soil decreases and the ability of a soil deposit to support the construction above it.

Due to the application of a dynamic loading, the shearing occurs and it is so rapid that it causes un-drained shearing condition to occur and due to this pore pressure keeps on increasing which in turn leads to decrease in effective stress since total stress remains same. According to Terzaghi since shear strength is a function of effective stress only, therefore, shear strength decreases. Finally when pore pressure increases much, effective stress becomes zero which means that our soil skeleton is not capable of taking any load and the entire load is governed by fluid material or water and since water cannot take any shear load, finally it bursts out i.e, pore pressure gets released as if there is no soil and entire thing flows like a fluid. Soil behaves more like a viscous fluid; heavy structures sink down while light structures float.

Strength of cohesion less soil is a function of overburden pressure and the angle of friction

i.e,  $S = \sigma' \tan$

When  $u$  increases more,  $\sigma - u = 0$  Or  $\sigma' = 0$

Or  $S = 0$  (full liquefaction) If there is a C- type of soil, we have

$$\tau = c + \sigma' \tan$$

During liquefaction even if  $\sigma'$  becomes zero still soil shows some shear strength because of cohesion. However due to pore pressure water generated inside will dominate and since it cannot take any shear load so entire clay material will be pumped out. This phenomenon is technically termed as clay pumping or mud pumping. So, clay pumping or mud pumping is the similar phenomenon like liquefaction but technically liquefaction is for cohesion less soil while mud pumping or clay pumping is for cohesive soils. Soil liquefaction can also exert higher pressure on retaining walls, which can cause them to slide or tilt. This movement can cause destruction of structures on the ground surface and settlement of the retained soil. As India experiencing lots of seismic threats, liquefaction is one of the major types of ground failure. 1934 Bihar-Nepal earthquake was one of the worst earthquakes in the history of Nepal and Bihar, India. A magnitude of 8.0 occurred on 15 January and caused widespread damage in northern Bihar and in Nepal. A large number of sand fountains were noticed during the Bihar earthquake (Housner, 1958, Dunnet al 1939). On August 6, 1988; several parts of the north-eastern India were rocked by an earthquake. The tremors were also felt in Nepal, Bangladesh, Burma and Soviet Union. On August 21, 1988 another earthquake occurred in the Bihar Nepal Border region.

A Large scale of liquefaction has been reported during these two earthquakes. After the 2001 Bhuj earthquake and recently 2015 Nepal earthquake attracted the greater attention to liquefaction studies. Present study liquefaction analysis carried out in Places along river Godavari is erosion, fault controlled and hence vulnerable to the seismicity of low to moderate intensity. Therefore, it is essential to take up seismic hazard studies at the micro level to improve safety norms for the port structure, industrial structures and underground pipelines

### **OBJECTIVES OF PRESENT STUDY**

The present study, soil liquefaction analysis is carried out in Places along river Godavari using 20 Standard penetration test borehole data collected from various sites. Using semi empirical equations developed by Idriss finding factor of safety. Factor of safety can be determined from the cyclic stress ratio and cyclic resistance ratio.

1. Peak Ground Acceleration (PGA) is an important parameter, occurred during an earthquake shaking at a location. In the present study PGA values are evaluated using a computer program LiqIT
2. Analysing the liquefied zones of particular locations through the LiqIT software.
3. To evaluate the liquefaction potential of different types of soils under varying earthquake loading conditions using laboratory testing methods.
4. We will get the detailed information regarding liquefied zones in the form of :
  - Graphs.
  - Tabular values.
  - Identification icons.
  - Factor of safety.
  - FS greater than 1 (no liquefaction).
  - FS less than 1 (Liquefaction effected).

### **EVALUATION OF LIQUEFACTION SUSCEPTIBILITY**

During cyclic undrained loading, like those imposed by earthquake shaking, almost all saturated cohesionless soils are subjected to significant pore pressure build-up. If there is shear stress reversal, the effective stress state can drop rapidly to zero. When a soil element reaches the condition of essentially zero effective stress, the soil has very little stiffness and large deformations. This phenomenon is generally referred to as liquefaction. Semi-empirical procedures for evaluating liquefaction potential of cohesionless soils during earthquakes basically consist of analytical approaches to explain experimental findings of past case histories, and the development of a suitable in-situ index to represent soil liquefaction characteristics.

### **METHODS OF REDUCING LIQUEFACTION HAZARDS**

By Avoiding Liquefaction Susceptible Soils.

- \_ Build Liquefaction Resistant Structures.
- \_ Improve the Soil
- \_ Construction on liquefaction susceptible soils is to be avoided.
- \_ The soil at a particular building site according to the various criterias available to determine the liquefaction potential of the soil in a site
- \_ The structure constructed should be liquefaction resistant

\_ The mitigation of the liquefaction hazards by improving the strength, density and drainage characteristics of the soil.

### **SUSCEPTIBILITY OF SOILS TO LIQUEFACTION IN EARTHQUAKES**

Liquefaction is most commonly observed in shallow, loose, saturated cohesion less soils subjected to strong ground motions in earthquakes. Unsaturated soils are not subject to liquefaction because volume compression does not generate excess pore water pressure. Liquefaction and large deformations are more associated with contractive soils while cyclic softening and limited deformations are more likely with expansive soils. In practice, the liquefaction potential in a given soil deposit during an earthquake is often evaluated using in-situ penetration tests and empirical procedures.

Since liquefaction phenomena arise because of the tendency of soil grains to rearrange when sheared, any factor that prevents the movement of soil grains will increase the liquefaction resistance of a soil deposit. Particle cementation, soil fabric, and again are some of the important factors that can hinder soil particle movement. Stress history is also crucial in determining the liquefaction resistance of a soil.

### **GROUND FAILURE RESULTING FROM SOIL LIQUEFACTION**

National Research Council (The Liquefaction..1985) lists eight types of ground failure commonly associated with the soil liquefaction in earthquakes:

- Sand boils resulting in land subsidence accompanied by a relatively minor change.
- Failure of retaining walls due to increased lateral loads from liquefied backfill or loss of support from the liquefied foundation soils.
- Ground settlement, generally linked with some other failure mechanism.
- Flow failures of slopes resulting in large down slope movements of a soil mass.
- Buoyant rise of buried structures such as tanks.
- Lateral spreads resulting from the lateral movements of gently sloping ground.
- Loss of bearing capacity resulting in foundation failures. Ground oscillation involving back and forth displacements of intact blocks of surface soil.

### **LITERATURE REVIEW**

When dense sands are sheared monotonically, the soil gets compressed first and then it gets dilated as sand particles move up and over one another. When dense saturated sands are

sheared impeding the pore water drainage, their tendency of volume increase results in a decrease in pore water pressure and an increase in the effective stress and shear strength. When dense sand is subjected to cyclic small shear strains under undrained pore water conditions excess pore water pressure may be generated in each load cycle leading to softening and the accumulation of deformations. However, at larger shear strains, increase in volume relieves the excess pore water pressure resulting in an increased shear resistance of the soil. After initial liquefaction if large deformations are prevented because of increased undrained shear strength then it is termed, limited liquefaction (Finn 1990). When dense saturated sands are subjected to static loading they have the tendency to progressively soften in undrained cyclic shear achieving limiting strains which is known as cyclic mobility. (Castro 1975; Castro and Poulos 1979). Cyclic mobility should not be confused with liquefaction. Both can be distinguished from the very fact that a liquefied soil displays no appreciable increase in shear resistance regardless of the magnitude of deformation (Seed 1979) Soils undergoing cyclic mobility first soften subjected to cyclic loading, but later when monotonically loaded without drainage stiffen because tendency to increase in volume reduce the pore pressures. During cyclic mobility, the driving static shear stress is less than the residual shear resistance and deformations get accumulated only during cyclic loading. However, in layman's language, a soil failure resulting from cyclic mobility is referred to as liquefaction. Robertson (1994) termed this, cyclic liquefaction. It involves some deformation occurring while static shear stresses exceed the shear resistance of the soil (when the state of zero effective stress is approached). However the deformations stop after cyclic loading ends as the tendency to expand quickly results in strain hardening. This type of failure in saturated, dense cohesion less soils is also referred to as liquefaction but with limited deformations. According to Selig and Chang (1981) and Robertson (1994), a dilative soil can attain a state of zero effective stress and shear resistance. Cyclic loads may produce a reversal in the shear stress direction when the initial static shear stress is low i.e. the stress path passes through a condition which is known as state of zero shear stress.

## METHODOLOGY

The stress-based approach for evaluating the potential for liquefaction triggering, by Idriss and Boulanger (2004). The basic framework, as adopted compares the earthquake induced cyclic stress ratios (CSR) with the cyclic resistance ratios (CRR) of the soil. The components

of this Methodology, as briefly summarized below, were developed to provide a rational treatment of the various factors that affect penetration resistance and cyclic resistance.

### **Evaluation of Cyclic Stress Ratio (CSR)**

The earthquake-induced CSR, at a given depth,  $z$ , within the soil profile, is usually expressed as a representative value (or equivalent uniform value) equal to 65% of the maximum cyclic shear stress ratio.

1. Evaluation of Cyclic Resistance Ratio
2. The cyclic resistance ratio represents the liquefaction resistance of the soil, expressed as CRR. That means cyclic stress required to induce liquefaction for a soil stratum.

### **Magnitude Scaling Factor**

The magnitude scaling factor (MSF) is used to account for duration effects (i.e., number of loading Cycles) on the triggering of liquefaction. The MSF relationship was derived by combining.

- Factor of Safety
- Factor of safety is defined as the ratio of cyclic resistance ratio (CRR) to cyclic stress ratio (CSR).
- Factor of Safety = Cyclic Resistance Ratio / Cyclic Stress Ratio

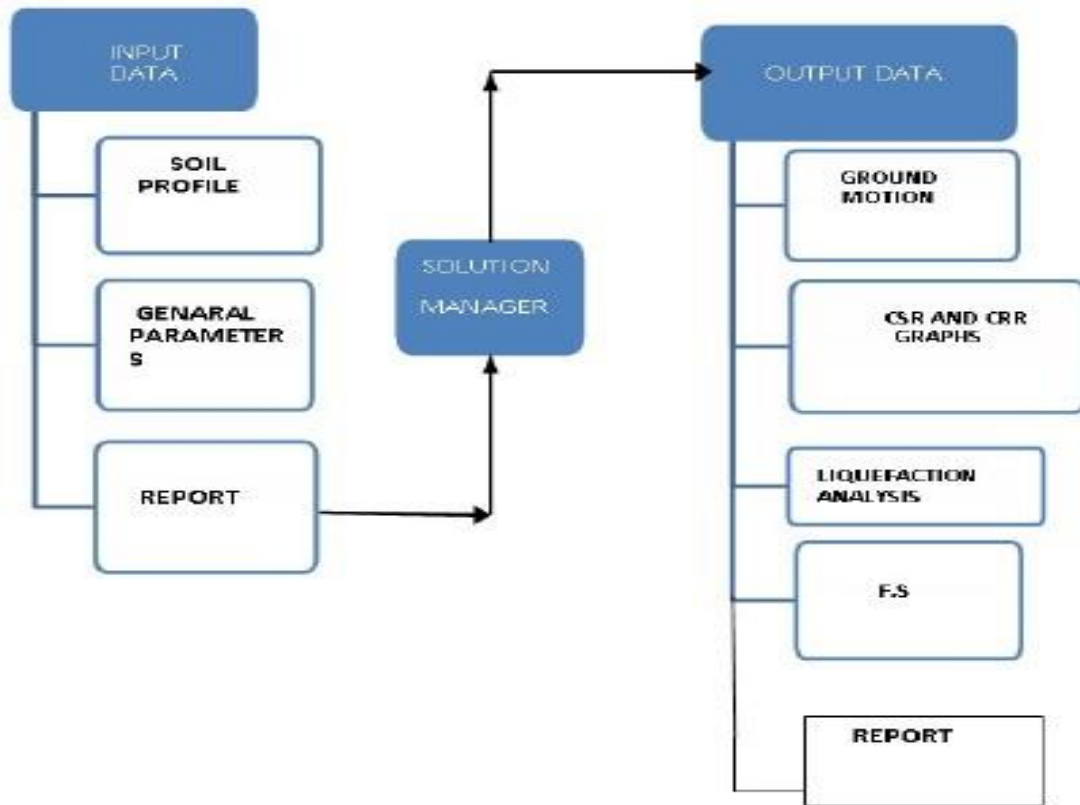
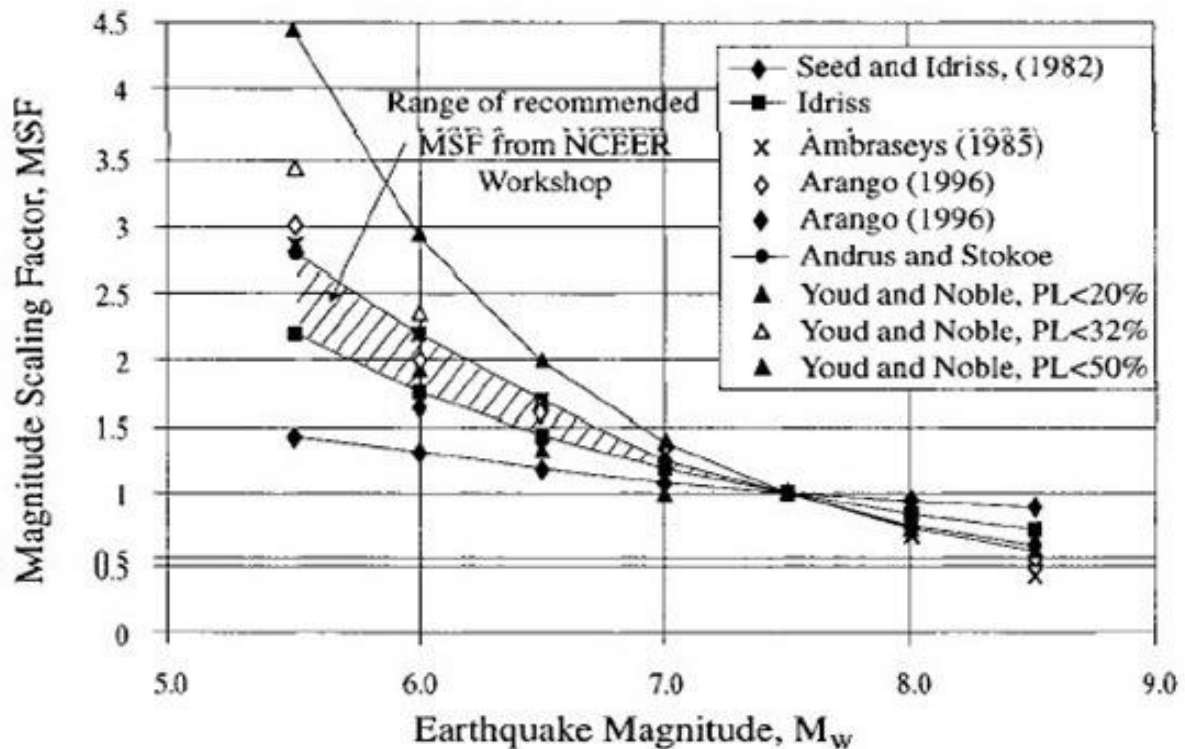


Fig. 3.1 Flow Chart

MAGNITUDE SCALING FACTOR

Factor	Equipment Variable	Correction for SPT zones
Overburden pressure	-	0.5
Energy ratio	Donut hammer	0.5-1
Energy ratio	Automatic trip donut	0.8-1.3
Energy ratio	Hammer	0.6
Borehole diameter	65-115 mm	1
Borehole diameter	150 mm	1.05
Borehole diameter	200 mm	1.15
Rod length	3 m	0.75
Rod length	3-4 m	0.8
Rod length	4-6 m	0.85
Rod length	6-10 m	0.95
Rod length	10-30 m	1
Sampling method	Standard sampler	1
Sampling method	Sampler without liner	1-1.3





## INTRODUCTION TO LIQIT SOFTWARE

Seismic ground acceleration plays an important role in assessing effects of earthquakes on the built environment, persons, and the natural environment. Earthquake shaking generally occurs in all three directions. Therefore, PGA is often split into the horizontal and vertical components. In present study peak ground acceleration is calculated using a computer based program, LiqIT.

## LIQIT PROGRAMME STRUCTURE

LiqIT is designed to provide an intuitive interface that simplifies and speeds the process of performing and interpreting the results of ground response analyses. The program is organized into three managers - an Input data Manager, a Solution , and an Output data Manager - and a Report. In the normal sequence of operations, the user will move from the Input data to the Solution Manager and then on to the Output data, as indicated graphically below.

## INPUT DATA MANAGER

The Input Data Manager allows all input data to be entered, checked, and saved prior to program execution. The Input data Manager provides a series of forms on which the required

data can be entered, and on which the desired output can be specified. Input data manager consists of soil profile, input motions and report. LiqIT allows you to view a variety of potential input motions and select the ones that are most appropriate for the analysis.

### **SOLUTION MANAGER**

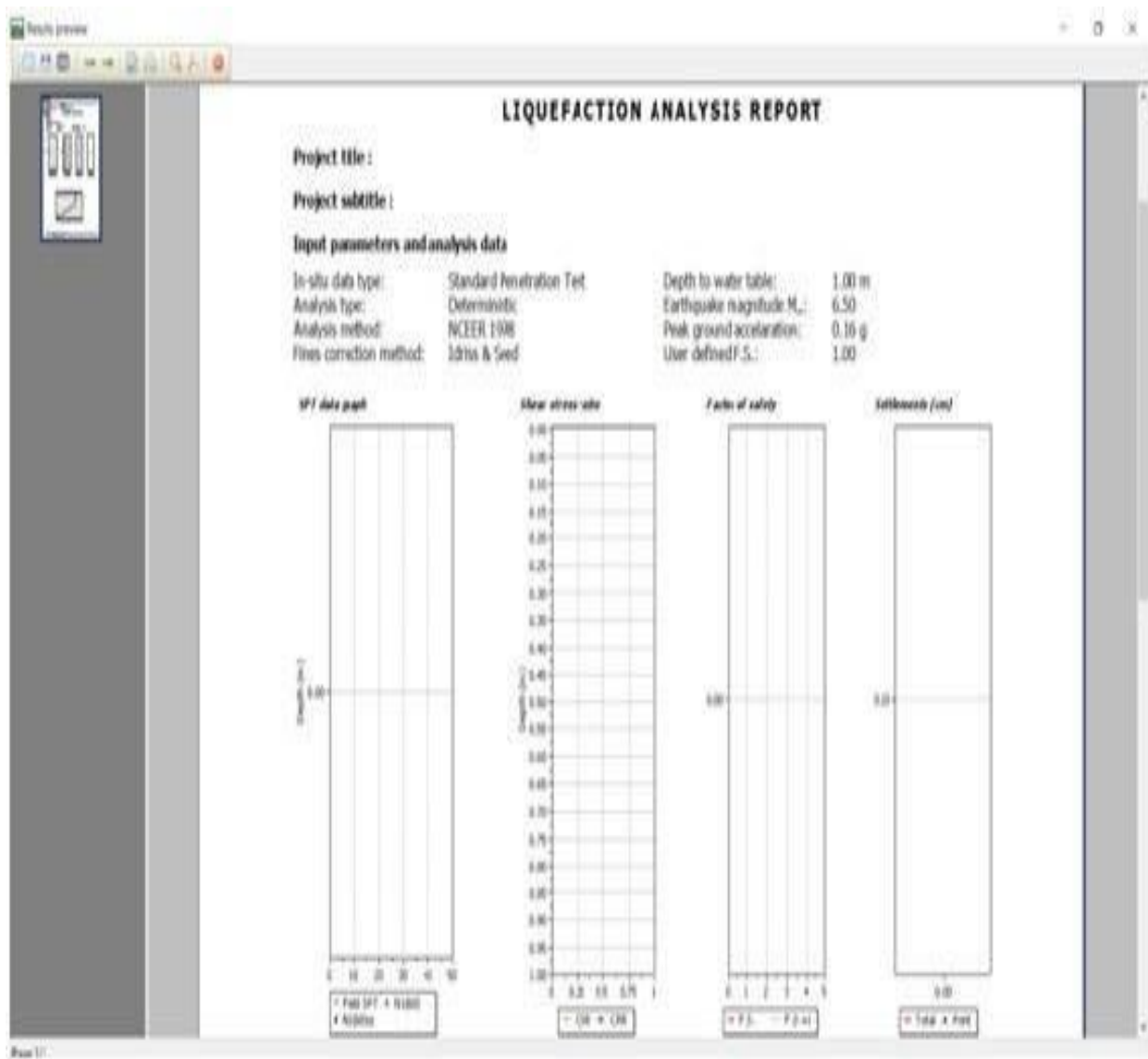
The Solution Manager performs the actual ground response analysis. It requires that the user specify a valid input data file (with the data extension) and then performs the required that allows the user to track the progress of the analysis. Upon completion of the analysis, the Solution Manager saves he results in a file.

### **OUTPUT DATA MANAGER**

The Output data Manager allows the user to generate a wide range of plots of the results of the analysis. It requires that the user specify a valid output data file, and then provides a number of forms for plotting time histories, spectra, variations of parameters with depth, and for computation of scalar parameters. The Output data Manager also allows the user to view an animation of the horizontal displacements throughout the soil profile- many users find this feature very helpful for developing an intuitive understanding of the response of the soil profile.



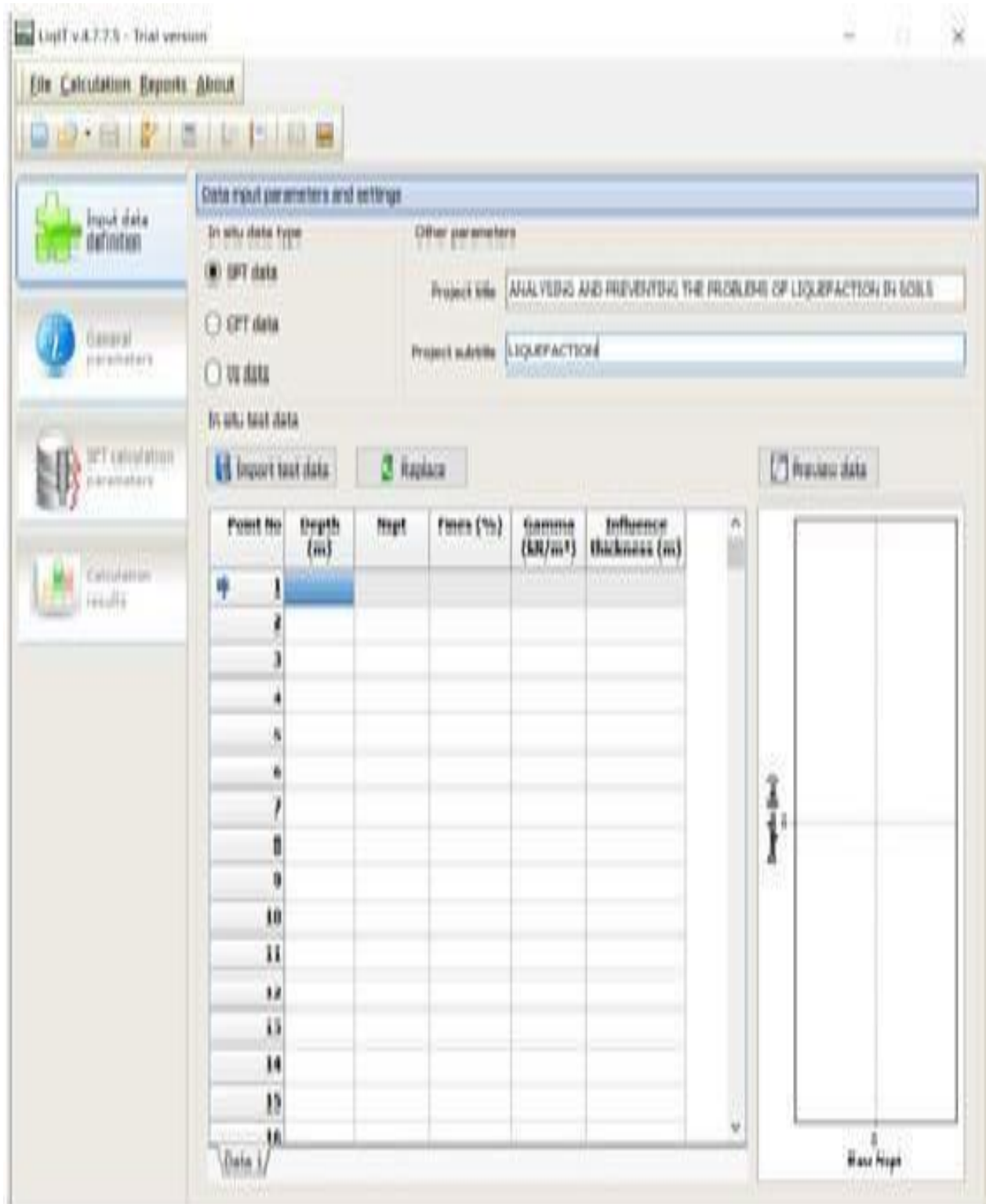
## REPORT



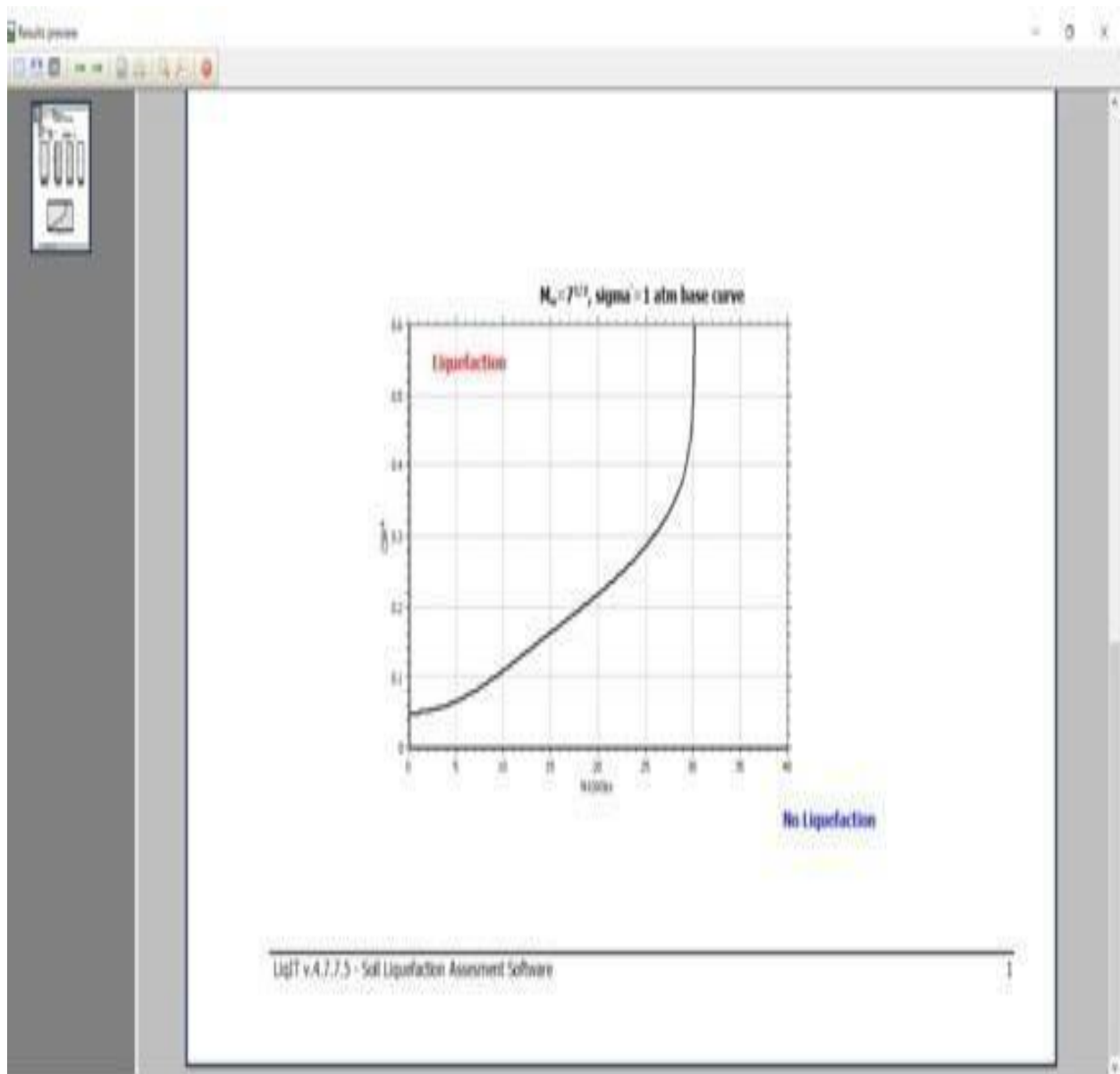
The Report produced by a word processor that is built into LiqIT. The Report allows the user to keep a record of each analysis. All input data is automatically written to the Report and updated when the Report is accessed. Many users find the Report useful for internal documentation of their analyses and for preparation of project reports for their clients. The below mentioned required data values are got through consultancy companies. LiqIT Software consists of:

1. Depth
2. Nspt
3. Fine content

4. Gamma
5. Input Parameters



## General Parameters



## Design of Factor of Safety Analyzing of Liquefaction

**CALCULATIONS AND DISCUSSIONS**

In present study N-values obtained from 20 locations at different depths are considered for assessment of liquefaction potential of soil. The Soil has been analyzed for peak ground acceleration levels obtained from LiqIT and Factor of safety is calculated by using Idriss method.

Liquefaction susceptibility through LiqIT software By calculating the factor of safety using the Idriss method, using the parameters, peak ground acceleration and SPT N values the susceptibility of liquefaction is measured along the borehole depth.

Susceptibility of liquefaction is measured along the depths of 2, 6, 10, up to 20m for 20 locations. The liquefaction susceptibility of various locations at 2, 6, 10 m depth are presented in tables and graphs with the help of LiqIT soil software.

#### Bore Hole Locations

The Present Study Liquefaction Analysis is carried at the following places:

1. Baramulla
2. Reassi
3. Ramban
4. Srinagar
5. Kupwara

The present study is carried out along 20 various sites as stated above, We have collected the SPT borehole data from sheri kashmir , geotechnical laboratory report section. We have also prepared a borehole location analysis of various sites using LiqIT software.

#### List of 20 Sites SPT Zones:

Details of locations Regarding liquefaction for SPT sites or zones:

KUPWARA: 5 Bore holes (SPT data) SRINAGAR : 7 Bore holes (SPT data) RAMBAN: 4 Bore holes (SPT data) REASSI: 3 Bore holes (SPT data) BARAMULLA: 2 Bore holes (SPT data)

#### RESULTS

Susceptibility of Liquefaction at a Depth of 2m by Idris and Boulanger Method

Susceptibility of Liquefaction at a Depth of 6m by Idris and Boulanger Method

Susceptibility of Liquefaction at a Depth of 10m by Idris and Boulanger Method

## Liquefaction Analysis: 1

<b>S.N o</b>	<b>Location</b>	<b>Liquefaction at a depth of 2m</b>
11	GUPKAR SRINAGAR	NO
12	MAIN MARKET REASSI	NO
13	URI DAM BARAMULLA	YES
14	RAMBAN	YES
15	BY PASS REASSI	YES
16	KHAN BUILDINGS BARAMULLA	YES
17	SHER E KASHMIR INSTITUTE SRINAGAR	YES
18	SURVEY NO 356/ A SRINAGAR	YES
19	KUPWARA	NO
20	KUPWARA	NO



## Liquefaction Analysis: 2

<b>S.No</b>	<b>Location</b>	<b>Liquefaction at a depth of 6m</b>
1	Raj bagh SRINAGAR	YES
2	SOURA SRINAGAR	YES
3	URI DAM BARAMULLA	NO
4	RAMSOO RAMBAN	YES
5	CHANDERKOTE RAMBAN	YES
6	FATEH PORA BARAMULLA	NO
7	HUMHAMA SRINAGAR	NO
8	BEMINA SRINAGAR	YES
9	RAMBAN RIDGE	YES
10	GREEN VALLEY	YES

## Liquefaction Analysis: 3

S.N	Location	Liquefaction at a depth of 10m
1	Srinagar - Baramulla	YES
2	Fatehpora	NO
3	Hyderpora	NO
4	Nowgam	NO
5	New colony Reassi	YES
6	Baramulla	YES
7	Gool Ramban	NO
8	Reassi	NO
9	Kreeri Baramulla	YES
10	Singhpora	NO

**CONCLUSION**

The present work is carried out to analyse the liquefaction potential and liquefied susceptibility in some places along River Godavari. The 20 bore hole data is collected from the places of Yanam, Rajahmundry, I.Polavaram, Tallarevu Katrenikona. A Semi Empirical Method, Idriss and Boulanger is used to determine, the liquefaction potential.

**CONCLUSIONS DRAWN FROM THE STUDY ABOUT LIQUEFACTION ANALYSIS :**

1. Soil layers with corrected SPT blow count ( ) less than 14 have been known to be liquefy in most of the cases.
2. Soil layers with corrected SPT blow count ( ) greater than 20 have been known to be safe against liquefaction in most of the cases.

3. The liquefaction potentiality which depends on vertical effective stress, from this analysis in all cases vertical effective stress greater than  $95 \text{ KN/m}^2$  is safe against liquefaction.
4. In srinagar region 7 Bore Hole Log Data are analyzed in which most cases revealed that Soil undergoes Liquefaction at Depths Ranging 3m-5m.
5. In kupwara region 5 Bore Hole Log Data are analyzed in which Soil undergone Liquefaction in 2 cases while in remaining 3 cases soil is safe against liquefaction.
6. In Reasi Region 3 Bore Hole Log Data are analyzed in which all cases revealed that Soil undergoes Liquefaction at Depths Ranging 2.5m-6m.
7. In Ramban region 4 Borehole Log Data are analyzed in which most cases revealed that Soil is safe against Liquefaction.
8. In Baramulla region 2 Bore Hole Log Data are analyzed in which Soil undergoes Liquefaction in both the cases.

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