RES MILITARIS
REVUE EUROPEENNE D ETUDES · EUROPEAN JOURNAL OF MILITARY STUDIES
Social Science Journal

ENHANCING RELIABILITY ANALYSIS OF RAFT FOUNDATION WITH CONFIDENCE LEVEL USING CHI-SQUARE METHOD

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Abstract:

The 21st century has witnessed a very rapid acceleration in the development of both technology and information. This century is known as the Information Age. As evidenced by the numerous discoveries that have been made in the fields of science, health, astronomy, education, and even construction, which are very helpful to the engineer when making or constructing facility projects. As a direct consequence of this, offering raft footing as a service is currently one of the most typical practises available on the market. This not only helps cut down on the cost of excavation but also the amount of effort that is required, and it also prevents the footings that are adjacent from sliding. The raft will be used because it is more cost-effective, and it functions as a kind of combined footing that has the potential to cover the entirety of the space under the structure while simultaneously supporting multiple columns as a single rigid body. Additionally, the raft functions as a kind of combined footing that has the potential to cover the entirety of the space under the structure.

During the process of building the foundation for the raft, a CPT-Test will be carried out at varying levels of ratios, and a reliability analysis will be carried out using the chi-square method. Both of these steps will take place concurrently. In the calculation of the raft foundation, the value of bearing capacity is used as a variable, and the value of chi square is the result of this calculation. This results in a distribution that is normal. The analysis of reliability has been carried out, and the degree of confidence will be figured out with the assistance of a crystal ball analysis. Following that, the data obtained from the experiment will be analysed utilising a variety of levels of confidence, and the reliability will be calculated utilising a variety of ratios.

Keywords: CHI-SQUARE, RELIABILITY, RAFT FOUNDATION, CPT-Test

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I. INTRODUCTION

The rate of progress in science and information has accelerated dramatically in the twenty-first century. The many scientific, medical, astronomical, educational, and even building breakthroughs that have aided the Engineer in making or facilitating their projects are ample proof of this. There were a plethora of methods used by the researchers. Many geotechnical projects in the 1990s relied on deterministic model analyses for their design. There has been a lot of work done using a deterministic approach,but in reality almost all soil properties are
different and homogeneous soil is extremely unlikely (Listyawan, 2006). Because of the limitations of deterministic methods, the idea of probability analysis provides superior solutions.

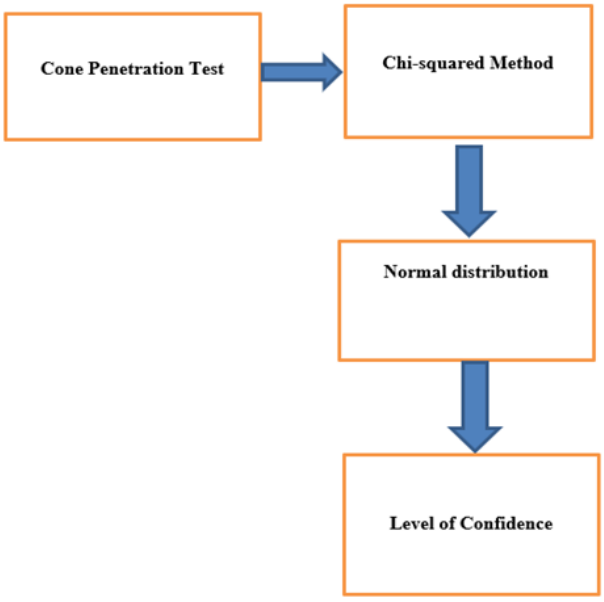
As opposed to the deterministic approach, which relies on a single value for a set of soil properties that are taken to be representative, the probability concept of soil properties makes use of all available data to account for any variation that may occur. The results of the cone penetration test (CPT), more commonly referred to in Indonesia as a "sondir," are one of the soil properties with a great deal of scatter in the data. In particular, the values of the CPT's tip resistance (qc) and sleeve friction (fs) show a large range of variation. Preparing

information for use in running probability models, which will be used in turn for analysing the raft's foundation stability. On the basis of the issues that have been outlined in the introduction, a formula may serve as a point of reference.

The following is a statement of the research project:

- It is necessary to carry out research to determine the stability of raft foundations in locations that have multiple stories of buildings.
- Obtaining the smallest possible value of the safety factor by calculating the value of the safety factors for the raft foundation using the various CPT data.

2. METHODOLOGY



2.1 Static Cone Penetration Test Apparatus, Principle and Procedure

Cone Penetration test (CPT) is a type of in-situ test which is carried out to determine different geotechnical properties of soil. CPT is of two types:

- Static Cone Penetration Test (SCPT)
- Dynamic Cone Penetration Test (DCPT)

Principle:

A static cone penetration test involves the penetration of a cone inside the ground and measures the cone resistance, friction resistance, friction ratio and pore water pressure.

Apparatus required:

1) A steel cones
2) A friction jackets
3) Sounding rod
4) Mantle tube
5) A driving mechanism
6) Measuring equipment

Procedure:

Step 1: The cone and friction jacket assembly is put vertically touching the ground.

Step 2: The cone is then pushed down at a constant speed of penetration ranging from 1.5 to 2.5cm/sec to a depth a (say 40 mm). Then, cone tip resistance (qc) is recorded.

Step 3: Now the sounding rod is pushed further to a depth b (say 40 mm). Then, sleeve friction (qf) is recorded.

Step 4: Then, the mantle tube is pushed down to a+b = 80mm depth. This brings the cone and jacket assembly to step 1.

Step 5: Then the friction ratio is calculated using the formula:

$$RS = qf / qc \quad (1)$$

Advantages:

1. SCPT is a simple and rapid test.
2. This test is economical to perform.
3. This test helps to identify the problem of soils.
4. This test provides us with detailed and precise data.
5. This test helps us with real-time measurement.

2.2 RAFT FOUNDATION

Raft Foundation is also known as Mat Foundation is a footing spread over the entire area of the foundation transferring the load of the entire structure to the ground by taking the load from the number of columns. Raft Footing as spread over the entire foundation transfers the equal load to soil hence causing the even settlement of the footing adding to its one of the best advantages.

A Raft or Mat Foundation firstly is a continuous slab on soil that extends over the whole footprint of

the building to be constructed by supporting the building and transferring its weight to the ground. When determining which foundation is the most economical (foundation), the engineer must consider superstructure load, subsoil conditions, as well as desirable tolerable settlement.

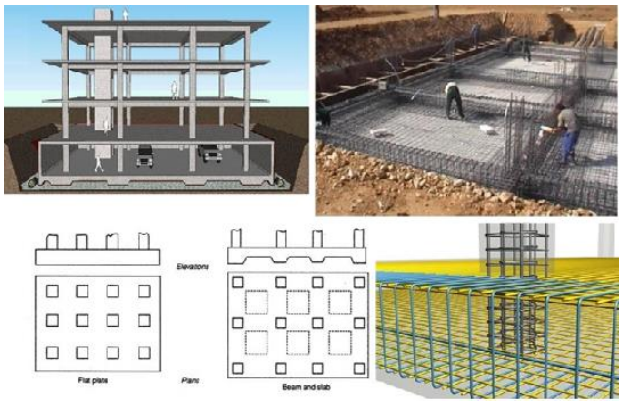


Figure 2: Raft Foundation

Raft Foundation Detail

- ✓ As the definition of Raft or mat Foundation suggests, the footing is spread over a wider area taking load from numbers of columns and in turn, transferring the load evenly over the entire span of footing
- ✓ Structure obtains high stability through this type of load transformation.
- ✓ The same is the reason for the even settlement of the soil hence ultimately the reason for the non-uneven settlement of the structure.
- ✓ In mat foundation, the wider area of footing is in the proximity of the soil as compared to other types of footing hence transferring the load over a larger area hence less stress is developed.
- ✓ Raft or mat foundation is suitable for weak soils hence if lesser stress is developed in the soil chances of shear failure decrease making soil suitable for bearing the structural load to an extent.

Following are the necessities of Raft or Mat Foundation:

1. Raft or mat foundation is beneficial for the poor quality of soils on which foundation is to be laid.

2. One of the necessary principles of adoption Raft or mat foundation is when the columns are closely placed and the load imposed is high by the structure.

3. If the water level is high in some subsequent areas where construction is to be carried out raft foundation is generally suggested by engineers.

4. If found to be constructed covers more than 60% of the total area of construction raft foundation is the most suitable one.

5. In the constructions where the task of waterproofing of substructure is to be rendered, mat foundation is adopted.

6. The stress of soil will be another factor where raft foundation is taken into consideration (As I reduce the stress on the soil.)

7. After the examination, if the soil is showing the signs of Shear failure under loading raft foundation is one of an option.

Following are the different raft foundation types:

- ➢ Flat Plate type Raft Foundation
- ➢ Plate thickened under the column
- ➢ Piled Raft Foundation
- ➢ Beam and Slab Type
- ➢ Cellular Raft Footing

2.3 Chi-squared Method:

A chi-squared test (also chi-square or $\chi 2$ test) is a statistical hypothesis test used in the analysis of contingency tables when the sample sizes are large. In simpler terms, this test is primarily used to examine whether two categorical variables (two dimensions of the contingency table) are independent in influencing the test statistic (values within the table).[1] The test is valid when the test statistic is chi-squared distributed under the null hypothesis, specifically Pearson's chi-squared test and variants thereof. Pearson's chi-squared test is used to determine whether there is a statistically significant difference between the expected frequencies and the observed frequencies in one or more categories of a contingency table. For contingency tables with smaller sample sizes, a Fisher's exact test is used instead.

In the standard applications of this test, the observations are classified into mutually exclusive classes. If the null hypothesis that there are no differences between the classes in the population is true, the test statistic computed from the observations follows a χ2 frequency distribution. The purpose of the test is to evaluate how likely the observed frequencies would be assuming the null hypothesis is true.

Test statistics that follow a χ2 distribution occur when the observations are independent. There are also χ2 tests for testing the null hypothesis of independence of a pair of random variables based on observations of the pairs.

Chi-squared tests often refers to tests for which the distribution of the test statistic approaches the χ2 distribution asymptotically, meaning that the sampling distribution (if the null hypothesis is true) of the test statistic approximates a chi-squared distribution more and more closely as sample sizes increase.

2.4 Normal distribution

The normal distribution is the most common type of distribution assumed in technical stock market analysis and in other types of statistical analyses. The standard normal distribution has two parameters: the mean and the standard deviation.

The normal distribution model is important in statistics and is key to the Central Limit Theorem (CLT). This theory states that averages calculated from independent, identically distributed random variables have approximately normal distributions, regardless of the type of distribution from which the variables are sampled (provided it has finite variance).

The normal distribution is one type of symmetrical distribution. Symmetrical distributions occur when where a dividing line produces two mirror images. Not all symmetrical distributions are normal, since some data could appear as two humps or a series of hills in addition to the bell curve that indicates a normal distribution.

Properties

- The normal distribution has several key features and properties that define it.
- First, its mean (average), median (midpoint), and mode (most frequent observation) are all equal to one another.
- Moreover, these values all represent the peak, or highest point, of the distribution.
- The distribution then falls symmetrically around the mean, the width of which is defined by the standard deviation.

2.5 Level of Confidence

In statistics, the confidence level indicates the probability, with which the estimation of the location of a statistical parameter (e.g. an arithmetic mean) in a sample survey is also true for the population.

When conducting a survey, confidence levels must be established in advance, as the margin of error as well as the necessary scope of the survey depends on them. In surveys, confidence levels of 90/95/99% are frequently used.

If the confidence level was to be established at 95%, a calculated statistical value that was based on a sample, would also be true for the whole population within the established confidence level – with a 95% chance. In other words: the chances are very high that the arithmetic mean (as a statistical value) of a population is exactly within the margins of error which were established for the survey based on a sample.

3.RESULTS & DISCUSSION

Table 1: Capacity of bearing at different depth

S.No.	DEPTH (mm)	CONE RESISTANCE q_c (Kpa)	FRICTION RESISTANCE q_f (Kpa)	FRICTION RATIO f_r	BEARING CAPACITY (KN/m²)
1	50	1860	22.02	1.19	98.5
2	150	1160	28.72	2.48	87.3
3	250	2280	24.89	1.09	110.2
4	350	290	12.44	4.29	90.6
5	450	380	15.32	4.03	89.4
6	550	400	14.74	3.69	92.1
7	650	6900	28.72	0.42	120.3

We use cone penetration test at different depths is carried out cone Resistance, friction Resistance and friction ratio by using formulas we carried out these values and Finally we carried out bearing capacity for using above values in formula and also carried out safe bearing capacity of soil.

3.1 Chi-squared test:

The chi-square test is used to estimate how

likely the observations that are made would be, by considering the assumption of the null hypothesis as true.

A hypothesis is a consideration that a given condition or statement might be true, which we can test afterwards. Chi-squared tests are usually created from a sum of squared falsities or errors over the sample variance.

Finding P-Value

P stands for probability here. To calculate the p-value, the chi-square test is used in statistics. The different values of p indicate the different hypothesis interpretation, are given below:

- P≤ 0.05; Hypothesis rejected
- P>.05; Hypothesis Accepted

Probability is all about chance or risk or uncertainty. It is the possibility of the outcome of the sample or the occurrence of an event. But when we talk about statistics, it is more about how we handle various data using different techniques. It helps to represent complicated data or bulk data in a very easy and understandable way. It describes the collection, analysis, interpretation, presentation, and organization of data. The concept of both probability and statistics is related to the chi-squared test.

Properties

The following are the important properties of the chi-square test:

- Two times the number of degrees of freedom is equal to the variance.
- The number of degrees of freedom is equal to the mean distribution
- The chi-square distribution curve approaches the normal distribution when the degree of freedom increases.

The chi-squared test is done to check if there is any difference between the observed value and expected value. The formula for chi-square can be written as

$$X^2 = \sum \frac{(\text{Observed value} - \text{Expected value})^2}{\text{Expected value}} \quad (2)$$

$$\sum_{i=1}^{7} \frac{(o_i - e_i)^2}{e_i} = 9.3934$$

Degree of freedom=n-1=7-1=6

$x^2_{Cal} < X^2_{table}$

9.3934 < 12.6

So accept null hypothesis.

Table 2: Comparison for observed and expected values

Observed	98.5	87.3	110.2	90.6	89.4	92.1	120.3
Expected	98.3	98.3	98.3	98.3	98.3	98.3	98.3

Table 3: observed value and expected value for using chi-square test

o_i	98.5	87.3	110.2	90.6	89.4	92.1	120.3
e_i	98.3	98.3	98.3	98.3	98.3	98.3	98.3
$(o_i - e_i)$	0.2	-11	11.9	-7.7	-8.9	-6.2	22
$(o_i - e_i)^2$	0.04	121	141.61	59.29	79.21	38.44	484
$\frac{(o_i - e_i)^2}{e_i}$	0.004	1.231	1.440	0.603	0.805	0.391	4.923

3.2 Normal distribution

The normal distribution is the most common type of distribution assumed in technical stock market analysis and in other types of statistical analyses. The standard normal distribution has two parameters: the mean and the standard deviation.

The normal distribution model is important in statistics and is key to the Central Limit Theorem (CLT). This theory states that averages calculated from independent, identically distributed random variables have approximately normal distributions, regardless of the type of distribution from which the variables are sampled (provided it has finite variance).

The normal distribution is one type of symmetrical distribution. Symmetrical distributions occur when where a dividing line produces two mirror images. Not all symmetrical distributions are normal, since some data could appear as two humps or a series of hills in addition to the bell curve that indicates a normal distribution.

Properties

The normal distribution has several key features and properties that define it.

First, its mean (average), median (midpoint), and mode (most frequent observation) are all equal to one another.

Moreover, these values all represent the peak,

or highest point, of the distribution.

The distribution then falls symmetrically around the mean, the width of which is defined by the standard deviation.

The normal distribution follows the following formula. Note that only the values of the mean (μ) and standard deviation (σ) are necessary

$F(x) = 1/(\sigma\sqrt{2\pi})e - [((x-\mu))^2/(2\sigma^2)]$ (3)

where:

x = value of the variable or data being examined and f(x) the probability function

μ = the mean

σ = the standard deviation

n = no.of samples = 7

xi = 1 to 7

Mean μ = (1+2+3+4+5+6+7)/7

= 4

Variance $(\sigma^2) = E(x^2) - E(〚x)〛^2 = 4$

Standard deviation $(\sigma) = \sqrt{(\sigma^2)} = 2$

Formula: $F(x) = 1/(\sigma\sqrt{2\pi})e - [((x-\mu))^2/(2\sigma^2)]$

F(1) = 0.0647

F(2) = 0.1209

F(3) = 0.1760

F(4) = 0.1994

F(5) = 0.1760

F(6) = 0.1209

F(7) = 0.0647

Table 4: Cumulative distribution & Probability distribution function

x	μ	σ	??	pdf	PDF
1	4	2	4	0.0239	0.0239
2	4	2	4	0.0478	0.0717
3	4	2	4	0.0675	0.1392
4	4	2	4	0.0753	0.2145
5	4	2	4	0.0675	0.2820
6	4	2	4	0.0478	0.3298
7	4	2	4	0.0239	0.3537

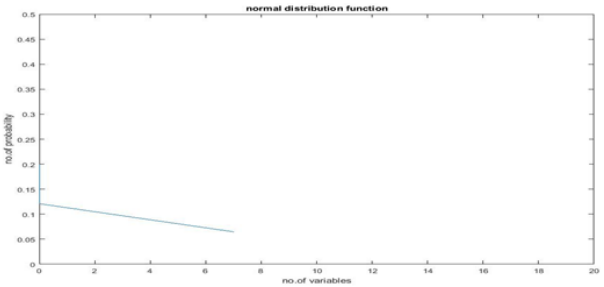


Figure 3: Output response for normal distribution function

The above output response represents the ratio of number of probability and number of variables at normal distribution function.

3.3 Confidence Interval (CI)

There are two types of estimates for each population parameter: the point estimate and confidence interval (CI) estimate. For both continuous variables (e.g., population mean) and dichotomous variables (e.g., population proportion) one first computes the point estimate from a sample. Recall that sample means, and sample proportions are unbiased estimates of the corresponding population parameters.

For both continuous and dichotomous variables, the confidence interval estimate (CI) is a range of likely values for the population parameter based on:

1. the point estimate, e.g., the sample mean
2. the investigator's desired level of confidence (most commonly 95%, but any level between 0-100% can be selected)
3. and the sampling variability or the standard error of the point estimate.

Desired properties

When applying standard statistical procedures, there will often be standard ways of constructing confidence intervals. These will have been devised so as to meet certain desirable properties, which will hold given that the assumptions on which the procedure relies are true. These desirable properties may be described as: validity, optimality, and invariance.

Of the three, "validity" is most important, followed closely by "optimality". "Invariance" may be considered as a property of the method of derivation of a confidence interval, rather than of

the rule for constructing the interval.

- For n > 30

$$X \pm Z\, S/\sqrt{n} \quad (4)$$

Use the Z table for the standard normal distribution.

- For n<30

$$X \pm Z\, S/\sqrt{n} \quad (5)$$

Assume ci = 98% = 0.98

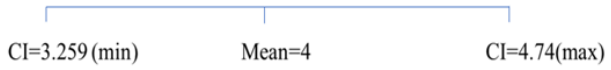
Mean (Z) = $S/\sqrt{n} = 4$

Standard deviation = 2

Standard error mean = $\sigma/\sqrt{n} = 0.7559$

No. of samples n = 7

Confidence interval = $4 \pm 0.98\ (2 \div \sqrt{7}) = 4.740, 3.259$



The confidence interval ranges between 3.259 and 4.740 which means the sample rate the product quality between 4& 5. The confidence level of 98%.

4.CONCLUSION

1. In the process of evaluating the soil, the parameters that are utilised include bearing capacity, cone resistance, friction resistance, and friction ratio. One more important parameter is the friction ratio.

2. The Chi-square test as well as the normal distribution Bearing capacity, cone resistance, friction resistance, and friction ratio are some of the parameters that are considered when conducting an analysis of the soil. The friction ratio is an additional important parameter to consider.

3. The Chi-square test and the normal distribution are the two primary tools that are utilised throughout the process of determining something. These tools are utilised in the process of determining something. This evidence might be interpreted as providing support for the null hypothesis, which is also sometimes written as Ho.

4. The level of confidence is the focus of research that is currently being conducted, and the ratings that can be assigned to it range anywhere from 3.259 to 4.740 out of 5. It is a significant part of the overall structural plan that you designed for the foundation of the raft, as it is an essential component of that plan and plays an important role in that plan. in the process of determining something, the two primary tools that are utilised are distribution and distribution. This evidence could be construed as lending support to the null hypothesis, also referred to as Ho.

5. The level of confidence is the subject of current research, and the possible ratings for it range anywhere from 3.259 to 4.740 out of 5. It is an essential part of the overall structural plan that you designed for the foundation of the raft, and it plays a significant role in that plan.

5. FUTURE SCOPE

Soil reinforcement and the addition of various chemical admixtures are essential for future work aiming to increase the capacity of foundations.

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