

# Effect of Uncertainty of Soil Influence on Shallow Foundations

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## Abstract

One of the most important challenges in the design of the foundation of the Earth layer below the surface, the Summit Foundation, which can be a very large impact on the sustainability and the structure of the desired user. Based on this analysis and design criteria of two successive ruptures (load bearing) and settlement. The design of foundation is usually the amount of designated critical foundation than the amount of force that sought the ability to transfer to the soil below. Informal mode using the average values of the parameter, transition effects on mechanical behavior of soil, a number of settlement any part of the amounts are determined by the foundation. Due to the nature of non-homogeneous soil and its parameters uncertainty, relying on one number as the amount of foundation settlement doesn't seem logical. This is while in the methods of the probability distribution function by taking the probability for each of the input parameters, or the characteristics of each parameter, the parameter values are likely to have the chance of occurrence. In this research, effort is made using the method of probabilistic Monte Carlo simulation, the effect of the uncertainty of parameters influencing the mechanical behaviour following the successive layers of earth and examined. This method is a kind of simulation is that the uncertainty in the different aspects of the issue to be obvious and a bit of the show. Monte Carlo simulation method for the determination of model uncertainty, a little bit for each of the input random variables is a function of the probability distribution which is considered. In the event that non-deterministic model input variables for describing, not non-deterministic model output as well. So the output of each method to analysis of the concept of the probability distribution function for the input variables is a function of the probability distribution for the target function. In this study, the reliability of the settlement for the three modes of settlement Center, corner of rigid foundation is fitted with two types of normal probability distribution and the log-normal distributions. For this purpose, the parameters of the effect of the transition on the analysis of soil modulus of elasticity of foundation, such as settlement and the coefficient of Poisson ratio dis-

tribution in probability using probabilistic log-normal and normal have been considered. Analysis indicated that the settlement in the center of the wake is flexible critical than the other two and has a higher probability of occurrence of the settlement in this part of the foundation. In the case of the normal distribution and the normal distribution graph of the log was used, the probability density function of the normal distribution is related to the log has a greater dispersion.

## Keywords

Settlement Foundation, Reliability, Uncertainty, The Log-Normal Distribution, Normal Distribution

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## 1. Introduction

Subsidence of structures occurs due to changes in the shape of the ground and its movement, changes in the soil volume, or substructures under tension from loading and unloading. Deformation under constant effective stress is called creep, while deformation under increasing tension is called compression or compaction. The above deformations are created as a result of the elastic and plastic volume change of grains, changes in the soil volume as a result of emitting water and air from the pores, and shear displacement of soil particles or a mass [1].

Several sources of uncertainty affect the mechanical behavior of soil factors that in terms of considering them, the combination of statistics and probability theory with Geotechnical methods is used as a tool for studying these issues. Such a process has been named as reliability assessment [2]. In normal mode using average values of the parameters affecting the behavior of soil mechanics, a number is determined as the subsidence level of each foundation part. Giving the heterogeneous nature of the soil and the uncertainty of its parameters, relying on a number as the foundation subsidence rate do not seem logical. By examining answers obtained from multiple analyses, the trust degree to the obtained results can be determined and accordingly the shares of errors in calculations are taken into account [3].

## 2. Statement of the Problem

The base, infrastructure or foundation is part of the building which is responsible for the task of transmitting the force from the columns to the land and its surrounding soil and based on the type of building and the forces, layers' texture and the type of soil and weather conditions of the area the type and dimensions of the foundation can be selected and specified [4]. Depth, length and width of foundations depend on the weight of the building, number of floors and the type of soil. Since the foundation is the lowest part of the building and has the task of stabilizing the overall structure, as a result, any errors or failures and subsidence

in this part can cause serious damage of the overall stability of the structure [5]. Given that in the applications of geotechnical engineering the capability of taking into account the uncertainty of soil parameters are not available, as a result, to review the impact of uncertainty of soil parameters on foundation subsidence the computer programs required must be written manually. To this end, firstly writing computer programs to examine the probability of rupture force under the foundation is dealt with then the probability distribution of sub soil subsidence will be determined [6]. By comparing the designated answers the foundation design can be examined from the perspective of possibilities. It should be noted that in this study, for separate analyses the finite element Geo Studio software will also be used [7].

### 3. Research Background

#### 3.1. Brzakala and Pula Study

In this research the analyses related to the subsidence of soil layer have been carried out taking into account existing uncertainties. For this purpose, three types of uncertainty in the analysis were intended as follows:

- 1) Uncertainty about the shape and placement of the soil layers
- 2) Uncertainties related to the parameters that affect the foundation subsidence
- 3) Uncertainties related to the loads applied to the intended foundation

The analysis using finite element analysis and taking into account the uncertainties have been carried out. Measuring the subsidence rate has been carried out using random finite element method that combines finite element method and the Monte Carlo method [8].

#### 3.2. Fenton and Griffiths study

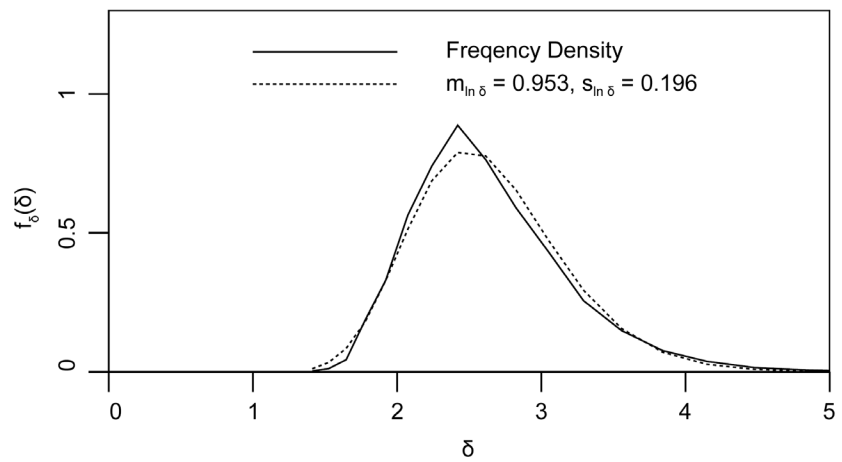
One of the main parameters that influence the determination of the sub soil subsidence is the modulus parameters of the soil elasticity. In this study, taking into account the modulus of elasticity using the log-normal probability distribution the analyses to determine the foundation's subsidence using the random finite element method was done. In this study, two types of modeling have been considered; in the first case a two-dimensional strip foundation, and in another two strip foundations were analyzed [9].

Using a combination of finite element methods and random field theory for the foundation subsidence the probability density is obtained. Based on the carried out analyses log-normal probability distribution has properly provided the whole subsidence as probabilities [10].

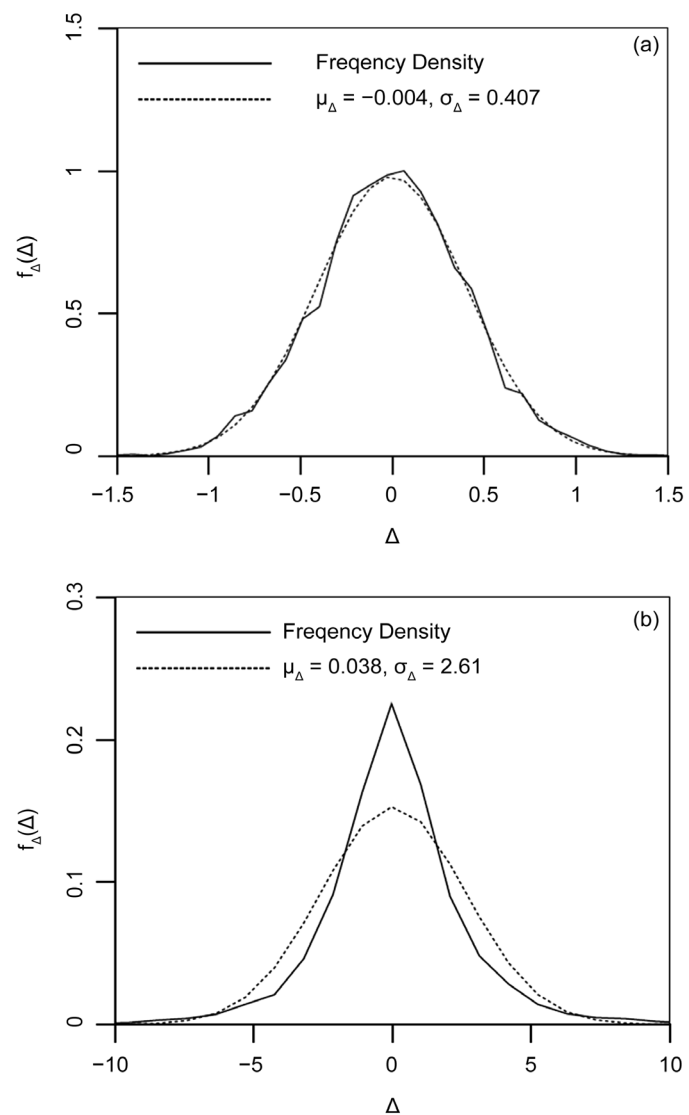
As can be seen from the (Figure 1 and Figure 2), normal probability distribution and Log normal have correctly presented the probabilistic behavior of the sub soil subsidence [11].

#### 3.3. Dubost *et al.* Study

In this study the subsidence took place in a column of soil considering the



**Figure 1.** Determined probability density function for the subsidence in a single strip foundation mode [11].

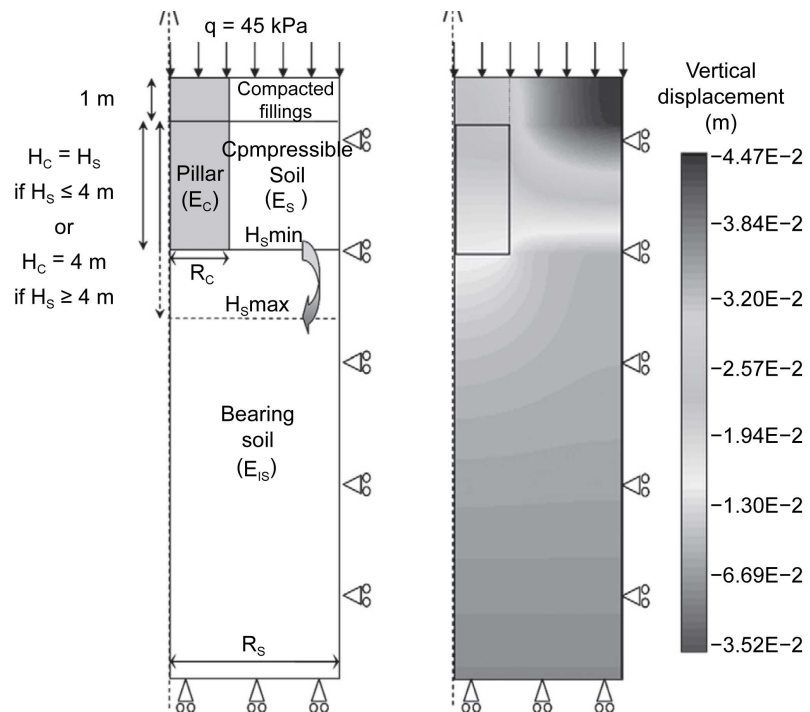


**Figure 2.** Probability density function set for the sub soil in a dual strip foundation mode [11].

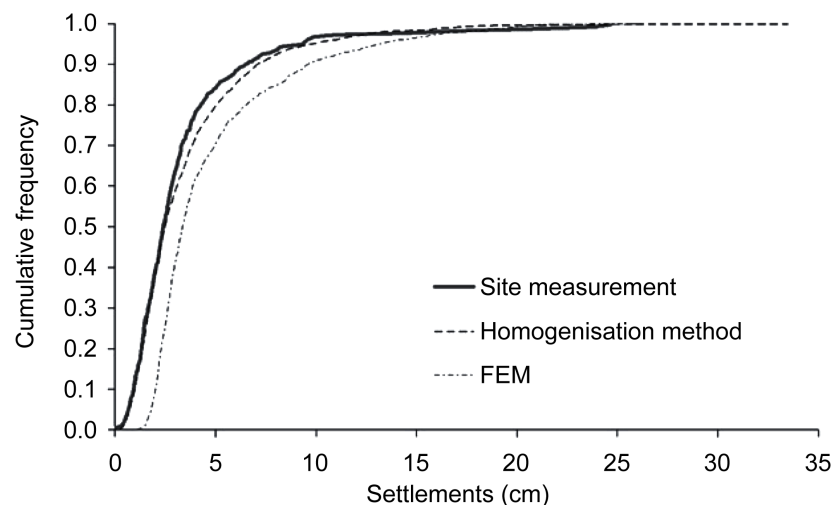
uncertainty parameters affecting soil and the geometry is studied. For this purpose, analytical and finite element methods are used that in considering the uncertainty, the methods listed were combined with Monte Carlo simulation. The built-in finite element analysis model is as follows.

(Figure 3), using Monte Carlo simulation probability distribution are properly combined and the possibility of any specified amount of soil columns subsidence were determined [12].

(Figure 4), implemented analyses showed that the length and elastic modulus



**Figure 3.** Modeling of soil column under the pressure of the foundation and the dynamic loads [12].



**Figure 4.** Cumulative distribution function (CDF) for the specified subsidence based on different methods [11].

of the soil in coarse grained soil columns have the greatest uncertainty and had the biggest impact on the determined subsidence [11].

#### 4. Research Hypotheses and Questions

Does increasing the effective distribution of soil parameters, reduce the possibility of subsidence more than 25 mm in the shallow foundations?

How is it possible to control the subsidence in shallow sub soil by applying uncertainty of soil parameters?

#### 5. Research Methodology

All types of subsidence are functions of extra applied pressure on the ground by the foundation. Thus, familiarity with the calculation equations of stress distribution in the soil due to applying foundation load is very important. Several equations has been provided to find out tensions conditions in the depth because of the loadings and the equations of *Boussinesq and Westergaard* has been more common that have been described in Soil Mechanics books and other Geotechnical sources [12]. It should be noted, however, that the exact distribution of stress in the depth is a necessary condition but not sufficient for the estimation of the subsidence. To investigate the effect of uncertainty of soil parameters on the foundation subsidence the required computer programs must be written manually. To this end, firstly, by writing computer programs using MATLAB software the probability of slip force regarding the sub soil is examined and then using other apps (using software MATLAB) probability distribution of sub soil subsidence will be determined.

#### 6. Foundation Subsidence

Mainly in designing shallow foundations, subsidence is a controlling factor in determining the allowable bearing capacity. Moreover, the issues in determining the allowable bearing capacity of the foundation geometry, strength and stiffness of soil under the foundation and service considerations of superstructure have been raised due to deformation tolerance and therefore, the load capacity and sub soil subsidence are having an interaction and we cannot deal with them separately [13]. Foundation subsidence in fine-grained soils with less precision than their bearing capability can be obtained because estimation of the subsidence in them depends on many factors that to justify their behavior need appropriate engineering judgment. Among the most important factors in this case are boundary conditions and the degree of saturation and preconsolidation pressure estimation which is the maximum pressure that had been applied to the soil so far. In general according to the grounds, the resulted subsidence in the calculations may be up to 100% coupled with an error. Structure subsidence seated on coarse soils is generally obtained with the empirical formula. Subsidence in these soils happens quickly and after applying the maximum load occurs during construction. Long-term subsidence regarding these loads can be neglected.

## 7. Permissible Subsidence and Resistance

We provided several theories in relation to the ultimate bearing capacity of shallow foundations. In designing each foundation, bearing capacity failure should be considered in conjunction with the subsidence, but in the design of most foundations there exist tolerances for the allowed subsidence. In the following figure the load diagram per unit area foundation  $q$  is shown versus foundation subsidence of  $S$ . According to this figure, it can be seen that the ultimate portorage capacity occurs at the  $S_u$  subsidence. Now suppose that  $S_{all}$  is the allowed foundation subsidence and  $q_{all(s)}$  is the allowable bearing capacity corresponding to it. If  $FS$  is the safety factor against bearing capacity failure, then the allowable bearing capacity is equal to  $q_{all(b)} = qu/FS$  while the corresponding subsidence of  $q_{all(b)}$  is  $S'$ . For the foundation of width  $B$  smaller,  $S'$  can be smaller than  $S_{all}$ . But for larger values of  $B$ ,  $S_{all} < S$ .

## 8. Reliability Assessment Methods

Reliability analysis methods as the methods based on possibility science, are practical tools for applying uncertainties in various parameters, to solve the problem. In general, the reliability evaluation methods can be divided into the following five categories:

- 1) The analytical methods such as composition method of distribution function curves regarding random variables and the first order reliability method.
- 2) Approximate methods such as the second anchor first order, points estimation method.
- 3) Method of Monte Carlo simulation.
- 4) Numerical methods such as finite element method and finite probabilistic random.

Given that in this study, reliability Assessment of soil slope stability is done through analysis method of curve composition distribution function of random variables and to verify the results of numerical simulation Monte Carlo method has also been used as a result, the basic principles governing these procedures are thoroughly examined below.

## 9. Assessing the Reliability of Shallow Foundation Subsidence

Given the heterogeneous nature of the soil and the uncertainty of its parameters, relying on a number as an effective parameters that affects the geotechnical analysis does not seem logical. In probabilistic approaches taking into account the probability distribution function for each input parameter, according to the characteristics of each parameter, all the possible values of the parameters are given the occurrence chance. This study attempted by importing the parameters determine the probability distribution for the sub soil subsidence and use it to investigate all possible values in their analysis [13].

Factors affecting these methods can be divided into two categories of geome-

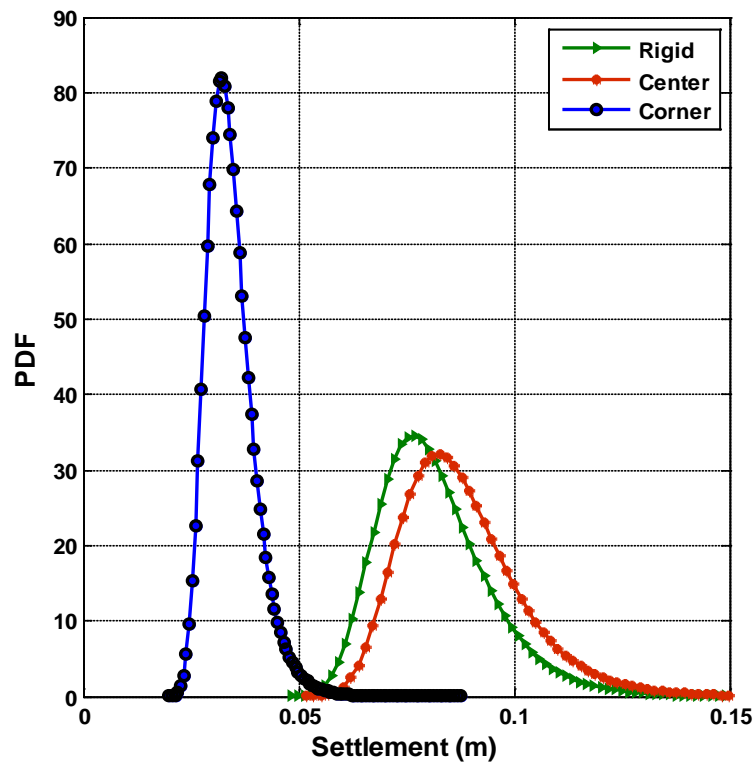
tric parameters and parameters related to soil type. The above represents the geometry of the foundation geometric parameters, the level of underground water and the manner of taking into account the Critical Slip Surface. The present study dealt more with the geometric parameters, final (given) and statistical soil mechanical parameters (probabilistic) and the effect of assumed uncertainty.

## 10. Comparing Sub Soil Subsidence Reliability

Sub soil subsidence was evaluated and studied by taking into account the effect of uncertainty soil parameters in three states. In this study the probability distribution are specified each according to intended conditions and characteristics and the probability of any value regarding sub soil subsidence was also determined.

Determined PDF diagrams sub soil subsidence for the three modes of flexible foundation center, flexible foundation corner and rigid foundation are presented in the following (Figure 5).

The determined values for the subsidence of the corner and center of flexible foundation the minimum and maximum values are determined respectively. Determined PDF Chart set for the center subsidence had more distribution and accordingly the PDF pie charts provided in this figure is more open than PDF corner subsidence pie chart and this indicates more scattering of the probability distribution regarding foundation center subsidence. According to the (Figure 5) it can be observed that the dispersion of the probability distribution of the



**Figure 5.** Comparing the center subsidence probability of density function curves and flexible foundation corner and rigid foundation [13].



rigid foundation subsidence have in-between scattered state relative to the other two distributions.

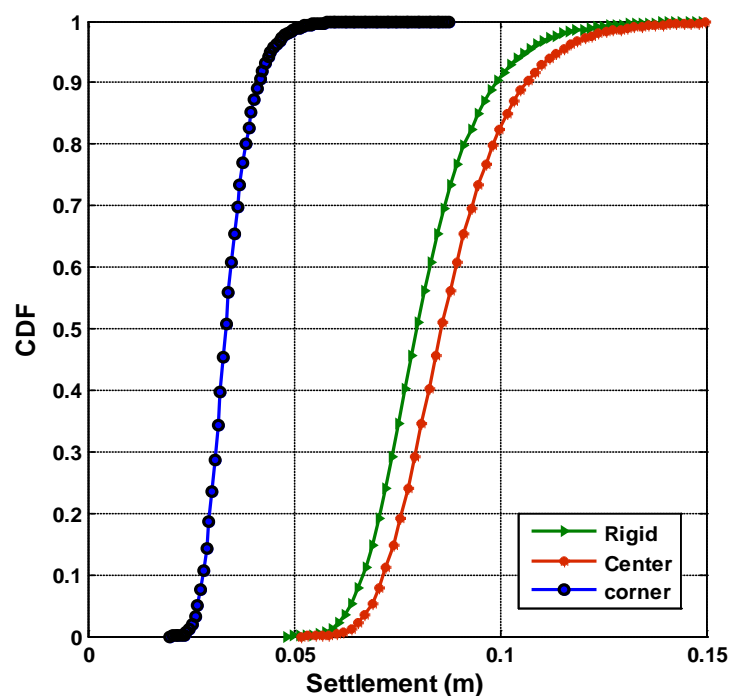
By integrating from the sub curve of PDF, CDF curve can be determined. In the following (Figure 6) CDF diagram of sub center subsidence and the corner of flexible foundation and rigid foundation are compared [13].

As expected based on the chart CDF, minimum and maximum values set for the subsidence were respectively related to the foundation center and flexible foundation corner. Accordingly diagram of center subsidence is more critical than the set subsidence of foundation corner. For example, the probability of subsidence 0.05 for the foundation center and rigid foundation, is zero, this suggests that the determined subsidence values are more critical for flexible foundation center than the determined subsidence values of foundation corner [13].

## 11. Conclusions

The results of this study are presented in the following section:

- The average rate of flexible foundation center is equal to 0.0879 meters and the amount corresponds to maximum frequency and maximum point of PDF charts. The obtained PDF distribution chart is cresset like and has fairly normal distribution that by moving from the beginning of the chart and the determined minimum amounts, the frequency increases and by reaching the mean value the frequency reaches its maximum value. By increasing the amount of subsidence and moving towards determined maximum amounts, the amount of frequency is reduced [14].



**Figure 6.** Comparing the cumulative distribution function curves of center subsidence the corner of flexible foundation and rigid foundation [13].

- By comparing the determined results of Geo-Studio analyses, the consistency of the obtained results can be realized using the finite element method. Since the mean subsidence of foundation sub center is equal to 0.0879 and the amount of subsidence of sub center using the finite element method is equal to 0.105, as a result, a substantial agreement between the results is determined using two methods mentioned.
- CDF graph regarding subsidence of foundation center is more critical than CDF graph of determined subsidence for the foundation corner. For example, the probability of foundation center subsidence 0.05, is zero percent, in other words, foundation center subsidence value is more than 0.05 and the subsidence is not expected for the regular foundation center subsidence; On the other hand the probability of this value of foundation corner subsidence is about 98%. *i.e.* there is a 98% probability of subsidence being occurred in the foundation corner which is less than 0.05 and only 2% of the value set for the foundation corner subsidence over this quantity.
- In the circular foundations, increasing the diameter of the foundation, which causes increasing subsidence in foundation center but subsidence in the corners, will cause different behaviors. And the probability of subsidence in the corners of circular foundations had different behavior so that subsidence probability in foundations with a diameter of 2 and 3 meters was more than circular foundations with less and more diameters [14].
- In circular foundations with diameters 2, 3 and 4, cumulative distribution function have equal treatment but in the foundations with a diameter of 1.5, this value has become smaller and this amount is, not far from the other values that have to be consistent to each other.
- Cumulative subsidence in the corners of flexible circular foundation in the circular foundation with a diameter of 4 meters had been more than the other foundations as in the second part of the analysis the subsidence reached 1.1 meters and at the end of the analysis again have followed the behavior of other circular foundations.
- The possibility of subsidence of circular foundation in the corner in the flexible foundation with a diameter increase has reached 75%, and this is despite the fact that the possibility in a foundation with a diameter of 1.5 was about 1%.

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