# Calculation of Bearing Capacity Under Shallow Foundations to Change From Global To Partial Factor in Geotechnical And Foundations Egyptian Code During The Transition Period

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## Abstract

This paper presents A review for the design by working or traditional method in the current Egyptian code and other branches around the world and the meaning of global factors of safety with the variation of its value , the theory of geotechnical limit state design ( ULS ) , the meaning and symbols of the different factors used in ( ULS ) . A comparison study for adopting the different limit state design approaches in the design of the shallow foundations. Finally the concepts of the suggested method to calculate the bearing capacity under shallow foundations by ultimate limit state theory and a review for all the needed curves for all types of soil and the theoretical analysis give these curves.

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## Introduction

The main goal of this paper is to find the partial factors of bearing capacity during the transition period from design by working to ultimate limit state method respectively, but we must know that the main goal of any engineering design is to have adequate structural resistance, serviceability and durability in an economical way for an indented design working life. the principal design idea used in all design approaches is the resistance of the soil ( R ) is greater than the effect of loads ( L ) on that approaches ( R > L ) . All design approaches lies to how to attain the acceptable level of safety. Actually all design approaches follow the same theoretical data base to evaluate resistance and deformation of the soil because the same parameters of soil used in all design approaches also the failure load of a given footing will be calculated using the same analytical theory in all design approaches. But we can say that the level of safety may differ from one country to another because the values of the safety factors nationally selected based on a specific minimum level of workmanship and quality management. Finally we can say that the main ideas we will take them in consideration are:

## Factors Affect Suggested Method for Design by ULS

There are three main factors which affect the suggested method for design by ULS:

(a) The partial factor for sand ($\gamma_{\tan\phi}$ ).

(b) The partial factor for clay ($\gamma_{C}$ ).

(c) The values of soil parameters (ϕ and C) because the last partial factors are related to the soil parameters as presented after that.

## Assumptions of suggested design method

**The main three assumptions in the suggested method for design by ultimate limit state are:**

For using ultimate limit state in bearing capacity calculations in EPC code like the Euro code LRFD code ….etc , the results must pass on transition period this period must have a head line is the results for bearing capacity by using ultimate limit state theory is the same by using working design . so the comparison between the two theories and the used factors in them ( partial factors in limit state design and global factor of safety in working design ) is an important part in determining the partial factors used in the suggested method for design by limit state in the EPC ( as a transition period ) as follow : -

- **working design**

In the early 1800's working stress design method (WSD) was introduced, for over the past century working stress design (WSD) has been the traditional basis for design in civil engineering. It is also known as allowable stress design (ASD) or global safety factor design method (GSFD). The basis of the design is to ensure that when a certain structure is subjected to the service applied load, the induced stresses are less than the allowable stresses. Under WSD, a single global factor of safety is used. This single global factor considers all uncertainties in design, whether it's applied to material strength and resistance, or applied to actions. During the process of design under WSD, the characteristic design loads which are applied to the structure are compared to the characteristic resistance through a factor of safety. Generally, factors of safety between 2 and 3 are considered to be adequate in bearing capacity foundation design. The assessment of the level of safety of the structure is made on the basis of global factors of safety, which were developed from previous experiences with similar structures in similar environments or under similar conditions. For foundation design, the factor of safety is generally applied to the geotechnical capacity as shown below:

$$F_n \leq Q_n/FS$$

Where, $F_n$ is the nominal load $Q_n$ is the nominal resistance and FS is the factor of safety.

The values of the global factor of safety selected for the design reflect past experiences and the consequences of failure. The more serious the consequences of failure or the higher the uncertainty, the higher the factor of safety, Shallow foundations are typically designed against modes of Failure.

The following table shows the ranges of customary global factors of safety, as stated by Terzaghi and Peck (1948, 1967).

**The Table Ranges of global factor of safety commonly used in foundation design (Terzaghi and peck (1948, 1967)**

| ilure Type | Item | ctor of safety, FS |
|---|---|---|
| Shearing | Earthworks<br>th retaining structures, excavations<br>Foundations | 1.3 - 1.5<br>1.5 - 2.0<br><br>2.0 - 3.0 |
| Seepage | Uplift heave<br>Exit gradient, piping | 1.5 - 2.0<br>2.0 - 3.0 |
| timate pile | Load tests | 1.5 - 2.0 |
| Loads | Dynamic formulae | 3.0 |

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A global factor of safety represents a relationship between allowable and applied quantities. This concept is simple and useful, but it is also accompanied with difficulties. Problems arise when factors of safety are used without firstly defining them and understanding why they were introduced. A single global factor of safety would have an unambiguous meaning if carefully prescribed standard procedures for selecting capacity, for defining loads, and for carrying out the analysis or calculations were always used in design. However, these steps are usually not well defined nor followed uniformly or consistently by all engineers. Different engineers will use different approaches and select different values of strength for design, even for the same site. For example, some engineers may use a mean value for strength, while others will use a much more conservative value such as minimum or lower bound values in measured strength. Therefore, for the same numerical value of global safety factor, the actual margin of safety can be very different. Hence, the value of the factor of safety tells us very little quantitatively as to the possibility of probability of failure. (Becker, 1996a)

- **ULS design**

To satisfy the ultimate limit state, the sum of the applied actions on the foundation must be less than the available resistance. The bearing resistance of shallow foundation is the bearing capacity multiplied by the plan area of the foundation. And will be a function of various material properties like ($\phi'$ and $\boldsymbol{C'}$). Defining the actions by Q and material properties by X, the criterion must be satisfied in design may be expressed as

$$\sum Q \leq R\,(X)$$

The last equation just satisfied when

$$\sum Q = R$$

However this will leave no margin for error associated with the three terms of the equation, including assumptions implicit in the bearing capacity equation, potential variability in actual soil properties from those derived from laboratory. As a result, partial factors of safety are used to modify the three terms give the design equation:

$$\sum \gamma_A\, Q \leq \frac{R\,(\frac{X}{\gamma_X})}{\gamma_R}$$

Where $\gamma_A$ are the partial factors applied to the action Q, $\gamma_X$ are the partial factors applied to material properties X and $\gamma_R$ are the partial factors applied to the resistance R. partial factors should not be confused with unit weights with which they share the same symbol , the partial factors all have a magnitude greater than or equal to 1.0 , so $\gamma_A$ will increase the magnitudes of actions , $\gamma_X$ reduces the values of material properties and $\gamma_R$ reduces the resistance . A characteristic value which has been modified by a partial factor is known as a design value.

The three set of partial factors are not necessarily all applied at the same time depending on the limit state design code which is being followed .in EC7, three design approaches are proposed:

- design approach 1 (DA1): (a) factoring actions only, (b) factoring materials only.

- design approach 2 (DA2): factoring actions and resistances (but not materials).

- design approach 1 (DA3): factoring structural actions only (geotechnical actions from the soil are unfactored) and materials.

It should be noted that the DA2 represents the approach used in LRFD.

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The following table represents the partial factors used in EC7:

| Partial factors to be taken from set… | | | |
|---|---|---|---|
| | Actions ($\gamma_A$) | Resistances ($\gamma_R$) | **Material properties($\gamma_X$)** |
| Design Approach 1a | $A_1$ | $R_1$ | $\mathbf{M_1}$ |
| Design Approach 1b | $A_2$ | $R_1$($R_4$ for piles) | $\mathbf{M_2}$ |
| Design Approach 2 | $A_1$ | $R_2$ | $\mathbf{M_1}$ |
| Design Approach 3 | $A_2$ | $R_3$ | $\mathbf{M_2}$ |

| **Action (Q)** | **Symbol** | **set** | |
|---|---|---|---|
| | | $\mathbf{A_1}$ | $\mathbf{A_2}$ |
| Permanent unfavourable action | ($\gamma_A$) | **1.35** | **1.00** |
| Variable unfavourable action | | **1.50** | **1.30** |
| Permanent favourable action | | **1.00** | **1.00** |
| Variable favourable action | | **0** | **0** |
| Accidental action | | **1.00** | **1.00** |

| **Material property (X)** | **Symbol** | **set** | |
|---|---|---|---|
| | | $\mathbf{A_1}$ | $\mathbf{A_2}$ |
| tan $ø^{/}$ | ($\gamma$ tan ø) | **1.00** | **1.25** |
| Cohesion intercept, $C^{/}$ | ($\gamma_c$) | **1.00** | **1.25** |
| Undrained shear strength, $C_U$ | ($\gamma_{cu}$) | **1.00** | **1.40** |
| Unit weight, $\gamma$ | ($\gamma_\gamma$) | **1.00** | **1.00** |

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- The second assumption is neglecting the partial factors used in loads or actions because the loads are already factored from the design of columns.

- The third assumption is the other partial factors used in the suggested method determined in every unit of the soil parameters (ϕ, C) to obtain very accurate results.

**Suggested Method Procedures**

pure sand (drained condition)

- This part means that the proposed shearing resistance factor ( $\gamma_{\tan\phi}$ ) due to equilibrium between allowable bearing capacity in working design and proposed ultimate limit state design.

**In working:**

-$q_{ult.net} = \gamma * D * N_q + 0.5 * \gamma * B * N_\gamma - \gamma * D$

-$q_{safe} = \frac{q_{ult\ net}}{F.S} + \gamma * D$

- In ultimate limit state:-

- $q_{ULS}$ = Ɣ * D * $N_{q'}$ + 0.50 * Ɣ * B * $N_{Ɣ'}$

-$N_{q'}$and$N_{Ɣ}$ are the coefficient of bearing capacity for internal angle of shearing resistance ϕ' .

- Whereϕ' can be given from the following relation

$$ϕ' = tan^{-1} \left( \frac{\tan ϕ}{Ɣ_{\tan ϕ}} \right).$$

- For determination $Ɣ_{\tan ϕ}$ for every degree of the internal shearing resistance factor from $25^0$ to $45^0$

Where the soil can be considered pure sand

- we consider a footing with DIM 2m * 2m, the foundation depth is 1.20 m, the soil effective unit weight is 1.75 t / m2, the internal angle of shearing resistance will be changed from $25^0$ to $45^0$ and we will find all the values of $q_{ULS}$ for the different values of the last angels of internal shearing resistance and with using shearing resistance factors from 1 to 2.50 with a step 0.05 for every angle and record it in table (1).

- Then we compute $q_{safe}$ for global F.S = (2.00, 2.25, 2.50, 2.75, 3.00) and record the results in table (2).

- after that we look for every value of $q_{safe}$ for every global safety factors in table ( 1 – 2 ) and we search in table ( 1 ) to get a $Ɣ_{\tan ϕ}$ for every value of $q_{safe}$ and written in table ( 1 ) under their angles and global safety factors and draw the figure ( 1 ) .

## pure clay (drained condition)

- The proposed cohesion factor ( $Ɣ_C$ ) due to equilibrium between allowable bearing capacity in working design and proposed ultimate limit state design.

- In working:

$$-q_{ult.net} = C * N_c$$
$$-q_{safe} = \frac{q_{ult\ net}}{F.S} + Ɣ * D$$

- In ultimate limit state:-

$$- q_{ULS} = \frac{C}{Ɣ_c} * N_c$$

- For determination $Ɣ_C$ for every t / $m^2$ in cohesion C

Where the soil can be considered pure clay

- we consider a footing with DIM 2m * 2m , the foundation depth is 1.20 m , the soil effective over burden pressure can be considered in three cases ( around 2 t/m , around 2.50 t/m and around 3 t/m2 ) the cohesion considered from 1 t/m2 to 40 t/m2 and this will enable us to obtain a very suitable cohesion factor for every case of C – Soil .

- We will find all the values of $q_{ult\ net}$ then $q_{safe}$ for the different values of the last cases of cohesion by using global F. S ( 2.00 , 2.25 , 2.50 , 2.75 , 3.00 ) after then we can find $q_{safe}$ ,$q_{ULS}$ after that we compute $\gamma_c$ and record all the last data in one table called ( 2 ) and finally we can draw the figure ( 2 ).

- We can use the following equations:

- $q_{safe} = q_{ult\ net} + \gamma * D = \frac{C * N_c}{F\ .\ S} + \gamma * D.$

- $q_{ULS} = \frac{C}{\gamma_c} * N_c$ .

- $\gamma_c = \frac{C * N_c}{q_{safe}}$ .

**clay drained condition ((C - ϕ) soil)**

The following equation divided to two parts

$$q_{ULS} = \frac{C}{\gamma_c} * N_c' + \gamma * D * N_q' + 0.50 * \gamma * B * N_\gamma'$$

Part (1): - $\frac{C}{\gamma_c} * N_c' = \frac{( C * N_c )}{F.S} \Rightarrow \gamma_c = F.S\ \frac{N_c'}{N_c}$

Part (2): - $\gamma_{\tan \phi}$ represented in drained condition.

Then we can draw curve (3 – 1).

## Results

The curves we can use it in the suggested theory as follow.

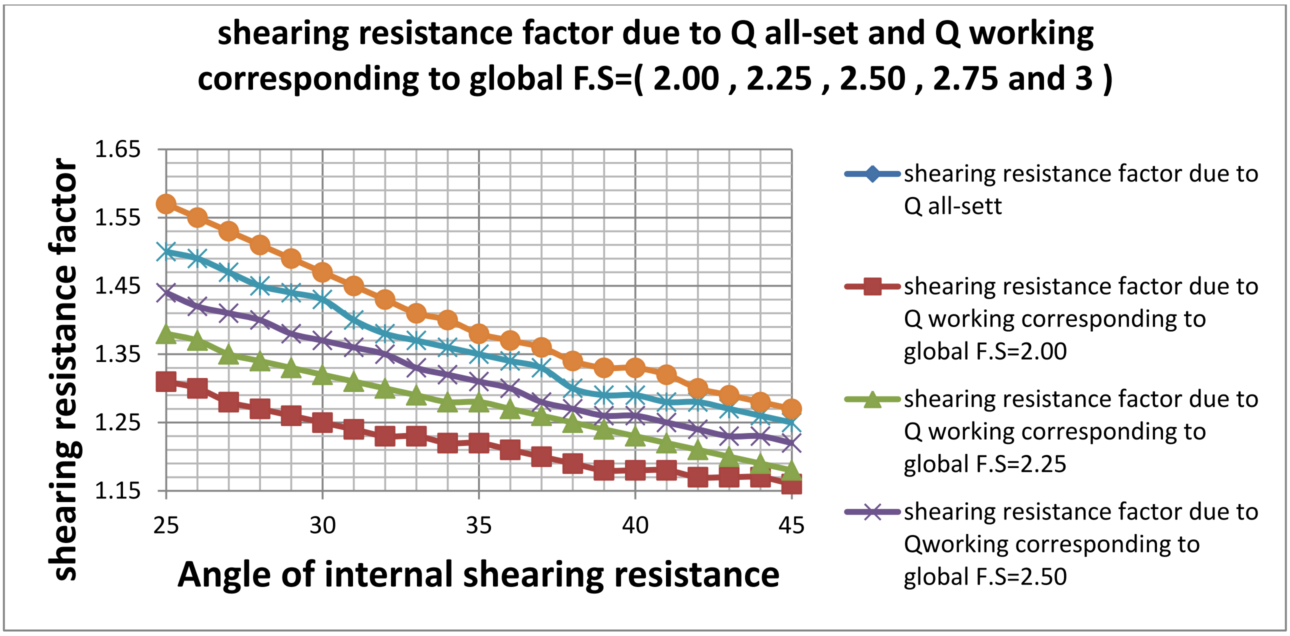


**Figure (1)**

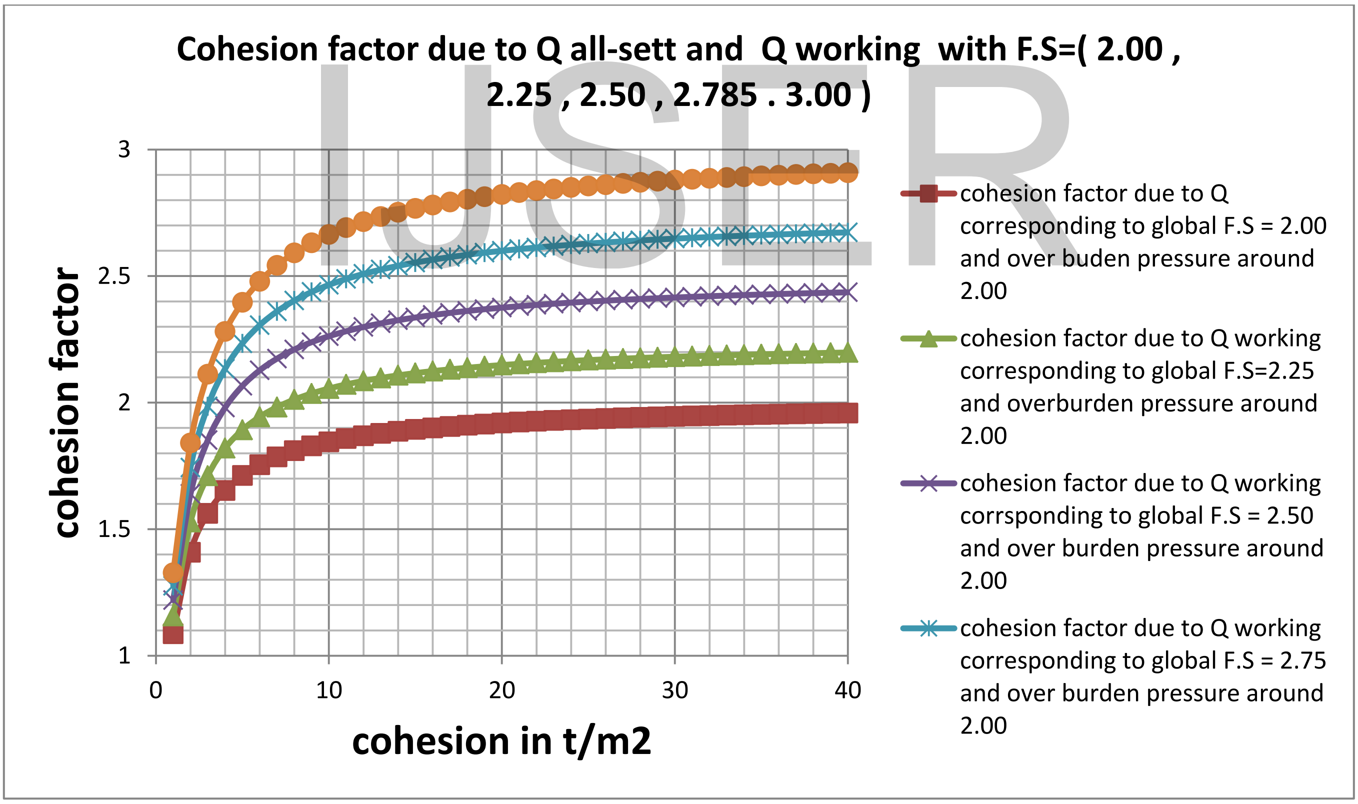


**Figure (2)**

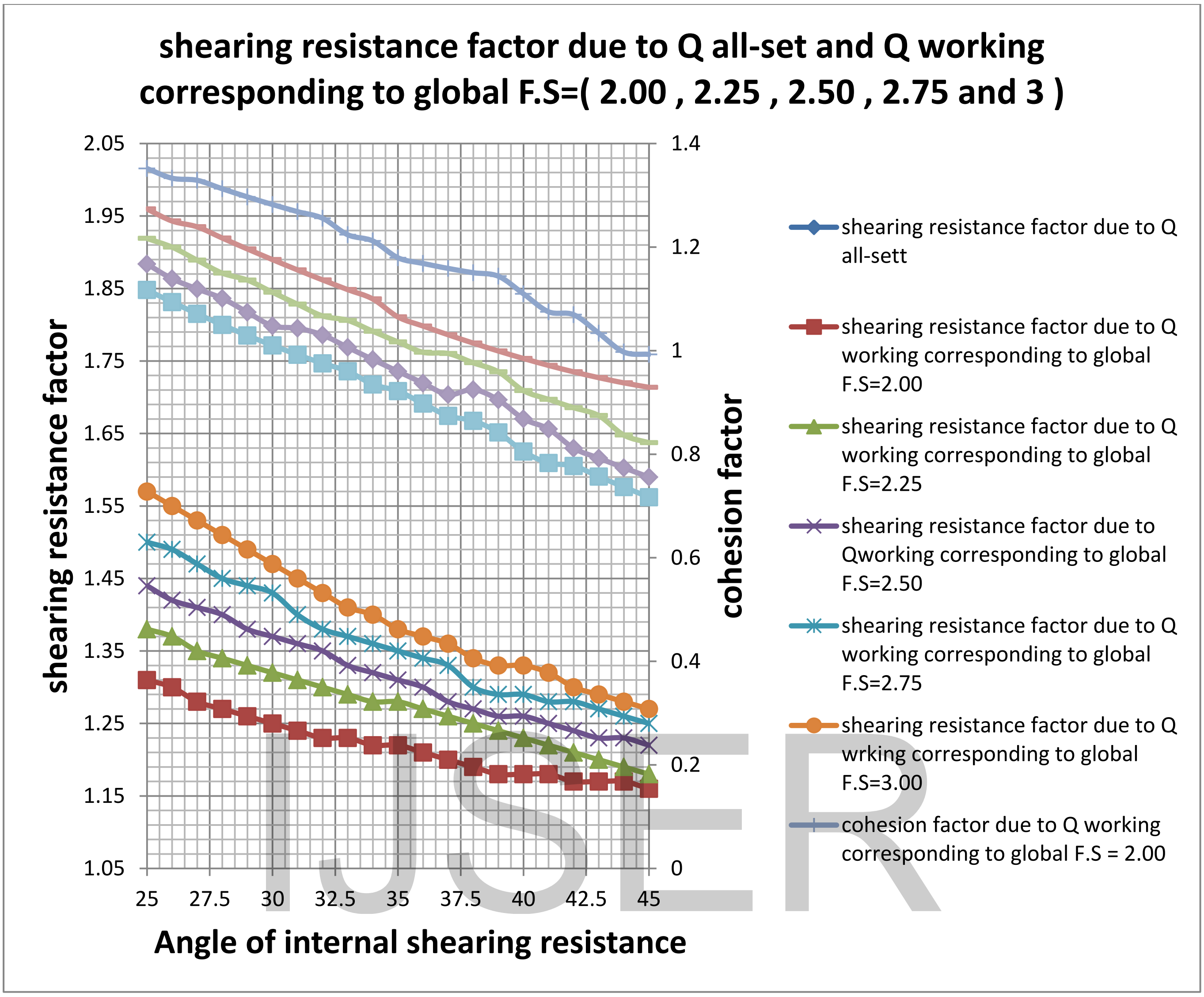


**Figure (3)**

## Hint: -

1- In curve (3 – 1) the upper group of lines used for $\gamma_c$ and the lower group of lines used for $\gamma_{\tan\phi}$ .

2 – We neglect partial factors for actions because it is already computed in the design of columns.

## Conclusions:

All current versions of the structural Egyptian design codes are based on LSD. A harmonization between the design codes is an essential requirement for the engineering practice. The main disadvantage of the WSD method is that it represents the loads and resistances by deterministic values. However, both loads and resistance are random variables due to different associate levels of uncertainties. Comparing the different Euro codes design Approaches, it can be inferred that DA3 shows the most conservative behavior among all EC7 approaches. The main advantages of the suggested theory for design by ULS are:

a – it neglect partial load factors because the loads factored in column design

b – It gives the same results exactly of design by WSD.

c - It makes a connection between partial factors and soil parameters (C, ϕ) every degree and cohesion unit respectively.

## References:

1. Allen, D.E. (1975) Limit States Design – A probabilistic Study. Canadian Journal of Civil Engineering, 36 (2): pp. 36–49.

2. Allen, D.E. (1994) the History and Future of Limit State Design. Journal of Thermal Insulation and Building Envelopes, 18: pp. 3-20.

3. ECP 202/3 (2001) Egyptian Code For Soil Mechanics, Design And Construction of Foundation – Part 3: Shallow Foundation. Housing and Building National Research Centre, Cairo, Egypt

4. Eurocode7.

5. The American Association of State Highway and Transportation Officials.(2007) AASHTO LRFD Bridge Design Specifications. 4th Edition SI units

6. Carig's soil mechanics – 2012.

7. Tarek, T. A. (2011) Overview for Adopting the Limit State Design Criterion in the Egyptian Geotechnical Code of Practice, Housing and Building National Research Centre.

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