EFFECT OF SOIL IN REDISTRIBUTION OF LOADS DUE TO COLLAPSE OF A COLUMN

By

Ahmed Hassan Mohamed Ibrahim Nada

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE
In
Structural Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Under the Supervision of

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The Title of Thesis:

Effect of soil in redistribution of loads due to collapse of a column

Key Words:
Progressive collapse; ABAQUS; Reinforced Concrete; Soil; Plasticity.

Summary:

The thesis discussed the effect of soil on the structure during the progressive collapse. ABAQUS is used to simulate the soil as 3D model rested on it the structure, the study compared the results from a structure designed due to the case of loading of DoD to the results get out from the ABAQUS taking into consideration the additional strainning actions results from the differential settlement and the plasticity of soil. The results show that the outer columns subjected to additional strainning actions cause the failure of the design of some outer column.
The study has been made on two types of constitutive methods, MC and MCC, the MC study the dry clay and the MCC for not fully saturated clay. Finally, A new case of loading was made one for the edge column and another for the corner column.

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List of Symbols and Abbreviations

symbol	description
GSA	general service administration
DoD	department of defense
MC	Mohr-coulomb
MCC	Modified Cam Clay
AP	The Alternate Path
SLR	The Specific Local Resistance
D or G	dead load
S	snow load
W	wind load
L	live load
P	relevant representative value of a pre-stressing action
A_d	design accidental action
Q	variable load (live load, snow load, wind load),
ϕ_1	factor for frequent value of a variable action
ϕ_2	Factor for quasi-permanent value of a variable action.
A_k	defined load
SSI	Soil structure interaction
E	Young's modulus
υ	Poisson's ratio
ϕ	the friction angle
C	cohesion
ψ	dilatancy angle
λ	the swelling index
M	friction constant
S_i	immediate settlement of a point on the surface
C_s	shape and rigidity factor
Q	equivalent uniform stress on the footing
B	characteristic dimension of the footing
v^2	Poisson's ratio
Eu	Un-drained elastic modulus (Young's modulus)
E	initial void ratio

Abstract

This thesis focuses on examining the representation of soil as a continuum element rather than a spring element. The analyses show how the approximation of soil behavior into a linear spring is different from a more realistic continuum representation. In addition, the thesis discusses the effects of two behaviours on the structure under standard and unusual conditions. Furthermore, the thesis illustrates the impact of 3D modelling for both structure and soil .

First, the thesis investigates the influence of soil on the structure within usual conditions using two case studies. The first case considers the impact of the elastic behaviour of soil by means of a spring element, using a Finite Element Software (FES) called ETABS, while the second case inspects soil as a continuum element, while taking into account the effect of the plasticity of the soil. In addition, Mohr-Coulomb, a constitutive method, is utilized for the sake of representing the plastic behaviour of soil, using another sophisticated FES called ABAQUS. This study reveals the redistribution of the axial force on columns, with special reference to the plastic behaviour .

Second, the thesis investigates soil's influence on the structure under unusual conditions. For example, the structure has been subjected to a destructive action which leads to a collapse of one of its columns. This destruction, in turn, sets the foundation of axial force redistribution on all columns, which may lead to progressive collapse. Many codes have been generated, in some cases of loading, in order to overcome such a problem. This has been applied to the department of defense (DOD). Therefore, to avoid this progressive collapse, the structure must be designed in accordance with one of these codes. In the situation of the loss of one column, there would appear two cases of redistribution of the axial force: one takes place owing to the influence of soil structure interaction, while the other takes place attributed to the redistribution of the axial force of the collapsed column.

The thesis explores the previously mentioned two cases of redistribution using three examples of column removal: corner, edge and middle. Furthermore, the thesis examines these three examples attributed to two soil behaviours. The argument has been contrasted about the plastic behavior of the soil using two constitutive methods, Mohr-Coulomb and Modified Cam Clay. Results show that the redistribution of axial force in the elastic response differs completely from the plastic behaviour. Also, it is noted that the axial force redistribution, taking into consideration the time effect, is different when it happens immediately from when it happens afterwards.

All the aforementioned results have been compared to a structure that has been designed in accordance with the DOD case of loading. This comparison has resulted in the following two cases. The first case denotes significant effects in the DOD case of loading only with the example of the middle column failure. In contrast, the second case is situated with regards to the corner and edge column removal, where the DOD case becomes unsafe. The results demonstrate the appearance of a progressive collapse in case of the edge column removal. Thus, the thesis has contributed to discovering two new cases of loading, one is concerned with the edge column, while the other focuses on the corner columns. Finally, the thesis has come up with a case of the beams loading that helps avoid any problems due to beam failure. .

Chapter 1 Introduction

1.1 General

The progressive collapse occurs as a result of a local failure in one structure element or more, which results in a successive failure of the whole structure. There appears to be multiple examples for progressive collapse. The first example has taken place with the Ronan point of a residential building. The collapse represents the cause for the first progressive collapse document in the British Standard. Nevertheless, following the collapse of the World Trade Center Towers, numerous activities have been undertaken for the serious consideration of more detailed guidelines in order to avoid such a collapse. The most important guidelines include that of the General Service Administration (GSA) and that of the Department of Defense (DOD)

1.2 Problem Statement

Two approaches have been considered to avert progressive collapse. The first approach adopts an indirect method which ensures that the structure commits to prescriptive design rules. Nevertheless, the second approach adopts a direct scheme by means of two possibilities, depending on the allowance of local failure. These two approaches exclude the influence of soil structure interaction in comparison to the present structure, in the time of the progressive collapse. The loss of one column in the structure causes a redistribution of the axial force on columns. In this case, if the columns were not able to carry the additional axial loads, the progressive collapse would take place as a result of such a thing. In this light, codes have been set with guidelines that constitute regulations in order to allow the columns to carry over additional loads.

Therefore, a double effect on the structure has been investigated in this study. The soil structure interaction is also taken into consideration, where the SSI results in a redistribution of the axial force. The two cases of the axial forces redistribution are as follows: one happens due to the loss of one column; nevertheless, the other happens due to the effect of the SSI.

1.3 Organization of The Thesis

The second chapter is the literature review, which studies the history of the progressive collapse, and how to overcome it, using two approaches. The thesis adopts the direct approach, leading to the prevention of any failure. The third chapter is concerned with the effect of soil on the structural element. This has been done using different constitutive methods like Mohr-Coulomb (MC) and Modified Cam Clay (MCC). Furthermore, this chapter includes a benchmark problem authentication, through the implementation of the new software program to figure out results. The thesis makes use of a DOD structure design, as a case study by employing different cases of removal and soil behaviours. The first case examines the effect of soil behaviour on the structure, with no cases of removal. The second case studies the effect of elastic behaviour, once by regarding the soil as springs and another by regarding the soil as a continuum element. The study has revealed significant differences in results. The same chapter considers the effect of the elastic behaviour on the progressive collapse. This study scrutinizes three cases of column removals, represented in the corner, the edge and the middle.

Chapter four explores the effect of the plastic behaviour of the soil, being a continuum element, at the time of the progressive collapse, and by using the constitutive method

Mohr-coulomb. This has led to significantly different results in comparison to the elastic behaviour.
Chapter five continues to examine the plastic behaviour of the soil. What differentiates chapter five from chapter four is that chapter five investigates the effect of time and pore pressure. This is done for two time intervals, one is a short run and the other is a long one. To inspect the short run, the Modified Cam Clay constitutive method is used. When comparing both the Modified Cam Clay and the Mohr-Coulomb on the short run time interval, results show a slight difference between both of them, while the long run time interval reveals a new redistribution for the axial columns.

Finally, results demonstrate the most affected columns being the outer columns, while there appears to be a decrease in the axial forces of the inner columns. Results also show that it's not safe to load the DOD for the outer columns. Therefore, the case of loading in the DOD needs to be modified accordingly. After several attempts, two new cases of loading have been discovered, one that deals with the corner columns and the other with the edge columns, respectively. In addition to that, a new case of loading that involves beams was designed, since the beams needed design adjustment.

This thesis centers only on the static effect. Therefore, future studies should focus on the dynamic effect, with the use of a different type of foundation, such as the deep foundation.