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RESEARCH ARTICLE

Studied the Impact of the Foundation on the Underground Cavity Using the Finite Element Method

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HIGHLIGHTS

- *Study and Examined the underground cavities*
- *The danger of instability of cavities in the field of civil engineering*
- *The danger of instability of cavities in the field of civil engineering*

GRAPHICAL ABSTRACT

The world is widely exposed to risks related to the presence of underground cavities, whether natural or linked to human activities. These cavities represent a potential risk of collapse and thus of danger, particularly in urban areas. This article aims to explore through numerical modeling the effect of the mechanical characteristics of the soil on the instability of the underground cavity. Subsequently, a parametric study was conducted to study the influence of certain factors, including the relative distance between the foundation and the cavity and the influence of the size of the cavity on the ground. The studies will be carried out after a calculation by the finite element method.

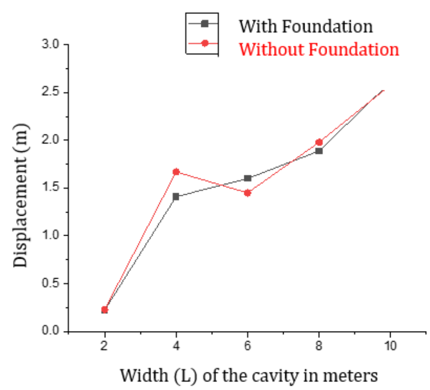

Figure 7. Displacement due to change in width L with and without foundation

Keywords:

- Finite Element Method
- Modeling
- Cavity
- Foundation
- Instability

Aim of Article: *The purpose of this research.is to study the effect of underground cavities with and without foundation.*

Theory and Methodology: *We used the modeling of this underground cavities by the finite elements in the presence and with absence of foundation.*

Findings and Results: *Results and findings shows that the underground cavities effects by the presence of the foundations. After a series of numerical modelling, the results indicate a linear increase of displacement for an increase of height H. The deformation field will be very remarkable and indicates the collapse of the underground cavity*.

Conclusion : *We calculate the hollow ground's instability (collapse), displacements, and deformation field both with and without a foundation. With the purpose of confirming the impact of the subterranean cavity's height H, breadth L, and distance D from the earth's free surface, the finite element technique the Plaxis code is employed..*

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HIGHLIGHTS

- *Study and Examined the underground cavities*
- *The danger of instability of cavities in the field of civil engineering*
- *Understand the phenomenon of cavities to find solutions*

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ABSTRACT

The world is widely exposed to risks related to the presence of underground cavities, whether natural or linked to human activities. These cavities represent a potential risk of collapse and thus of danger, particularly in urban areas. This article aims to explore through numerical modeling the effect of the mechanical characteristics of the soil on the instability of the underground cavity. Subsequently, a parametric study was conducted to study the influence of certain factors, including the relative distance between the foundation and the cavity and the influence of the size of the cavity on the ground. The studies will be carried out after a calculation by the finite element method.

Keywords: *Finite Element Method, Modeling, Cavity, Foundation, Instability.*

I. INTRODUCTION

The progressive development of the territory leads to the exploitation of new lands, currently abandoned because they present risks to the safety of users [1-6]. This is notably the case for potential collapse zones, which are linked to the presence of underground cavities. Ground movements include a set of more or less brutal displacements of the ground or subsoil, of natural or anthropic origin. The volumes involved are between a few cubic meters and a few million cubic meters. The displacements can be slow (a few millimeters per year) or very fast (a few hundred meters per day), and are a function of the nature and layout of the geological layers [7-8]. The risk of underground cavities is one of the risks of ground movement. Underground cavities are particularly present in the plain. They are either anthropic cavities (quarries, marl pits, etc.) dug by man to extract materials or natural cavities (sinkholes); see figure 1.

The proposed study focuses on the particular geotechnical context of numerical modeling of an underground cavity, especially the awareness of ground displacement (instability) or collapse related to the change in distance between the underground cavity and the free surface of the earth, the change in height and width of this cavity. This communication is an attempt to comprehend the phenomenon, that there are numerous possibilities for finding solutions, to reinforce the underground cavity, and, of course, to discover simple, quick, cost-effective, and environmentally friendly solutions.

Figure. 1. Underground cavities in residential areas [9]

II. Presentation of the Case Study

Given the total geometry, the case studied corresponds to an underground cavity of 3 m in height and 3 m in width, the ground with a single layer under the presence of a foundation of 2 m in length, and this ground of 27 m in height and 40 m in length.

The project is symmetrical (Figure 2); it will be modeled by a 2D axisymmetric geometric model. The numerical modeling is performed using PLAXIS-2D. The MOHR-COULOMB model (MC) is used to simulate the behavior of the cavity. The following table 1 represents the geotechnical parameters of the terrain for the evaluation of the displacement under the effect of the presence of the underground cavity.

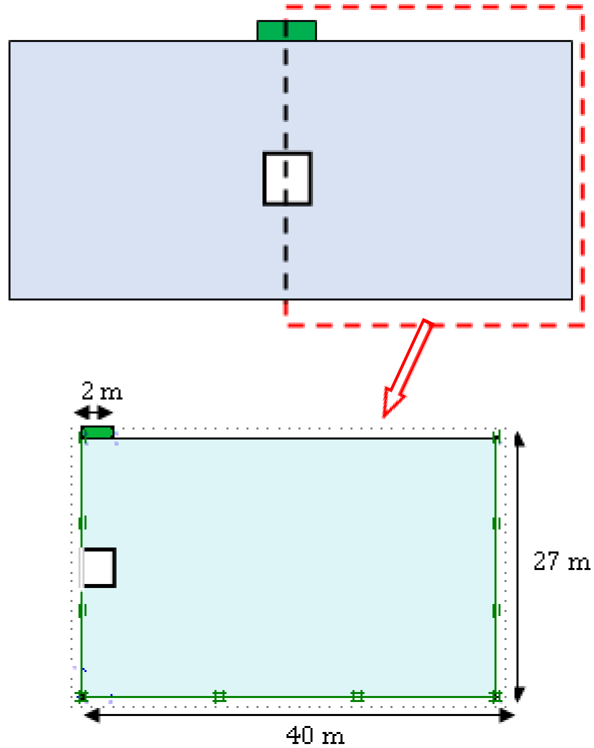

Figure. 2. Geometry of the model

Table I.
Geotechnical Properties

Symbol	Parameters	Soil	foundation
	Model of behavior	M-C	Non-porous elastic liner
γ_h	Bulk density	16.0 (KN/m^3)	24.0
γ_s	Saturated density	18.0 (KN/m^3)	-
E	Young's modulus	2.00E+06 (KN/m^2)	6.680E+07
ν	Poisson's ratio	0.35	0.20
C	Cohesion	2	-
φ	Friction angle	24.0	-

The case studied consists of analyzing the behavior of a ground in the presence of an underground cavity.

III. Results And Discussion

The method of the finite elements axisymmetric model is used to simulate the underground cavity. The presence of an underground cavity in a land with two phases, the first without a foundation and the second with a foundation, is investigated in this study through a series of modeling. We are interested in the influence of the three following parameters:

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1) Variation in the distance (D) between the underground cavity and the earth's free surface (Figure 5(a)).
2) Change in the width (L) of the cavity (Figure 8, a);
3) Change in the height of the underground cavity (Figure 12, a).

The following figure shows the modeling of the ground displacement field with a foundation without underground cavity the total displacement is 0.012 m.

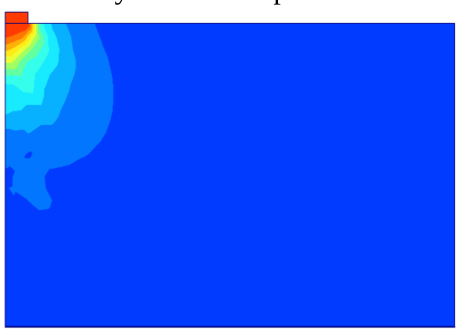

Figure. 3. Ground displacement field with the presence of a foundation without cavity

The study is framed in these parameters by the effect of the cavity's distance D on the total displacement of the ground.

A. The Effect of the Distance (D) Between the Cavity and the Free Surface of the Earth

In this paper, we recall that the shape, width, and height (3 m and 3 m, respectively) are fixed, and the change in distance D only occurs between 5 m and 21 m (see Figure 5 a), with and without foundation. The sensitivity study of a distance parameter on the total displacement gives the results in the following graph:

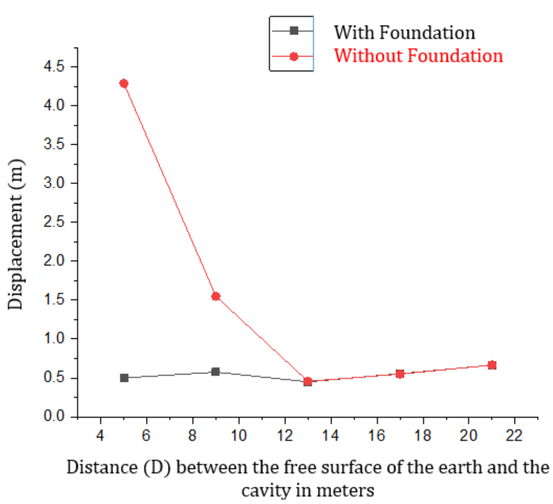

Figure. 4. Ground displacement under the effect of distance D with and without foundation

1) Without foundation: it is noticed that the displacements are almost the same between 0.67 m and 0.50 m, so the presence of the cavities without weight (exploitation or permanent) influences (the instability) collapse of the underground cavities.
2) With a foundation: if the underground cavity is very close (5-11 m) to the free surface of the earth, the displacements will be very large up to 4.29 m

Considering that the total displacements were nearly the same from 13 m to 21 m with and without the foundation, these results indicate that the influence of this weight (the foundation) ended at 13 m.

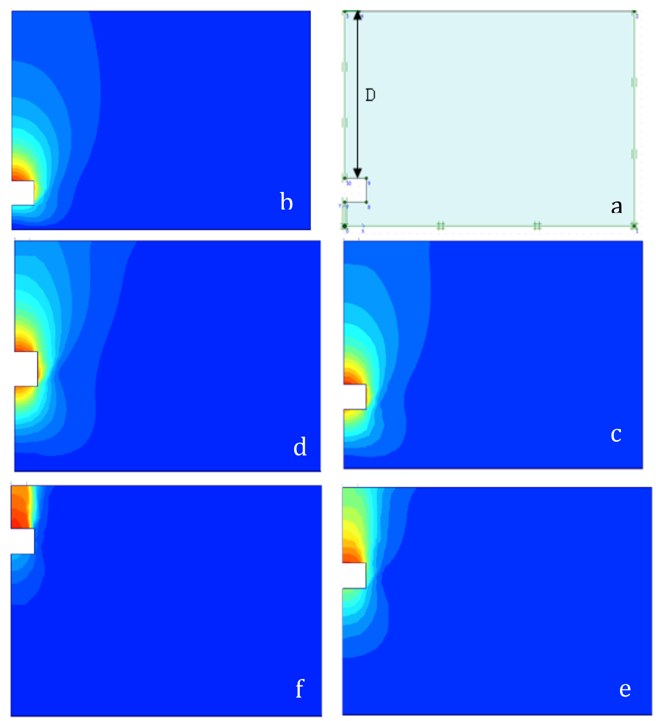

Figure. 5. Displacement fields without foundation with change of distance D (b = 21, c = 17, d = 13, e = 9, f = 5 m)

Figure (5, b) depicts the effect of the distance D (21 m) on the total displacement of the ground without foundation; it depicts the displacement spindle around the underground cavity and the weak displacements on the earth's free surface. Figures (5, c, and d) show the importance of the displacement on the free surface of the ground with D = 17 and 13 m. On the other hand, figures (5, e, and f) illustrated the distances D = 5 m and 9 m and the situation of the large displacement of the free surface of the ground above the underground cavity, indicated by the red color.

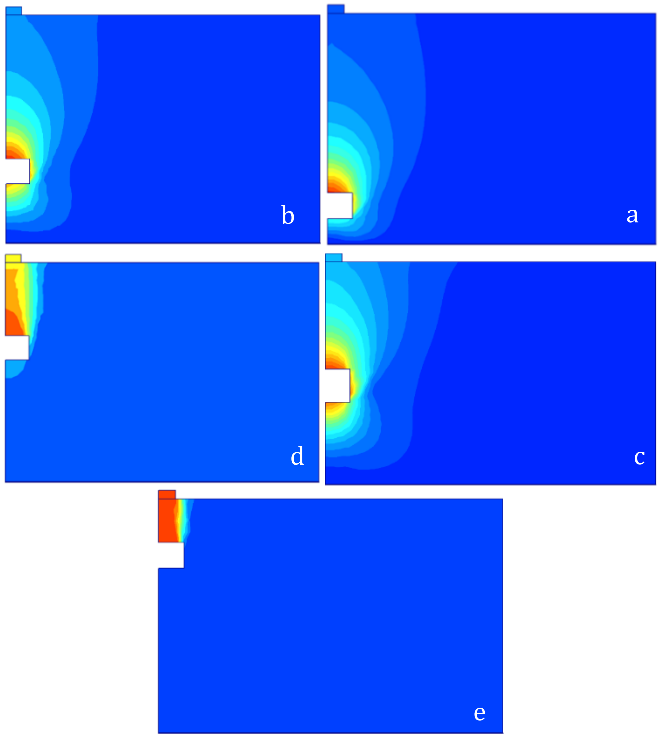

Figure. 6. Displacement fields in the presence of a foundation with change in distance D (a = 21, b = 17, c = 13, d = 9, e = 5 m)

In the presence of a foundation with the same characteristics and distances, the models are shown in Figure 6. The free surfaces of the earth are influenced by the distance D (21, 17 and 13 m), as shown in Figure 6 (a, b, and c), and the displacements are significant. In figures (6 d and e), the displacement field on the free surface is a little bit smaller compared to figures (6 a, b, and c), but the displacement is big between the underground cavity and the foundation because of the small distance D (5 m).

B. The Effect of the Width (L) of the Underground Cavity

For the evaluation of the total ground displacement and the deformation field, we change the width L of the underground cavity each time; we recall that the cavity of 1 m height and distance D 11 m are fixed; in this part of the modeling, the change of width is between 2 and 10 m (see Figure 8 a), in this modeling series of courses with and without foundation.

The results of the different calculations are shown in this graph (Figure 7). It shows an almost linear increase in the total displacement of the ground without foundation for a variable cavity width (2 m, up to 10 m) and fixed height H (1 m). Thus, with the increasing width of the underground cavity, the displacement increases progressively.

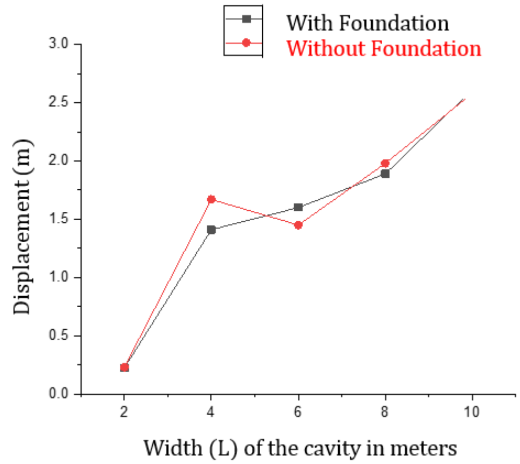

Figure. 7. Displacement due to change in width L with and without foundation

Modeling with foundation almost the same remarks with the previous series of modeling (without foundation), increase of displacements with enlargement of the width of the underground cavity, in modeling of 6 m width the displacement a little small than the displacement of same width without foundation. The maximum displacement in this modeling is 2.61 m.

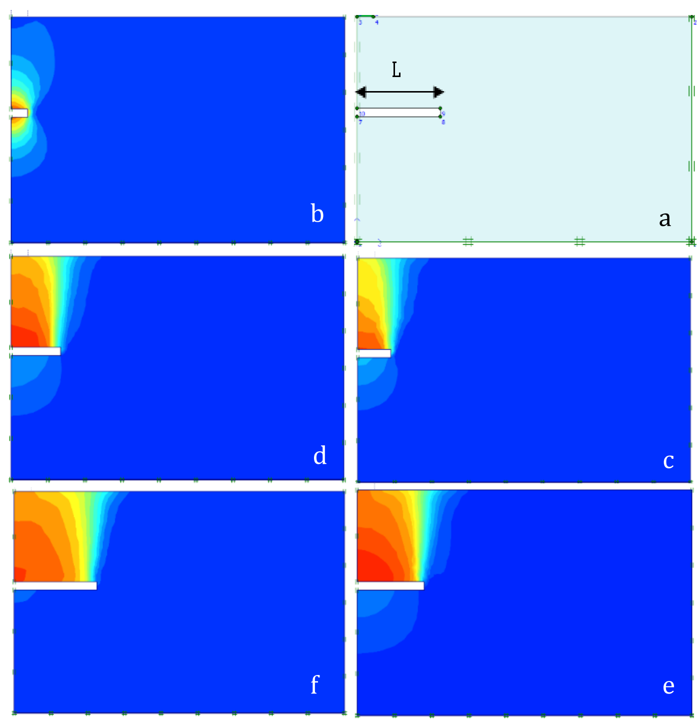

Figure. 8. Displacement fields without foundation with change in width L (b = 2, c = 4, d = 6, e = 8, f = 10 m)

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In this section, we will present a study that allows us to better understand the effect of changes in cavity width (L) on the deformation field and the total shape of the earth (Figure 8). In Figure (8 b), small displacements around the underground cavity are observed in relation to other shapes, while Figures (8 c, d, e, and f) present a proportional increase in the deformation of the ground with the increase in the width of the underground cavity.

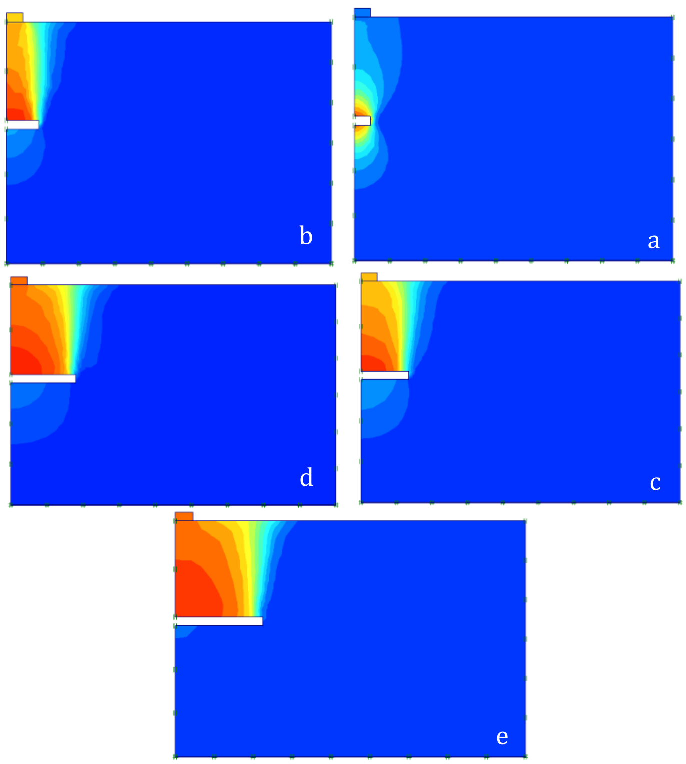

Figure. 9. Displacement fields in the presence of a foundation with a change in width L (a = 2, b = 4, c = 6, d = 8, e = 10 m)

C. The Effect of the Height (H) of the Underground Cavity

Finally, this part concerns the influence of the height of the underground cavity on the total displacement of land and the form of deformation. Currently, in this section of the modeling, the change will be in the height H only, and this change will be between 2 and 9 meters, as shown in Figure 11 a. the first without foundation and the second in the presence of a foundation.

The results of the different calculations are shown in this graph (Figure 10), shows a linear increase in displacement for a variable height H (between 2 m and 9 m).

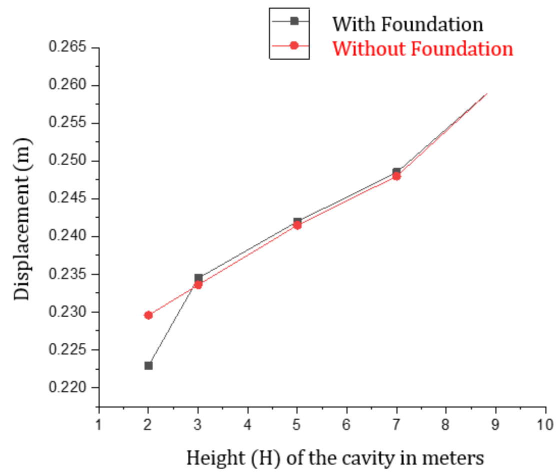

Figure. 10. Displacement due to change in H-height with and without foundation

The results of the total displacements with and without foundation illustrated that the displacements increase with an increase in the height of the underground cavity. We also notice that in the height of 2 m with a foundation, the displacement is a little larger than in the modeling without a foundation, and the other modeling is almost the same.

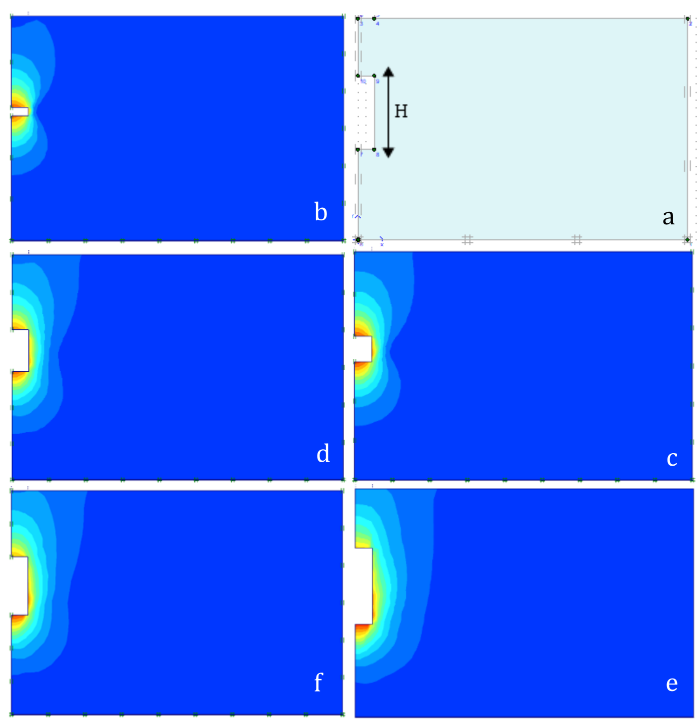

Figure. 11. Displacement fields without foundation with change of H (b = 2, c = 3, d = 5, e = 7, f = 9 m)

In the models of underground cavities without foundation, we fixed the width of this cavity (2 m) and changed the height H of the cavity. Figure 11 b) depicts the kinematics of the deformation field around the opening; on the other hand, in figures 11 c, d, e, and f, with an increase in height H, we also have an increase in the deformation field on the free surface of the earth.

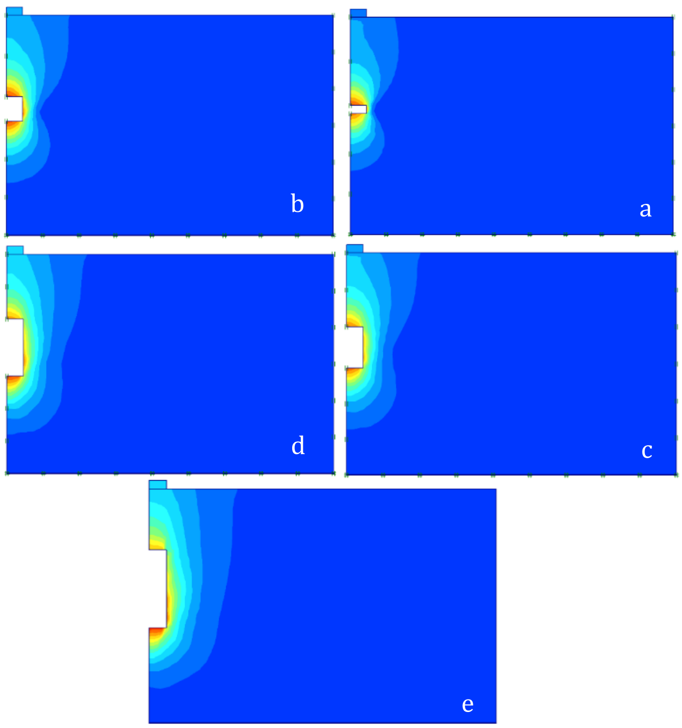

Figure. 12. Displacement fields in the presence of a foundation with a change in height H (a = 2, b = 3, c = 5, d = 7, e = 9 m)

Now we are interested in the influence of the foundation and the modification of the height H of the underground cavity on the total ground displacement and the deformation shape. In this section of the modeling, we see the same effects as in the series of models without foundation, but with the influence of foundation at the free surface level, we see an amplification of the deformation field on the ground's free surface.

IV. CONCLUSION

In this paper, we determine the instability (collapse), displacements, and deformation field of the cavity ground, with and without the presence of a foundation. The method used is the finite element method by the Plaxis code, with the aim of verifying the effect of the distance D between the underground cavity and the free surface of the earth, the height H, and the width L of the cavity. Our results showed:

A. The influence of the distance D:

1) The results show that the displacement increases with the cavity near the free surface of the earth, for a smaller distance, the displacement becomes larger;
2) The deformation field will be very remarkable and indicates the collapse of the underground cavity

B. The influence of width L:

1) The displacement is almost proportional to the increase in the width of the underground cavity;
2) We notice that there are remarkable effects on the fields of ground deformations without and with foundations because of influence of width of underground cavity, we also notice the collapse of the underground cavity once we increase width of this cavity.

C. The influence of the height H:

1) After a series of numerical modelling, the results indicate a linear increase of displacement for an increase of height H.
2) The results of height change with presence or absence of foundations, give different collapse (destabilization) regimes of underground cavities, deformation fields in continuous increase i.e. displacement in accordance with height.

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