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The Influence of Neighboring Foundations on the Stress and Settlement of the Foundation in the Case of the Strip Foundation Problem

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Abstract: **Estimating foundation settlement is one of the steps in the foundation design process. In a construction project, when foundations are placed close to each other, there will be mutual interaction in terms of total settlement and differential settlement. By accounting for the mutual interaction and considering factors such as foundation geometry, soil properties, and load distribution, geotechnical designers can estimate the total settlement and differential settlement more accurately. This enables them to design foundations that can accommodate the expected settlement behavior and minimize the potential adverse effects. The layout of the foundation in the building and the geotechnical parameters of the underlying soil layer are important through interactive calculations. In this paper, a typical problem is studied to investigate the settlement characteristics of two strip foundations (The symbols are used as strip Foundation A and strip Foundation B) placed close together on compressed soil. The interaction of two neighboring foundations is analyzed in the case of strip foundations A and B are built simultaneously. Theo elastic stress distribution theory, a simple method can be used to determine the total increase in vertical stress at the edge of the strip foundation at any depth z.**

This simplified method is valuable not only for calculating the stable settlement of individual foundations but also for illustrating the deformation mechanism of the ground beneath closely spaced foundations in each situation. The results show that, in each case, the ground tends to show different deformation characteristics, such as tilting forward and against each other.

Keywords **- closely spaced foundation; differential and total settlements; strip foundation problem; neighboring foundations**

I. INTRODUCTION

Shallow foundation solutions are used in cases where the basic soil has a good load-bearing capacity. When the basic soil has a high load-bearing capacity and meets the requirements of the project, using a shallow foundation is an economic and effective solution. This applies to projects such as residential houses, high-rise buildings, factories, and projects that do not require low settlement. Reasonable construction and transportation costs: Shallow foundations are often easy to construct and require few materials compared to other types of deep foundations, such as pile foundations or tank foundations. As the construction and transportation costs of deep foundations are significantly higher, using shallow foundations can be an economical choice.

Favorable geological conditions: To use shallow foundations effectively, the basic soil needs to meet stability and load-bearing requirements. Favorable geological conditions, including clay, sandy soil, clayey sandy soil, or sandy rock soil, are often ideal for the use of shallow foundations. But the use of shallow foundations needs to be well thought out and predicated on a thorough engineering evaluation of the building site. In order to determine the best foundation solution, a number of factors must be taken into account, including load, allowable settlement, soil mechanical properties, and project requirements.

Interaction between adjacent footings can result in greater settlement than would be the case with a single footing. This effect can be very important in some cases. If the influence between adjacent foundations is not fully considered, it may result in an unwanted or excessive settlement.

Evaluating and simulating the interactions between adjacent foundations is an important part of the foundation design process. Engineers use computational and modeling methods to quantify and predict this interaction. Factors such as the distance between foundations, mechanical properties of the soil, and load distribution between foundations are all considered to come up with appropriate design solutions.

It is important that geotechnical engineers do not ignore the influence of interactions between adjacent foundations when evaluating settlement and designing foundations. This helps ensure that structures will not experience unwanted settlement problems and operate stably over the long term.

The research content in this article is to consider two strip foundations placed close together under specific geological conditions. Conduct an interactive analysis of stress and settlement at selected survey points with varying distances between the two foundations. From there, analyze, compare, and draw conclusions about the differences in settlements and rotatation angles of the strip foundations.

II. LITERATURE REVIEW

Geotechnical engineers tend to adopt the most economic type of foundations for structures where stability and settlement conditions are satisfied. In order to satisfy the settlement criteria, the influence of neighboring footings or loaded areas must be considered with great care. The interaction between adjacent footings may result in settlements greater than those

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for isolated footings. Such an effect might be vital in some cases.

A few researchers are working on an analytical offer to look into the issue of interfering with nearby foundations. In 1962, Stuart presented the first attempt to use the limit equilibrium method to find the efficiency factor for soil bearing capacity. Using different techniques for analysis, other researchers adopted the same methodology [1]. In their 1984 study, Graham et al. used the stress-characteristics method [2]. In 2006, Griffiths et al adopted a probabilistic approach [3]. An upper bound limit analysis method was calculated by Kumar and Ghosh in 2007 [4]. The theory of elasticity approach was reposed by Ghosh and Sharma in 2010 [5].

Shahein and Hefdhallah (2013) presented a case history that shows the importance of such an effect. The case history in hand consists of 28 auxiliary buildings of an Electrical Power plant near Cairo, Egypt. A total of 175 boreholes were drilled to characterize the ground conditions in the site. The maximum allowable settlement was one of the major criteria of the project. Settlement analysis had to be carried out for each of the project building. In each building, the settlement was calculated under the center of each footing due to the load imposed from the footing and that due to the stresses on the surrounding footings of the structure. In addition, Settlement was computed for the case of single footing without influence of surrounding loaded footings as the case of the common practice in the geotechnical engineering profession. Settlement analysis was carried out by computing a profile of elastic stress increase due to all loaded areas at the foundation level. Settlement at a point is then computed at the foundation level by integrating vertical strains of the layered ground under the footing. The results of the analysis suggested that the effect neighboring footings could be important to the extent that necessitates the change of the foundation system from isolated footings to raft foundation in the light of the maximum allowable settlement of each foundation system [6].

This problem involved numerical analyses as well. A few of these studies used the finite element analysis of foundations under the influence of both horizontal and vertical loads to study the issue. In this regard, reference is made to Gourvenec and Steinepreis 2007 [10], Nainegali et al. 2013 [11], and Stergiou et al. 2015[12].

III. ANALYSIS OF STRESS AND SETTLEMENT

The analysis of the stress and settlement behavior of strip foundations in the case analyzed here can be explained by considering one of the study cases, which is width B = 2,0 m strip foundations built at a 1,0 m distance on a fully saturated soil, where the total load transferred to the soil is 100 kPa. The interaction between the two strip foundations can be analyzed in two cases, as given in Fig. 1.

The geological conditions of Binh Duong Province, Vietnam, are compiled from geological survey reports of actual projects used in this study.

The stratigraphic column consists of two soil layers. The top soil layer is clay loam with a thickness of 1.5 m, and below is a very thick clay layer that does not end at a depth of 20 m. The unit volume weight of clay loam is $\gamma = 17$ kN/m^3, and that of the clay layer is $\gamma_{sat} = 20.11$ kN/m^3. The water table is at a depth of 1.5 m. The depth of the strip foundation is chosen to be 1.5 m from the ground surface and equal to the underground water level.

Fig. 2 shows the deformation characteristics of the clay layer (soil layer 2) in the consolidation test. There is a relationship graph between Void ratio (e) and p (pressure) in the normally consolidated clay layer, which includes an unloading and compression curve.

We assume for the purposes of this survey problem that strip foundations A and B are constructed concurrently, in accordance with the conventional approach.

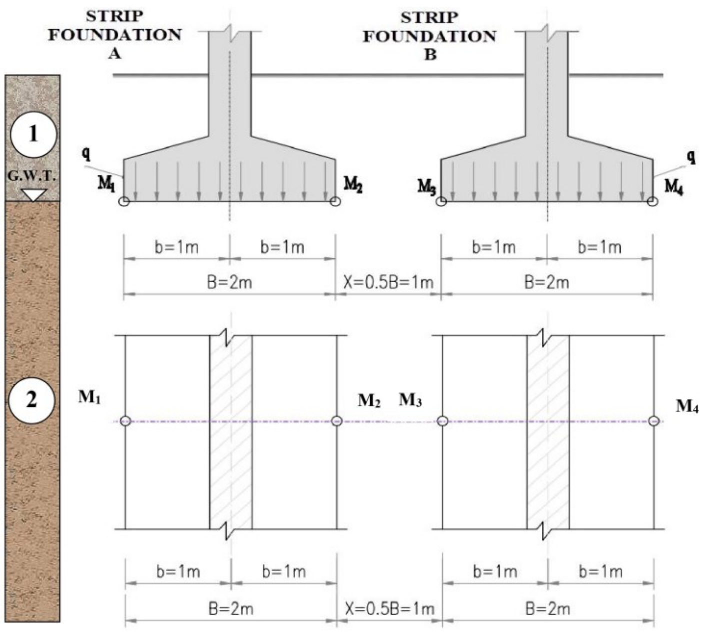

Fig. 1. Diagram of the laying strip foundation and geological conditions in the survey problem

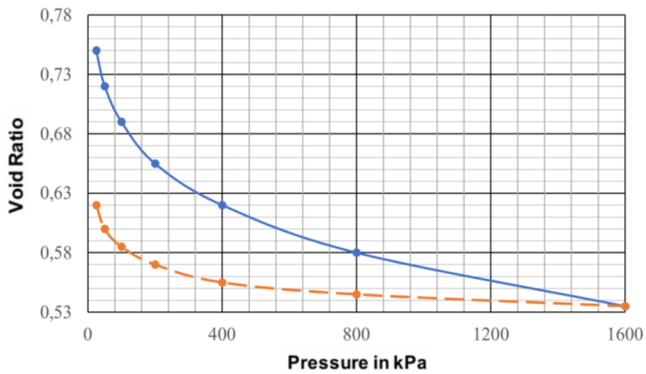

Fig. 2. Graph showing the clay layer's consolidation test results (e-p curve)

A. Vertical stress is caused by a uniformly distributed strip load at a point in the ground.

Overview of determining vertical stress at a point in the ground below an area subjected to a uniformly distributed strip load according to elasticity theory.

Fig. 3 shows the case where a uniform vertical load of q per unit area is acting on a flexible infinite strip on the surface of a semi-infinite elastic mass. To obtain the stresses at a point M(x,

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z), we can consider an elementary strip of width *ds* located at a distance *s* from the centerline of the load.The load per unit length of this elementary strip is *q·ds*, and it can be approximated as a line load.
The increase of vertical stress, σ_z, at M due to the elementary strip loading can be obtained by substituting *x - s* for *x* and *q · ds* for *q*.

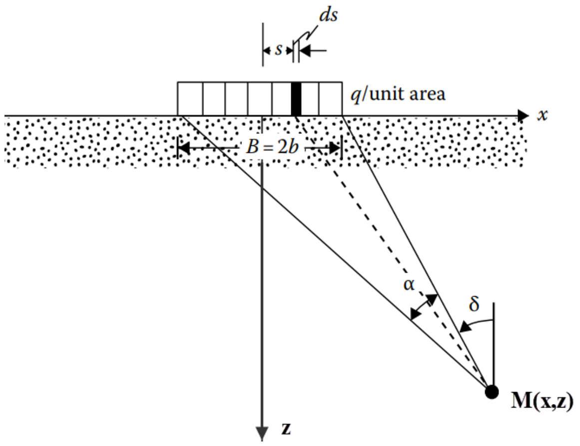

Fig. 3. Uniform vertical loading on an infinite strip

$$d\sigma_z = \frac{2qds}{\pi}\frac{z^3}{\left[(x-s)^2+z^2\right]^2} \qquad (1)$$

The total increase of vertical stress, Δσ, at M due to the loaded strip can be determined by integrating Equation (1) with limits of *s* = *b* to *s* = *-b*; so.

$$\sigma_z = \int d\sigma_z = \frac{2q}{\pi}\int_{-b}^{+b}\frac{z^3}{\left[(x-z)^2+z^2\right]^2}ds = \qquad (2)$$
$$\frac{q}{\pi}\left[\tan^{-1}\frac{z}{x-b} - \tan^{-1}\frac{z}{x+b} - \frac{2bz(x^2-z^2-b^2)}{(x^2-z^2-b^2)^2+4b^2z^2}\right]$$

The expressions for σ_z in Equations (2) can be presented in a simplified form:

$$\sigma_z = \frac{q}{\pi}\left[\alpha + \sin\alpha in\alpha\left(\alpha+2\delta\right)\right] \qquad (3)$$

where α and δ are the angles shown in Fig. 3.

In the case of two uniformly distributed load areas acting on the soil, we can use the principle of load superposition to determine the stress value.

According to elasticity theory, we can use the aforementioned formulas to find the stress at various points in the ground for the survey problem.

Specifically, it is necessary to determine the stress at points in the ground on the axis through points M_1, M_2, M_3, and M_4 designated as the problem diagram in Fig. 1.

The results of calculating the stress in the soil at the points to be calculated will be shown in Fig. 4 and Fig. 5, respectively.

Note: The stress values Δσ shown in the Figures are at soil depths 1 m apart.

- The stress Δσ created only by the evenly distributed load area in the form of strip foundation A will be shown in Fig. 4.

- The stress Δσ only caused by the evenly distributed load area in the form of strip foundation B is shown in Fig. 5.

- According to the superposition principle, we can calculate the stress Δσ in the soil caused by the load of the two foundations. The stress Δσ that strip foundations A and B have caused to the ground below points M_1, M_2, M_3, and M_4 is shown in Fig. 6.

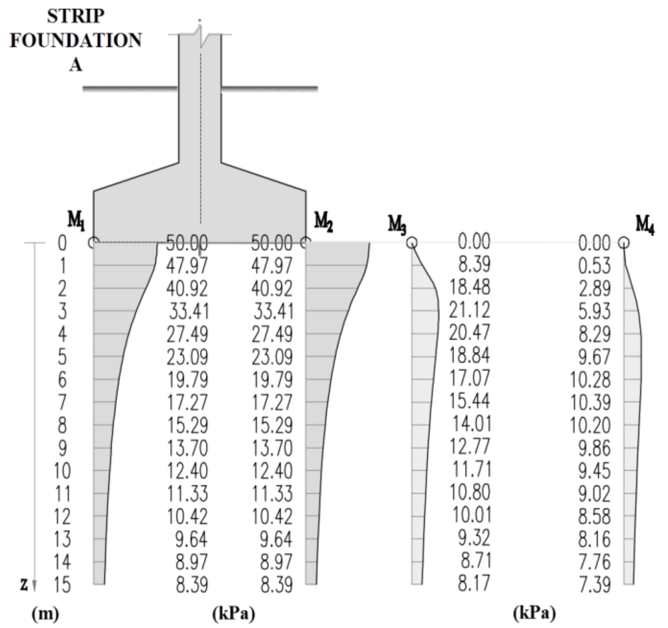

Fig. 4. Stress values Δσ at points on the axis through points M_1, M_2, M_3, and M_4 caused by A strip foundation load.

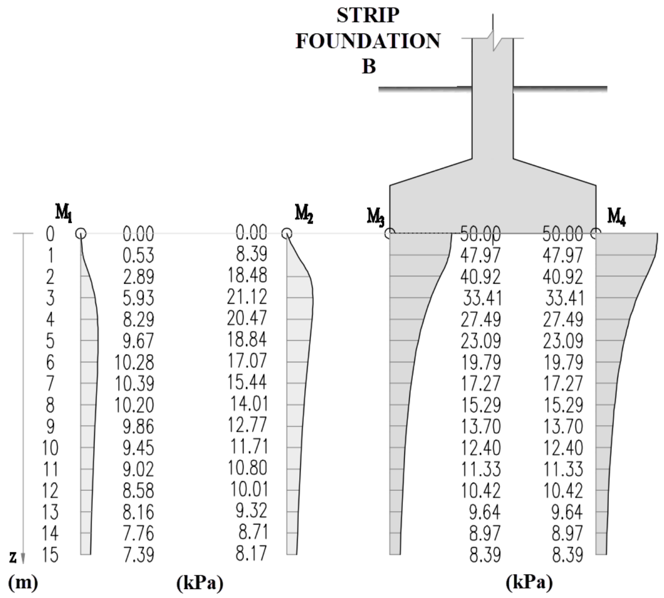

Fig. 5. Stress values Δσ at points on the axis through points M_1, M_2, M_3, and M_4 caused by B strip foundation load.

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Some remarks:
- The stress values, σ_z in Fig. 4 and Fig. 5 will be symmetrical since the problem is symmetrical.
- A soil load of q = 100 kPa causes the value of stress to progressively drop. The stress value is roughly 0.2 times q at a depth of 12 m below the foundation's bottom (see Fig.6).

- Based on the stress values σ_z at points inside the ground caused by construction loads, as well as the effective stress value due to the self-weight of the soil, combined with the compaction and settlement of the ground, we will calculate achieve stable settlement of the ground under the foundation due to construction loads.

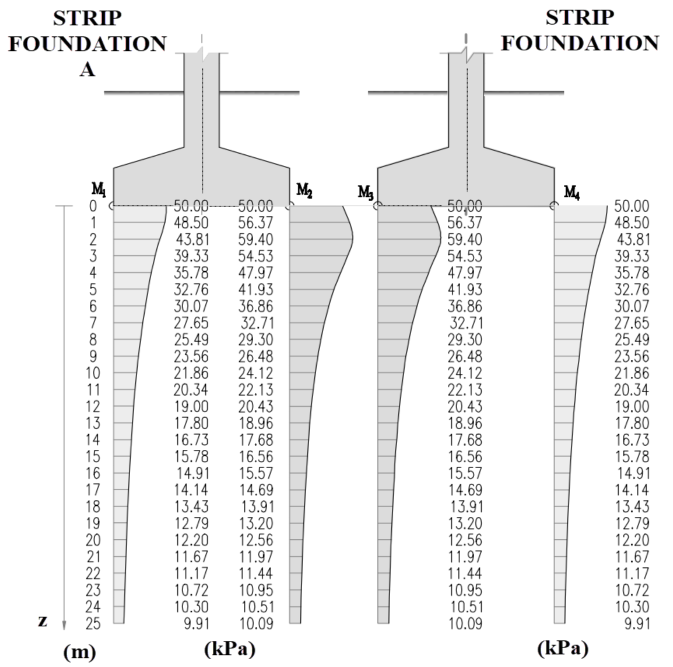

Fig. 6. Stress values $\Delta\sigma$ at points on the axis through points M_1, M_2, M_3, and M_4 caused by A strip foundation load.

B. Settlement analysis

In this section, we will calculate the stable settlement of the foundation at points M_1, M_2, M_3, and M_4, as shown in Fig. 1 of the survey problem diagram.

Firstly, a summary of the formula for determining element layer settlement using the method of determining settlement plus element layer settlement.

The final settlement of a thin soil layer is calculated as follows:

$$s_i = \frac{e_{1i} - e_{2i}}{1 + e_{1i}} h_i \qquad (4)$$

Where e_{1i}, e_{2i} are void ratios of soil which are between layer i^{th} before and after applying load, respectively. These void ratios are determined from compression curve of the consolidation test; h_i is thickness of layer i^{th}.
In this paper, the foundation width and the spacing of neighboring foundations are the primary variables. For the typical case the foundation width is assumed to be 2 m where the spacing between two neighboring footings are 1 m, the depth of the compressible clay layer is chosen as 12 m. The total settlements are calculated by using Terzaghi's theory (Terzaghi,1943) and the compression soil layer was divided into twelve thin layers. Therefore, the total settlement is determined by summing the individual settlements:

$$s = \sum s_i \qquad (5)$$

Settlement analysis in the case of strip foundations A and B is constructed concurrently. Given that the loadings and geometry of both foundations are symmetrical, As a result, an increase in stress will occur:

$$\Delta\sigma_{A1} = \Delta\sigma_{A2} = \Delta\sigma_{B3} = \Delta\sigma_{B4} = \Delta\sigma$$

$$\Delta\sigma_{A4} = \Delta\sigma_{B1} < \Delta\sigma_{B2} = \Delta\sigma_{A3} < \Delta\sigma$$

$\Delta\sigma_{A1}$ denotes the increase in stress brought on by strip foundation A under point M_1, and the other notations play the same part.

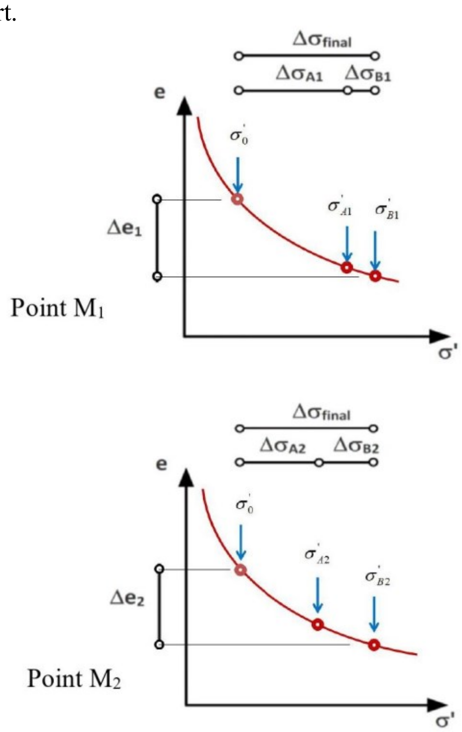

Fig. 7. Diagram for determining stable settlement in a thin layer of soil at Point M_1 and Point M_2.

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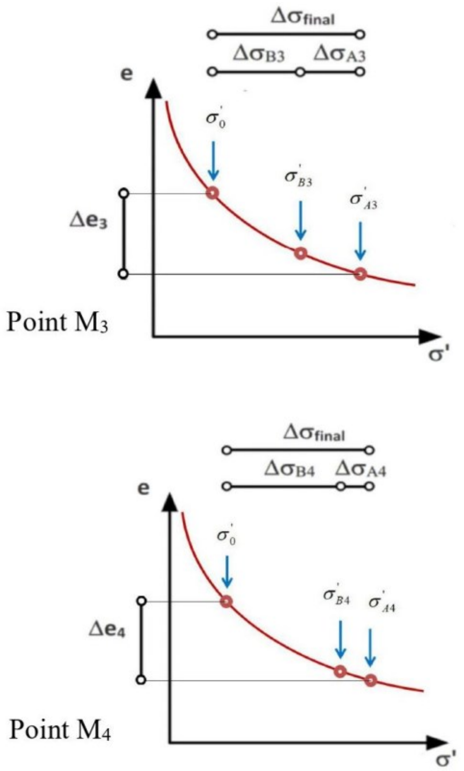

Fig. 8. Diagram for determining stable settlement in a thin layer of soil at Point M_3 and Point M_4.

From Fig. 7, it is clear that $\Delta e_1 = \Delta e_4 < \Delta e_2 = \Delta e_3$, and the resultant settlement is calculated as follows: The total settlement under point M_1 is a result of the foundation itself and the neighboring foundation. Therefore, the resultant settlement under point M_1 is the combination of the stress increments of Foundation A (Fig. 4) and Foundation B (Fig. 5). We are able to explain that: Because of the soil's self-weight, the stress causing settlement is less than one-fifth of the effective stress at a depth of 12 meters below the foundation's bottom. In order to calculate the settlement, the soil region subject to compression and subsidence can therefore be found down to a depth of 12 m and divided into six element layers, each with a thickness of 2.0 m.

Table I and Table II provide the specifics of the calculation used to determine the soil's settlement at point M_1.

Due to axial symmetry, the settlement at point M_1 is equal to the settlement at point M_4. Hence, the total settlement under Points M_1 and M_4 is 12.15 cm.

TABLE I. CALCULATED SETTLEMENTS UNDER POINT M_1

i	z_i (m)	h_i (m)	γ' (kN/m³)	$\sigma'_0 = \sigma'_{1i}$ (kPa)	Void ratio e_{1i}
1	3.5	2.0	10.3	35.80	0.73704
2	5.5	2.0	10.3	56.40	0.71616
3	7.5	2.0	10.3	77.00	0.70380
4	9.5	2.0	10.3	97.60	0.69144
5	11.5	2.0	10.3	118.20	0.68363
6	13.5	2.0	10.3	138.80	0.67642

TABLE II. CALCULATED SETTLEMENTS UNDER POINT M_1

i	$\Delta\sigma_{A1}$ (kPa)	$\Delta\sigma_{B1}$ (kPa)	$\Delta\sigma_{total}$ (kPa)	$\sigma'_{2i} = \sigma'_{1i} + \Delta\sigma_{total}$ (kPa)	Void ratio e_{2i}	S_i (cm)
1	47.97	0.53	48.50	84.30	0.69942	4.332
2	33.41	5.93	39.33	95.73	0.69256	2.750
3	23.09	9.67	32.76	109.76	0.68658	2.021
4	17.27	10.39	27.65	125.25	0.68116	1.215
5	13.70	9.86	23.56	141.76	0.67538	0.980
6	11.33	9.02	20.34	159.14	0.66930	0.849
Total settlement						**12.15**

The settlement at point M_2 can be estimated by following the same steps as the settlement at point M_1. Tables I and III provide a detailed presentation of the settlement results that were estimated below point M_2.

Due to axial symmetry, the settlement at point M_2 is equal to the settlement at point M_3. Hence, the total settlement under Points M_2 and M_3 is 14.22 cm.

The final settlements due to strip Foundation A and strip Foundation B on points M_1, M_2, M_3 and M_4 are summarized in Table IV.

TABLE III. CALCULATED SETTLEMENTS UNDER POINT M_2

i	$\Delta\sigma_{A1}$ (kPa)	$\Delta\sigma_{B1}$ (kPa)	$\Delta\sigma_{total}$ (kPa)	$\sigma'_{2i} = \sigma'_{1i} + \Delta\sigma_{total}$ (kPa)	Void ratio e_{2i}	S_i (cm)
1	47.97	8.39	56.37	92.17	0.69470	4.875
2	33.41	21.12	54.53	110.93	0.68617	3.495
3	23.09	18.84	41.93	118.93	0.68337	2.398
4	17.27	15.44	32.71	130.31	0.67939	1.425
5	13.70	12.77	26.48	144.68	0.67436	1.101
6	11.33	10.80	22.13	160.93	0.66868	0.924
Total settlement						**14.22**

TABLE IV. FINAL SETTLEMENT BENEATH STRIP FOUNDATION A AND STRIP FOUNDATION B

Foundation Points	M_1	M_2	M_3	M_4
Settlements (cm)	12.15	14.22	14.22	12.15

In order to clarify the deformation schemas of both foundations and their interaction with each other an illustration is given in Fig. 9. The value of the differential settlement, Δs, between the foundation's two edges is 2.07 cm.

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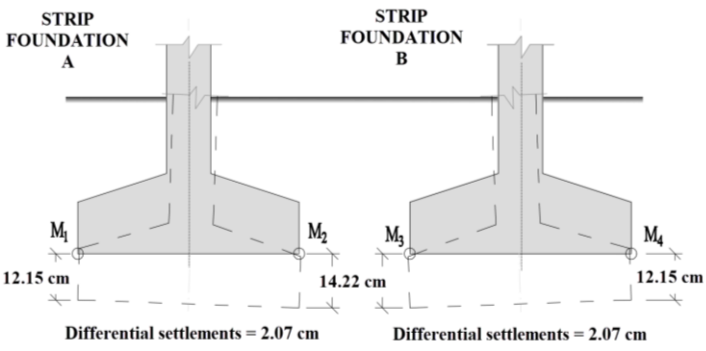

Fig. 9. A summary of the two foundations' inclination and settlement in the example problem.

IV. INVESTIGATE THE INFLUENCE OF SOME PARAMETERS ON FOUNDATION SETTLEMENT

A. Investigate a case involving two strip foundations that are the same width.

In this case, two strip foundations have the same width B and are placed close to each other at a distance of X. The load at the foundation bottom level is q = 100 kPa. The ground at the foundation construction site is as mentioned in Section III.3.

The value of foundation width B and the distance between the two foundations selected in the survey problem are summarized in Table V. Additionally, refer to the symbols in Fig. 10.

TABLE V. STUDY PARAMETERS

Parameter name	Symbol	Unit	Values
Foundation Spacing	X	m	0.25, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0
Foundation Width	B	m	2.0, 3.0, 4.0, 5.0

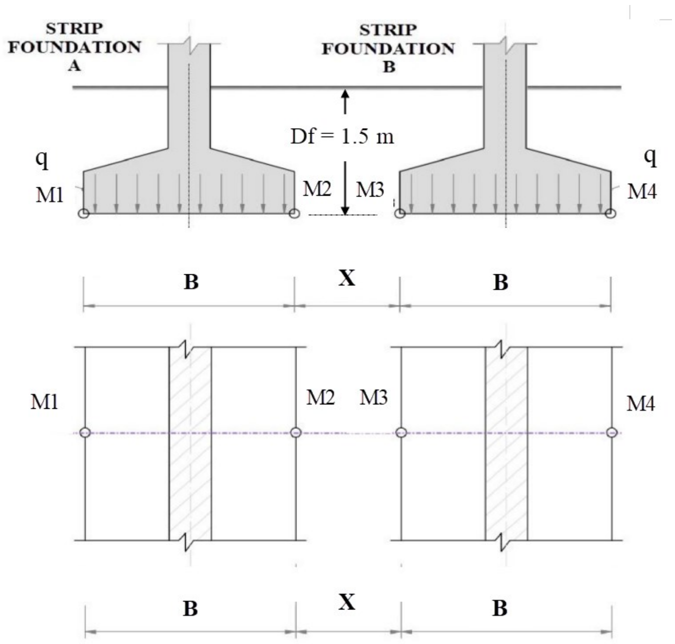

Fig. 10. The survey problem's parameter illustration and symbols

Since both strip foundations are built simultaneously with the same geometries and loading, hence the differential settlements beneath footings where equal and identical against each other as showed in Fig. 9. However, differential settlement values vary with changing foundation spacing and foundation width. The calculation of settlement at the foundation's edge points are similar to that of the above-mentioned typical example. Calculation of stable settlement below points M_1 and M_2 when changing parameters is shown in Table VI and Table VII, respectively. The settlement difference, symbolized by the letter Δs, is calculated and showed in Fig. 11 and Table VIII.

TABLE VI. SETTLEMENTS UNDER POINT M_1 (CM)

Foundation spacing X (m)	Strip foundation width, B (m)			
	2.0	3.0	4.0	5.0
0.25	12.75	14.21	15.08	15.61
0.50	12.52	14.05	14.94	15.50
1.00	12.15	13.77	14.70	15.30
1.50	11.85	13.54	14.49	15.12
2.00	11.60	13.32	14.31	14.97
2.50	11.39	13.13	14.15	14.83
3.00	11.22	12.96	14.02	14.72

TABLE VII. SETTLEMENTS UNDER POINT M_2, (CM)

Foundation spacing X (m)	Foundation width, B (m)			
	2.0	3.0	4.0	5.0
0.25	16.07	18.88	20.95	22.51
0.50	15.39	18.10	20.10	21.61
1.00	14.22	16.80	18.69	20.11
1.50	13.47	15.90	17.69	19.03
2.00	12.96	15.27	16.97	18.25
2.50	12.52	14.78	16.40	17.63
3.00	12.15	14.39	15.94	17.11

TABLE VIII. SETTLEMENT DIFFERENCE , Δs (CM)

Foundation spacing X (m)	Foundation width, B (m)			
	2.0	3.0	4.0	5.0
0.25	3.33	4.67	5.88	6.89
0.50	2.87	4.05	5.16	6.11
1.00	2.07	3.03	3.99	4.82
1.50	1.62	2.37	3.20	4.82
2.00	1.37	1.96	2.66	3.28
2.50	1.13	1.66	2.25	2.79
3.00	0.93	1.42	1.92	2.40

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From Fig. 11, it is clear that increasing the distance between foundations will decrease the differential settlements significantly. With the same value of distance between foundations (X), the greater the width of the foundation (B), the greater the value of the settlement difference (Δs).

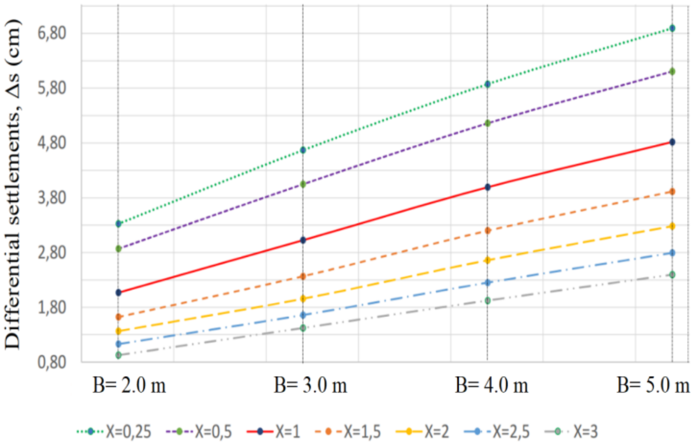

Fig. 11. Differential foundation settlements with respect to foundation width (B) and spacing (X).

The ratio of the difference between settlement and foundation width, Δs/B, is the foundation's rotation angle. The results of calculating these values are shown in Table IX.

Fig. 12 shows the angular rotations of both foundations result from the differential settlements. At lower spacing values, both footings reveal higher angular rotations. These values reduce gradually with increasing foundation width.

TABLE IX. FOUNDATION'S ROTATION ANGLE, Δs/B

Foundation spacing X (m)	Foundation width, B (m)			
	2.0	3.0	4.0	5.0
0.25	1.66%	1.56%	1.47%	1.38%
0.50	1.43%	1.35%	1.29%	1.22%
1.00	1.03%	1.01%	1.00%	0.96%
1.50	0.81%	0.79%	0.80%	0.78%
2.00	0.68%	0.65%	0.67%	0.66%
2.50	0.57%	0.55%	0.56%	0.56%
3.00	0.46%	0.47%	0.48%	0.48%

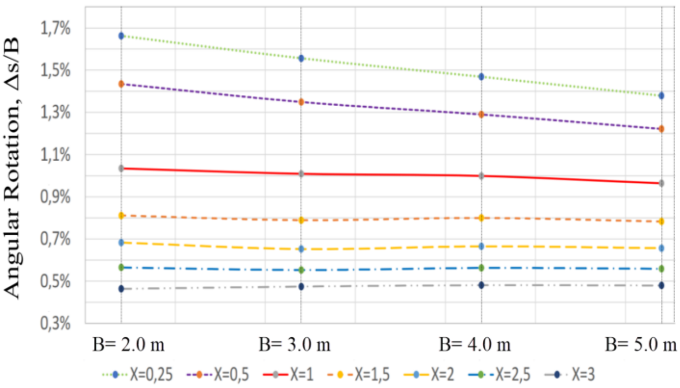

Fig. 12. The foundation's rotation angle with respect to foundation width (B) and spacing (X).

B. Investigate the case of two strip foundations with different widths.

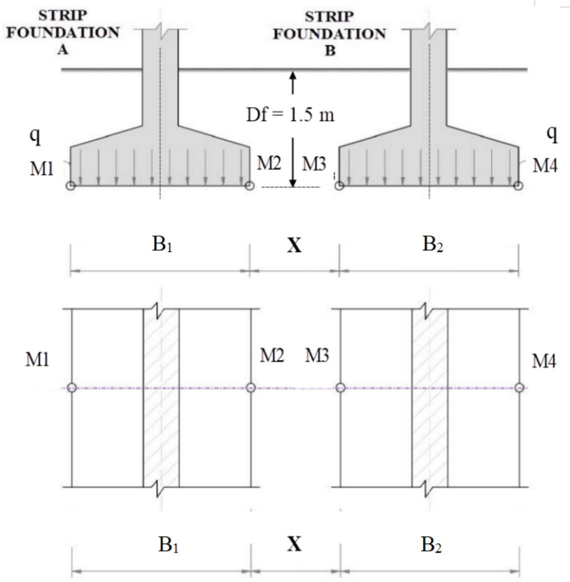

Fig. 13. The survey problem's parameter illustration and symbols - The widths of strip foundations A and B are B_1 and B_2, respectively.

TABLE X. STUDY PARAMETERS

Parameter name	Symbol	Unit	Values
Foundation Spacing	X	m	0.25, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0
Width of strip foundation A	B_1	m	2.0
Width of strip foundation B	B_2	m	2.0, 3.0, 4.0, 5.0

The results of the settlement below points M_1 and M_2 are shown in Table XI and Table XII. From there, the differential settlement is calculated as shown in Table XIII and Fig. 14.

TABLE XI. SETTLEMENTS UNDER POINT M_1 (CM), B_1= 2.0 M

Foundation spacing X (m)	Foundation width, B_2 (m)			
	2.0	3.0	4.0	5.0
0.25	12.75	13.51	14.09	14.53
0.50	12.52	13.27	13.82	14.24
1.00	12.15	12.79	13.28	13.66
1.50	11.85	12.41	12.84	13.17
2.00	11.60	12.09	12.47	12.76
2.50	11.39	11.82	12.15	12.41
3.00	11.22	11.60	11.89	12.12

TABLE XII. SETTLEMENTS UNDER POINT M_2 (CM), B_1= 2.0 M

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Foundation spacing X (m)	Foundation width, B_2 (m)			
	2.0	3.0	4.0	5.0
0.25	16.07	17.42	18.42	19.17
0.50	15.39	16.64	17.57	18.27
1.00	14.22	15.30	16.11	16.72
1.50	13.47	14.40	15.10	15.64
2.00	12.96	13.77	14.39	14.86
2.50	12.52	13.27	13.82	14.24
3.00	12.15	12.79	13.28	13.66

TABLE XIII. SETTLEMENT DIFFERENCE , FOUNDATION A, ΔS (CM)

Foundation spacing X (m)	Foundation width, B_2 (m)			
	2.0	3.0	4.0	5.0
0.25	3.33	3.91	4.33	4.64
0.50	2.87	3.37	3.75	4.03
1.00	2.07	2.51	2.82	3.06
1.50	1.62	1.99	2.27	2.47
2.00	1.37	1.68	1.92	2.10
2.50	1.13	1.45	1.67	1.82
3.00	0.93	1.20	1.40	1.54

The results of calculating the rotation angle of strip foundation A when changing the distance between the two foundations and the width of strip foundation B but keeping the width of foundation A constant at 2.0 m are presented in Table XIV and shown in Fig. 15.

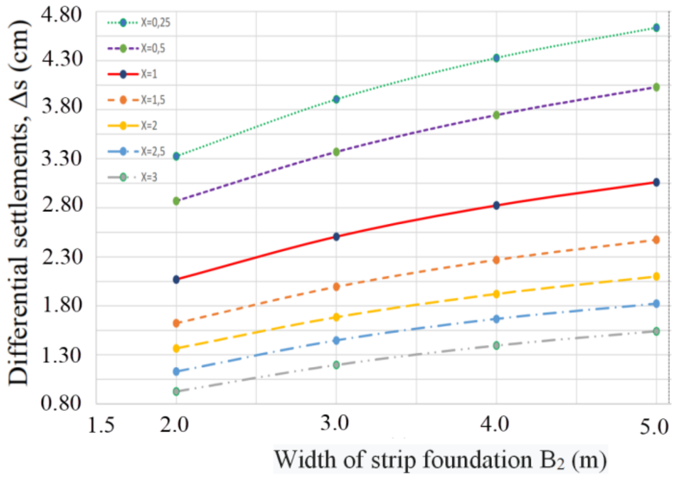

Fig. 14. Differential settlements of A foundation with respect to foundation width (B_2) and spacing (X).

TABLE XIV. ROTATION ANGLE OF A FOUNDATION , $\Delta s/B_1$

Foundation spacing X (m)	Foundation width, B_2 (m)			
	2.0	3.0	4.0	5.0
0.25	1.66%	1.95%	2.16%	2.32%
0.50	1.43%	1.68%	1.87%	2.02%
1.00	1.03%	1.25%	1.41%	1.53%
1.50	0.81%	1.00%	1.13%	1.24%
2.00	0.68%	0.84%	0.96%	1.05%
2.50	0.57%	0.72%	0.83%	0.91%
3.00	0.46%	0.60%	0.70%	0.77%

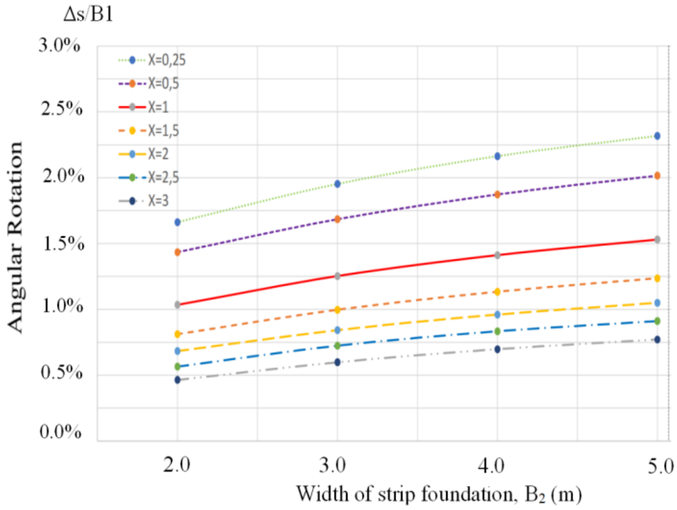

Fig. 15. Rotation angle of an A-strip foundation with respect to foundation width (B_2) and spacing (X).

By doing the same as calculating the settlement at foundation edge point A, we will also calculate the stable settlement below foundation edge points M_3 and M_4 of foundation B. The calculation results are presented in Table XV and Table XVI.

TABLE XV. SETTLEMENTS UNDER POINT M_3 (CM), $B_1 = 2.0$ M

Foundation spacing X (m)	Foundation width, B_2 (m)			
	2.0	3.0	4.0	5.0
0.25	16.07	17.53	18.61	19.41
0.50	15.39	16.85	17.93	18.73
1.00	14.22	15.72	16.80	17.61
1.50	13.47	14.97	16.05	16.86
2.00	12.96	14.46	15.55	16.36
2.50	12.52	14.08	15.16	15.97
3.00	12.15	13.77	14.86	15.66

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TABLE XVI. SETTLEMENTS UNDER POINT M_4 (CM), B_1= 2.0 M

Foundation spacing X (m)	Foundation width, B_2 (m)			
	2.0	3.0	4.0	5.0
0.25	12.75	13.64	14.29	14.79
0.50	12.52	13.52	14.20	14.72
1.00	12.15	13.30	14.05	14.61
1.50	11.85	13.11	13.92	14.51
2.00	11.60	12.94	13.80	14.42
2.50	11.39	12.79	13.70	14.35
3.00	11.22	12.67	13.61	14.28

From the data in Table XV and Table XVI, we can calculate the settlement difference of foundation B as recorded in Table XVII and shown in Fig. 16.

TABLE XVII. SETTLEMENT DIFFERENCE , FOUNDATION B, ΔS (CM)

Foundation spacing X (m)	Foundation width, B_2 (m)			
	2.0	3.0	4.0	5.0
0.25	3.33	3.89	4.31	4.62
0.50	2.87	3.34	3.72	4.01
1.00	2.07	2.41	2.82	3.06
1.50	1.62	2.86	2.14	2.35
2.00	1.37	1.53	1.75	1.93
2.50	1.13	1.29	1.46	1.63
3.00	0.93	1.10	1.24	1.38

The results of calculating the rotation angle of strip foundation B when changing the distance between the two foundations and the width of strip foundation B but keeping the width of foundation A constant at 2.0 m are presented in Table XVIII and shown in Fig. 17.

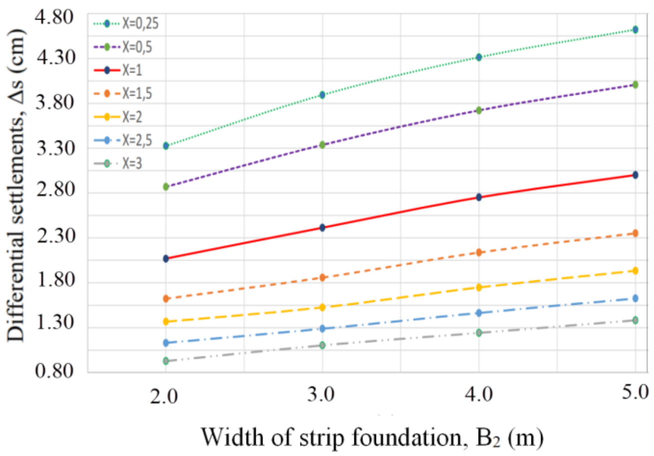

Fig. 16. Differential settlements of B foundation with respect to foundation width (B_2) and spacing (X).

TABLE XVIII. ROTATION ANGLE OF B FOUNDATION , $\Delta s/B_2$

Foundation spacing X (m)	Foundation width, B (m)			
	2.0	3.0	4.0	5.0
0.25	1.66%	1.30%	1.08%	0.92%
0.50	1.43%	1.11%	0.93%	0.80%
1.00	1.03%	0.80%	0.69%	0.60%
1.50	0.81%	0.62%	0.53%	0.47%
2.00	0.68%	0.51%	0.44%	0.39%
2.50	0.57%	0.43%	0.37%	0.33%
3.00	0.46%	0.37%	0.31%	0.28%

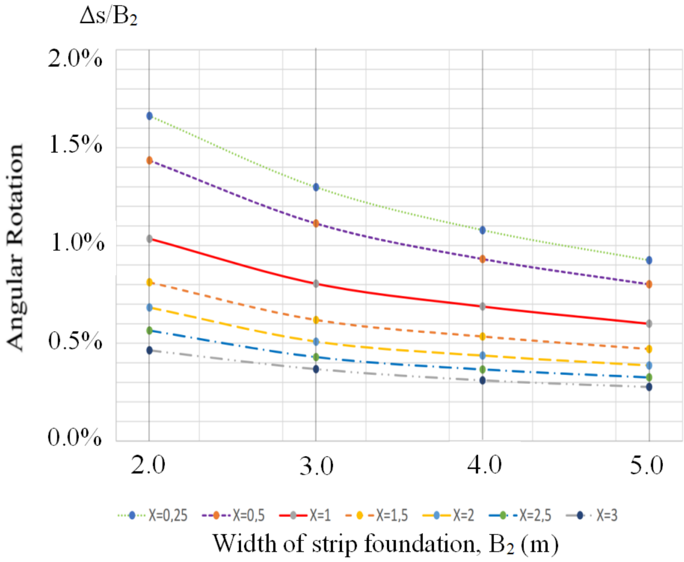

Fig. 17. Rotation angle of an B-strip foundation with respect to foundation width (B_2) and spacing (X).

V. CONCLUSIONS

The effects of closely spaced foundations constructed on compressible soil are investigated in this paper. The conclusions mentioned below are based on the findings of interaction calculations performed for both total and differential settlements as well as the rotation angle of the foundation.

- This study's simplified model works well for understanding the interactions between nearby structures and finding out the differential settlement beneath foundations.

- The spacing between two foundations has a significant impact on the stress transfer as well as the total and differential settlements because of the foundation-soil-foundation interaction, which transfers stresses from closely located foundations to neighboring soils.

● Case 1: The foundation widths of strip foundations A and strip foundation B are equal.

- Simultaneously constructed foundations with the same geometry and loading histories result in equal stress increments for each foundation. As a result, the foundations provide symmetric differential settlements and tilt against one another.

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- Increasing the distance between foundations will reduce the interaction effects which decrease the differential settlements. It is obvious that one can ignore the interaction between two foundations when their distance is greater than the foundation width.
- By increasing the distance between foundations, one can control the angular rotation of the foundations.

● Case 2: Two strip foundations A and B have different foundation widths.

Foundation A's width is 2.0 meters, and foundation B's width is designated as B_2. Changing the width of foundation B_2 and the distance between the two foundations while maintaining the width of foundation B_1 results in the following findings:

- With the same foundation distance, as the width of foundation B_2 increases, the settlement of both foundation A and B increases and the difference in settlement of foundation A increases larger than that of foundation B.
- When constructing two foundations close together, increasing the width of foundation B has a significant impact on the rotation angle of foundation A.

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