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EFFECT OF MUTUAL INTERFERENCE PILES ON SEEPAGE PROPERTIES UNDER HYDRAULIC STRUCTURES

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ABSTRACT

The seepage phenomenon (uplift pressure - flow rate - exit gradient of hydraulic structures) is one of the main causes of failure or collapse of hydraulic structures, so it has been reduced using sheet piles under floor of hydraulic structures.

In this study, effect of mutual interference piles were studied on seepage phenomenon by using finite elements program ANSYS. The results were verified with the practical results L-SAYED which given a good correlation.

It was found that the use of the pile in the upstream reduced the uplift pressures by 8.36%, and the pile in the downstream increased it by 11.66%, the flow rate reduced by 66.8% and exit gradient of the hydraulic structures reduced by 28.28%.

KEYWORDS: Seepage; Sheet pile; exit gradient; finite element ANSYS

1. INTRODUCTION

Because the different head of water between upstream and downstream to weirs, regulator and dams ..etc. lead to the water movement from higher head to lower head passing through the permeable layer of soil, it's under structures. Therefore, generates uplift pressures under floor hydraulic structures and piping phenomenal.

Asmaa, (2017) studied the Effect of Two Sheet Piles In Double Soil Layers on Seepage Properties(uplift pressure and exit gradient) by computer program (Geo – Studio SEEP/ W model), used three parameters upstream sheet piles , downstream piles and permeability of two layers , and estimation empirical equation to seepage discharge , uplift pressures and exit gradient by statistics software program (SPSS).

EL- Sayed and Ali, (2002) studied the effect sub- layers of soil on seepage properties without sheet pile was studied experimentally and discussed with numerically solution ,the main result when decreased permeability of lower sub soil the uplift pressures was increased and degreased the seepage discharge.

Formulation for creeping theory,Bligh's according to indian hydraulic structures , he produced empirical theory to estimate the path of creep by total length of traveling of water form upstream end to downstream end so that named this formula Bligh’s Creep theory . Lan's according to more than 200 dams, proposed his weighting – creep theory, this theory give the vertical creep thee time more than weight of horizontal creep. Khosla’s also estimated equation to measured uplift pressure according Darcy equation and neglect thickness of floor , influence mutual interference of pile and slope of floor , wherefore suggested correction for it (Grag, 1976).

Imad, (2013) studied the effect location and inclination angle of sheet pile on seepage control under floor of dam structures by computer languish FORTRAN90, and determine the uplift pressure at nodal point , exit gradients and seepage quantity behind cutoff walls.

Najm and Hala, (2015) studied experimentally cases for one layer of soil to analysis the effect inclination angle on exit gradient , factor of safety , uplift pressure and quantity of seepage by using seepage tank were made in laboratory of Babylon university .

Nassralla and Rabea, (2015) studied the effect use two- layers of soil on seepage properties with sheet pile was studied experimentally and discussed with numerically computer program (Geo – Studio SEEP/ W model) ,the result were uplift pressures degreased path the floor in case the upstream pile was less than half depth of soil layer to comparison with numerical results given good agreement .

Saleh and Hayder, (2011) studied the effect of location and angle of sheet pile at downstream on uplift pressure and exit gradient used finite element method analysis by computer program software (ANSYS version 11.0). The main result the best angle of sheet pile was 120°.

Saleh and Aqeel, (2009) studied the effect of removing one of the three sheet piles by computer program finite element (GEO-SLOPE , SEEP/W).

Wesam, (2011) studied the effect of intermediate sheet pile on uplift pressure by numerical solution(used computer language QBASIC) to calculate final pressures for the any length or position for intermediate pile , and comparison with Khosla's result for it.

In this study used one layer isotropic homogenous soil with three sheet pile and discussed the effect mutual interference between pile on uplift pressures under and exit gradient at toe of hydraulic structures by finite element software (ANSYS).

2. MODELING& VERIFICATION

Finite element method ANSYS (ANalysis SYStem) (version 15.0) computer program has been used to represent seepage flow passing through soil underneath hydraulic structure to define the mutual interference pile by 2D element (plan 77) (eight node – one degree of free dome – head). The best mesh of modeling to find path uplift pressure under structures without sheet pile shown in Fig. 1 number element between 714 and 6250 no deference result so used diminution of element (1m*1m) is (1000) element at Fig. 2 and physical properties of soil at Table 1 , the result of uplift pressure at Figs. 3 and 4 comparison with Experimental result EL-Sayed and Ali, (2002) at Fig. 5 given good agreement .

Table 1. Physical properties of soil.

Layers	Type of soil classification	Void ratio	Unite weight KN/m3	Gs	Value of hydraulic conductivity m/s
1	Sandy silty clay	0.52	20.65	2.75	$5.23*10^{-7}$

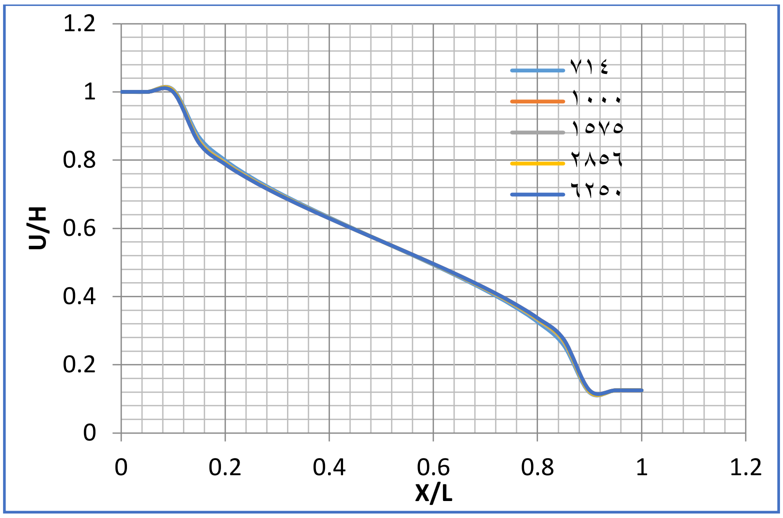


Fig. 1. The best number of element.

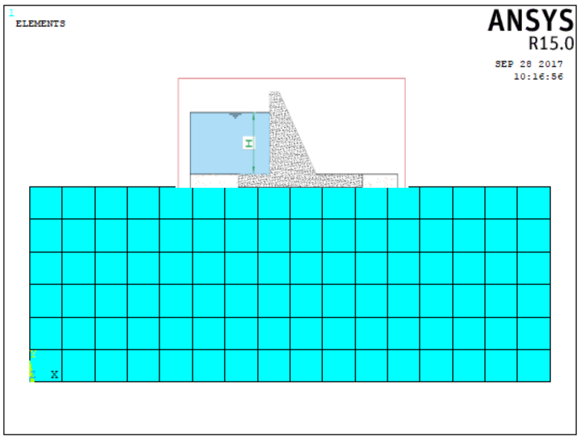


Fig. 2. ANSYS Finite element mesh

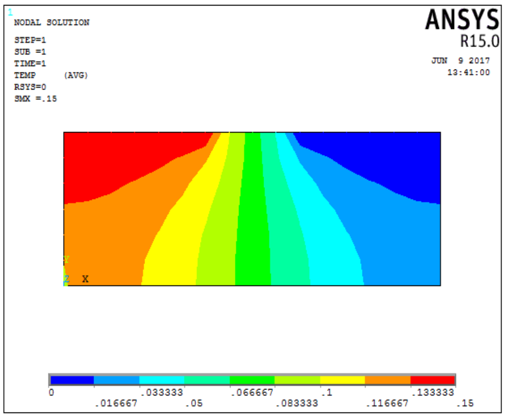


Fig. 3. Uplift pressure under structures.

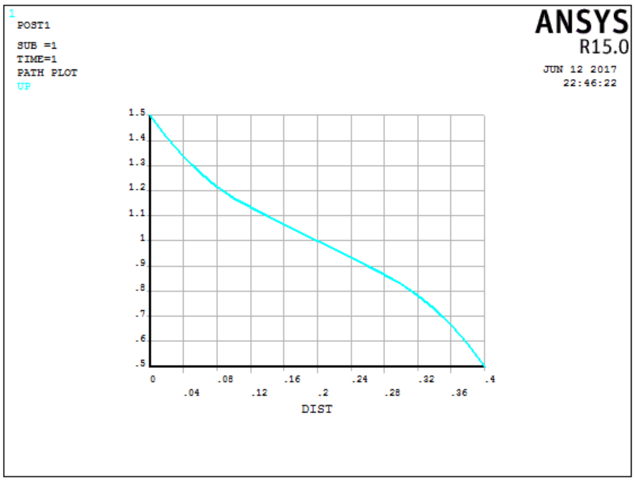


Fig. 4. Distribution Uplift pressure under structures

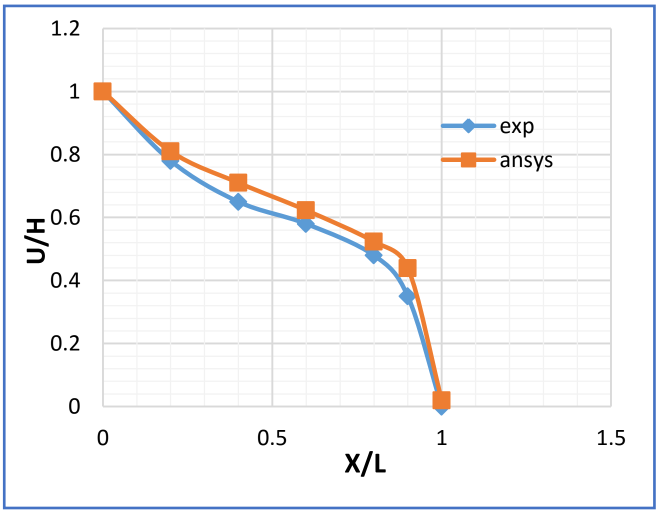


Fig. 5. Comparative (ANSYS) results with EXP. Results El-sayed of uplift pressure under hydraulic structures

3. CASES OF SHEET PILES AND STRUCTURES USED

In this research study many cases for many sheet piles at horizontal floor for the hydraulic structures, that has variable depth pile number (1, 2 and 3) and position middle pile. to hydraulic structures shown in Fig.6 the model was chosen to make discussion under this condition:-

- Total length of floor for hydraulic structures L= 50 m
- Water level at upstream = 4m
- Water level at downstream = 0.5m
- Hydraulic conductivity Kxx=Kyy= 0.0000265 m/sec
- Depth of pile no. 1 at upstream d1 = (2,4,6,8,10,12)m
- Depth of pile no. 2 at middle d2 = (2,4,6,8,10,12)m
- Depth of pile no. 3 at downstream d3 = (2,4,6,8,10,12)m
- Distances between pile no. 1 and of pile no. 2 if location of pile no.2 is variable X= (2,5,10,15,20,25,30,35,38) m

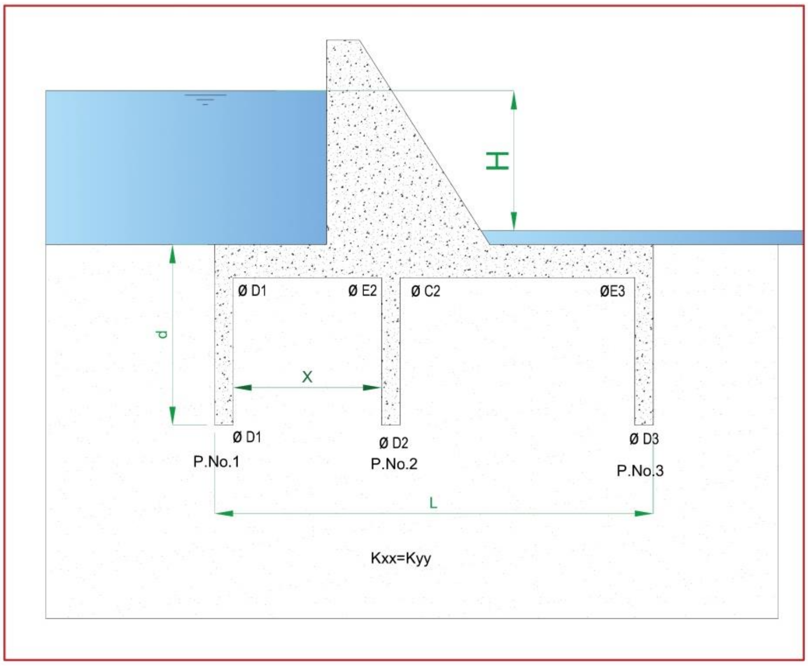


Fig. 6. The models of hydraulic structures and symbols of condition.

4. RESULTS AND DISCUSSIONS

Using ANSYS program (V.15) to simulated seepage and estimate uplift pressure and exit gradient under hydraulic structures by finite element analysis, cases study

4.1. Comparison between no sheet pile and two sheet pile

From Fig. 7 the result of used two pile is discussion the uplift pressures reducing 8.36% at pile no. 1 & increasing 11.66% at pile no. 2 because downstream pile lead to effect interference the flow , exit gradient reduce 28.28 % and quantity of seepage reduce 66.8% because the sheet pile increase path line under hydraulic structures and downstream pile

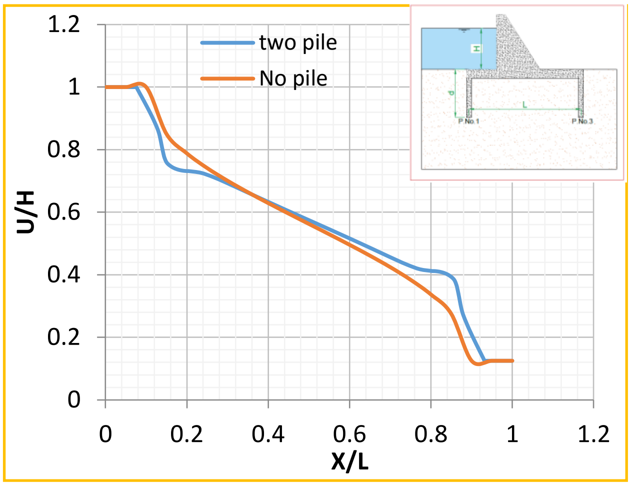


Fig. 7. Comparative of uplift pressure between used no & two piles

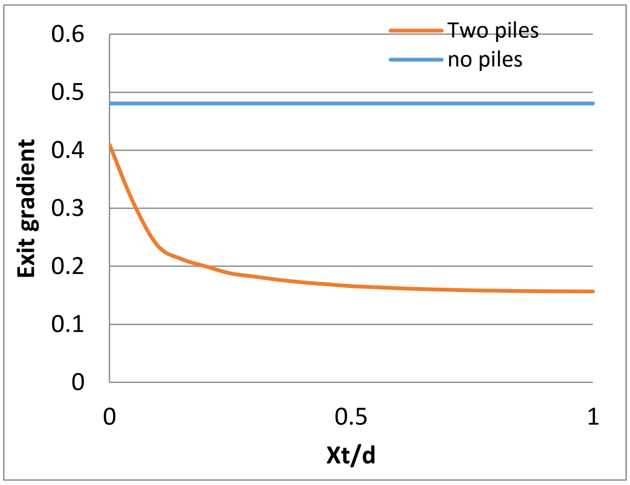


Fig. 8. Effect no pile and two pile on exit gradient at downstream pile

4.2. If used three sheet pile and discussion

I. The effect of location pile no.2 on uplift pressures at key points shown in Fig. 6 ($ØC_1$, $ØD_1$, $ØE_3$, $ØD_3$,), quantity of seepage and exit gradient that's shown in Figs. 9, 10, 11 and 12 respectively with constant other variable .

1. Form Fig. 9 which the percentage pressure at point ($ØC_1$ & $ØD_1$) reducing (5.43 & 1.47) % respectively when the distance between piles expansion perform the mutual interference low effect.
2. From Fig. 10 the percentage pressure at point ($ØE_3$ & $ØD_3$) increase (10.7 & 2.56) % when the distance between piles shrinking perform the mutual interference increase effect.
3. From Figs. 11, 12 and 13 location of pile no.2 no effect on quantity of seepage and exit gradient.

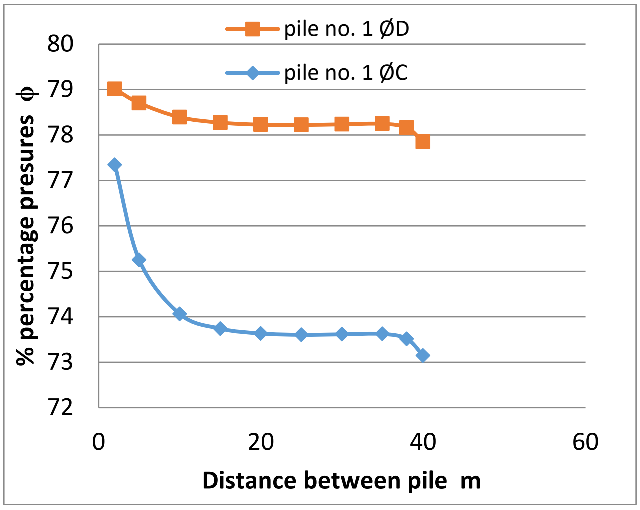


Fig. 9. Effect of distances on Uplift pressures pile No. 1 at ØD & ØC.

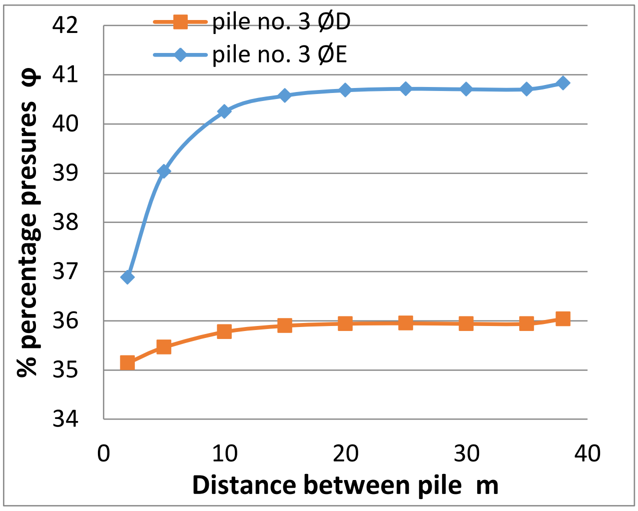


Fig. 10. Effect of distances on Uplift pressures pile No.3 at ØE & ØD.

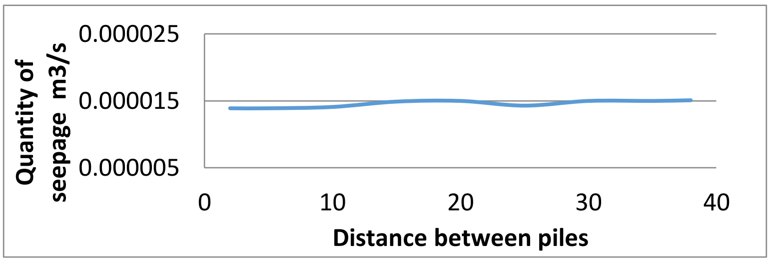


Fig. 11. Effect of distances on quantity of seepage

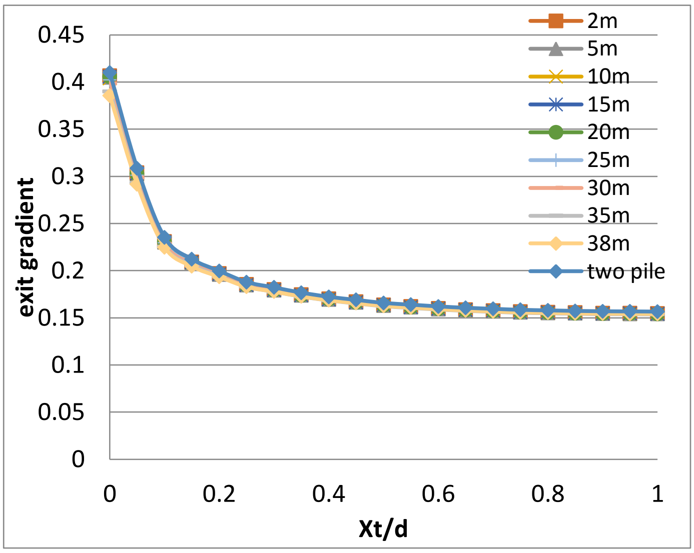


Fig. 12. Effect of distances on exit gradient at downstream pile.

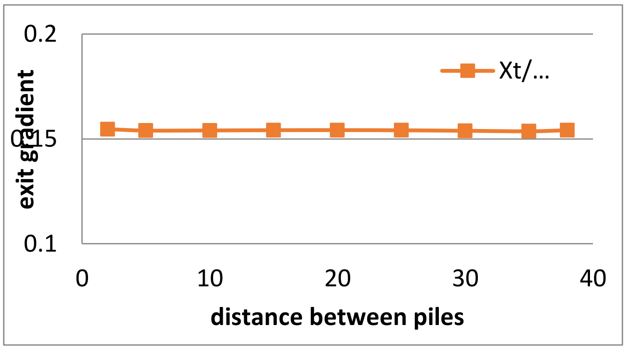


Fig. 13. Effect of distances on exit gradient at downstream pile.

II. Effect of depth pile no. 1 on uplift pressures at key points shown in Fig. 6 (ØC1 , ØD1, ØE2, ØD2, ØC2, ØE3, ØD3) , quantity of seepage and exit gradient that's shown in Fig. 14, 15, 16, 17, 18 and 19 respectively with constant other variable .

Form Fig. 14 which the percentage pressure at point (ØC1 & ØD1) reduce (33.59 & 25.76) % respectively when the depth pile increased.

From Fig. 15 the percentage pressure at point (ØE2, ØD2, ØC2) reduce (25.53,24.63&23.89)% respectively when the depth pile increased .

Form Fig. 16 the percentage pressure at point (ØE3 & ØD3) reduce (21.52 & 20.35) % respectively when the depth pile increased.

From Fig. 17 the quantity of seepage reduce (29.6) % when the depth pile increased.

From Fig. 18 and 19 the exit gradient reduce (30.38) % when the depth pile increased.

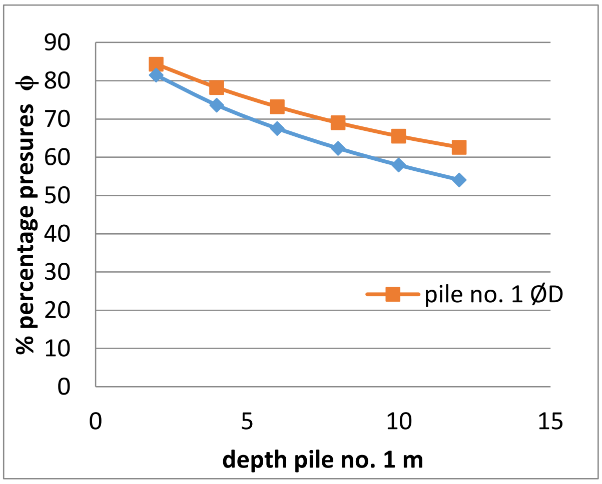


Fig. 14. Effect of depth pile No.1 on Uplift pressures pile No. 1 at ØC & ØD.

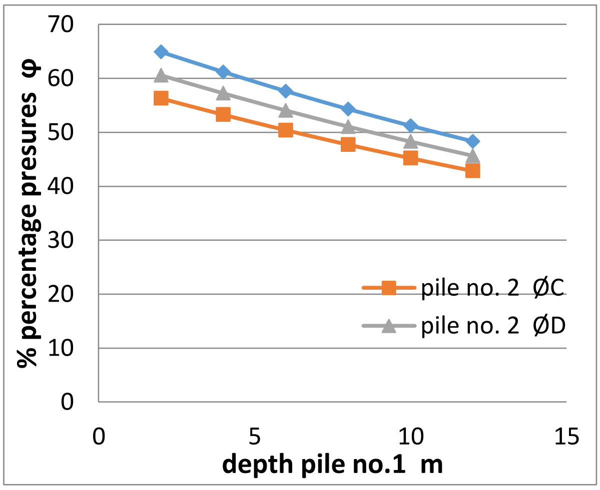


Fig. 15. Effect of depth pile No.1 on Uplift pressures pile No.2 at ØE, ØC & ØD.

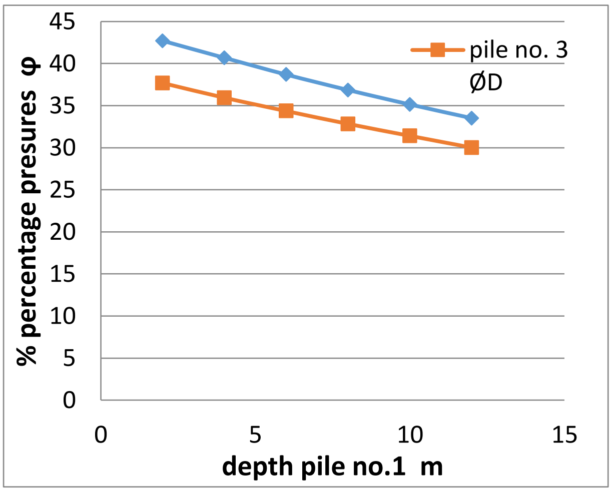


Fig. 16. Effect of depth pile No.1 on Uplift pressures pile No.3 at ØE & ØD.

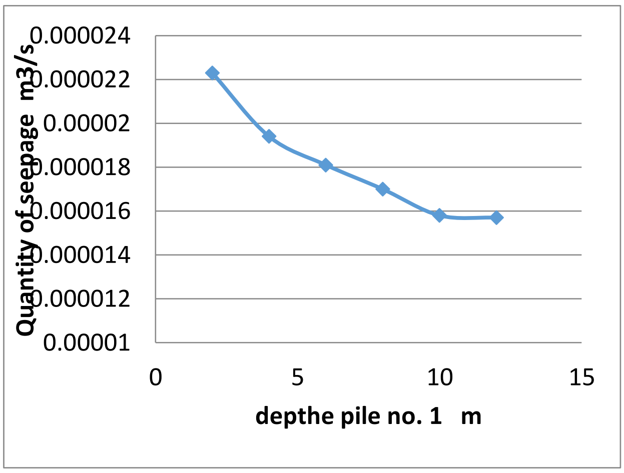


Fig. 17. Effect of depth pile no.1 on quantity of seepage.

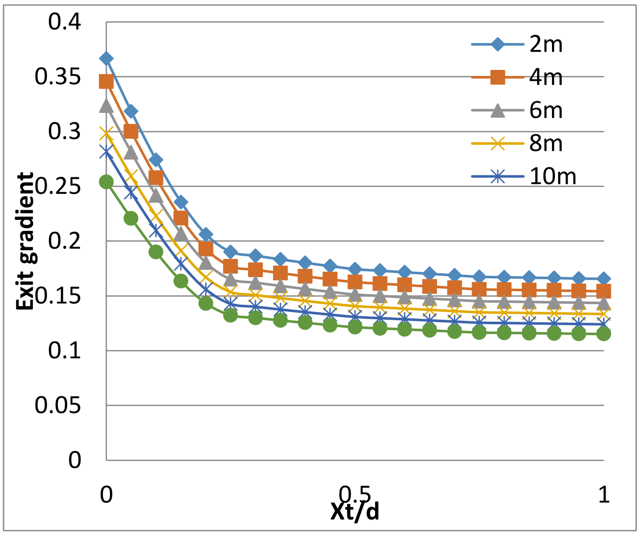


Fig. 18. Effect of depth pile No.1 on exit gradient at downstream pile.

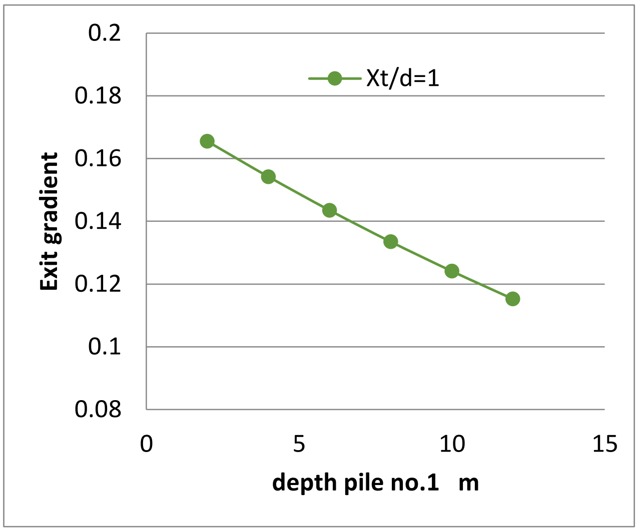


Fig. 19. Effect of depth pile No.1 on exit gradient at downstream pile.

III. Effect of depth pile no. 2 on uplift pressures at key points shown in Fig. 6 (ØC1 , ØD1 , ØE2 , ØD2 , ØC2 , ØE3 , ØD3) , quantity of seepage and exit gradient that's shown in Figs. 14, 15, 16, 17, 18 and 19 respectively with constant other variable .

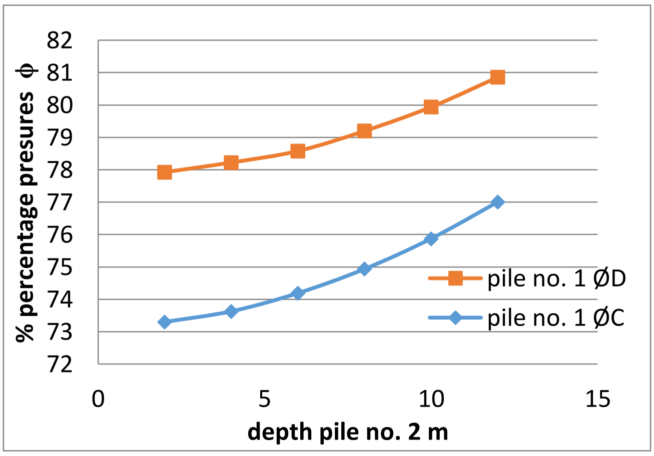
Form Fig. 20 the percentage pressure at point (ØC1 & ØD1) increase (5.06 &3.67)% respectively when the depth pile increased

From Fig.(21) the percentage pressure at point (ØE2 , ØD2 , ØC2) increase (15.65)% for point (ØE2) and reduce (12.28&0.2)% respectively when the depth pile increased.

Form Fig. (22) the percentage pressure at point (ØE3 & ØD3) reduce (9.56& 8.65)% respectively when the depth pile increased .

From Fig (23) the quantity of seepage constant from (2-8)m depth of pile and reduce (14.98)% when the depth pile increased more than (8, 12)m .

From Fig (24 & 25) the exit gradient reduce (12.68) % when the depth pile increased.



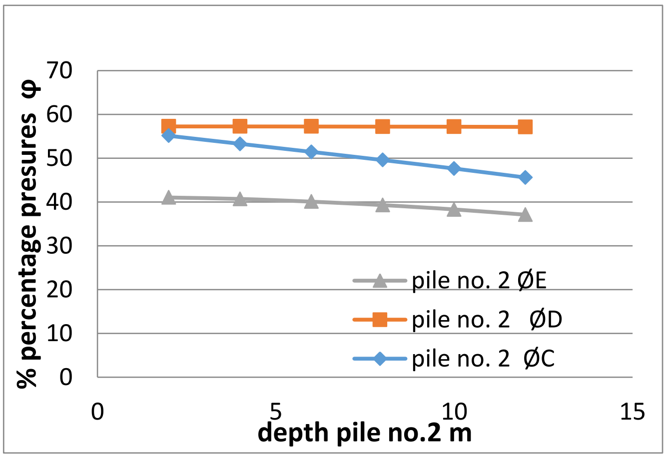
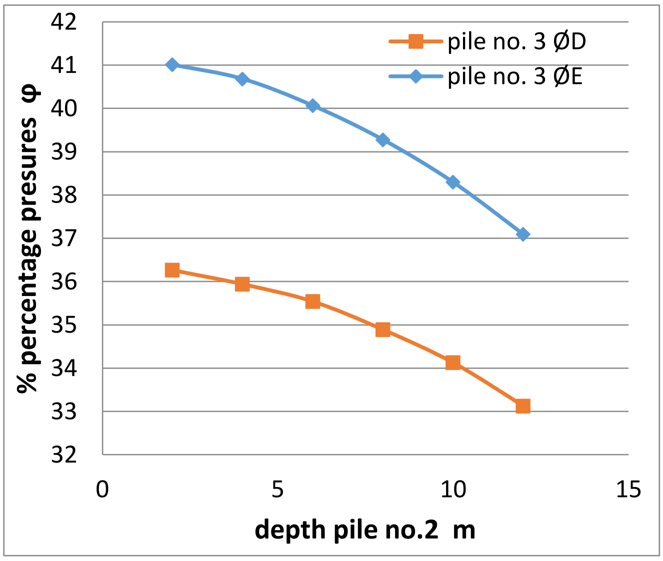


Fig. 20. Effect of depth pile No.2on Uplift pressures pile No. 1 at ØC & ØD.



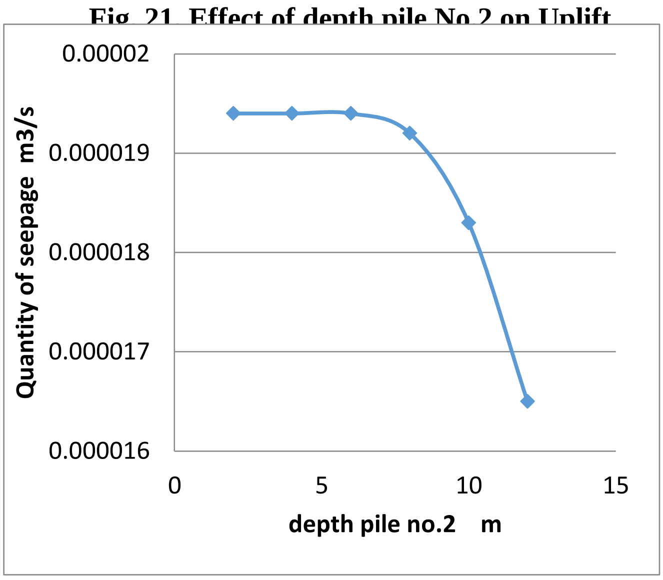


Fig. 22. Effect of depth pile No.2 on Uplift pressures pile No.3 at ØE & ØD.

Fig. 23. Effect of depth pile no.2 on quantity of seepage.

IV. Effect of depth pile no. 3 on uplift pressures at key points shown in Fig(6) (ØC1 , ØD1 , ØE2 , ØD2 , ØC2 , ØE3 , ØD3) , quantity of seepage and exit gradient that's shown in Fig.(26,27,28,29,30&31) respectively with constant other variable .

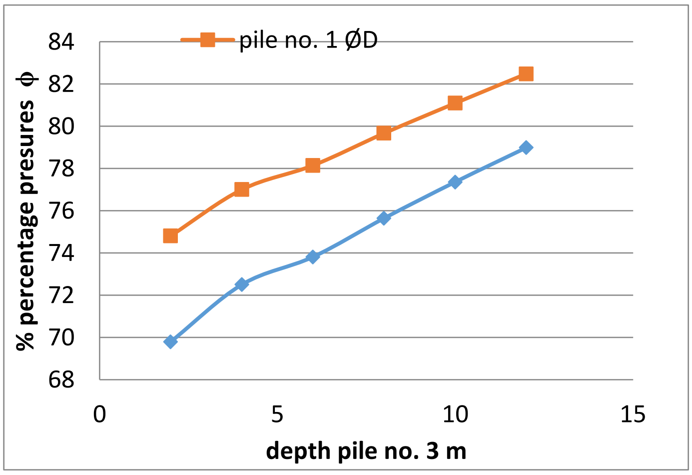
Form Fig. (26) the percentage pressure at point (ØC1 & ØD1) increase (13.17 &10.25)% respectively when the depth pile increased

From Fig.(27) the percentage pressure at point (ØE2 , ØD2 , ØC2) increase (23.92 , 28.72 , 34.84)% respectively when the depth pile increased .

Form Fig. (28) the percentage pressure at point (ØE3 & ØD3) increase (88.08 & 77.18)% respectively when the depth pile increased .

From Fig (29) the quantity of seepage reduce (29.86)% when the depth pile increased.

From Fig (30 & 31) the exit gradient reduce (42.5)% when the depth pile increased.



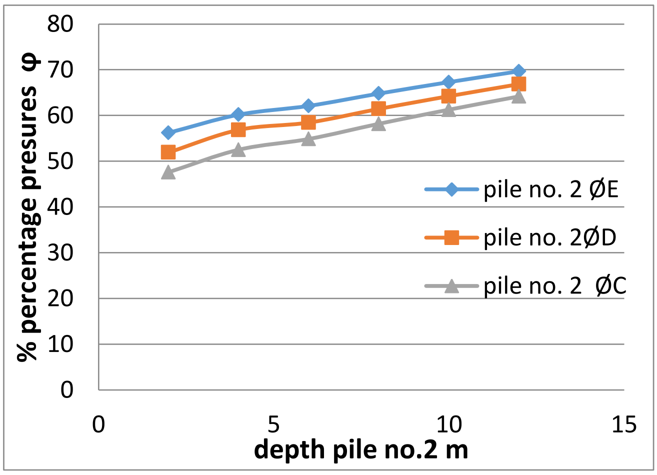
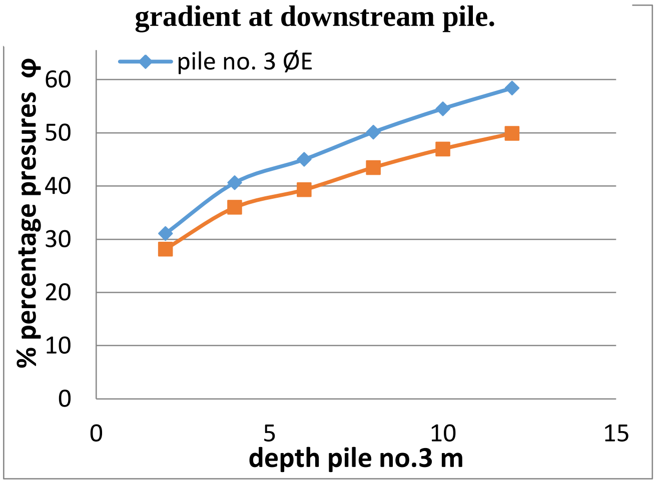


Fig. 24. Effect of depth pile No.2 on exit gradient at downstream pile.

Fig. 25. Effect of depth pile No.2 on exit gradient at downstream pile.



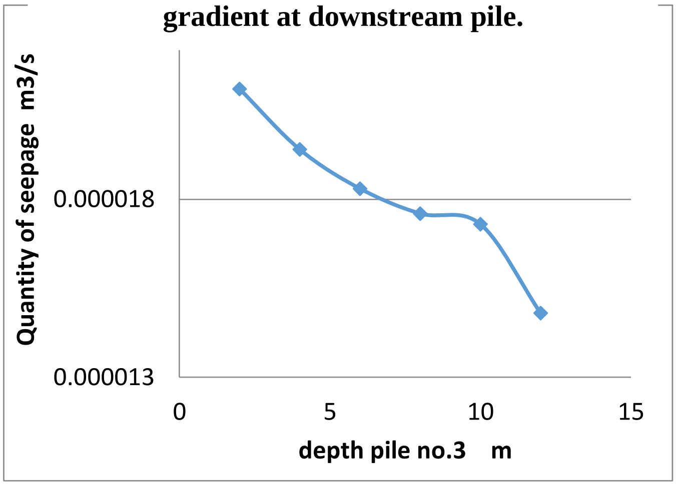
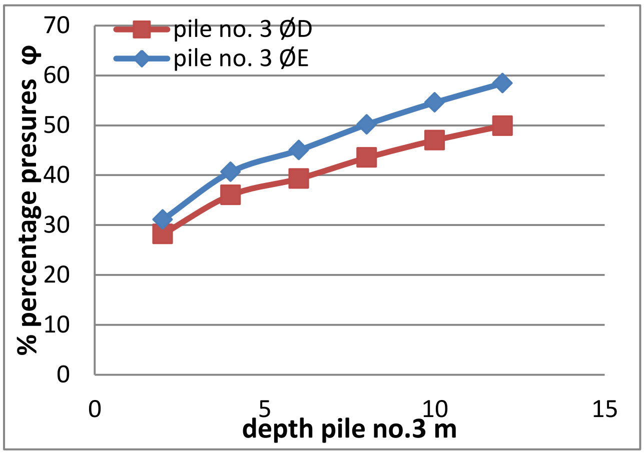


Fig. 26. Effect of depth of pile No. ٣on Uplift pressures pile No. 1 at ØC & ØD

Fig. 27 Effect of depth pile No. ٣ on Uplift pressures pile No.2 at ØE, ØC & ØD.



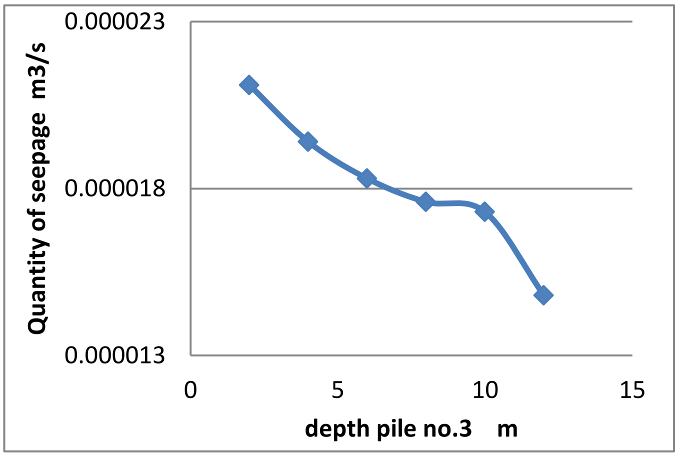
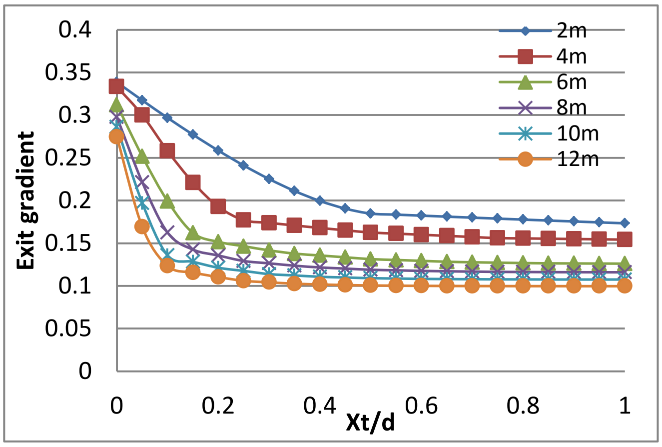


Fig. 28. Effect of depth pile No.3 on Uplift pressures pile No.3 at ØE & ØD.

Fig. 29.Effect of depth pile no.3 on quantity of seepage.



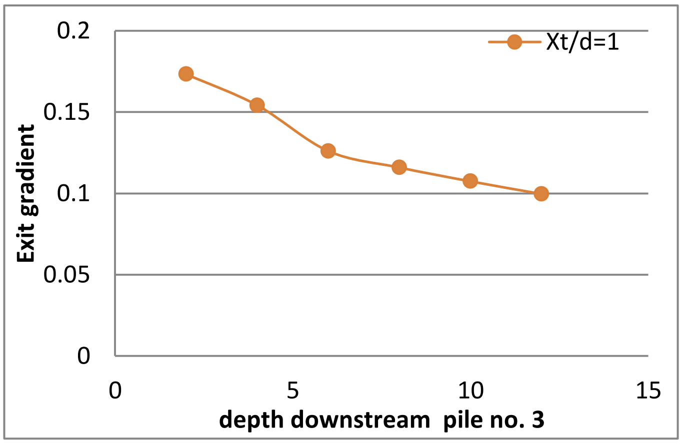


Fig. 30. Effect of depth pile No.3 on exit gradient at downstream pile.

Fig. 31. Effect of depth pile No.3 on exit gradient at downstream. pile

5. CONCLUSION

Of the studied cases, we can conclude that

- To comparison between no pile and two pile the result of two pile is
  - The uplift pressure decreased 8.36% at pile No.1 and increased 11.66% at pile No.2
  - Quantity of seepage reduced 66.8%
  - Exit gradient reduced 28.28%
- Increased distance between sheet piles
  - The uplift pressure at pile No.1 upstream decreased 5.43%and pile no.3 at downstream increased 10.7%
  - Quantity of seepage no effect stay constant
  - Exit gradient no effect stay constant
- Increased depth sheet pile no.1 at upstream
  - The uplift pressure at pile no.1 upstream decreased 33.59%, pile no.2 form upstream side decreased 25.53%, downstream side decreased 23.89% and pile no.3 at downstream decreased 21.52%.
  - Quantity of seepage decreased 29.6%
  - Exit gradient decreased 30.38%
- Increased depth sheet pile no.2 at intermediate

- The uplift pressure at pile no.1 upstream increased 5.06%, pile no.2 form upstream side increased 15.65%, downstream side decreased 12.2% and pile no.3 at downstream decreased 9.56%.
- Quantity of seepage no effect stay constant from (2-8) m depth and decreased 14.98% when the depth more than (8m).
- Exit gradient decreased 12.68%

- Increased depth sheet pile no.3 at downstream

- The uplift pressure at pile no.1 upstream increased 13.17% , pile no.2 form upstream side increased 23.92% , downstream side increased 34.84% and pile no.3 at downstream increased 88.08%.
- Quantity of seepage decreased 29.86%
- Exit gradient decreased 42.5%

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