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Effect of Two Sheet Piles In Double Soil Layers on Seepage Properties Under Hydraulic Structure Using SEEP/W Program

Asmaa Abdul Jabbar Jamel
Civil Engineering Dep., Tikrit University, Iraq
en_assmaa@yahoo.com

Abstract:

This paper is intended to study the effect of using upstream and downstream sheet pile in double soil layer on the seepage, uplift pressure exit gradient at toe of hydraulic structure using computer program SEEP/W software.

Depended on the software program tests were carried out with three different value of each following parameter: upstream sheet pile depth, downstream sheet pile depth, permeability for first and second soil layer, depth of first and second soil layer, with using constant upstream head and distance between the two sheet pile. For each test the quantity of seepage, exit gradient and uplift pressure at toe of hydraulics structure were determined. Based on the results of these runs an empirical equations developed to determine the quantity of seepage, uplift pressure and exit gradient at toe of hydraulic structure by using SPSS software. Also, Verify the SEEP/W results and the suggested equations with artificial neural network (ANN). The verification show difference less than 5% , 2% and 6% for exit gradient, discharge and uplift pressure respectively at toe of hydraulic structure.

Keywords: Up lift pressure, Exit gradient**,** Discharge, Seepage, SEEP/W, ANN, SPSS.

Nomenclature

q = Discharge (L^3/T/L).
P= uplift pressure head (L)
i= exit gradient (L/L)
B = distance between two sheet pile (L).
H = Upstream head (L).
k = Hydraulic conductivity of soil (L/T).
d_1 = depth of first sheet pile (L).
d_2 = depth of second sheet pile (L).
S_1 = depth of first soil layer (L).
S_2 = depth of second soil layer (L).

I. Introduction

The hydraulic engineer should prudently design the hydraulic structures such that it can do its purpose safely. The most critical feature of the design of such structures is the design concerning its foundation. Many failures had been stated in works due to either foundation failure or due to general stability of the structure. The most critical features that the designer should take into account are the failure due to uplift pressure and / or piping phenomenon at the toe of the structure.

Najm and Hala[1], studied experimentally the pizometric head distribution under hydraulic structures by determining the flow net in order to analyses seepage flow through single-layer soil foundation underneath hydraulic structure. Also, they studied the importance of the cut-off inclination angle on exit gradient, factor of safety, uplift pressure and quantity of seepage by using seepage tank were designed in the laboratory with proper dimensions with two cutoffs.

Behnam et al.[2], studied the effect of location and angle of cutoff Wall on uplift pressure in diversion dam by comparing the efficiency of cutoff wall on some design parameters in an assumed diversion dam cross-section.

Khalili and Amiri[3], studied the effects of blanket, drains and cutoff wall on reducing uplift pressure, seepage, and exit gradient under hydraulic structures for different inclined angles of cutoff walls, lengths of upstream blankets and various positions of drains within the simulation mathematical model.

Olsen et al.[4]،used the representative elementary volume to improve the calculation of exit gradients in seepage evaluations by supporting this suggestion using results from finite element modeling, preliminary results from physical model testing, and a compilation of existing research results.

Karim[5], studied seepage analysis through and under hydraulic structures applying finite volume method by studying the effect of heterogeneous foundations on the uplift pressure and exit gradients at the downstream and comparison with homogenous foundations. Also it studied the evaluation of effect of position and inclination of cut-offs at upstream or downstream of structures and the effect of impervious body inside the structure or foundation on uplift pressure and exit gradients at downstream.

Tokaldany and Shayan[6], studied the uplift force, seepage, and exit gradient under diversion dams, by carrying out a set of experiments on a laboratory model, and based on the finite-element method, a set of graphs is presented to estimate the exit gradient in different conditions with the presence of a cutoff wall at the downstream end or without any cutoff wall.

Imad[7], studied the effect of position and inclination angle of cutoff wall on seepage control in the foundation of dam structure by computer program using FORTRAN 90, and determine the pressure head at nodal points, the exit gradients and the seepage discharge behind inclined cutoff walls.

Salim et al.[8], studied the effect of weep hole and cut-off in decreasing of uplift pressure and exit gradient (Case Study: Yusefkand Mahabad Diversion Dam) by simulation it in Seep/W software. The diversion dams designed by minim concrete costs and hence become economical design.

Abbas[9], obtained an analytical solution for seepage flow below a dam structure with inclined cutoff located anywhere along the base of the dam. The equations derived have been used for computation of hydraulic gradient along the downstream bed and for the pressure at key points.

Ashraf and Azza [10], studied the effect of sheet pile configuration on seepage beneath hydraulic structures, the uplift force on downstream apron of floor and the exit gradient at the end toe of the apron by using the finite element method and based on the fixed mesh approach which was used to locate the free surface of water.

Saleh et al.[11], studied the distribution underneath diyala weir foundation and the effect of removing one of the three sheet piles rows on the quantity of seepage, uplift pressure and expected exit hydraulic gradient by using SEEP/W finite element package.

Cheleng and Sahar[12], used experimental and theoretical study for pizometric head distribution under hydraulic structures for upstream, intermediate and downstream sheet piles inclination.

Senda [13], developed an analytical model for one-dimensional transient flow in a confined aquifer under a levee in response to river stage fluctuations using SEEP2D finite element program.

Phanuwat and Pachern [14], normalized graphs for seepage analyses along single sheet pile in double soil layers seepage by using finite element program called SEEP/W.

Adel and Mohamed [15], studied the characteristics of seepage and exit gradient underneath a heading-up structure and a subsidiary one.

For this study in order to provide the required factor safety against both uplift pressure and piping due to exit gradient provide the foundation of the hydraulic structures with sheet pile at the upstream and the downstream sides of it in double soil layer, depend on software program SEEP/W results, and using software program SPSS-19 Statistics, equations will provide information on the amount of seepage running downstream the hydraulic structure, uplift pressure at toe of hydraulics structure and exit gradient. Also verification for these results done using artificial neural network (ANN).

II. Procedure Setup

For the purpose of running SEEP/W model tests, using three different values for each variable affect on the seepage properties in double soil layer, which are Upstream sheet pile depth (first sheet pile) (d_1= 2.5, 4.5 and 5.5)m, downstream sheet pile depth (second sheet pile) (d_2=2, 2.5 and 4.5)m, depth of first soil layer (S_1=3, 3.5and 4)m, depth of second soil layer (S_2=3.5, 4.5 and 5.5)m, permeability of first soil layer ($K_1=10^{-2}, 10^{-3}$ and 10^{-4}) m/sec and permeability of second soil ($K_2=10^{-5}$, 10^{-6} and 10^{-7}) m/sec, for constant upstream head (6m) and distance between sheet piles (25m). The overall runs are (729) runs. For each run the amount of the seepage discharge at toe of hydraulic structure, exit gradient and uplift pressure at toe of hydraulic structure are determined. The figure (1) show designation for a sample group when (d_1=2.5m), which it's the same producer for second and third groups by changing the value of (d_1=4.5m) and (d_1=5.5m) respectively, and for each group using the different value of (S_1) and (S_2) by sequence. The value of the depth of first and second sheet pile taken to be in three cases:

First case $d_1 \& d_2 < S_1$ [which mean the two sheet pile not extend to the second soil layer (S_2)]. Second case $d_1 > S_1, d_2 < S_1$ [which mean only first sheet pile extend to the second soil layer (S_2)]. Third case $d_1 \& d_2 > S_1$ [which mean the two sheet pile extend to the second soil layer (S_2)].

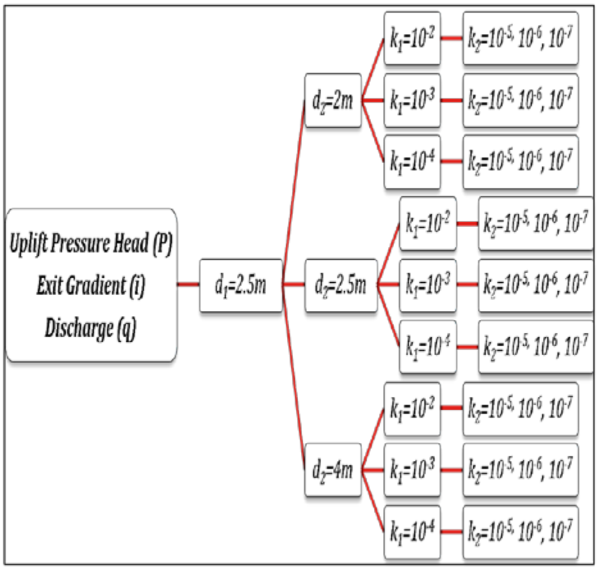

Figure 1. The tests for first group (d_1=2.5)m,(H=6)m , (S_1=3)m, (S_2=3.5)m, (b=25)m overall first group test (243) run.

III. Experimental Parameter

The variation of uplift pressure under the hydraulic structure, discharge at toe of hydraulic structure and the exit gradient were investigated depending on the parameters shown in equations (1), (2) and (3) respectively.

$$P = f(d_1, d_2, S_1, S_2, K_1, K_2, H, b) \quad \ldots (1)$$

$$q = f(d_1, d_2, S_1, S_2, K_1, K_2, H, b) \quad \ldots (2)$$

$$i = f(d_1, d_2, S_1, S_2, K_1, K_2, H, b) \quad \ldots (3)$$

In order to develop empirical equations to determine the uplift pressure and discharge at the toe of hydraulic structure and the exit gradient downstream of the structure to the above equations can be rewrite as shown below:

$$P = f\left(\frac{d_1}{d_2}, \frac{S_1}{S_2}, K_1, K_2, H, b\right) \quad \ldots (4)$$

$$q = f\left(\frac{d_1}{d_2}, \frac{S_1}{S_2}, K_1, K_2, H, b\right) \quad \ldots (5)$$

$$i = f\left(\frac{d_1}{d_2}, \frac{S_1}{S_2}, K_1, K_2, H, b\right) \quad \ldots (6)$$

Figure (2) shows the possible variables that can be affect on uplift pressure at toe of hydraulic structure, discharge at downstream of hydraulic structure and the exit gradient for the three different cases $(d_1 \& d_2 < S_1)$,$(d_1 > S_1, d_2 < S_1)$, $(d_1 \& d_2 > S_1)$.

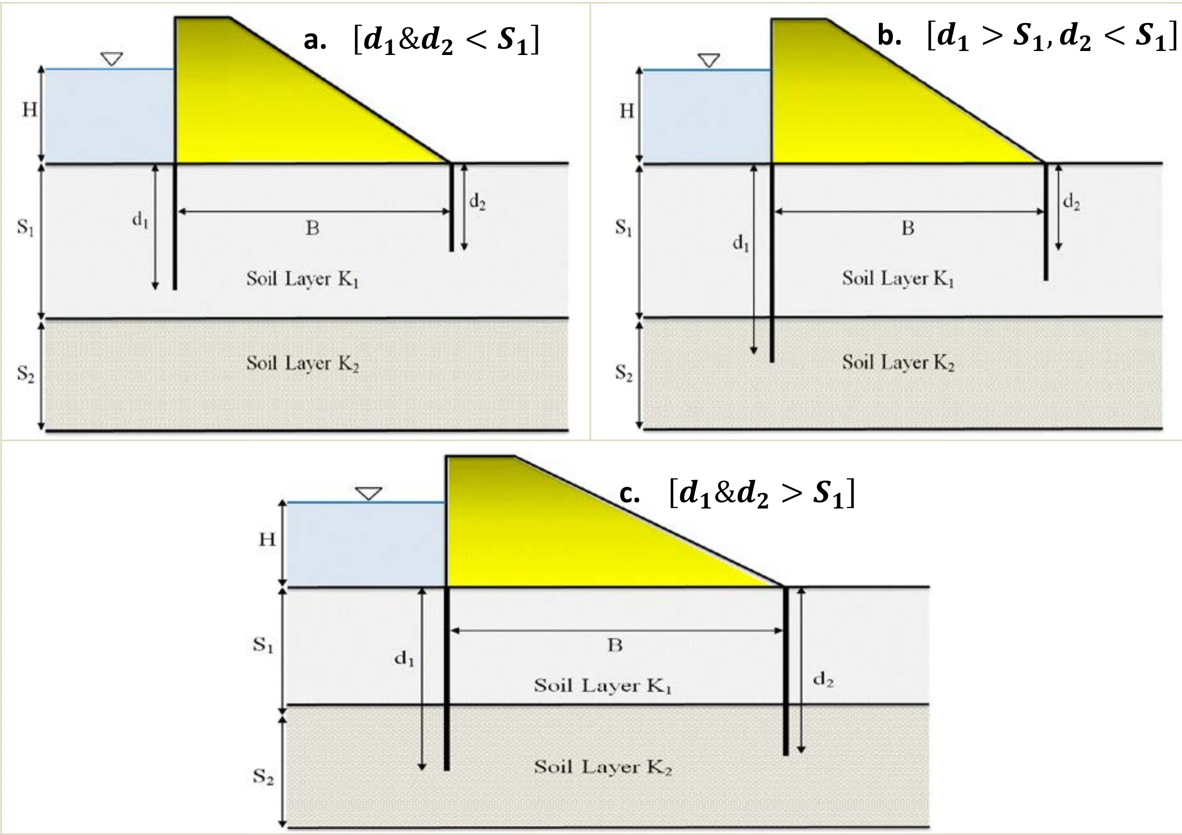

Figure 2: The general section of double sheet pile in double soil layer

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IV. Results and Discussion

I. Relations Between The Variables

Figure (5) shows the relationship between the depth of first layer of soil to the second layer of soil (S_1/S_2) with the discharge exit downstream hydraulic structure (q) with boundary conditions of constant depth of first and last sheet pile (d_1, d_2) respectively, depth of first soil layer (S_1), with three different permeability for the first and second soil layer (K_1,K_2) respectively. From this figure it can be shown that the discharge decrees with increasing (S_1/S_2) which mean at constant (S_1) the discharge increases with increasing (S_2), the discharge increases by approximately (8.4%) when increases (S_2) from (3.5m) to (4.5m), and increases by approximately (5.6%) when increases (S_2) from (4.5m) to (5.5m) in most cases where (d_1) or (d_2) extend to the second soil layer (S_2), and increases by approximately (0.012%) in most cases where (d_1) and (d_2) not extend to the second soil layer (S_2), Also, the figure show that the discharge increases with increasing the soil permeability for the two soil layer which increase approximate about (89%) when increases the permeability (10^{-1} m/sec).

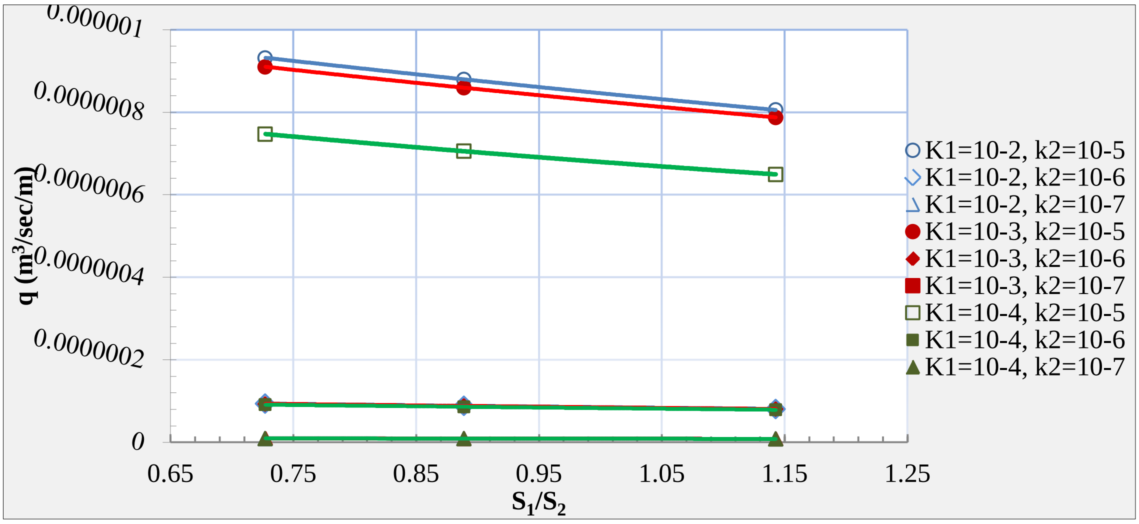

Figure 5: Relationship between (q) and (S_1/S_2) at d_1=5.5m , d_2=4.5m and S_1=4m

. Figure (6) shows the relationship between the depth of first sheet pile to the depth of second sheet pile (d_1/d_2) against the discharge exit downstream hydraulic structure (q) with boundary conditions of constant depth of first and second soil layer (S_1, S_2) respectively, depth of first sheet pile (d_1), with three different permeability for the first and second soil layer (K_1,K_2) respectively.

From this figure it can be shown that the discharge decreases with decreasing (d_1/d_2) which mean at constant (d_1) the discharge decreases with increasing (d_2), the discharge decreases by approximately (5.6%) when increases (d_2) from (2m) to (2.5m), and decreases by approximately (60.5%) when increases (d_2) from (2.5m) to (4.5m) in most cases. Also, the figure show that the discharge increases with increasing the soil permeability for the two soil layer which increase approximate about (89%) when increases the permeability (10^{-1} m/sec).

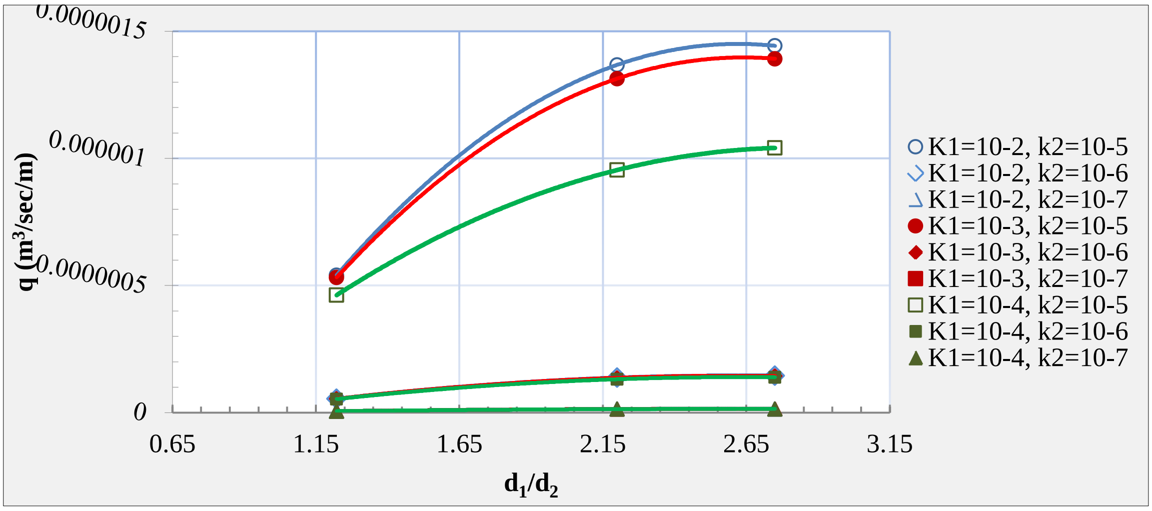

Figure 6: Relationship between (q) and (d_1/d_2) at S_1=3m , S_2=3.5m and d_1=5.5m.

Figure (7) shows the relationship between the depth of first layer of soil to the second layer of soil (S_1/S_2) with the discharge exit downstream hydraulic structure (q) with boundary conditions of constant depth of first and last sheet pile (d_1, d_2) respectively, with three different depth of second layer of soil (S_2). From this figure it can be shown that the discharge increase with increasing (S_1/S_2) which mean at constant (S_2) the discharge increases with increasing (S_1), the discharge increases by approximately (15.4%) when increases (S_1) in most cases.

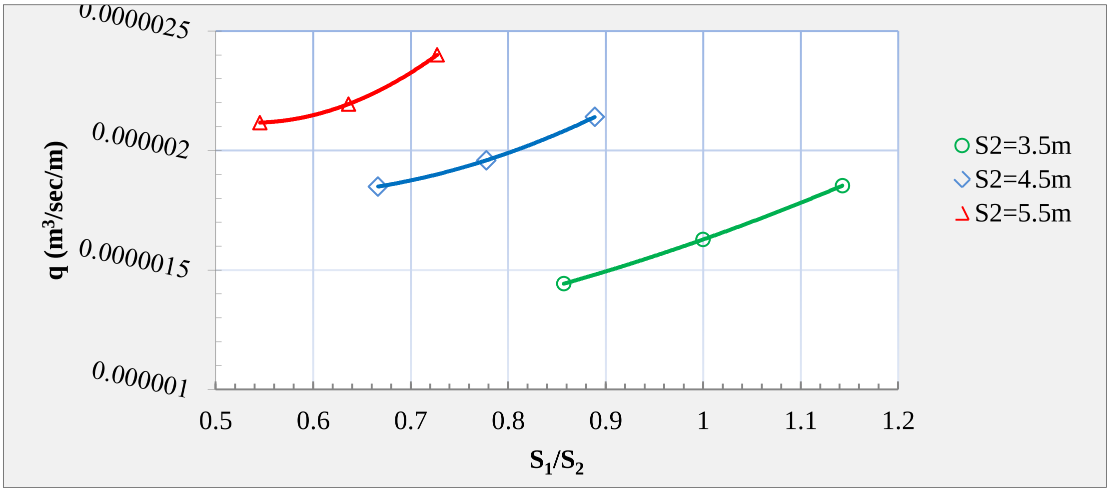

Figure 7: Relationship between (q) and (S_1/S_2) at d_1=5.5m , d_2=2m.

Figure (8)) shows the relationship between the depth of first layer of soil to the second layer of soil (S_1/S_2) with the uplift pressure under hydraulic structure (P) with boundary conditions of constant depth of first and last sheet pile (d_1, d_2) respectively, depth of first soil layer (S_1), with three different permeability for the first and second soil layer (K_1,K_2) respectively. From this figure it can be shown that the uplift pressure decrees with increasing (S_1/S_2) which mean at constant (S_1) the uplift pressure increases with increasing (S_2), the uplift pressure increases by approximately (3.5%) when increases (S_2) from (3.5m) to (4.5m), and increases by approximately (2%) when increases (S_2) from (4.5m) to (5.5m) in most cases where (d_1) and (d_2) extend to the second soil layer (S_2), increases by approximately (8.5%) in most cases where only (d_1) extend to the second soil layer (S_2), and increases by approximately (0.008%) in most cases where (d_1) and (d_2) not extend to the second soil layer (S_2), Also, the figure show that the uplift pressure increases with increasing the soil permeability for the two soil layer.

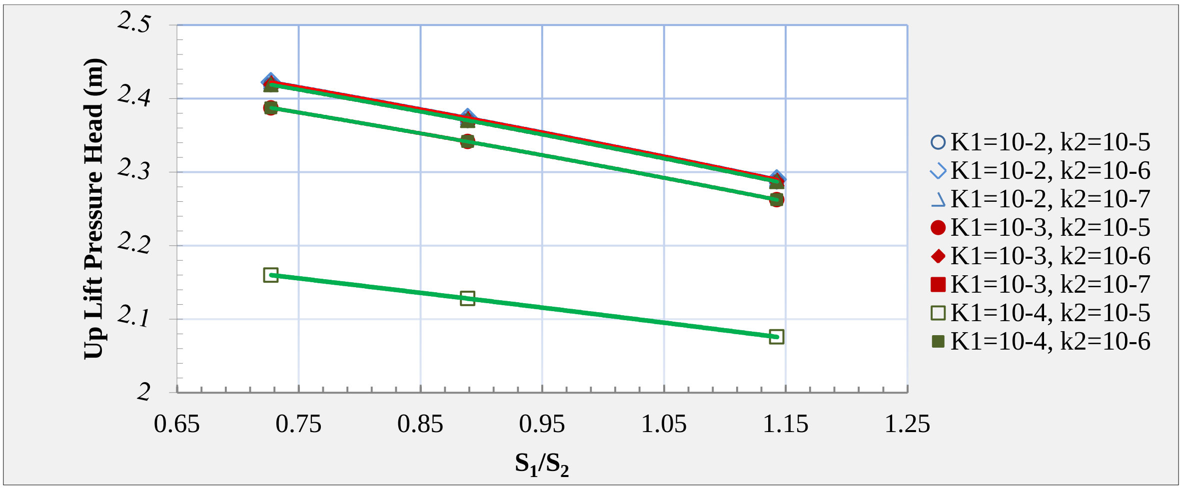

Figure 8: Relationship between Uplift pressure (P) and (S_1/S_2) at d_1=5.5m , d_2=4.5m and S_1=4m.

Figure (9) shows the relationship between the depth of first sheet pile to the depth of second sheet pile (d_1/d_2) with the uplift pressure under hydraulic structure (P) with boundary conditions of constant depth of first and second soil layer (S_1, S_2) respectively, depth of first sheet pile (d_1), with three different permeability for the first and second soil layer (K_1,K_2) respectively. From this figure it can be shown that the uplift pressure decrees with increasing (d_1/d_2) which mean at constant (d_1) the uplift pressure increases with increasing (d_2), the uplift pressure increases by approximately (30.8%) when increases (d_2) from (2m) to (2.5m), and increases by approximately (90%) when increases (d_2) from (2.5m) to (4.5m) in most cases.

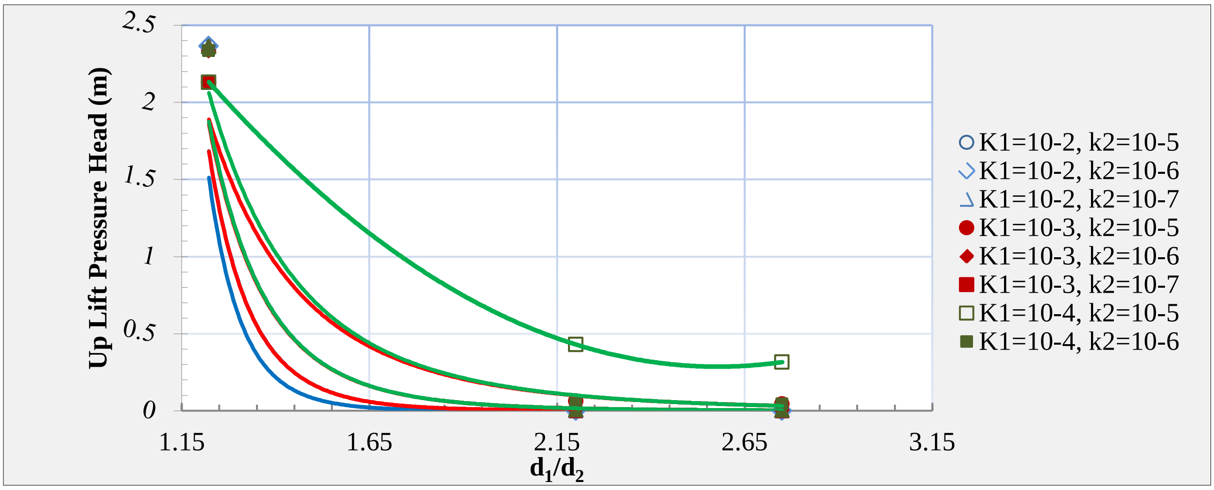

Figure 9: Relationship between uplift pressure (P) and (d_1/d_2) at S_1=3m , S_2=3.5m and d_1=5.5m

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Figure (10) shows the relationship between the depth of first layer of soil to the second layer of soil (S_1/S_2) with the uplift pressure under hydraulic structure (P) with boundary conditions of constant depth of first and last sheet pile (d_1, d_2) respectively, with three different depth of second layer of soil (S_2). From this figure it can be shown that the uplift pressure increase with increasing (S_1/S_2) which mean at constant (S_2) the uplift pressure increases with increasing (S_1).

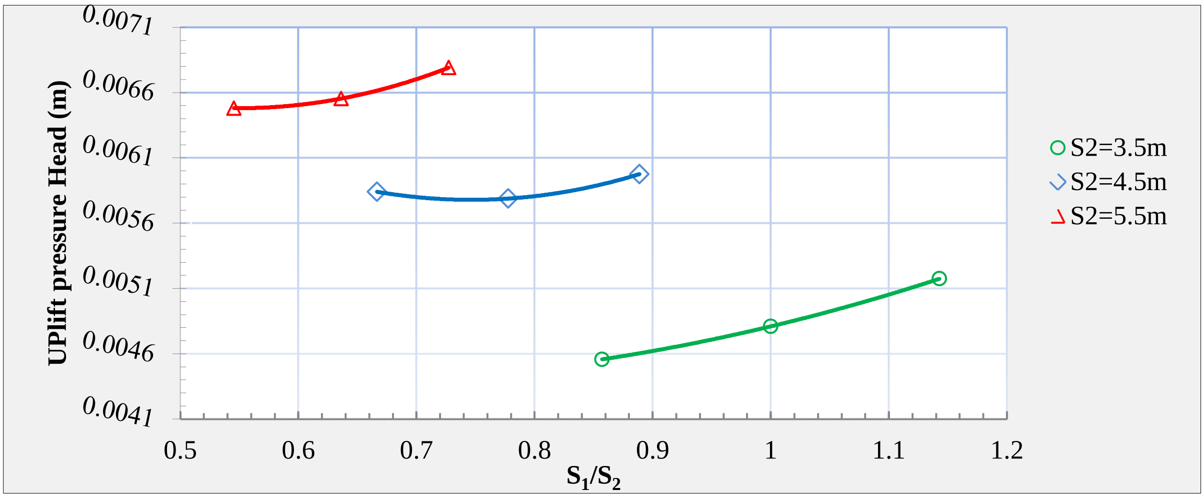

Figure 10: Relationship between (uplift pressure) and (S_1/S_2) at d_1=5.5m , d_2=2m.

Figure (11) shows (semi-log) relationship between the depth of first layer of soil to the second layer of soil (S_1/S_2) with the exit gradient (i) with boundary conditions of constant depth of first and last sheet pile (d_1, d_2) respectively, depth of first soil layer (S_1), with three different permeability for the first and second soil layer (K_1,K_2) respectively. From this figure it can be shown that the exit gradient decreases with increasing (S_1/S_2) which mean at constant (S_1) the exit gradient increases with increasing (S_2). The exit gradient increases by approximately (8.3%) when increases (S_2) from (3.5m) to (4.5m), and increasing by approximately (2%) when increases (S_2) from (4.5m) to (5.5m) in most cases where (d_1) and (d_2) extend to the second soil layer (S_2). Also the exit gradient increasing by approximately (0.011%) in most cases where (d_1) and (d_2) not extend to the second soil layer (S_2) and increases by approximately (8.5%) in most cases where only (d_1) extend to the second soil layer (S_2). Also, the figure show that the exit gradient increases with decreasing the soil permeability for the second soil layer (K_2) and increasing first soil layer permeability (K_1).

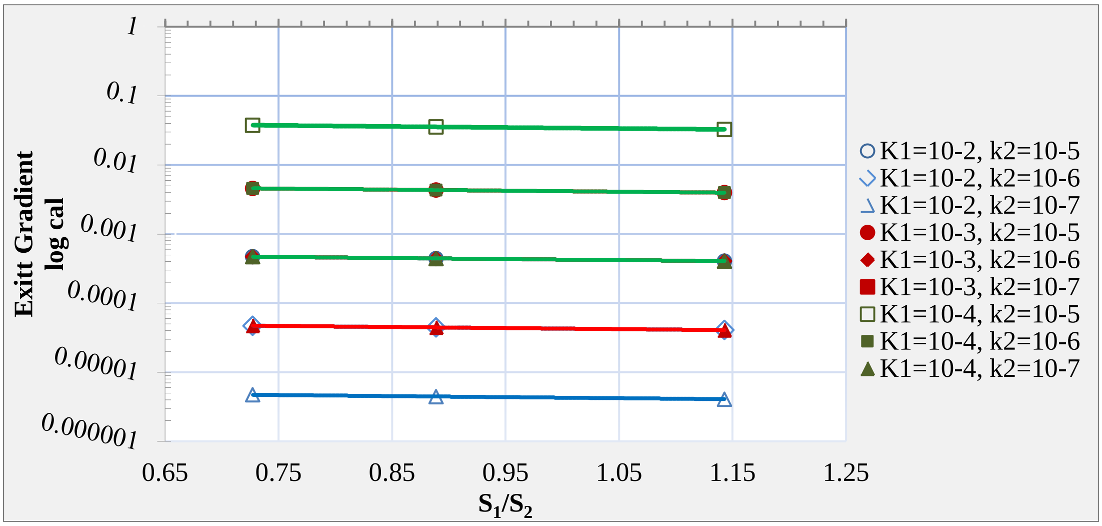

Figure 11: Relationship between Exit Gradient (i) and (S_1/S_2) at d_1=5.5m, d_2=4.5m and S_1=4m.

Figure (12) shows (semi-log) relationship between the depth of first sheet pile to the depth of second sheet pile (d_1/d_2) with the exit gradient (i) with boundary conditions of constant depth of first and second soil layer (S_1, S_2) respectively, depth of first sheet pile (d_1), with three different permeability for the first and second soil layer (K_1,K_2) respectively. From this figure it can be shown that the exit gradient increase with increasing (d_1/d_2) which mean at constant (d_1) the exit gradient decreases with increasing (d_2), the exit gradient decreases by approximately (5.5%) when increases (d_2) from (2m) to (2.5m), and decreases by approximately (90%) when increases (d_2) from (2.5m) to (4.5m) in most cases. Also, the figure show that the exit gradient increases with decreasing the soil permeability for the second soil layer (K_2) and increasing first soil layer permeability (K_1).

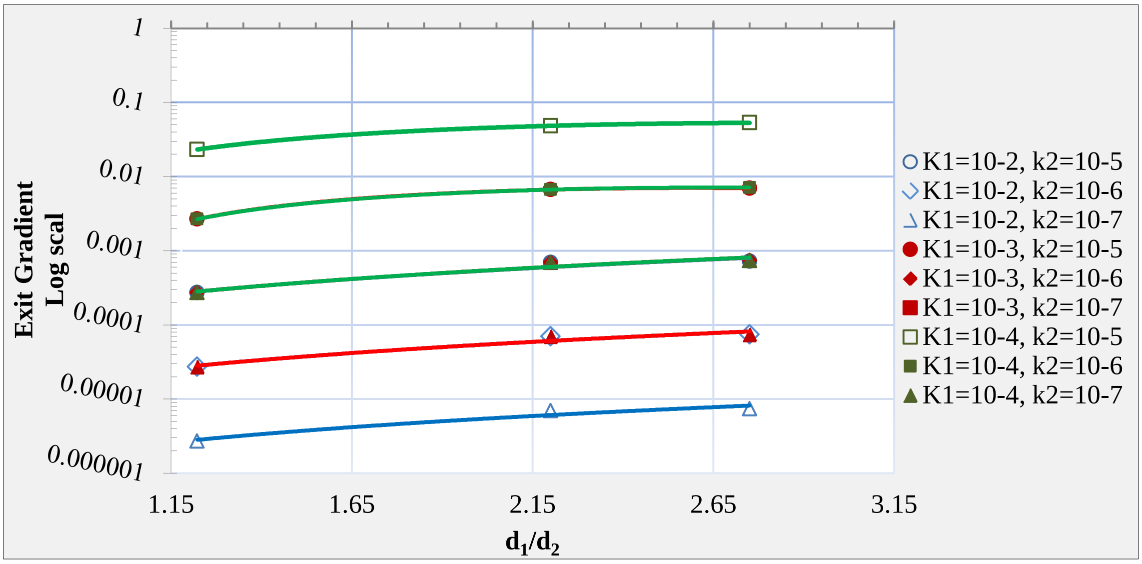

Figure 12: Relationship between exit gradient (i) and (d_1/d_2) at S_1=3m , S_2=3.5m and d_1=5.5m.

Figure (13) shows the relationship between the depth of first layer of soil to the second layer of soil (S_1/S_2) with the exit gradient (i) with boundary conditions of constant depth of first and last sheet pile (d_1, d_2) respectively, with three different depth of second layer of soil (S_2). From this figure it can be shown that the exit gradient increases with increasing (S_1/S_2) which mean at constant (S_2) the exit gradient increases with increasing (S_1).

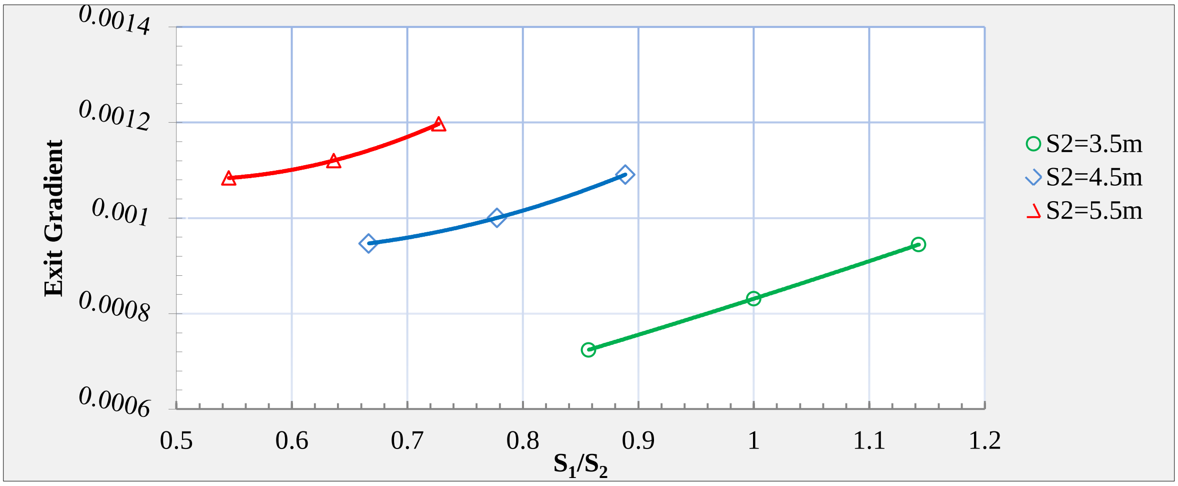

Figure 13: Relationship between exit gradient (i) and (S_1/S_2) at d_1=5.5m , d_2=2m.

V. Equations for Computing the Discharge Exit gradient and Uplift pressure head, at toe of hydraulic structure.

By substituting approximately two thirds of the SEEP/W results in software program SPSS-19 Statistics to develop equations used to determine the quantity of seepage and uplift pressure at toe of hydraulic structure, and exit gradient.

$$q = \frac{0.049\ S_1^{0.611}\ S_2^{0.00024923}\ K_1^{0.999}\ K_2^{0.00015547}\ H^{2.187}\ b^{1.308}}{d_1^{9.705}\ d_2^{0.497}}$$

(R^2=1) … (7)

$$i = \frac{0.136 S_1^{0.576}\ S_2^{0.012}\ K_2^{0.009}\ H^{0.89}\ b^{0.74}}{d_1^{4.348}\ d_2^{0.551}\ K_1^{0.009}}$$

(R^2=0.947) … (8)

$$P = \frac{1.313\ d_2^{3.097}\ S_1^{0.016}\ S_2^{0.112}\ H^{0.347}\ b^{0.716}}{d_1^{1.662}\ K_1^{0.00003994}\ K_2^{0.013}}$$

(R^2=0.932) … (9)

The remain one third of results used to verify the equations, figures (14, 15, 16) shows the comparison between the remaining data of the discharge, exit gradient and uplift pressure respectively by SEEP/W and those that which calculated from the equations (7, 8 and 9) at the same characteristics and geometry boundary conditions. The figures below show good agreement between the calculated discharge, exit gradient and uplift pressure from the equations (7, 8 and 9) respectively and those from SEEP/W model.

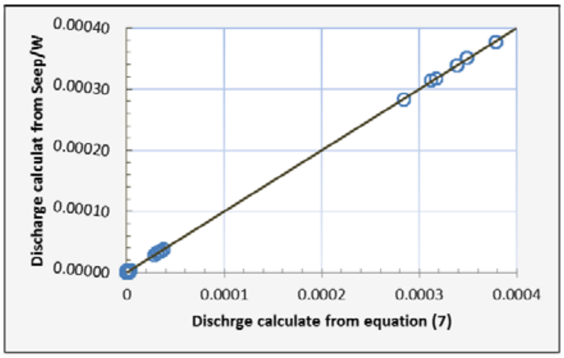

Figure 14: Comparison between the calculated discharge from the equation (7) and those from SEEP/W model.

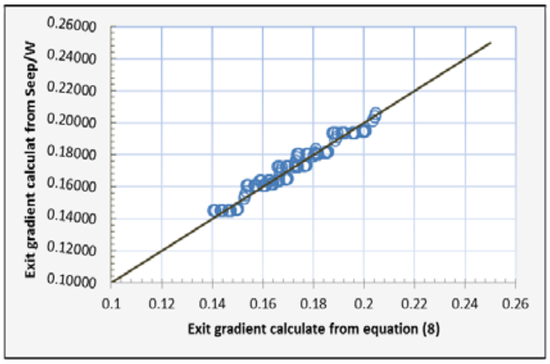

Figure 15: Comparison between the calculated exit gradient from the equation (8) and measuring from SEEP/W model.

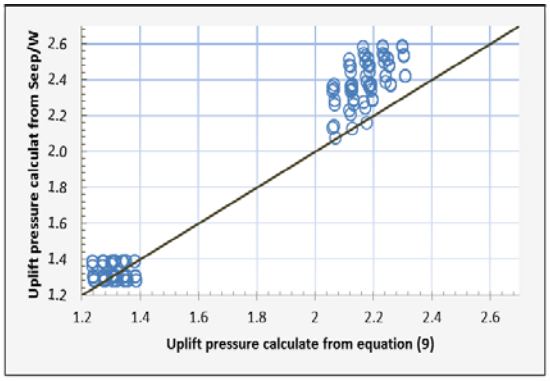

Figure 16: Comparison between the calculated uplift pressure from the equation (9) and measuring from SEEP/W model.

VI. Verification of SEEP/W and Suggested Equations

ANN is composed of a number of interconnected simple processing elements called neurons or nodes with the attractive attribute of information processing characteristics such as nonlinearity, parallelism, noise tolerance, and learning and generalization capability.[16]

After trials several ANN architectures were made a Multilayer Perceptron (MLP), ANN model with one hidden layers was used due to its accurate results compared to others.

(Figure 17) shows good agreement between SEEP/W, equations (7, 8, 9) and ANN (MLP) results.

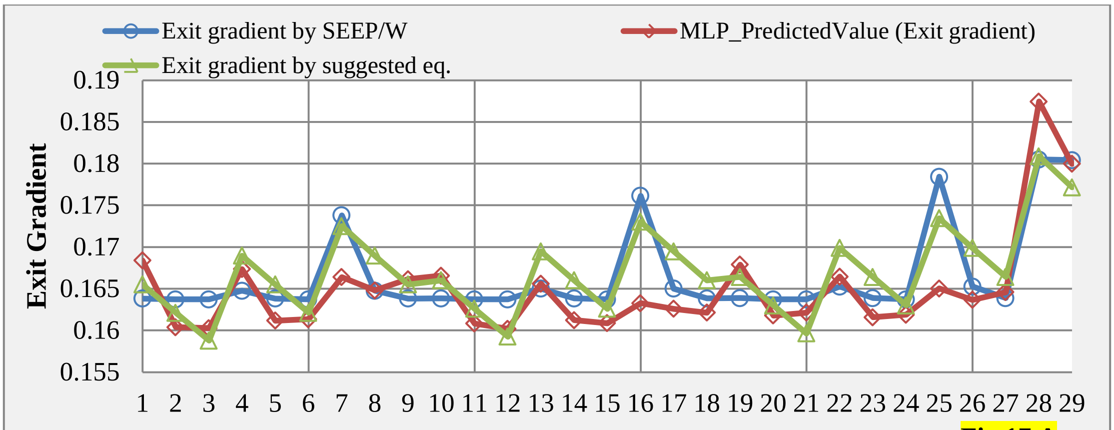

Fig 17.A

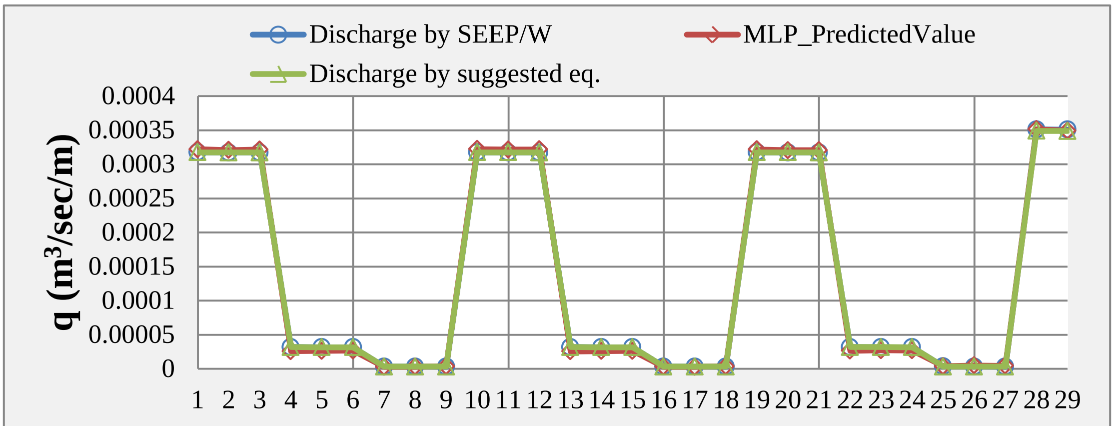

Fig 17.B

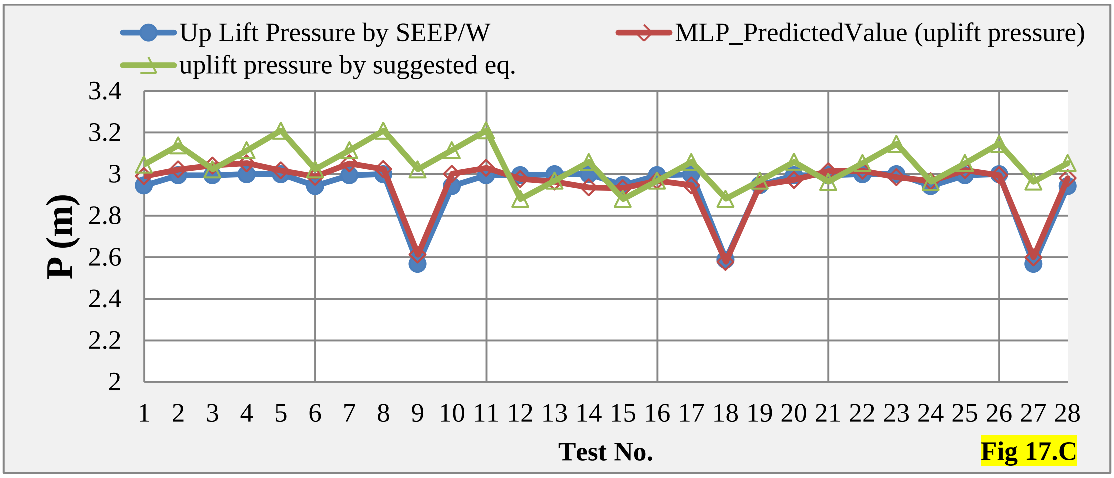

Figure 17: Comparison between the calculated exit gradient, discharge and uplift pressure for randomly tests with different method.

Also, by compare the suggested equations with ANN its show difference most tests less than 5%, 2% and 6% for discharge, exit gradient, and uplift pressure respectively.

VI. Conclusions

In this paper, the SEEP/W model was used to simulate the seepage discharge, uplift pressure and exit gradient at toe of hydraulic structure with double sheet pile in double soil layers. It was found for seepage discharge that:

1. discharge increases with increasing (S_2) by approximately (8.4%) when increases (S_2) from (3.5m) to (4.5m), and (5.6%) when increases (S_2) from (4.5m) to (5.5m) in most cases where (d_1) or (d_2) extend to the second soil layer (S_2). Also increases by approximately (0.012%) when (d_1) and (d_2) not extend to the second soil layer (S_2). The discharge increases approximate about (89%) when increases the permeability (10^{-1} m/sec).
2. the discharge decreases with increasing (d_2), by approximately (5.6%) when increases (d_2) from (2m) to (2.5m), and (60.5%) when increases (d_2) from (2.5m) to (4.5m) in most cases.
3. The discharge increases with increasing (S_1), by approximately (15.4%).

Also results for uplift pressure at toe of hydraulic structure show:

1. The uplift pressure increases with increasing (S_2), by approximately (3.5%) when increases (S_2) from (3.5m) to (4.5m), and increases by approximately (2%) when increases (S_2) from (4.5m) to (5.5m) in most cases where (d_1) and (d_2) extend to the second soil layer (S_2). Also increases by approximately (8.5%) when only (d_1) extend to the second soil layer (S_2), and increases by approximately (0.008%) when increases in most cases where (d_1) and (d_2) not extend to the second soil layer (S_2), Also, the uplift pressure increases with increasing the soil permeability for the two soil layer.
2. Uplift pressure increases with increasing (d_2), by approximately (30.8%) when increases (d_2) from (2m) to (2.5m), and increases by approximately (90%) when increases (d_2) from (2.5m) to (4.5m) in most cases.
3. The uplift pressure increases with increasing (S_1).

And for exit gradient at toe of hydraulic structure results show:

1. The exit gradient increases with increasing (S_2 by approximately (8.3%) when increases (S_2) from (3.5m) to (4.5m), and increases by approximately (2%) when increases (S_2) from (4.5m) to (5.5m) in most cases where (d_1) and (d_2) extend to the second soil layer (S_2). Also increases by approximately (0.011%) when (d_1) and (d_2) not extend to the second soil layer (S_2). And increases by approximately (8.5%) in most cases where only (d_1) extend to the second soil layer (S_2), Also, the exit gradient increases with decreasing the soil permeability for the second soil layer (K_2) and increasing first soil layer permeability (K_1).
2. Exit gradient decreases with increasing (d_2) by approximately (5.5%) when increases (d_2) from (2m) to (2.5m), and decreases by approximately (90%) when increases (d_2) from (2.5m) to (4.5m) in most cases. Also, the exit gradient increases with decreasing the soil permeability for the second soil layer (K_2) and increasing first soil layer permeability (K_1).
3. The exit gradient increases with increasing (S_1).

Depended on the SEEP/W results equations are to determine the seepage discharge, uplift pressure and exit gradient at toe of hydraulic structure for two sheet pile in double soil layer.

Also verifying the suggested equations with ANN showing difference most tests less than 5%, 2% and 6% for discharge, exit gradient, and uplift pressure respectively.

VII. Example

Two soil layers as shown in (Figure 2) which have hydraulic conductivity: (1.5×10^{-3} and 1.5×10^{-6}) m/sec for first and second soil layer respectively, depth of sheet piles were (3.5, 2.5)m for upstream and downstream pile respectively, thickness for first layer (3.5m) and (4m) for second layer. The upstream head is (5m), the distance between the two sheet pile (26m). What will be the quantity of seepage and uplift pressure head at toe of hydraulic structure, and exit gradient.

Given: $K_1= 1.5\times10^{-3}$m/sec, $K_2=1.5\times10^{-6}$m/sec, $d_1=3.5$m, $d_2=2.5$m, $S_1=3.5$m, $S_2=4$m, H=5m, b=26m.

Solution: by using equation (7),

$$q = 1.26549\times 10^{-6}\, {}^{\frac{m^3}{sec}}\!\!/_{m}\ (Ans.)$$

from equation (8), $i = 0.03247 (Ans.)$

from equation (9) $P = 0.6727m\ (Ans.)$

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تأثير استخدام ركيزتين بتربه ذات طبقتين على خصائص التسرب تحت المنشأ الهيدروليكي باستخدام برنامج SEEP/W

أسماء عبد الجبار جميل
جامعة تكريت، كلية الهندسة ، قسم الهندسة المدنية

الخلاصة:

يهدف هذا البحث لدراسة تأثير استخدام ركيزة في مقدمه ومؤخره المنشأ بتربه ذات طبقتين على قيم التسرب وضغط الاصعاد وتدرج المخرج عند مؤخر المنشأ الهيدروليكي باستخدام البرنامج الحاسوبي ***SEEP/W***.
بالاعتماد على تجارب ***SEEP/W*** تم اجراء تجارب بثلاث قيم متغيره لكل عامل من العوامل التالية وهي عمق ركيزة المقدم وعمق ركيزة المؤخر ونفاذية التربة للطبقة الاولى ونفاذية التربة للطبقة الثانية وعمق الطبقة الأولى للتربة وعمق الطبقة الثانية للتربة وذلك عند قيمه ثابته لارتفاع الماء في مقدم المنشأ والمسافة بين الركيزتين. لكل تجربه تم ايجاد قيمة التصريف وضغط الاصعاد وتدرج المخرج في مؤخر المنشأ الهيدروليكي. وبالاعتماد على هذه النتائج تم ايجاد معادلات وضعيه لقيم التصريف وضغط الاصعاد وتدرج المخرج عند مؤخر المنشأ. كما تم التحقق من النتائج المتحصلة ببرنامج ***SEEP/W*** والمعادلات المقترحة عن طريق استخدام الشبكة الصناعية العصبية ***(ANN)*** والتي من خلالها استحصل مقدار التغير بالنتائج اقل من 5% لنتائج تدرج المخرج واقل من 2% لنتائج التصريف و اقل من 6% لنتائج ضغط الاصعاد عند مؤخر المنشأ.