International Journal of Engineering & Technology, 7 (4.20) (2018) 95-102

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper



Numerical Analysis to Assess the Vertical Drainage Within Flexible Pavement.

[1]Aqeel Al-Adili*, [2]Rasha H. Abdul-Amir, [3]Osamah Hassan Chfat

[1]University of Technology, Baghdad , IRAQ
[2] University of Tchnology, Baghdad, IRAQ
[3]University of Al-Qadisiyah, Al-Diwanyah, IRAQ
**Corresponding author E-mail: aqeeladili@hotmail.com*

Abstract

In this research the work methodology include the software program SEEP/W routine of the GEOSLOPE 2012; which was used to simulate and analyze the vertical drainage of the pavement cross section using steady-state and transient analysis. A laboratory model consisting of typical structure layers of flexible pavement was considered in this research with a 2% slope with the influence of three different rain intensities (30mm/min, 60mm/min and 90mm/min); in which each one has a duration differs from the other. The results indicated that the value of the pore-water pressure in the surface layer resulting from 90 mm/min rainfall intensity is 83.65% greater than the pressure generated by the 60mm/min intensity of rain and 91.076% greater than the pressure produced from 30mm/min intensity. The average of accumulation water produced by the 30mm/min rainfall intensity in the pavement structure is 44.73 % greater than the average of accumulation of water from the 60mm/min intensity and 77.85% higher than the 90mm/min intensity of rain. The water flux through the pavement cross section during the rainy period of 30 mm/min was 8.42% higher than the water flux of 60 mm/min and 49.82% of the water flux of 90 mm/min intensity of rain.

Keywords: *Flexible pavement, modeling, rain intensity, pore water pressure, seepage.*

1. Introduction

Providing adequate drainage to a pavement system has been considered as an important design consideration to prevent premature failures due to water related problems such as pumping action, loss of support, and rutting, among others. Most water in pavements is due to rainfall infiltration into unsaturated pavement layers, through joints, cracks, shoulder edges, and various other defects, especially in older deteriorated pavements. Water also seep upward from a high groundwater table due to capillary suction or vapor movements, or it may flow laterally from the pavement edges and side ditches (Rokade et al., 2012) . Drainage quality is an important parameter which affects the highway pavement performance. The excessive water content in the pavement base, sub-base, and subgrade soils can cause early distress and lead to a structural or functional failure of pavement (TIZA, 2016). The aim of this research is to simulate and analyze the vertical drainage on flexible pavement cross section using steady-state and transient analysis by considering three different rain intensities (30, 60 and 90mm/min) and three different duration.

2. Methodology

2.1. Model dimension

In this research, the laboratory simulation model consist of steel container with external dimensions of 150 cm length, 80 cm width and 135 cm depth is adopted to simulate the pavement layers (subgrade, sub base, crushed gravel base, binder and asphalt surface layers) according to typical cross sections that which constructed by Ministry of Construction and Housing / State Corporation for Roads and Bridges.

2.2. Selection of rain intensity

For this work, three types of rainfall intensity were selected according to recent measurements of rainy years in Iraq; low intensity rain with 30mm/min., intermediate intensity rain with 60mm/min. and high intensity rain with 90mm/min. A long-term duration (90minutes) was used for low rainfall intensity. As for rainfall intensities with intermediate value and high value, middle-term (60minutes) and short-term (30minutes) duration of rain were used.

3. Seepage modeling with seep/w 2012

A numerical model is a mathematical simulation of a real physical process. SEEP/W is a numerical model that can mathematically simulate the real physical process of water flowing through a particulate medium. Numerical modelling is purely mathematical and in this sense is very different than scaled physical modelling in the laboratory or full-scaled field modelling.
Finite Element Analysis (FEA) is a numerical analysis technique for obtaining approximate solutions to many types of engineering problems. The need for numerical methods arises from the fact that for most practical engineering problems analytical solutions cannot be obtained. SEEP/W 2012 is a 2-D finite element software product that can be used to model the movement and pore-water pressure distribution within porous materials such as asphalt, soil and rock

Copyright © 2018 Authors. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

(Krahn, 2012). It can model both saturated and unsaturated flow, a feature that greatly broadens the range of problems that can be analyzed. SEEP/W includes three executable programs: DEFINE, for defining the model, SOLVE for solving the problem, and CONTOUR for presenting the results in a graphical form.

4. Materials properties

The properties of subgrade, sub base, crushed gravel base, binder and asphalt surface layers had to be determined as they were inputs to the finite element analysis. Table1 summarized the properties for these materials.

Table 1: Properties of the Materials which used as input data

Index Property	sub-grade layer	subbase layer	crushed gravel base layer	binder layer	Surface layer
Coeffi-cient of Permea-bility, K (cm/sec).	5.67E-6	1.98E-05	3.07E-04	26.39E-05	25.22E-05
poros-ity(%) n	30	34	36	--------	--------
Percent Air Voids (VA %).	--------	----------	---------	5.3%	4.9%
Volume of the air voids Va (cm^3).	--------	----------	---------	41.62	19.28

5. Analysis approach

The drainage analyses were conducted using the SEEP/W routine of the GEOSLOPE-2012 computer program. The finite element models in this study were developed based upon a steady-state and transient saturated flow assumption. The models have been used to determine the flow paths, seepage velocity and rate (water flux m^3/sec), cumulative water flux (m^3), through the cross-sectional area of the pavement.

When developing the finite element mesh, 246-node and 216 elements were used for all layers of the cross section of pavement. A constant water head of H = 1.3605m, 1.361m and1.3615m for 30mm/min, 60mm/min and 90mm/min rainfall intensity respectively, were applied on the surface of the pavement depending on the lab. Tests. Around the drainage channel, a constant head of H = 1.32m was applied. The boundary condition of this model has been also assumed that the both sides and bottom of the pavement were impermeable.

The profile of the layers, dimensions, and layer components are listed in Table 2. The cross slope of the pavement is simulated as 2 % (Bridges, 2005). Figure 1 illustrates the pavement profile, and Figure 2 shows finite element mesh and boundary conditions for 30mm/min intensity of rainfall.

Table 2: Pavement Profile Dimensions and Layer Components

Layer Materials	Layer Thickness(cm)
HMA Wearing	5
HMA Binder	10
Crushed Gravel Base	40
Sub-base	40

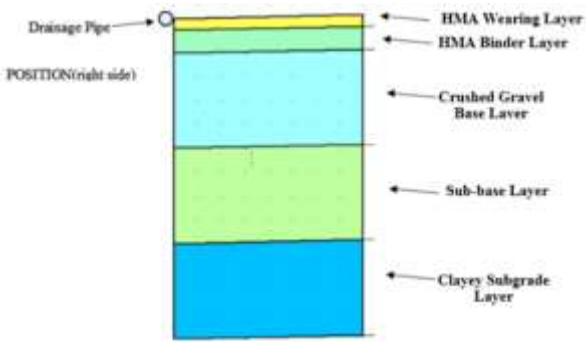


Fig. 1: Pavement Profile

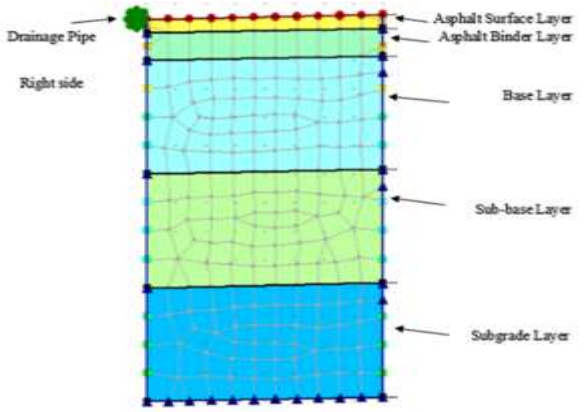


Fig. 2: Finite Element Mesh and Boundary Conditions

6. Analysis and results of 30mm/min rainfall intensity modeling

This calculation stage explains the flow paths, water flux, cumulative water flux, total head diagram, pore water pressure diagram, pressure head diagram, through the cross-sectional area of the pavement during the rain period for intensity rain 30mm/min. The duration of this intensity was 5400seconds (90 minutes). Figure 3 shows the flow paths and velocity vector of the infiltration water. For this scenario, most of water goes through the drainage system (drainage channel at the right side), and little amount of water was infiltrated into the pavement layers which indicates that drainage system, geometry and surface layer are efficient.

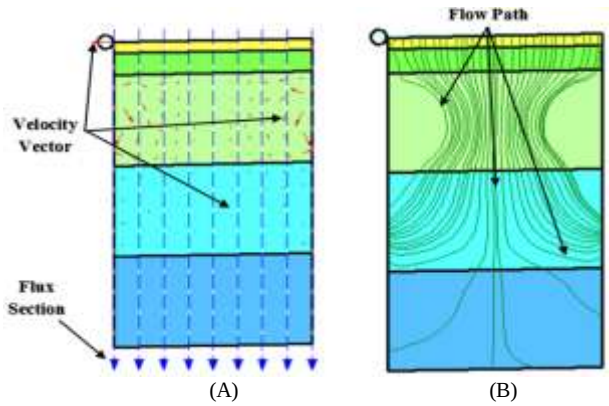


Fig.3: (A) Velocity Vector, (B) Flow Paths during 5400sec Time Duration for 30mm/min Intensity of Rain.

6.1. Results of pore water –pressure

The steady-state and transient analyses have been conducted to review the pore water–pressure through the pavement cross section during 5400 seconds time duration for 30mm/min intensity of rain.

6.1.1. Steady-state analysis results of pore water –pressure

The diagrams for the pore water pressure are depicted in Figure 4, which shows that the pore water pressure reached the greatest possible value at the bottom of the subgrade layer in the region under the contour line 0.4. The red colour grade represented the greatest value of pore water pressure. Then this value starts to decrease markedly with moving towards the surface. As result, the higher depth leads to increase the pore water pressure.

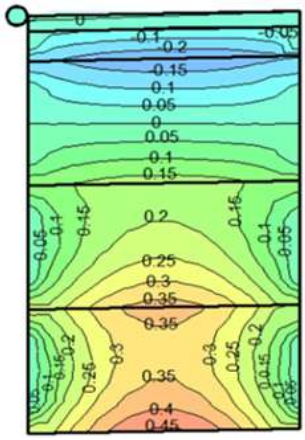


Fig. 4: Pore Water Pressure Diagram during 5400 sec Time Duration for 30mm/min Intensity of Rain from the Steady-State Analysis.

6.1.2. Transient analysis results of pore water –pressure

Transient analysis is used to study the pore water pressure changes over time and at different depths. From transient analysis is depicted in Figure 5, which shows that the maximum magnitude of the pore water- pressure is at a point which is located near the surface of pavement. From the results of the transient analysis, the pore water- pressure changes with time during the rain and with depth.

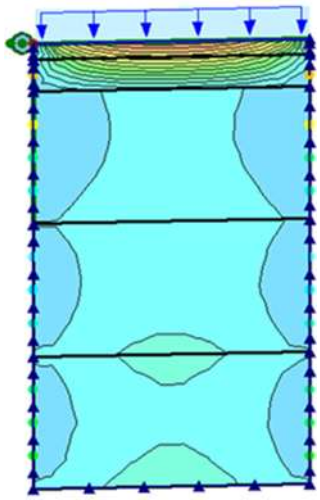


Fig. 5: Pore Water Pressure Diagram during 5400 sec Time Duration for 30mm/min Intensity of Rain from the Transient analysis

Table 3 illustrates the pore-water pressure results from the transient analysis. This table shows that the value of the pore water- pressure is higher when the point is close to the surface layer. In this point which has a depth of zero meters, the greatest value of pore water pressure is equal to 25.28 kPa. As moving down from the surface, the value of the pore water- pressure decreases until it reaches its lowest value which is equal to 4.84 kPa at depth1.34m as shown in Figure 6.

Table 3: Pore-Water Pressure Results for 30mm/min. Intensity of Rain for a Period 5400 sec.

Depth (m)	Pore-Water Pressure (kPa)
0.00	25.283
0.04	17.277
0.14	2.497
0.28	2.279
0.40	2.598
0.54	3.553
0.68	3.204
0.80	3.448
0.94	4.44
1.08	3.790
1.20	3.907
1.34	4.840
0.00	25.283
0.04	17.277
0.14	2.497
0.28	2.279

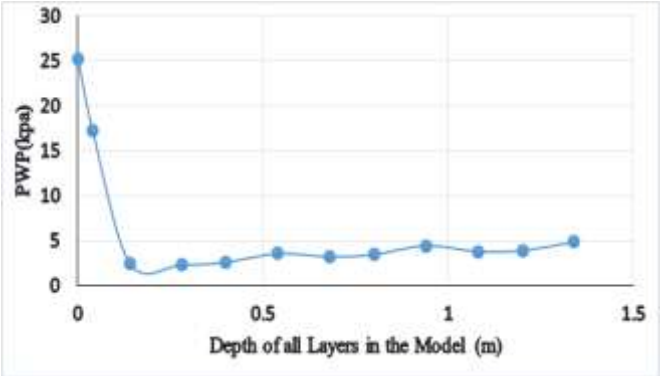


Fig. 6: Relationship between Pour Water Pressure and Depth for the Rainy Period 5400 seconds.

6.2. Results of water flux

6.2.1 steady-state analysis results of water flux value

The steady -state analysis was conducted to determine the water flux values through the pavement at various distances from the right end of the pavement cross section.

Figure 7 shows the water flux values through the pavement cross section at various distances from the left end of the pavement. This figure shows that the quantity of the water flux through the pavement layers slightly decreases when distance increases. At the beginning of the pavement from the left end of the pavement, the value of water flux reached its highest point (2.32E-05 m3/s) at the right edge of the pavement. In the middle of the pavement section, the value of water flux records its lowest value which is (1.50E-07 m3/s) at (0.4 meter) of the distances from the right end of the pavement as shown in Table 4. Because of the cross slope of the pavement, which is equal to (2%), the time required for the drainage of the surface water will be less ***(Al Adili et al., 2017)*** and therefore the amount of water flux in the areas near the discharge pipe will be large.

Table 4: Water Flux through the Pavement Cross Section

Distances from the Right End of the Pavement (m)	Water Flux Quantity(m^3/sec)
0.1	2.32E-05
0.2	4.77E-06
0.3	3.67E-06
0.4	1.34E-06
0.5	1.50E-07
0.6	1.04E-06
0.7	3.35E-06
0.8	4.40E-06

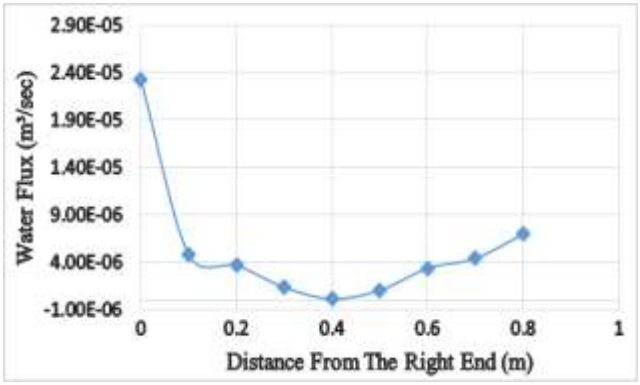


Fig.7: Relationship between Water Flux and Distance from the Right End of the Pavement.

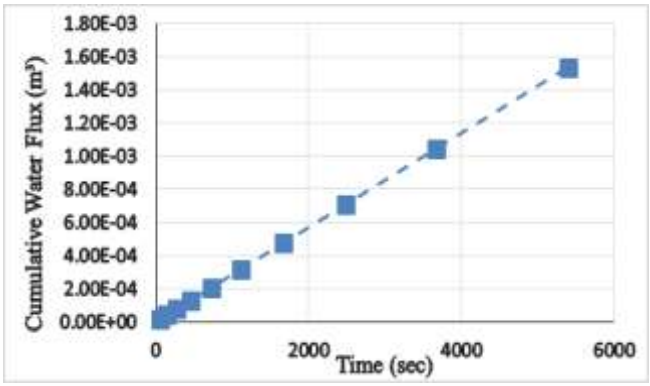


Fig. 8: Relationship between Cumulative Water Flux and Time during the Rainy Period 5400 sec.

6.2.2. Transient analysis results of water flux value

In this stage of modelling, the transient analysis was conducted to determine water flux through the pavement at various times during the rainy period 5400 seconds. Table 5 shows the water flux results through the pavement cross section during the rainy period 5400seconds. Table-5 illustrate that the value of the water flux has reached (2.85E-07m3/s) at time60 seconds and the rest of this value is fixed until the end of the rain period.

Table 5: Water Flux through the Pavement Cross Section during the Rainy Period 5400 seconds

Water Flux (m³/sec)	Time (sec.)
2.85E-07	60
2.85E-07	148
2.85E-07	274
2.85E-07	458
2.85E-07	725
2.85E-07	1112
2.85E-07	1675
2.85E-07	2492
2.85E-07	3678
2.85E-07	5400

6.2.3. Transient analysis results of cumulative water flux value

In this calculation results, the transient analysis was conducted to determine the cumulative water flux value through the pavement at various times. Figure 8 explain the cumulative water flux values during the rainy period 5400 seconds. This figure shows that the amount of cumulative water flux through the pavement layers significantly increases with time increases. At 5400 seconds during the rainy period, the value of water flux reached its highest point (0.001536505 m3/s) because the rate of precipitation and the amount of water flux with time was constant. Table 6 shows the constant increase in the amount of accumulated water.

Table 6: Cumulative Water Flux through the Pavement Cross Section at Deferent Time during the Rainy Period 5400 seconds.

Time (sec.)	Cumulative Water Flux (m³)
0	0
60	1.71E-05
148	4.21E-05
274	7.80E-05
458	0.00013
725	0.00020
1112	0.00031
1675	0.00047
2492	0.00070
3678	0.00104
5400	0.00153

7. Analysis and results of 60mm/min rainfall intensity modeling

In these computing results, the flow paths, water flux, cumulative water flux, pore water pressure diagram, through the cross-sectional area of the pavement during the rain period for intermediate intensity rain 60mm/min. have been studied. The duration of this intensity was 3600seconds (60 minutes).
Figure 9 shows the flow paths and velocity vector of the infiltration water. For this scenario, most of water goes through the drainage system and fewer amount of water was infiltrated into the pavement layers which indicates that that drainage system, geometry and surface layer are efficient.

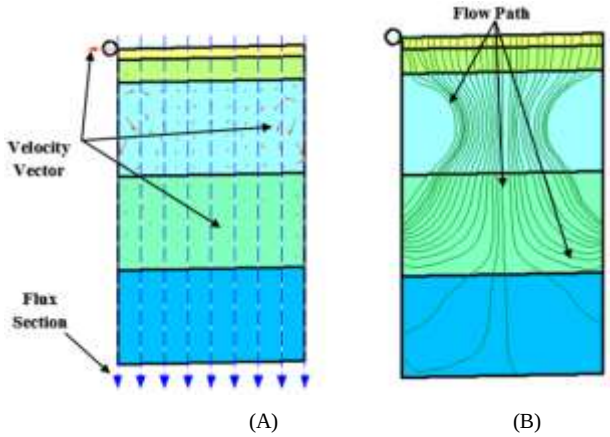


Fig.9: (A) Velocity Vector, (B) Flow Paths during 3600 seconds Time Duration for 60mm/min Intensity of Rain.

7.1 results of pore water pressure

The steady-state and transient analysis were conducted to review the pore water–pressure through the pavement cross section during 3600 seconds time duration for 60mm/min intensity of rain.

7.1.1. Steady-state analysis results of pore water -pressure

The diagrams for the pore water pressure were depicted in Figure 10 during 3600 seconds time duration for 60mm/min intensity of rain. This figure shows that the pore water pressure reached the greatest possible value at the bottom of the subgrade layer in the region under the contour line 0.4. The red color represented a greatest value of pore water pressure. Then this value starts to decrease markedly with a move towards the surface. As result, the higher depth lead to increase the pore water pressure.

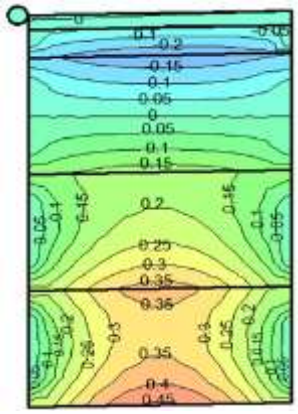


Fig.10: Pore Water Pressure diagram during 3600 sec Time Duration for 60mm/min Intensity of Rain from the Steady-State Analysis.

7.1.2. Transient analysis results of pore water –pressure

Transient analysis is used to study the pore water pressure changes over time and at different depths. The pore water- pressure from transient analysis is depicted in Figure 11, which also shows that the maximum magnitude of the pore water- pressure is at a point which is located near the surface of pavement. From the results of the transient analysis the pore water- pressure changes with time during the rain and with depth.

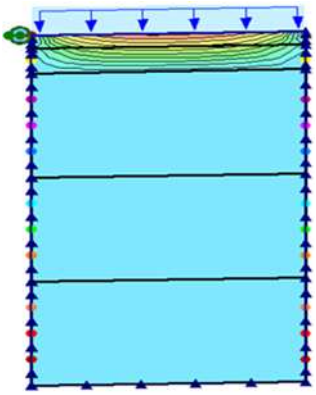


Fig. 11: Pour Water Pressure Diagram during 3600 sec Time Duration for 60mm/min Intensity of Rain from the Transient analysis.

Table 9 shows that the value of pore water pressure during the rainfall period, which equals to 3600 seconds, is higher when the point is close to the surface layer. In the point on the surface of the pavement, which has a depth of 0 meters, the greatest value of pore water pressure is equal to 187.89 kPa. As we move away from the surface, the value of the pore water pressure decreases until it reaches its lowest value which is equal to 5.99 kPa at a depth of1.34 as shown in Figure 12.

Table 9: Pore-Water Pressure Results for 60mm/min Intensity of Rain for a Period 3600 seconds

Depth (m)	Pore-Water Pressure (kPa)
0.00	187.8898434
0.04	127.567557
0.14	7.353085325
0.28	5.596855871
0.40	5.189093428
0.54	5.819652106
0.68	4.880405728
0.80	4.884696493
0.94	5.791366846
1.08	5.002807871
1.20	5.070019814
1.34	5.997445795

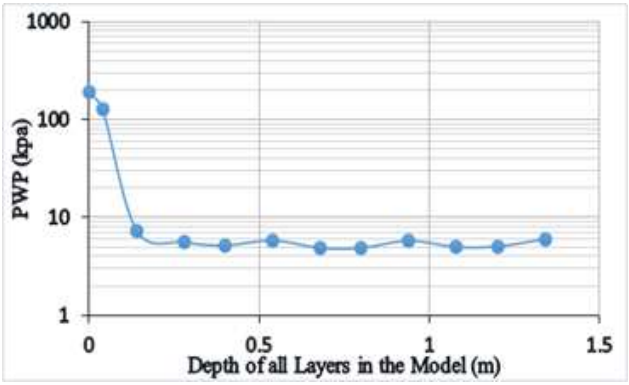


Fig. 12: Relationship between Pour Water Pressure and Depth for a Rainy Period 3600 seconds.

7.2. Results of water flux

7.2.1. Steady-state analysis results of water flux values

Figure 13 shows the water flux values through the pavement cross section at various distances from the right end (edge) of the pavement. This figure shows that the water flux values through the pavement layers is slightly decreased when distance increases. At the (0 meter) of the distances from the right end of the pavement, the amount of the water decreases. The amount of absorbed water reached its highest point as presented in table 10. Because of the cross slope of the pavement, which is equal to (2%), the time required for the drainage of the surface water will be small (FHWA, 1992) and therefore the amount of water flux in the areas near the discharge pipe will be large.

Table 10: Water Flux Quantity through the Pavement Cross Section

Distances from the Left End of the Pavement (m)	Water Flux (m^3/sec.)
0	
0.1	5.76E-06
0.2	4.78E-06
0.3	3.67E-06
0.4	1.34E-06
0.5	1.55E-07
0.6	1.03E-06
0.7	3.35E-06
0.8	4.44E-06

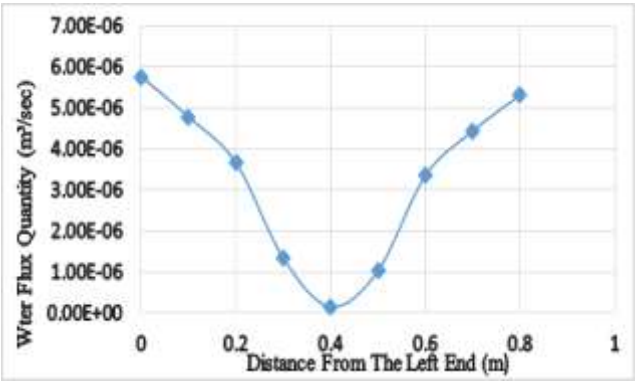


Fig. 13: Water Flux Quantity through the Pavement Cross Section at Various Distances from the Right end of Pavement.

7.2.2. Transient analysis results of water flux values

Table 11 shows the results of the water flux through the pavement cross section during the rainy period 3600seconds. This table shows that the value of the water flux after 60 seconds and until the end of the period of rain remained the same as it reached 2.61E-07m3/s.

Table 11: Water Flux through the Pavement Cross Section at Different Time.

Time (sec.)	Water Flux (m³/sec.)
0	0
60	2.61E-07
143	2.61E-07
255	2.61E-07
409	2.61E-07
620	2.61E-07
909	2.61E-07
1304	2.61E-07
1845	2.61E-07
2586	2.61E-07
3600	2.61E-07

7.2.3. Transient analysis results of cumulative water flux value

Figure 14 shows the cumulative water flux through the pavement cross section during the rainy period. This figure explain that the amount of cumulative water flux increases visibly over time until it reaches its maximum amount at time 3600 seconds due to continuous rainfall as shown in Table 12.

Table 12: Cumulative Water Flux through the Pavement Cross Section at Deferent Time during the Rainy Period 3600 seconds

Time (sec.)	Cumulative Water Flux (m³)
0	0
60	3.07568E-05
143	5.48459E-05
255	8.79686E-05
409	0.000133351
620	0.00019551
909	0.000280467
1304	0.000396826
1845	0.000556203
2586	0.000774295
3600	1.29049E-05

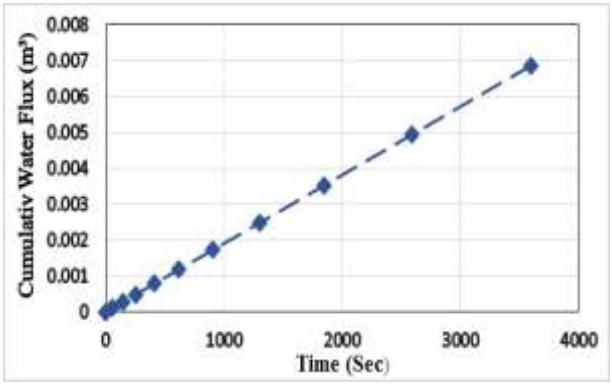


Fig.14: Relationship between Cumulative Water Fluxes through the Pavement Cross Section and Time during the Rainy Period 3600 seconds.

8. Analysis and results of 90mm/min rainfall intensity modeling

In this calculation results, the results of the flow paths diagram, water flux through the cross-sectional area of the pavement for intensity rain 90mm/min have been explained. The duration of this intensity was 1800 seconds (30 minutes). Figure 15 shows the flow paths and velocity vector of the infiltration water. For the scenario presented in Figure 15, most of water goes through the drainage system and a little amount of water was infiltrated into the pavement layers which indicates that drainage system, geometry and surface layer are efficient.

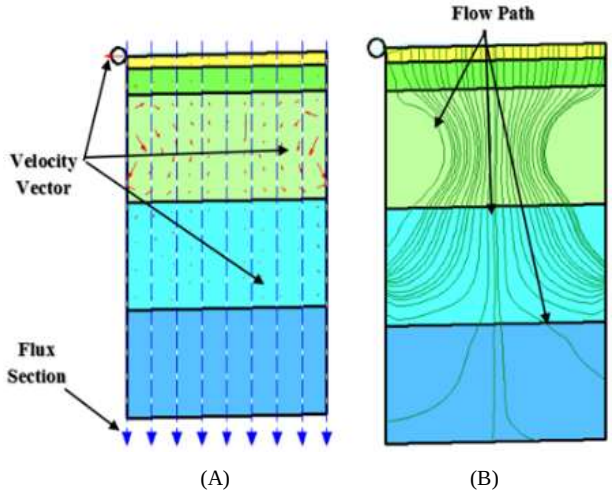


Fig.15: (A) Velocity Vector, (B) Flow Paths during 1800 seconds Time Duration for 90mm/min Intensity of Rain.

8.1. Results of pore-pressure

8.1.1. Steady-state analysis results of pore water -pressure

In this calculation result, the diagrams for the pore water pressure were depicted in Figure 16 during1800 seconds (30minuts) time duration for 90mm/min intensity of rain. This figure shows that the pore water pressure reached the greatest possible value at the bottom of the subgrade layer in the region under the contour line 0.4. The red color represented a greatest value of pore water pressure. After that, this value starts to decrease markedly with a move towards the surface. Resulting from the above results; the higher depth leads to increase the pore water pressure.

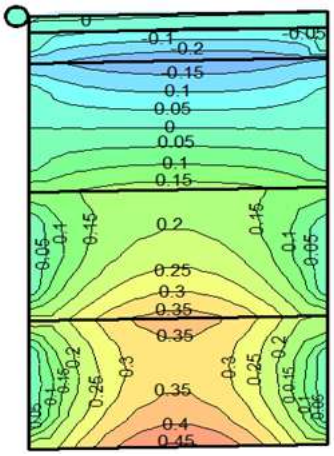


Fig. 16: Pore water Pressure during 1800 second Time Duration for 90mm/min Intensity of Rain from the Steady-State Analysis.

8.1.2. Transient analysis results of pore water –pressure

Transient analysis is used to analyze the pore water pressure changes over time and at different depths. The pore water- pressure from transient analysis is depicted in Figure 17. This figure shows that the maximum magnitude of the pore water- pressure is at a point which is located near the surface of pavement. From the results of the transient analysis, the pore water- pressure changes with time during the rain and with depth.

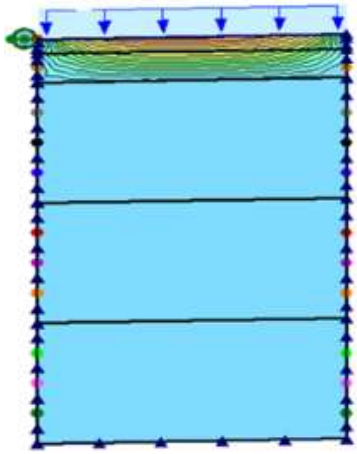


Fig.17: Pore Water Pressure Diagram during 1800 sec Time Duration for 90mm/min Intensity of Rain from the Transient Analysis.

Table 15 shows that the value of pore water pressure during the rainfall period, which equals 1800 seconds, is higher when the point is close to the surface layer. In a point on the surface of the pavement, which has a depth of 0 meters, the greatest value of pore water pressure is equal to 283.32 kPa. As moving away from the surface, the value of the pore water pressure decreases until it reaches its lowest value which is equal to 6.345 kPa at a depth of 1.34 as shown in Figure 18.

Table15: Pore-Water Pressure Results for 90mm/min. Intensity of Rain for a Period 1800 sec.

Depth (m)	Pore-Water Pressure (kPa)
0.00	283.328
0.04	192.573
0.14	11.859
0.28	8.596
0.40	7.406
0.54	7.720
0.68	6.120
0.80	5.817
0.94	6.609
1.08	5.525
1.20	5.457
1.34	6.3456

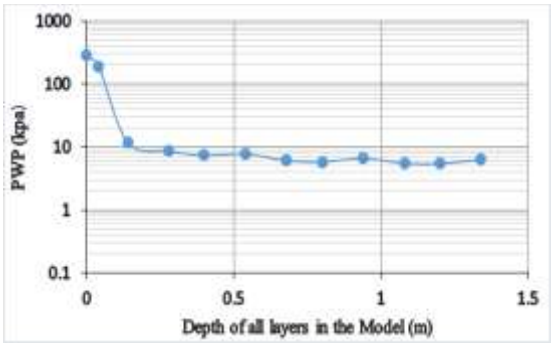


Fig.18: Relationship between Pore Water Pressure and Depth for a Rainy Period 1800 seconds.

From the test results, the value of the pore-water pressure in the surface layer resulting from high rainfall intensity and presence of wheel load of 32.21% greater than the pressure generated by the medium intensity of rain and 85.9% greater than the pressure produced due to low intensity as shown in Figure 19. The surface layer of the asphalt pavement is more prone to deterioration in the case of high rainfall intensity due to the generation of high pore-water pressure, which contributes to the occurrence of ruts and potholes in the asphalt pavement layer, compared to the low rainfall.

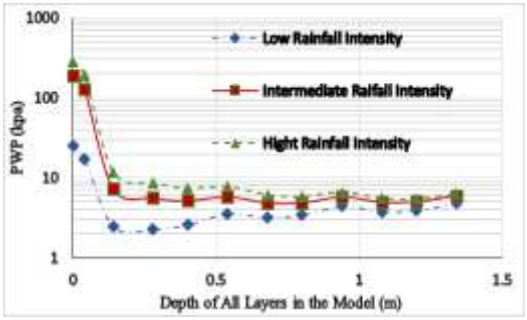


Fig. 19: Relationship between Pore-Water Pressure and Depth for Different Rainfall Intensities.

8.2. Results of water flux

8.2.1. Steady-state analysis results of water flux value

Figure 20 shows the water flux values through the pavement cross section at various distances from the right end (edge) of the pavement. This figure shows that the quantity of the water flux through the pavement layers slightly decreases when distance increases. At zero meter of the distances from the right end of the pavement, the value of water flux reached its highest point (5.78E-06 m3/s) at the right edge of the pavement. In the middle of the pavement cross section, the value of water flux records its lowest value which is (1.20E-06 m3/s) at (0.5meter) of the distances from the left end of the pavement which is the midway of the section (position of the wheel) as shown in Table 16.

Table 16: Water Flux Quantity through the Pavement Cross Section

Distances from Right End of Pavement (m)	Water Flux(m³/sec)
0	5.78E-06
0.1	4.80E-06
0.2	3.69E-06
0.3	1.35E-06
0.4	1.60E-07
0.5	1.20E-06
0.6	3.35E-06
0.7	4.41E-06
0.8	5.31E-06

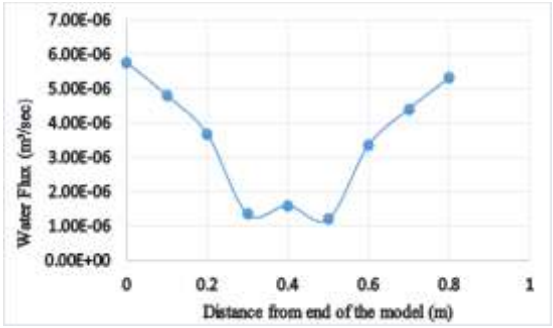


Fig.20: Relationship between Water Flux and Depth.

8.2.2. Transient analysis results of water flux values

Table 17 shows the results of water flux through the pavement cross section during the rainy period 1800seconds. This table shows that the value of the water flux after 60 seconds and until the end of the period of rain remained the same as it reached (1.43388E-07 m3/s).

Table 17: Water Flux through the Pavement Cross Section at Different Times (sec) during the Rainy Period 1800 seconds.

Time (sec)	Water Flux (m³/sec)
0	0
60	1.43388E-07
134	1.43388E-07
225	1.43388E-07
336	1.43388E-07

473	1.43388E-07
642	1.43388E-07
849	1.43388E-07
1103	1.43388E-07
1416	1.43388E-07
1800	1.43388E-07

8.2.3. Transient analysis results of cumulative water flux value

Figure 21 shows the relationship between cumulative water flux and time through the pavement cross section during the rainy period of 1800 seconds. Figure 21 explain that the amount of cumulative water flux increases significantly over time until it reaches its maximum amount at time 1800 seconds due to continuous rainfall as shown in Table18 .

Table 18: Cumulative Water Flux through the Pavement Cross Section at Different Times during the Rainy Period 1800 seconds.

Cumulative Water Flux (m^3)	Time (sec.)
0	0
8.60329E-06	60
1.92139E-05	134
3.22624E-05	225
4.81784E-05	336
6.78225E-05	473
9.20551E-05	642
0.000121736	849
0.000158157	1103
0.000203038	1416
0.0002580980	1800

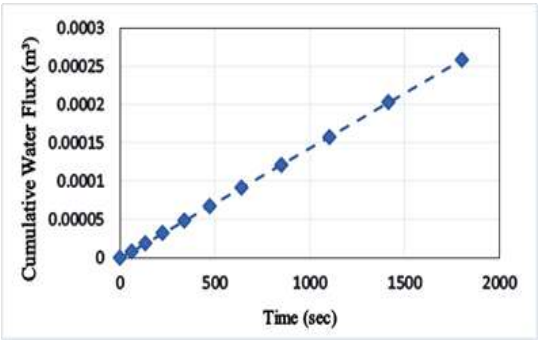


Fig. 21: Relationship between Cumulative Water Flux and Time during the Rainy Period1800 seconds.

Average of accumulation water produced by the 30mm/min rainfall intensity in the pavement structure is 44.73 % greater than the average of accumulation of this water from the 60mm/min intensity and 77.85% higher than the 90mm/min intensity of rain. Water will need a long period of rain to accumulate in the structure of the pavement even if the intensity of the rainfall was low. The accumulation of this water will lead to an increase in the degree of saturation of the pavement structure and this in turn leads to deterioration and problems in the layers of the pavement structure reflected negatively on the performance of the surface layer and sub-surface layers as shown in Figure 22.

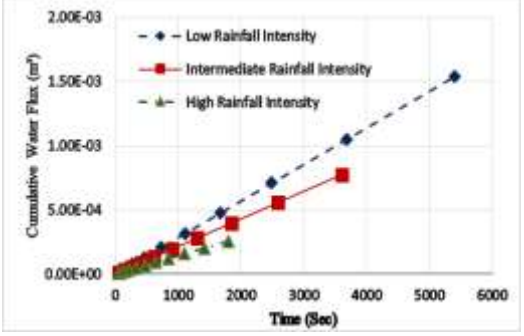


Fig. 22: Relationship between Cumulative Water Flux and Time for Different Rainfall Intensity.

9. Conclusions

1. The transient analysis resulted from numerical analysis model showed that the value of the pore-water pressure in the surface layer resulting from 90mm/min rainfall intensity and presence of wheel load is 32.21% greater than the pressure generated by the 60mm/min intensity of rain and 85.9% greater than the pressure produced due to 30mm/min intensity. The surface layer of the asphalt pavement is more prone to deterioration in the case of high rainfall intensity due to the generation of high pore-water pressure.
2. The steady-state analysis showed that the average water flux values through the pavement cross section at various distances from the right end (edge) of the pavement of 30 mm/min was 41% higher than the average water flux of 60 mm/min and 42% of the average water flux of 90 mm/min intensity of rain.
3. The transient analysis resulted from numerical analysis model showed that the water flux through the pavement cross section during the rainy period of 30 mm/min was 8.42% higher than the water flux of 60 mm/min and 49.82% of the water flux of 90 mm/min intensity of rain.
4. The transient analysis revealed that the average of accumulation water produced by the 30mm/min rainfall intensity in the pavement structure is 44.73 % greater than the average of accumulation of this water from the 60mm/min intensity and 77.85% higher than the 90mm/min intensity of rain. Water will need a long period of rain to accumulate in the structure of the pavement even if the intensity of the fall of rain was low.
5. The accumulation of this water will lead to an increase in the degree of saturation of the pavement structure and this in turn leads to deterioration and problems in the layers of the pavement structure reflected negatively on the performance of the surface layer and sub-surface layers.

References

[1] AL ADILI, A., AL RUBAEE, R. H. & ABASS, H. A., 2017. "Steady of Surface Drainage Runoff and Vertical Drainage of Flexible Pavement under Laboratory Wheel Track Test", Civil Engineering Research Journal, Vol.1, Issu1, pp1-11.
[2] BRIDGES, I. S. C. F. R. A. 2005. "Highway Design Manual". 2nd edition, Republic of Iraq, planning and designs department, p50.
[3] CEDERGREN, H. R. 1974. "Drainage of highway and airfield pavements", Malabar, Fla.: R.E. Krieger Pub., p 289.
[4] FHWA, D., 1992. "Drainable Pavement Systems, Participant Notebook", Office of Technology Applications and Office of Engineering, No. FHWA-SA-92-008,
[5] MUKHERJEE, M. D., 2014. "Highway Surface Drainage System & Problems of Water Logging In Road Section". The International Journal of Engineering and Science (IJES), Vol. 3, Issu11, pp 44-51.
[6] ONG, G. P. & FWA, T. F., 2005." Analysis and Design of Vertical-Drainage Geosynthetic-Reinforced Porous Pavement for Roads and Car Parks". Journal of the Eastern Asia Society for Transportation Studies, Vol.6, pp 1286-1301.
[7] ROKADE, S., AGARWAL, P. & SHRIVASTAVA, R., 2012. "Steady on drainage related performance of flexible highway pavements". International Journal of Advanced Engineering Technology (IJAET), Vol.3, Issu1, pp334-337.
[8] Tiza, M. T., Iorver, Vitalis Terpase, Iortyom, Enoch Terlumun, 2016."The Effects Of Poor Drainage System On Road Pavement: A Review ", International Journal for Innovative Research in Multidisciplinary Field, Vol.2, Issue 8, pp 216-223.