إقــــــرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Study the Effect of Joints, Block Shape, and Pavement Pattern on the Permeability of Concrete Block Pavement (Interlock Pavement)

دراسة تأثير الفواصل وشكل الحجر ونمط الرصفة على نَفاذِية المياه في الرصفة الخَرسانية المُتداخلة (الإنترلوك)

أقر بأن ما اشتملت عليه هذه الرسالة إنما هو نتاج جهدي الخاص، باستثناء ما تمت الإشارة إليه حيثما ورد، وإن هذه الرسالة ككل أو أي جزء منها لم يقدم من قبل لنيل درجة أو لقب علمي أو بحثي لدى أي مؤسسة تعليمية أو بحثية أخرى.

DECLARATION

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's name: Mohammed I. M. Madhoun اسم الطالب: **محمد إسماعيل محمد المدهون**

Signature: التوقيع:

Date: 25/5/2014 التاريخ: 2014/5/25م

The Islamic University of Gaza
Deanship of Higher Studies
Faculty of Engineering
Civil Engineering Department
Infrastructure Management

Study the Effect of Joints, Block Shape and Pavement Pattern on the Permeability of Concrete Block Pavement (Interlock Pavement)

دراسة تأثير الفواصل وشكل الحجر ونمط الرصفة على نَفاذِية المياه في الرصفة الخَرسانية المُتداخلة (الإنترلوك)

Submitted by:

Mohammed Ismail Al-Madhoun

Supervised by:

Prof. Dr. Shafik Jendia

A Thesis Submitted in Partial Fulfillment of Requirements for the Degree of Master of Science in Civil Engineering - Infrastructure Management

1435هـ - 2014م

بسم الله الرحمن الرحيم

الجامعة الإسلامية – غزة
The Islamic University - Gaza

مكتب نائب الرئيس للبحث العلمي والدراسات العليا   هاتف داخلي 1150

الرقم...ج س غ/35/....... Ref

التاريخ......2014/05/13...... Date

نتيجة الحكم على أطروحة ماجستير

بناءً على موافقة شئون البحث العلمي والدراسات العليا بالجامعة الإسلامية بغزة على تشكيل لجنة الحكم على أطروحة الباحث/ **محمد اسماعيل محمد المدهون** لنيل درجة الماجستير في **كلية *الهندسة*** قسم الهندسة المدنية – البنى التحتية وموضوعها:

Study the Effect of Joints, Block Shape and Pavement Pattern on the Permeability of Concrete Block Pavement (Interlock Pavement)

وبعد المناقشة العلنية التي تمت اليوم الثلاثاء 14 رجب 1435هـ، الموافق 2014/05/13م الساعة الواحدة والنصف ظهراً بمبنى القدس، اجتمعت لجنة الحكم على الأطروحة والمكونة من:

أ.د. شفيق مسعود جندية	**مشرفاً ورئيساً**	....
د. يونس خليل المغير	**مناقشاً داخلياً**	....
د. مازن طه أبو الطيف	**مناقشاً خارجيًا**	....

وبعد المداولة أوصت اللجنة بمنح الباحث درجة الماجستير في **كلية *الهندسة*/** قسم **الهندسة المدنية- البنى التحتية.**

واللجنة إذ تمنحه هذه الدرجة فإنها توصيه بتقوى الله ولزوم طاعته وأن يسخر علمه في خدمة دينه ووطنه.

والله ولي التوفيق،،،

مساعد نائب الرئيس للبحث العلمي والدراسات العليا

أ.د. فؤاد علي العاجز

بسم الله الرحمن الرحيم

﴿يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ﴾

المجادلة (11)

صدق الله العظيم

Dedication

I dedicate this work to:

My father, my mother,

My beloved wife, my sisters,

& To all my kids Ismail, Anas & Hala

Acknowledgements

I thank Allah, for helping me to finish this effort and achieving it in reality, and given me the strength until this research is finally completed.

Correspondingly, I extend my sincere appreciation and special thanks to my supervisor **Prof. Dr. Shafik Jendia** for his guidance, supervision as well as his effort in the coordination of this research until its completion.

I would like to thank all lecturers in Islamic University of Gaza who have helped me during my study in master program, and special thanks to **Dr. Yunes Mogheir** and **Dr. Mazen Abualtayef.**

Finally, I would like to thank all the staff of the Materials testing laboratory on the Association of engineers - Gaza Governorates, Palestine Co. for building material (Automatic Factory) presented by Mr. Fadel Ahmaed Aljaroo and Mushtaha & Hassouna Co. LTD presented by Mr. Safwat Mushtaha who have supported and encouraged me to accomplish this work.

Eng. Mohammed I. Al-Madhoun

Abstract

Gaza is facing an unprecedented increasing the numbers of buildings, concrete ceilings, paving main roads and many other vital projects. This increases the runoff of rain water and possibility of infiltration/drain to the aquifer.

This study aims to determine the impact of the shape, pattern and joints of concrete block pavement (Interlock) in places which have low loads such as squares, car parking, stadiums,…. etc. to infiltrate the water through joints.

In this study, several experiments were conducted to measure the impact of the joints, shape, and the pattern of pavement on the water permeability in concrete block pavement through several models on pavement which has an area of $1m^2$ in order to find the pavement permeability percentage and to reach the highest permeability percentage possible without runoff of water on the surface.

This study contains five models for different block type, joints between block and different pattern pavements, with three different base course under pavements and five scenarios of gradually intensity of rainfall (15, 30, 45, 60, 120 mm/h) over a period of 60 min.

The results showed that the water permeability of rectangular block pavement 10 x 20 cm have the best permeability percentage, where it was noted that the water permeability percentage in the intensity of rainfall at 15 mm/h amounted to about 76% without any surface runoff, while at the intensity of rainfall 120 mm/h water permeability percentage did not exceed 32.5 % with high surface runoff in the existence of sand layer under the tiles.

When replacing the sand layer with a coarse aggregate layer, the permeability percentage reached 89.6% in the low intensity of rainfall and 75% in the largest intensity of rainfall and less of surface water runoff was observed.

The results showed that the use of coarse aggregate "Adasia" (0/12.5) mm gives slightly higher permeability percentage than the use of aggregate "Simsimia" (0/9.50) in the bottom of the tile layers, and without using sand in the bottom layer gives very high permeability percentage.

When changing patterns of tiles, the results didn't show significant effect on permeability percentage through the intensity of water mentioned above.

As for the increase of joints between interlock tiles, no large effect has been noticed in the percentage of water permeability during low intensity of water, while little increase was observed in the water permeability during the high water intensity.

ملخص البحث

تواجه مدينة غزة نهضةً عمرانية غير مسبوقة من حيث الزيادة في أعداد المباني والأسقف الخرسانية وتعبيد الطرق الرئيسية والعديد من المشاريع الحيوية في المدينة، مما يزيد الجريان السطحي لمياه الأمطار ويقلل من إمكانية وصولها ونفاذيتها للخزان الجوفي.

هذه الدراسة تهدف الى معرفة تأثير كل من شكل الحجر ونمط الرصيف والفواصل في الرصفة الخرسانية المتداخلة (الإنترلوك) في الأماكن ذات الاحمال المنخفضة كالساحات العامة وكراجات السيارات والملاعب....الخ، لتكون منفذة للمياه من خلال الفواصل المتواجدة بين البلاط.

في هذه الدراسة تم اجراء العديد من التجارب العملية للتعرف على مدى تأثير كل من الفواصل وشكل الحجر ونمط الرصفة على نفاذية المياه في الرصفة الخرسانية المتداخلة (الإنترلوك) وذلك من خلال عمل محاكاه لسقوط مياه الأمطار على رصفة خرسانة متداخلة مساحتها 1م^2 بغرض ايجاد مدى نفاذية الرصفة للمياه، والوصول الى أعلى نفاذية ممكنه بدون جريان سطحي للمياه.

لقد احتوت الدراسة على 5 سيناريوهات مختلفة من حيث نوع البلاط المستخدم والمسافات الفاصلة ونمط البلاط، بالإضافة الى استخدام ثلاثة انواع من طبقات الرصف المختلفة التدرج، وتم عمل محاكاه لشدة مياه الأمطار المتساقطة بشكل متدرج (15، 30، 45، 60، 120 ملم/ساعة) لكل رصفة منهم، وذلك على مدار 60 دقيقة متتالية.

وبتسجيل النتائج تبين أن نفاذية المياه لرصفة البلاط المستطيل 10 x 20 سم هي الأعلى، حيث لوحظ ان نفاذية المياه في شدة تساقط الأمطار 15 ملم/ساعة بلغت حوالي 76% بدون أي جريان سطحي للمياه، بينما عند شدة مياه 120 ملم/ساعة فإن نسبة النفاذية لم تتجاوز 32.5% مع جريان سطحي للمياه عند وجود طبقة رملية أسفل البلاط، وباستبدال طبقة الرمل بطبقة حصويات بلغت النفاذية 89.6% في شدة مياه المنخفضة و 75% في شده المياه الكبرى ولوحظ جريان سطحي اقل.

كما وأظهرت النتائج أن استخدام حصويات ذات تدرج 12.5/0 (عدسية) يعطى نسبة نفاذية أعلى بقليل من استخدام حصويات ذات تدرج 9.5/0 (سمسمية) أسفل البلاط، وعدم استخدام طبقة الرمل اسفل الحصويات يعطى نسبة نفاذية عالية جداً، وأظهرت النتائج عند تغير نمط الرصيف إنه لا تأثير محسوس على نفاذية المياه خلال شدة المياه المذكورة.

وبخصوص زيادة المسافات الفاصلة بين البلاط فإنه لم يلاحظ وجود تأثير كبير على نسبة نفاذية المياه أثناء شدة مياه الأمطار المنخفضة، بينما لوحظ وجود زيادة بسيطة على نسبة نفاذية المياه أثناء شدة المياه الكبيرة.

Table of Contents

List of Tables

List of Figures

List of Abbreviation

CMWU	Coastal Municipalities Water Utility
EPA	Environmental Protection Agency
FIRL	Franklin Institute Research Laboratories
ICPI	Interlocking Concrete Pavement Institute
MCIA	Mississippi Concrete Industries Association
mm/yr	Millimeter per year
Mm^3/yr	Million cubic meter per year
MOA	Ministry of Agriculture
MOLG	Ministry of Local Governorates
NGOs	Non-governmental organizations
PSI	Palestine Standards Institution
PCBP	Permeable Concrete Block Pavement
PWA	Palestinian Water Authority
RI	Rain Intensity
TBRs	Tipping Bucket Rain gauges

Chapter (1)
Introduction

1.1 Background

Increasing of urban development in our present time replaced many of the wide open spaces and agricultural lands as permeable surfaces (pervious surfaces), with impermeable surfaces, such as roadways, parking and buildings. The management of storm water runoff at these places and its impact has become a major issue for all levels of government, where storm water gathered especially in low areas that are without drainage system causing a problem in roads, stop traffic and sometimes lead to destroy the infrastructure sectors.

On the other hand, the shortage of water in the aquifer should be taken in consideration, then the water must be collected and re-injected to underground or reused for agricultural sector. Therefore, using porous or permeable pavement are recommended to give appropriate solutions are alternatives to these issues.

A porous pavement is a distinct pavement type that permits fluids either from precipitation or elsewhere, to pass freely through the structure reducing or controlling the amount of water surrounding area. By allowing precipitation to flow through the structure, this pavement type can be applied as a storm water management practice (Schaus, 2007).

Permeable pavement allows storm water to quickly infiltrate the surface layer to enter a high-void aggregate base layer. The captured runoff is stored in this reservoir until it either percolates into the underlying sub-grade, or is routed through a perforated under drain system to a conventional storm water conveyance. Appropriately designed interlocking permeable pavement may reduce the amount of pollutants reaching receiving waters (James and Langsdorff, 2003).

The practical matter of this case presented by using of Permeable Concrete Block Pavement (PCBP), and to study the effect of joints, filling materials, block shape and pavement pattern at permeability of water. The shape of fixed interlock together with a lot of joints between the block to permit the water and passing quickly into the underlying layers, the joints around the block can be filled with fine aggregate.

A permeable interlock pavements can be used in the building of roads, parking lots, residential streets, sidewalks, and pedestrian plazas.

1.2 Storm water management

The traditional approach to storm water management is based on the development of urban drainage networks to convey storm water away from developed areas as quickly as possible to receiving waters safely. With the increase in impermeable surfaces in urban areas, the runoff generated by storm water significantly increases, overloading existing storm water infrastructure. Earlier the emphasis was to remove the water as quickly as possible with little regard to how it was done or evaluating the adverse impact of receiving water.

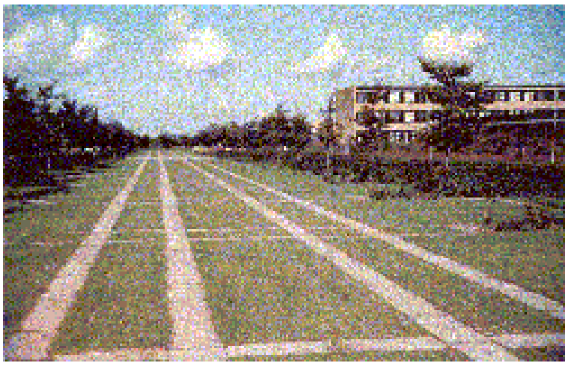
Studies conducted overseas have proved that a properly designed pervious pavement system will function in an urban environment effectively to manage storm water hydraulically and to improve water quality (Zhang, 2006).

1.3 Pervious pavements

Pervious pavements are one of the storm water management techniques developed in the past 20 years to harness the improve water quality and reuse the water for productive purposes. A pervious pavement is a load bearing pavement structure that is permeable to water overlying a reservoir storage layer. The pervious pavements can be applied to low traffic areas such as driveways, footpaths and car parks.

The designed philosophy of pervious pavements is quite different to the traditional urban drainage design. In a traditional car park, engineers will design an impervious surface to protect the base material contacting with the water. While for pervious pavements, the aim of construction is to allow the water to infiltrate through the pavement surface into a temporary storage layer or percolate the storm water gradually recharging the ground water aquifer. The pavement surface will trap pollutants while infiltrating through the surface.

Pervious pavements can be defined as porous pavements or permeable pavements based on the surface type. Porous pavements are normally constructed with pervious paver materials where water can infiltrate through the entire surface area. However, for permeable pavements, the paver material is made out of impervious blocks while the spaces between the paver blocks are filled with coarse grained materials which allow water to pass through (Zhang, 2006). Figure (1.1) shows the concrete block pavements an example of permeable pavements.



a. Large elemental surfacing blocks

b. Small elemental surfacing blocks

Figure (1.1): Examples of permeable pavements (Zhang, 2006)

1.4 Statement of the problem

Water in Gaza strip like many arid and semiarid areas is becoming an increasingly scarce and planners are forced to consider any sources of water which might be used economically and effectively to promote future development (Khalaf, 2005).

With increased population and climate change water shortage problems are troubling mankind all over the world. How to harvest the water during rainfall events for use at times of need is of major interest subject to civil engineers, environmentalists and to the community. On the other hand, with urbanization, more impervious road and roof surfaces appear resulting in increased runoff from rainfall. This fact led to search about the useful solution of this problem and to improve of the quality and the quantity of groundwater, and to be more focus to find the tools for treatment of storm water and recharge it to the groundwater (Khalaf, 2005). Figure (1.2) shows the bad storm water situation in Gaza strip.

Figure (1.2): The bad storm water situation in the Gaza strip

1.5 Research Importance

- Finding useful methods to reduce the amount of water accumulated at roads, that causing damage and contamination of the environment.
- Preservation of the natural water and natural resources.
- Suggesting useful way to collect water and recharging in ground water.

1.6 Research goal and objectives

1.6.1 Goal

- The goal of this research is to investigate the possibility of using permeable concrete block pavement (interlock pavement) to drainage the water through the joints between block pavement, under the local conditions in the Gaza Strip.

1.6.2 Objectives

- Achieve the maximum permeability of water through the joints between block pavement with maintaining the stability of the pavement.
- Find out the effect of different shapes, pattern and joints at the permeability.

This study aims to provide guidance for engineers, contractors, and government agencies in dealing with permeable pavement as a storm water management technique in Gaza strip.

1.7 Research methodology

To achieve study goals, the following steps were carried out:

a. Literature review of previous studies and data collection about the average rainfall intensity in Gaza Strip.

b. Deep study of concrete block types and shapes that available in Gaza and knowledge of its dimensions and characteristics, then study the properties of filling materials between joints as a fine aggregate.

c. Study the effect of joints, block shape and pavement pattern to achieve maximum permeability of water.

d. After carrying out the above studies and deciding which approach is suitable for permeability to make a prototype test, the material needed for the study was collected such as interlock shape and filling or beading materials, data includes information needed for modeling must be used to develop a rainfall simulator with certain or different intensity, then several scenarios were developed to evaluate infiltration capacity with different impact factors (time, intensity of rainfall water, base course and joints).

e. Discussion of testing results.

f. Drawing conclusion and recommendations.

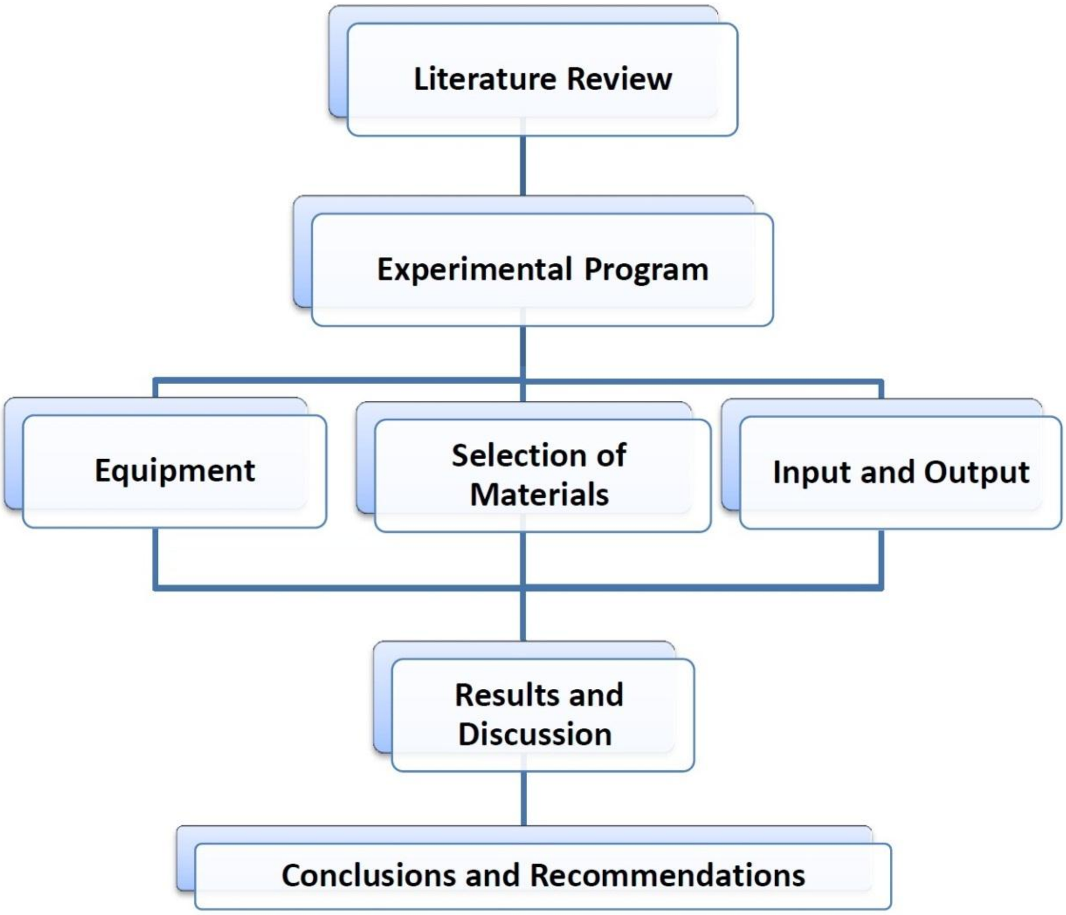


Figure (1.3): Flow chart of the research methodology

1.8 Thesis outline

The undertaken research consists of five chapters that cover the subject as follows:

Chapter One (Introduction): this chapter consists of a general introduction with an overview of the storm water infiltration, definition and the types of permeable pavements. The advantages of using permeable pavements such as reducing storm water peak flow rates, problem identification, objectives and methodology of the research also described.

Chapter Two (Literature Review): this chapter begins with a brief literature review of details the work carried out by other researchers on monitoring peak discharges and improvements observed to storm water quality when using permeable pavements. also reports different types of pavement structures.

Chapter Three (Experimental Program): this chapter describes the experimental program in laboratory, and testing method. The infiltration tests carried out on the laboratory pavement and the results of these tests were presented in this chapter, and the scenarios that have been used on study.

Chapter Four (Results and Discussions): this chapter includes a summary of the experimental results and discussion.

Chapter Five (Conclusions and Recommendations): this chapter ends up with conclusion and recommendations.

Chapter (2)
Literature Review

2.1 Introduction

This chapter provides an overview of the different types of permeable pavements, the configuration of the permeable pavement structure, infiltration rates of water between joints of interlock tiles and base course under interlock tiles. The preparation of the layer under permeable pavement includes material selection for the bedding and base course. The major characteristic of permeable pavements were reviewed and investigated the traditional concrete block types, some studies were conducted in this concern and the outcome of these studies was reviewed.

2.2 Concrete block pavement

Pavements have been surfaced with stone blocks since ancient times and even up to the end of the 19th century surfaces of dressed stone or hardwood blocks were common. Developments in concrete technology and improved plant for block manufacture led to acceptance of small concrete blocks for pavement surfaces in Western Europe about 60 years ago (CCA, 1988).

Benefits of using concrete pavement shows its effect on quality and economy of modern technology, which has now spread throughout the world. There are a wide range of applications including malls, public forecourts, motorway on/off ramps, suburban streets, driveways, footpaths, residential patios, car parking areas, airports and container parks (CCANZ, 2013).

2.2.1 Applications of concrete block pavement

Concrete pavers are a versatile paving material, which due to the availability of many shapes, sizes and colors, have endless streetscape design possibilities. The use of concrete block paving can be divided in to the following categories:

- **Roads:**

Main roads, residential roads, urban renewal, intersections, toll plazas, pedestrian crossings, taxi ranks, steep slopes, pavements (sidewalks).

- **Commercial projects:**

Car parks, shopping centers and malls, parks and recreation centers, golf courses and country clubs, zoos, office parks, service stations, bus termini.

- **Industrial areas:**

Factories and warehouses, container depots, military applications, mines, wastewater reduction works.

- **Domestic paving**

Pool surrounds, driveways, patios, townhouses and cluster homes, specialized applications, cladding vertical surfaces, storm water channels, embankment protection under freeways, roof decks (CMA, 2004).

2.2.2 Advantages of concrete block pavements

Two of the major advantages of concrete block pavements are their aesthetic appeal and their high strength. In addition the riding surface of good quality concrete offers high durability, skid resistance, abrasion and scuffing resistance.

Block pavements may be opened to traffic immediately on completion of construction, the surface is not as smooth as asphalt or cast in situ concrete so interlocking pavements are generally recommended for where traffic speeds are less than 50 - 60 km/h. Because of its segmental nature, interlocking blocks can be recycled. Once the pavement has been broken, paving blocks can be lifted and recovered for re-use and only a small stock of replacement blocks needs to be maintained. This facilitates access to underground services and permits the subsequent restoration of the pavement with little material cost and no discontinuity of the surface. Pavement shape correction if required can also be accomplished at low material cost (CCA, 1988).

2.2.3 Structure of concrete block pavements

Interlocking concrete block pavements usually consist of three layers: surface, base-course and subgrade. On low strength soils a further layer, ie: a sub base or working platform, may be included. The layers are described as follows and are shown in Figure (2.1).

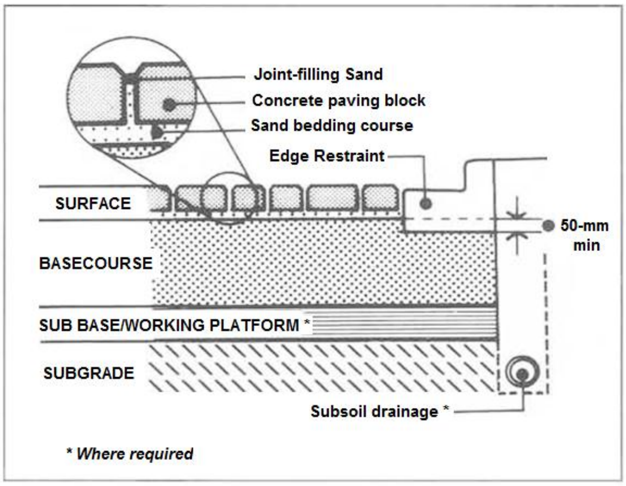


Figure (2.1): Interlocking concrete block pavements structure

(CCA, 1988)

- **Surface**

The surface layer comprises the concrete interlocking paving blocks, a sand bedding course and edge restraints, Gaps, usually referred to as "joints", between paving blocks are completely filled with a fine joint-filling sand.

- **Base-course**

The base course consists of one or more layers of either high quality unbound or lime and/or cement modified crushed and graded aggregate or natural gravel, or a cement bound crushed rock or gravel.

- **Sub-base/working platform**

With law strength subgrade soils, a sub base or stabilized subgrade or other material may reduce costs by substituting for part of the base course thickness and/or may be required to provide a stable platform on which to construct the base course.

- **Subgrade**

The subgrade is the prepared in situ soil or fill on which the pavement is constructed (CCA, 1988)

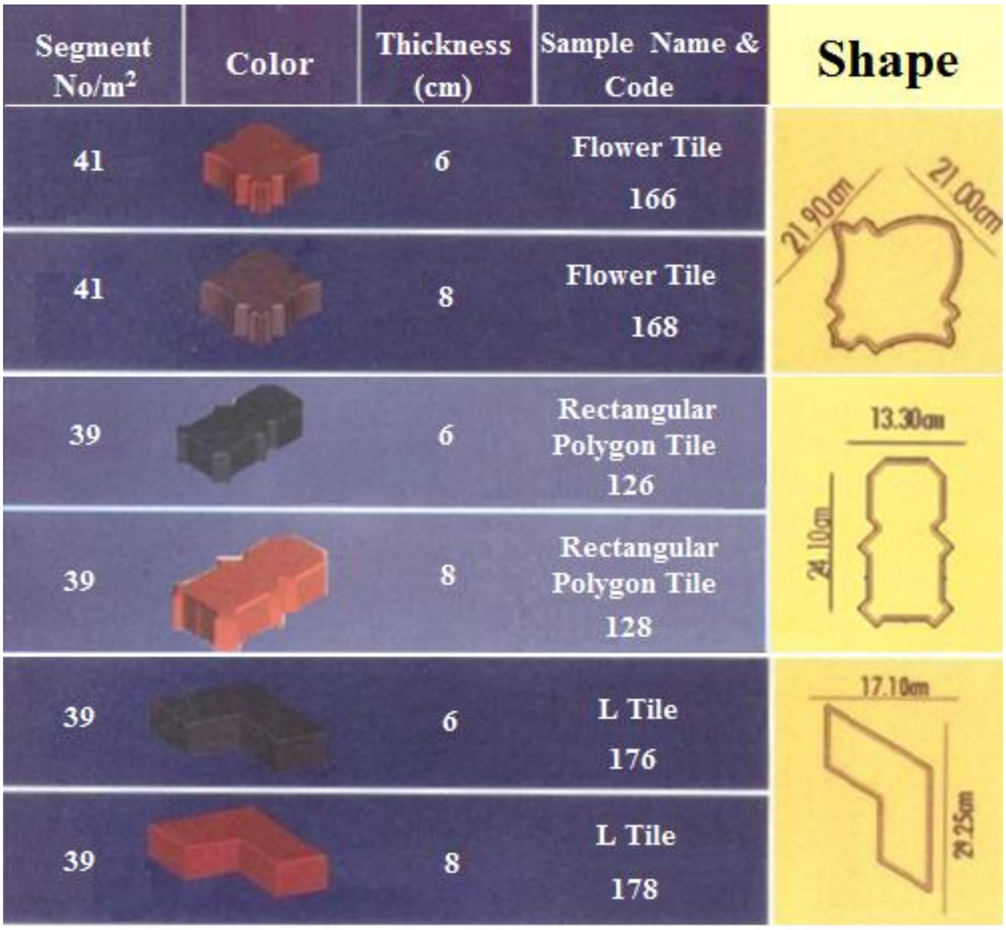
2.2.4 Shapes and colors of concrete block pavements

Concrete block pavements are produced in a variety of shapes, typical paving block shapes available in the Gaza strip are shown in Figure (2.2).

Segment No/m²	Color	Thickness (cm)	Sample Name & Code	Shape
36		6	H Tile 106	16.30cm, 19.80cm
36		8	H Tile 108	
26		6	Polygon Tile 116	25.80cm, 23.80cm
26		8	Polygon Tile 118	
50		6	Rectangular Tile 136	9.80cm, 19.80cm
50		8	Rectangular Tile 138	
40		6	Star Tile 146	19.60cm, 18.20cm
40		8	Star Tile 148	
37		6	Octagon Tile 156	23.30cm, 19.40cm
37		8	Octagon Tile 158	

Figure (2.2): Available Block shapes in the Gaza strip

(Mushtaha & Hassouna Co., 2013)



Segment No/m²	Color	Thickness (cm)	Sample Name & Code	Shape
41		6	Flower Tile 166	21.90cm 21.00cm
41		8	Flower Tile 168	
39		6	Rectangular Polygon Tile 126	13.30cm 24.10cm
39		8	Rectangular Polygon Tile 128	
39		6	L Tile 176	17.10cm 29.25cm
39		8	L Tile 178	

Figure (2.2): Available Block shapes in the Gaza strip

(Mushtaha & Hassouna Co., 2013)

2.2.5 Characteristics of concrete block pavements in Gaza

Palestine Standards Institution (PSI) shows the characteristics and specifications as:

- The compressive strength of concrete block has been stated to range between 45 and 50 MPa.
- The value of the Abrasion value rate should be no more than 5-6 mm.
- The Maximum absorption when placed in water for 10 minutes no more than 2% and when placed in water for 24 hour no more than 5%.

2.2.6 Joint filling of concrete block pavements

The small gaps or joints between paving units are filled with a joint filling sand. The joints are typically 2-4 mm wide and require a relatively fine sand, having a different grading to that required for bedding sand (CCA, 1988).

2.3 Porous pavements

In the late 1960's, research into a new type of pavement structure was commencing at The Franklin Institute Research Laboratories (FIRL) in the United States. With the support of the United States Environmental Protection Agency (EPA), a porous pavement program was developed. This new pavement structure was initially installed in parking lots (Schaus, 2007).

Porous pavements have been installed since the early 1980's throughout the United States, installed over on parking lots, pathways, and trails for universities, libraries, religious centers, prisons, industrial parks, commercial plazas, and municipal buildings (Adams, 2006).

A porous pavement is a distinct pavement type that permits fluids either from precipitation or elsewhere, to pass freely through the structure reducing or controlling the amount of run off from the surrounding area. By allowing precipitation and run off to flow through the structure, this pavement type can be applied as a storm water management practice, these particular types of pavements may also result in a reduction in the amount of pollutants entering the ground water by filtering the run off, they are generally designed for parking areas or roads with lighter traffic (EPA, 1999).

The original proposed structure of a porous pavement consisted of an open graded surface course placed over a filter course and an open graded base course (or reservoir) all constructed on a permeable subgrade. Storm water infiltrations using pervious pavements have been investigated by researchers as a method of managing storm water (Schaus, 2007).

2.4 Permeable interlock concrete: structure and properties

Permeable interlocking concrete pavers offer an additional type of paving material to be installed as a best management practice for storm water management. The permeable pavers consist of infiltration trenches with a paving material over top to support vehicle and pedestrian loads (Burak, 2004).

For the general paver design, the interlocking geometry provides regular void spacing throughout the system. The voids are typically filled with sand allowing for appropriate drainage while maintaining a suitable surface. The infiltrated precipitation is collected within a drainage layer and transported to a storm water collection system or reservoir designed to infiltrate precipitation into the subgrade below. Typical application sites include low traffic roadways, mainly local streets and parking facilities (Schaus, 2007).

A pervious pavement structure includes a surface layer, a base and a sub base to allow stormwater to percolate into the sub grade or to divert into stormwater drainage while retaining pollutants on the paver surface. Depending on the purpose of the pervious pavement and the sub grade soil conditions, a geotextile will be placed between the sub base layer and the sub grade soil to avoid pollutants percolating into the groundwater (Zhango, 2006), Figure (2.3) illustrates a typical permeable paver structure.

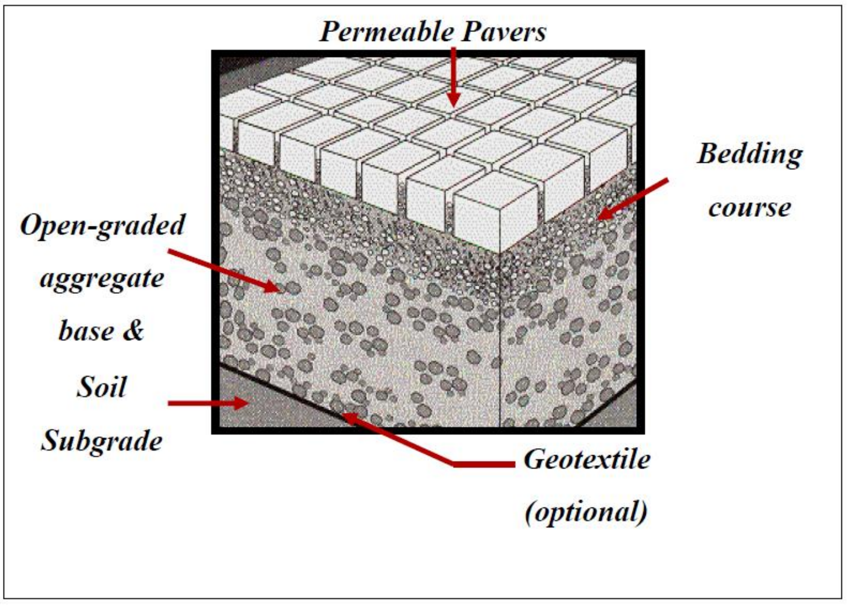


Figure (2.3): The structure of a typical permeable pervious pavement (Zhango, 2006)

Permeable surfaces are more suitable in car parks or driveways than the porous pavements. The voids between the paver materials are more widely open and can infiltrate higher rainfall intensity than porous pavements (Zhango, 2006).

On the other hand, permeable pavement surfaces are normally constructed by impervious paver concrete blocks with infiltration voids between the blocks. Infiltration capacities of permeable pavements are high due to the coarse aggregate between concrete blocks.

2.4.1 Types of permeable concrete pavers

The Interlocking Concrete Pavement Institute (ICPI) suggests four various types of permeable pavers. Interlocking shapes with openings are designed with specific patterns allowing fluid to drain through the openings. The specific shape of the units creates the drainage openings while maintaining high side-to-side contact between the units. Enlarged permeable joints are
constructed with large joints allowing fluid to penetrate the system, these enlarged joints may be as wide as 35 mm. The pavers are placed directly beside one another, and fluid is able to penetrate directly through the concrete (ICPI, 2006). Figure (2.4) illustrates the various types of permeable pavers.

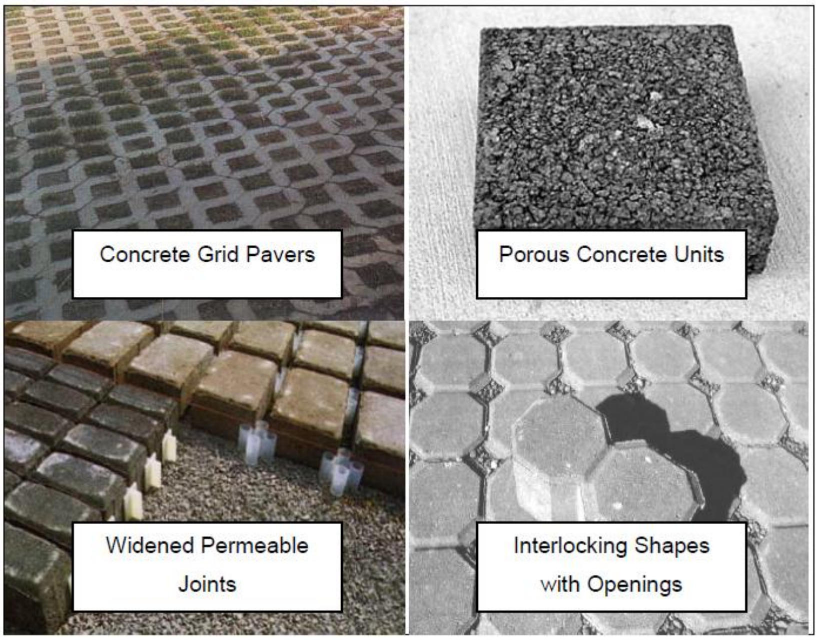
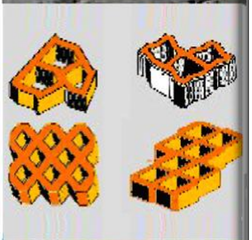


Figure (2.4): Types of Permeable Pavers (ICPI, 2006)

A guide to permeable interlocking concrete pavements show that permeable pavers allow water to infiltrate the surface by using shapes that create drainage openings along the joints or by the use of oversized spacers which widen the joints. It is possible to classify permeable pavers in terms of infiltration and to rank their suitability for traffic into the four groups shown in Table (2.1) (CMAA, 2010).

Table (2.1) : Classification of block pavements (CMAA, 2010)

Paver Type	Description	Suitability to carry traffic	Example
Pavers with openings along joints	Pavers have normal joints but openings are provided along these at intervals. The openings and joints are filled with 2-5 mm aggregate. Water flows only through openings and joints	General traffic	
Pavers with widened joints	Pavers provided with slots or wider (< 10mm) joints than those customarily specified (2 to 5mm). Slots and joints are filled with aggregate. Water flows through slots or joints	General traffic	
Grass stones and grids	Pavers with large openings filled with soil within which grass is grown. These are effective in trapping pollutants but permit only small water flows. To increase flows, openings may be filled with aggregate instead of soil.	Light traffic with only occasional trucks	
Paving systems with enlarged grass joints	Pavers are widely spaced using plastic or concrete spacers so that grass can grow between the pavers. Used primarily for landscaping.	Car parking only – No commercial vehicles	

2.4.2 Patterns of interlock concrete

Laying patterns of pavers are identified as being either herringbone, basket weave, or stretcher as shown below. Each of these may be laid at either 90^o or 45^o to the line of edge restraints. A variation of stretcher is the Zig zag running bond (CMA , 2004). Figure (2.5), shows the pavement pattern.

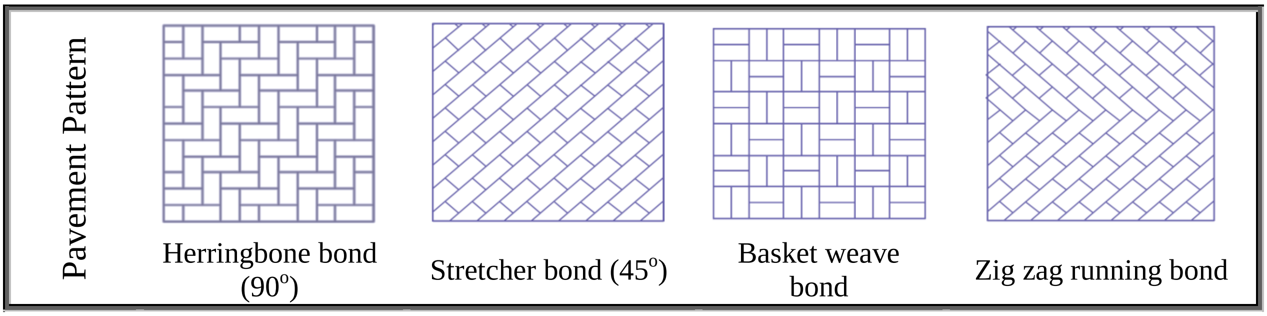


Figure (2.5) : Pavement Patterns (CMA , 2004)

2.4.3 Bedding course material characteristics

The purpose of the reservoir course is to store the infiltrated water until the water can penetrate the underlying soil. This engineering layer in the pavement structure acts similarly as a retention basin (Thelen and Howe, 1978).

The reservoir course functions as a holding tank until the water can infiltrate into the underlying soil or sub drains. Similarly, The Franklin Institute recommended that the percentage of voids in the reservoir should be equal to or greater than 40% in order to collect the precipitation. High air voids are critical for the reservoir course. This engineered layer must provide sufficient storage capacity for the infiltrated fluids (Thelen and Howe, 1978). Table (2.2) and Figure (2.6) indicate the recommended gradations for the bedding course.

Table (2.2): Recommended design gradation for bedding course

Sieve Size		Percent Passing (%)
Metric	Imperial	
75 mm	3 “	100
	2.5 “	90-100
50 mm	2 “	35-75
37.5 mm	1.5 “	0-15
19 mm	0.75 “	0-5
12.5 mm	0.5 “	
0.150 mm	No. 100	0-2

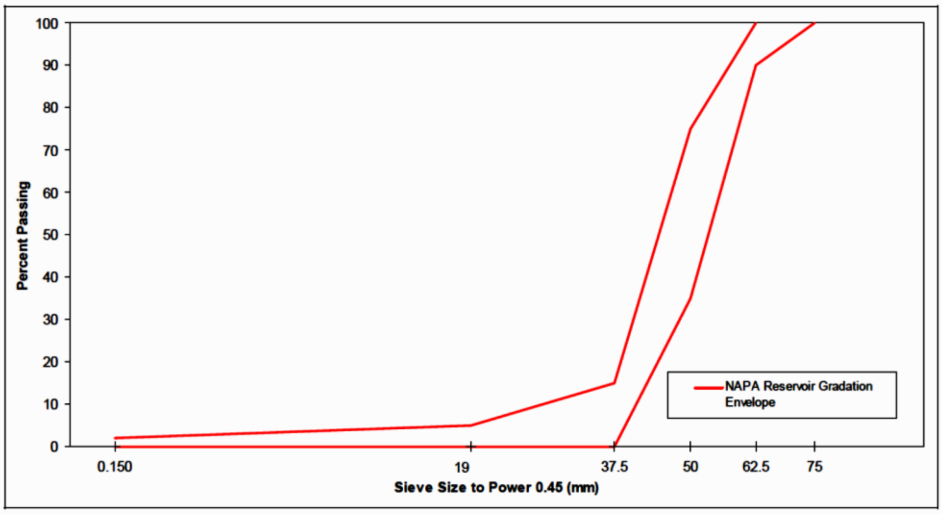


Figure (2.6) Recommended gradation for bedding course

2.4.4 Filter course material characteristics

The purpose of the filter in the structure is to provide a working/ construction platform for the surface course and provide limited filtering capabilities (Ferguson, 2005& NAPA, 2003). Table (2.3) provides recommended gradations for the filter course.

Table (2.3): Recommended design gradation for filter course

Sieve Size		Percent Passing (%)
Metric	Imperial	
12.5 mm	0.5 "	100
9.5 mm	0.375 "	0-5

2.4.5 Drainage design for permeable pavement

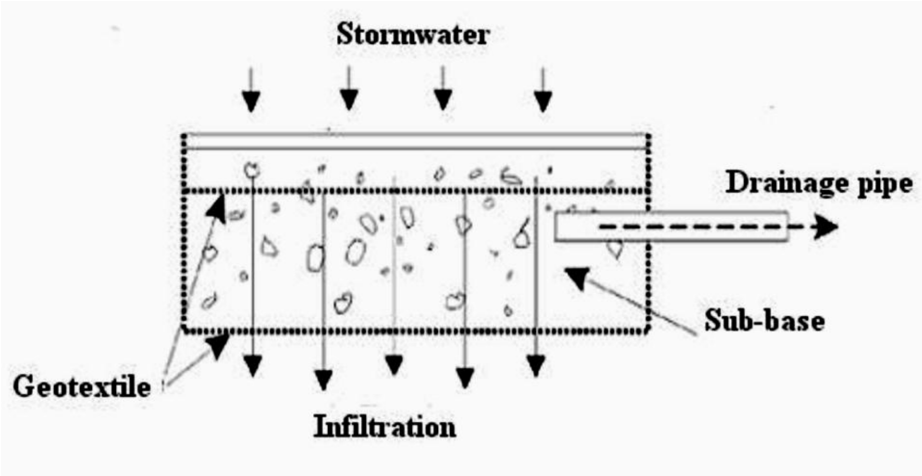
Drainage design is only one important part of the integrated pervious pavement system. According to different drainage designs underneath the pervious surface, pervious pavements can achieve two objectives when used as a storm water management method. Normally the designed flows will be estimated by the Rational Method, as show in eq. (2.1).

$$\boldsymbol{Q = C\,I\,A} \qquad \text{--} \ (2.1)$$

Where,

Q = Storm water quantity, (m^3/h)
C = Coefficient of Runoff, (dimensionless)
I = Rainfall intensity, (mm/h)
A = Catchment Area, (m^2)

According to the local environmental and storm water resource requirements, different drainage pipe designs can be integrated into the pervious pavement systems at design. For example, if the local groundwater table is at a significant low depth, storm water is an ideal resource to recharge groundwater. Under this situation, the aim of the pervious pavement is to allow more water to percolate into the groundwater bringing it up ready for reuse. In this situation the drainage pipe is laid close to the bottom of bedding layer. Figure (2.7) is a schematic diagram of pervious pavement used to infiltrate storm water with the potential for reuse. The drainage pipes are laid at the bottom of the sub base layer Figure (2.8) if the aim of the pervious pavement is to attenuate the peak flow rate.



Figure(2.7) Pervious pavement used to infiltrate storm water to the groundwater Infiltration

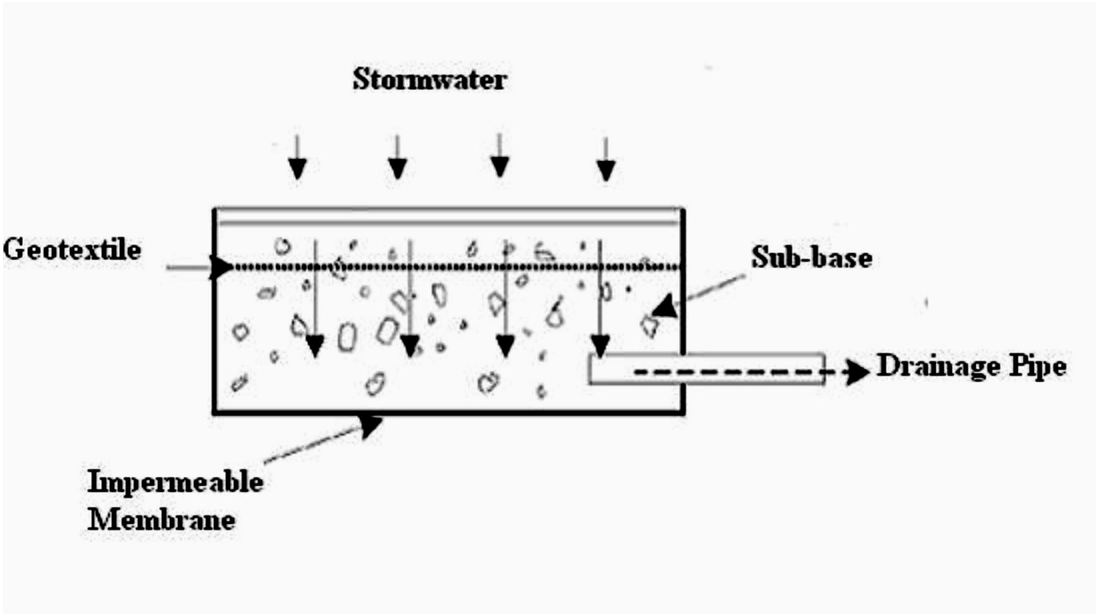


Figure (2.8): Pervious pavement used for attenuation (NAPA, 2003)

2.4.6 Limitations of using preamble pavements

Davies et al., (2002), investigated the infiltration rate through a permeable concrete layer in the lab. They tested the infiltration rates in the surface with clean concrete blocks with different gradients. The above author found that the infiltration capacities to be high at gradients as high as 10 %. Subsequently they applied two types of silt on the pavement to observe the effects of surface clogging on infiltration. The volume of water infiltrated reduced by 44 %, 36 % and 26 % with both types of silt in 1 %, 5 % and 10 % gradients respectively. The research found that mechanical cleaning of the surfaces could significantly improve infiltration.

2.4.7 Maintenance and cleaning of preamble pavements

The primary goal of the maintenance activities for preamble concrete is concerned with the prevention of clogging within the structure.

Vacuuming of the structure annually (or as required) is recommended to ensure that void structure is clear of dirt and debris (Tennis, 2004). The Mississippi Concrete Industries Association (MCIA) indicates that pressure washing of pervious concrete can restore 80% - 90% of the permeability of the pervious concrete (MCIA, 2002). The ACI provides a suggested maintenance schedule for pervious concrete (ACI, 2006). Table (2.4) provides the recommended maintenance activities specifically for pervious concrete.

Table (2.4): Recommended maintenance activities specifically for pervious concrete

Maintenance Activity	Frequency
-Ensure that paving area is clean of debris -Ensure that the area is clean of sediments	Monthly
-Seed bare upland areas -Vacuum sweep to keep the surface free of sediment	As needed
-Inspect the surface for deterioration	Annually

Dierkes et al., (2002) claimed that maintenance is an important factor to maintain the infiltration capacity of permeable pavement. They carried out a field investigation to address the infiltration capacities of the permeable pavement before and after the cleaning. The research found that the infiltration capacity of the pavement increased from 1L/(s/ha) to 1500L/(s/ha). That means the fully clogged permeable pavement can be reactivated through a regular cleaning.

Environment Protection Agency (EPA, 1999) recommended the following maintenance methods for pervious pavements:

- Four times per year high suction vacuum sweeping and/or high pressure jet hosing to maintain porosity.
- Repair potholes and cracks.
- Replace clogged areas of the pervious pavement which could be observed by water collected on the surface.
- Rectification of any differences in pavement levels.

James et al. (2003), reported porous pavements can easily get compacted and clogged with sediments. As a result, the pavements have to be reconstructed once every 8 years. They also reported that porous pavements can easily be rutted by traffic and freeze easier than normal pavements.

Cahill et al. (2003) listed some guidelines to construct pervious pavements:

- Pervious pavements are not suitable for slopes larger than 5 %;
- The bottom of sub-base should be 1.2 meters higher than the local seasonal; water table to avoid pollute groundwater;
- Wash the selected aggregates to remove fines prior to the installation;

2.5 Storm water data in Gaza

The necessary information required by the research have been collected from the relevant institutions such as Palestinian water authority (PWA), municipalities, the Ministry of Local Government (MoLG), the Ministry of Agriculture (MoA), Coastal municipal water utility (CMWU) and local NGOs.

The available storm water quantities that flow from the existing urban areas in Gaza were calculated to be 22 Mm^3 every year. Since urbanization in the Gaza Strip is a continuous process, the flowing storm water quantities from the planned land use were estimated to be 37 Mm^3 every year (Hamdan, and Nassar, A., 2007).

The available groundwater system which is part of the coastal aquifer showed fast response to natural rainfall infiltration. However, in the dry season, the decrease in the water table was around 1.5 meters due to groundwater abstraction. This means that the supply to the aquifer is much less than the demand through abstraction. At the same times, there it gives us an indication that, artificial recharge of groundwater with storm water will have quick positive effect to balance the gap between aquifer supply and demand (Hamdan, and Nassar, A., 2007).

2.5.1 Rain Intensity

Improvement of the reliability of Rain Intensity (RI) measurements as obtained by traditional tipping-bucket rain gauges Tipping Bucket Rain gauges (TBRs) and other types of gauges (optical, weighting, floating/siphoning, etc.) is therefore required for use in climatologic and hydrological studies and operationally e.g. in flood frequency analysis for engineering design. Standardization of high quality rainfall measurements is also required to provide a basis for the exchange and valuation of rainfall data sets among different countries, especially in case trans boundary problems such as severe weather/flood forecasting, river management and water quality control are operationally involved. Figure(2.9) shows the intensity duration frequency curve in Gaza city, where the intensity readings taken from curves of return period.

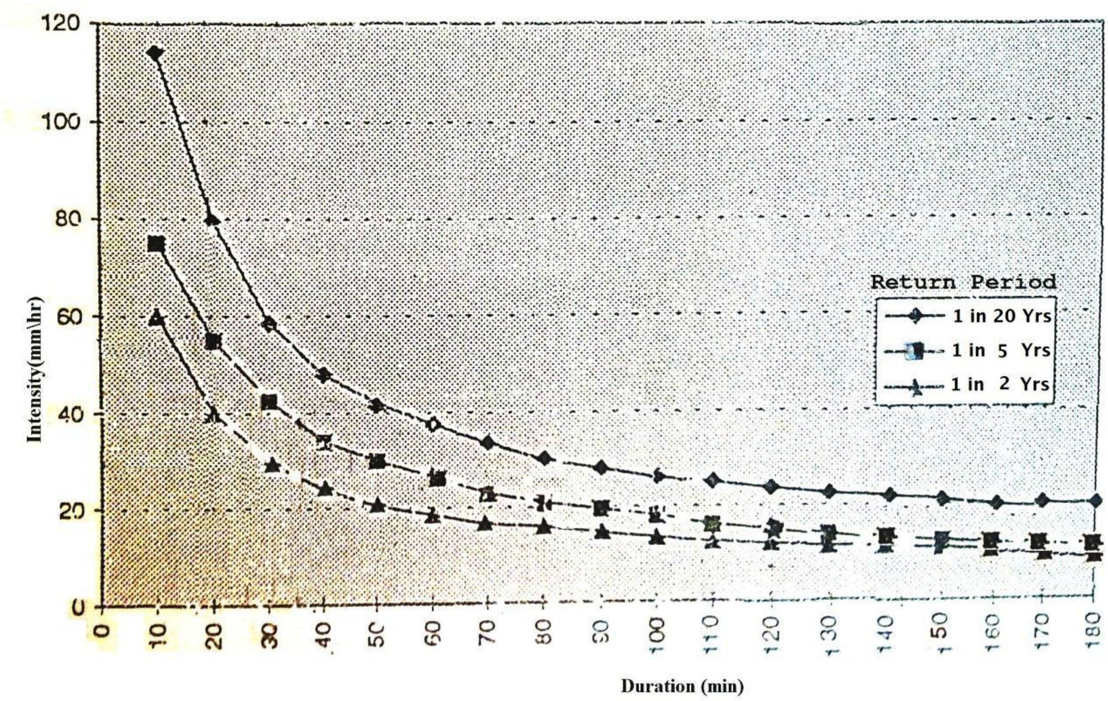


Figure (2.9): Rainfall Intensity/Duration Meteorological Recording Station (Rabah , 2008)

2.6 Laboratory Studies related of permeable pavement

2.6.1 Studies related of pavement material selection

The physical properties of the bedding material for permeable pavements have been studied by **Shackel et al. (1996)**, the study was focused on the selection of bedding and jointing material. The material included different grading curves with 2 mm sands to 10mm aggregates. A 1.5 m square steel box was set up in the laboratory to construct the eco-paver and bedding material inside. The study found that fewer fines in the bedding material resulted in a higher infiltration rate. A uniform 2~5 mm aggregate achieved an infiltration rate of 600L/ha/sec (218mm/hr), which was the highest infiltration rate obtained with different combinations of aggregates. The voids between pavers have to be filled to obtain a sufficient structural capacity of the pavement. The study recommended that in order to reach an optimal infiltration rate and maximum stress loading capacity, a maximum size between 4 and 5 mm uniform bedding and jointing material need to be selected.

Shackel et al. (2003), constructed a permeable pavement lane with the interlock concrete block described the structure of the constructed permeable pavement as below:

- Paver: interlock concrete block (80mm, thickness)
- Bedding: 2~5 mm crushed aggregate (30mm, thickness)
- Sub-base: 5~20 mm open graded aggregate (200mm, thickness)

This permeable pavement was successfully constructed and operated. The long term infiltration and water quality data are still being collected for research.

Tobermore (a pavement industry in UK) (2003), provided design guidelines based on different sub grade soil conditions and the objective of the constructed pavement. They also selected the ‘four layers’ (a paver surface, bedding, a sub-base and a geotextile) structure for their pavement products. They have successfully constructed permeable pavements in the UK, such as a car park at a call center in Armagh, UK and a car park at the Building Research Establishment, UK. According to different objectives of the pavement, they adjusted the thickness of the sub-base layer and placed an extra layer to achieve a higher load bearing capacity. The different structures used so far in practice are detailed in Table (2.5).

Table (2.5): Different structures of Tobermore pavers for different construction purposes (Tobermore, 2003)

Purpose	Permeable Surface	Bedding	Sub-base	Geotextile	Extra layer
Pedestrian use only (applies for all ground conditions)	80mm Tobermore Permeable paver	50mm thickness of 6mm grit	175mm thickness of 20mm coarse graded aggregate	1000 gauge polyethylene sheet	None
Driveway over 2% CBR soil	80mm Tobermore Permeable paver	50mm thickness of 6mm grit	250mm thickness of 20mm coarse graded aggregate	1000 gauge polyethylene sheet	150mm thickness granular sub-base material and 150mm capping material
Driveway over 7% CBR soil	80mm Tobermore Permeable paver	50mm thickness of 6mm grit	250mm thickness of 20mm coarse graded aggregate	1000 gauge polyethylene sheet	None
7.5ton weight vehicle use over 2% CBR	80mm Tobermore Permeable paver	50mm thickness of 6mm grit	350mm thickness of 20mm coarse graded aggregate	1000 gauge polyethylene sheet	150mm thickness granular sub-base material and 250mm capping material
7.5ton weight vehicle use over 7% CBR	80mm Tobermore Permeable paver	50mm thickness of 6mm grit	350mm thickness of 20mm coarse graded aggregate	1000 gauge polyethylene sheet	None

Permapave, is a company manufacturing permeable pavements in Australia. They introduce the bedding structure for their product as:

- *Permapave* Permeable pavers (surface cover)
- Up to 100mm depth of fines free 5mm~20mm screen crushed rock.

2.6.2 Studies related of water infiltration rates in urban area

The infiltration rates are dependent upon texture of the soil material, but more important is the structural condition of the soil material. Soil in an undisturbed forest condition will have a high infiltration rate, compared to the same soil in an agricultural field. The infiltration rate is reduced under the highly disturbed urban condition where structure may be nearly destroyed. Consequently, significant decline in infiltration rates is attributed to urban disturbances (khalaf, 2005).

Storm water infiltration is one of the key attributes of a pervious pavement. The hydraulic performance of the pavement depends on the selection of the paver material and the sub-structure material. It is obvious that the infiltration capacity of pervious pavements is higher than conventional pavements. The infiltration capacity and total amount of water infiltrated are important parameters in pervious pavements.

According to Sharma (1983), infiltration refers to the entrance of water into soil or porous material through the interstices or pores of a soil or other porous medium. Infiltration is the sole source of soil water to sustain the growth of vegetation and of the groundwater supply of wells, springs, and streams (Schwab, et.al., 1993).

The capacity of any soil to absorb the rainwater falling continuously at an excessive rate goes on decreasing with time until a minimum rate of infiltration reached. The infiltration rate is a function of time, and has the dimensions of volume per unit of time per unit of area. These units reduce to depth per unit time; it is expressed in (mm/min) (Suresh, 1993).

Smith (1984), carried out a field test in two similarly constructed car parks (with grass concrete and impermeable asphalt) to test the runoff quantity. They found that the runoff from the previous car park is as low as 35 % of the impermeable car park. It also concluded that the number of dry days between storms is an important factor which affects the performance of the pervious pavement.

Pratt et al. (1989), indicated that the peak runoff rate from the previous pavement was 30 % of the conventional pavement. The time to peak flow rate was 5 to 10 minutes compared to the 2 to 3 minutes from the conventional pavement resulting in significant benefit.

Bond et al. (1999) monitored the water quantity from a car park in Nottingham. A significant decrease in the quantity of water discharged to the drain was noted. Two types of sub base materials (blast furnace slag and granite) were investigated. The total discharge was reduced by 34 % and by 47 % respectively. This was due to the water storage (wetting and absorption) in the sub base of the constructed car park. The rate of outflow is slower, extending the period of discharge to days.

Newton et al. (2003) investigated the surface runoff volume reduction through a porous pavement by constructing two sealed stainless steel boxes with 0.25 m^2 surface area and 0.15m deep. The research showed that the entire porous pavement can reduce surface runoff volume by 30 % to 60 %. The above researchers also reported that in a combined pervious and impervious pavement system, the reduction volume will depend on the ratio of impervious to pervious pavement area.

Shackel et al. and Pearson (2004), indicated that infiltration capacity of porous pavements are not sufficiently high for rainfall conditions and can easily clog within a short period.

According to above authors, permeable pavements are more suitable. As a result this research study focuses on permeable pavements.

2.7 Conclusion of previous studies

After reviewing the previous studies related to porous/permeable/pervious pavements with respect to interlocking concrete pavers, all of these pavements are designed to allow free draining through the structure. The literature review also provided a summary of the history of traditional pavement designs and the specific design principles associated with porous pavement technology. Porous pavements are generally designed for parking areas or roads with lighter traffic.

By permitting fluids to pass freely through the structure it can assist in reducing or controlling the amount of run off from the surrounding area, and therefore, it can be applied as a storm water management practice.

One of the key components to the success of porous pavements is the permeability or infiltration capabilities of the structure. High porosity is required for the structure to remain functional. The permeable course must store a significantly higher amount of fluid within the structure, and therefore, the porosity of the reservoir course should be approximately 40% air voids.

The current research was concentrated on the permeable surface. It is important to be able to determine the infiltration capacity of a permeable pavement to successfully design the infrastructure to reduce storm water effectively and efficiently in the urban environment.

Chapter (3)
Experimental Program

3.1 Introduction

The literature review in the preceding chapter clearly indicated that the use of permeable pavements to manage storm water is a concept feasible for lightly loaded pavement structures. It is clear that to achieve an efficient and durable solution, a careful design of pavement layers and choice of surface pavement product. The objective of the present study is to understand the infiltration through joints of interlock pavement surface only.

As a result, it was decided to build a practical experiment pavement to monitor the infiltration rates through the pavement structure. The simulated rainfall events were modeled using the small pipe and nozzles on steel box. The water infiltrated through the pavement collected by funnel.

All the testing is conducted using equipment and devices available in the laboratories of Association of Engineers - Gaza governorates to evaluate the properties of bedding material and base course material as sand and aggregates. The sieve analysis is carried out for each aggregate type to obtain the grading of aggregate sizes.

Firstly, this chapter presents the laboratory studies carried out to determine the parameters necessary to build the pavement and to monitor the infiltration rate. Secondly, to describe how experimental work has been done and the possible scenarios to achieve study objectives**.**

3.2 Experiment setup

The design of experiment was constructed in a 1.0 x 1.0 m with 0.35 m depth from steel box, which was set up with hole on the bottom plate for water to pass through, as shown in Figure (3.1). A rainfall simulator with 25 Nozzles (sprays) and the distance between them is 20 cm installed at 80 cm from the surface of the pavement, as shown in Figure (3.2). Applied rainfall intensities were controlled by a flow meter.

The water flowing through the pavement was collected from underneath the pavement via a funnel with hole on the middle, as shown in Figure (3.3). The diameter of the hole is 1" (25mm). In order to simulate field conditions, the pavement is constructed at a slope of 2%.

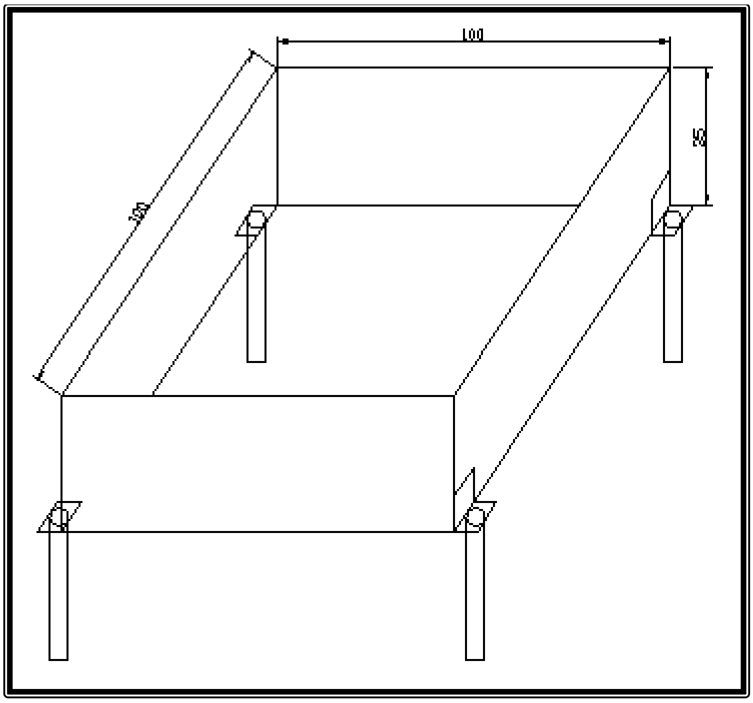


Figure (3.1): The experimental steel box of the permeable pavement

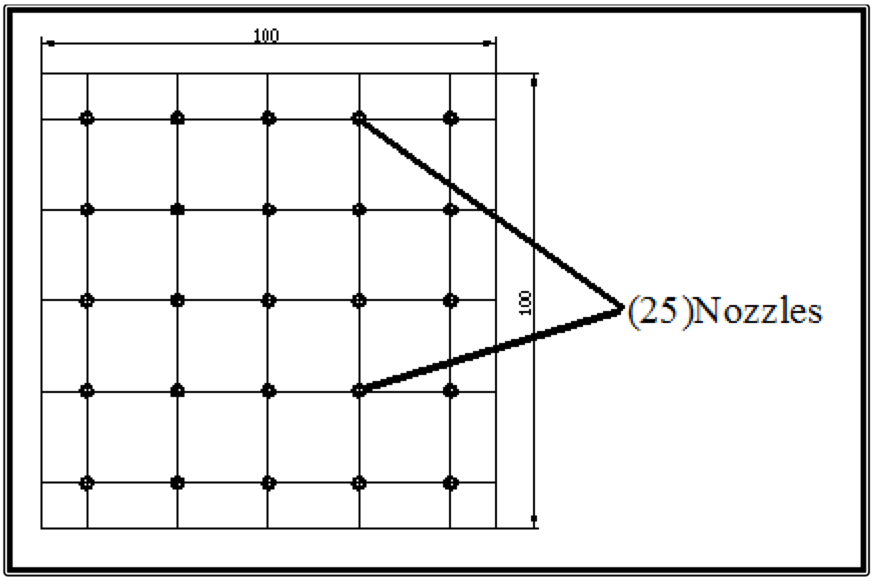


Figure (3.2): The schematic setup of the nozzles

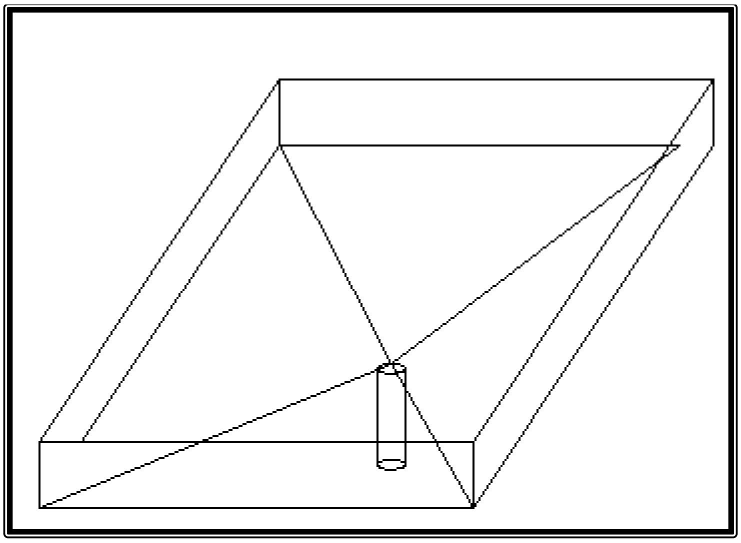


Figure (3.3): Infiltrated water collecting funnel with hole

3.3 Pavement structure

Figure (3.4) shows the cross section of pavement structure. The pavement was constructed in the experimental steel box. As mentioned a decision was taken to monitor the infiltration rate. In construction the pavement, structure was based on recommendations for bedding and base course aggregate sizes and thicknesses. The interlock concrete blocks were used for the surface is (8 cm). The coarse aggregate for bedding layer in the range of (5 cm) and base course layer in the range of (15 cm).

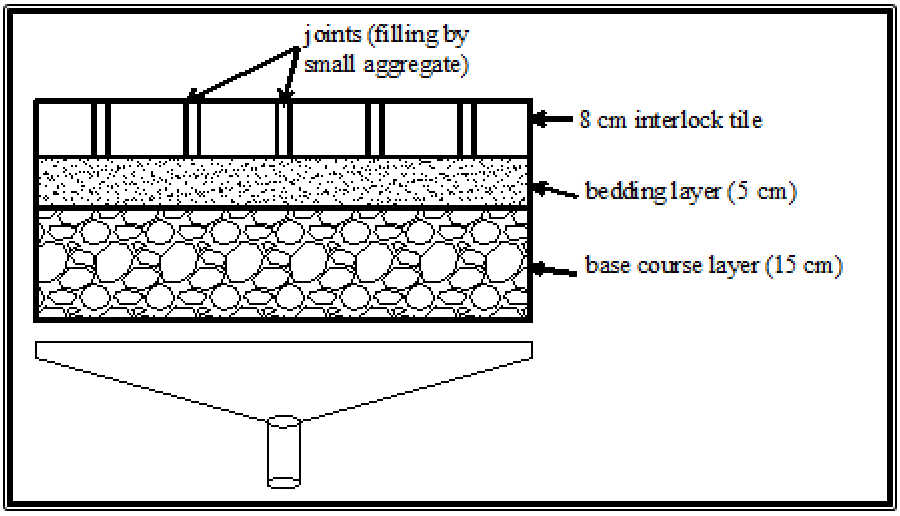


Figure (3.4): The layout of the designed permeable pavement

3.4 Material selection

The necessary materials for this study was collected from local factory in Gaza strip, such as interlock tiles, bedding materials and bases course material selection. Table (3.1) shows main and local sources of these materials and Table (3.2) shows interlock shapes available in Gaza factories, Figures (3.5, 3.6, 3.7) show the sources of sand, aggregates and interlock .

Table (3.1): Main and local sources of used materials

Material	Source	
	Main	Local
Interlock tiles	1) Cement (Egypt) 2) Crushed rocks (Egypt)	Palestine co. for building material (Automatic Factory)& Mushtaha Hassouna Trading co. for and General Contracting
Coarse Aggregates	(Egypt)	(Automatic Factory)
Fine Aggregates (material between joints)	Crushed rocks(Egypt)	(Fine Aggregates used in water well-Marshoud)
Sand	Local sand	(Automatic Factory)

Table (3.2): Interlock shapes available in Gaza factories

Type	No. /m2	Area (m2)	Perimeter (m)	Dimensions (m)	
Rectangular Tile	50	0.020	0.6	0.10x0.20	
H Tile	36	0.029	0.72	0.16x0.20	
Star Tile	40	0.026	0.63	0.182x0.196	
Hexagonal Tile	23	0.049	0.72	0.22x0.22	
polygonal Tile	26	0.062	0.75	0.238x0.258	
Rectangular polygon Tile	39	0.032	0.75	0.241x0.133	

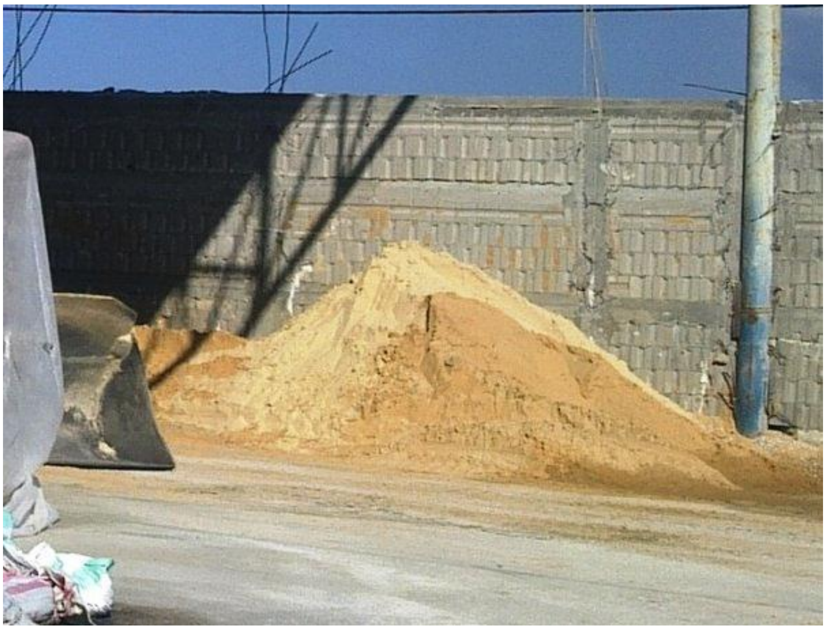


Figure (3.5): Source of Sand (Palestine co. for building material)

Figure (3.6): Source of aggregates (Palestine co. for building material)

Figure (3.7): Source of Interlock tiles (Palestine co. for building material)

3.5 Material properties

In order to obtain the necessary information to construct permeable pavements, laboratory tests were carried out to determine the selected interlock tiles and aggregate properties for bedding materials and base course.

3.5.1 Interlock tile properties

The results of laboratory tests, as following:

- The average compressive strength of testing samples of interlock concrete was 627 kg/cm^2 = 62 MPa (min. range 50 MPa)
- The average value of the Abrasion resistance value is 2.83 mm (Range should be no more than 5 ~ 6 mm).
- The average absorption when placed in water for 24 hour is 2.2 % (Maximum range absorption when placed in water for 10 minutes no more than 2% and when placed in water for 24 hour no more than 5%) (All test on Appendix C)

The interlock test results fall within the (PSI).

3.5.2 Aggregates properties

The aggregates commonly used for bedding materials or base course material are natural fine and coarse aggregates. The aggregates used can be divided into two types as shown in Table (3.3) and Figure (3.8), gradation tests were conducted to determine the size distribution for each aggregate type. Figure (3.9) shows aggregate used to filling between joints. (All test on Appendix B)

Table (3.3): Used aggregates types

	Type of aggregate	Particle size(mm)
Coarse	Adasia	0/12.5
	Simsimia	0/9.50
Fine	Between joints	0/2.36
	Sand	0/0.6

Figure (3.8): Aggregate types used

Figure (3.9): Filling material between joints

3.5.3 Physical properties of aggregates

In order to define the properties of used aggregates, number of laboratory tests have been done, these tests include:

a. Sieve Analysis (ASTM C 136).

b. Specific gravity test (ASTM C127).

c. Water absorption (ASTM C128).

d. Los Angles abrasion (ASTM C131).

Table (3.4) presents the aggregate tests results.

Table (3.4): Results of aggregate tests

Test	Adasia 0/12.5	Simsimia 0/9.50	Between joints 0/2.36	Sand 0/0.6	Designation No.
Bulk dry S.G	2.49	2.54	2.67	2.58	ASTM :C127
Bulk SSD S.G	2.55	2.61	2.73	2.63	
Apparent S.G	2.65	2.73	2.85	2.72	
Effective S.G	2.63	2.70	2.76	2.65	
Absorption (%)	2.49	2.79	2.46	2.02	
Abrasion value (%)	22.4	--	--	--	ASTM : C128

3.5.4 Sieve analysis of aggregates

Tests according to specification (ASTM C 136) is performed on a sample of used aggregate for each type of aggregate in a laboratory as shown in Figure (3.10 and 3.11), and the results are presented below in Table (3.5) and Figures (3.12 - 3.16).

Figure (3.10): Gradation test standard sieves devices

Figure (3.11): Sieve analysis for aggregate between joints (0/2.36)

Table (3.5): Aggregates sieve analysis results

Sieve Opening Size (mm)	Sieve No. #	Sample Passing %			
		Adasia 0/ 12.5	*Simsimia* 0/ 9.50	*Between joints* 0/2.36	*Sand* 0/0.6
19	3/4"	100	100	100	100
12.5	1/2"	57.2	99.6	100	100
9.5	3/8"	9.8	97.1	100	100
4.75	#4	1	23	100	100
2.36	#8	0.8	8.6	97	100
1.18	# 16	0.8	4.3	41	99.9
0.6	# 30	0.8	3.9	4.6	99.6
0.3	#50	0.7	3.7	1.3	93.7
0.15	# 100	0.6	3.4	0.3	2
0.075	# 200	0.5	2.9	0.1	0.2
pan		0.0	0.0	0.0	0.0

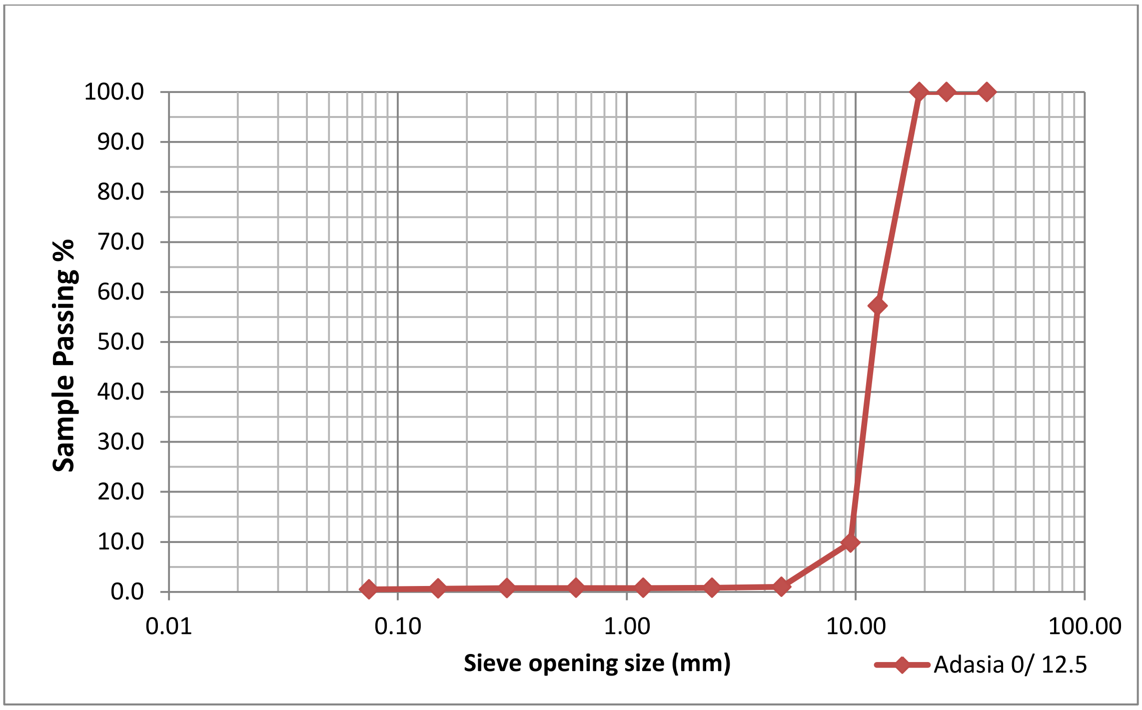


Figure (3.12): Gradation curve for used (Adasia0/ 12.5) aggregate

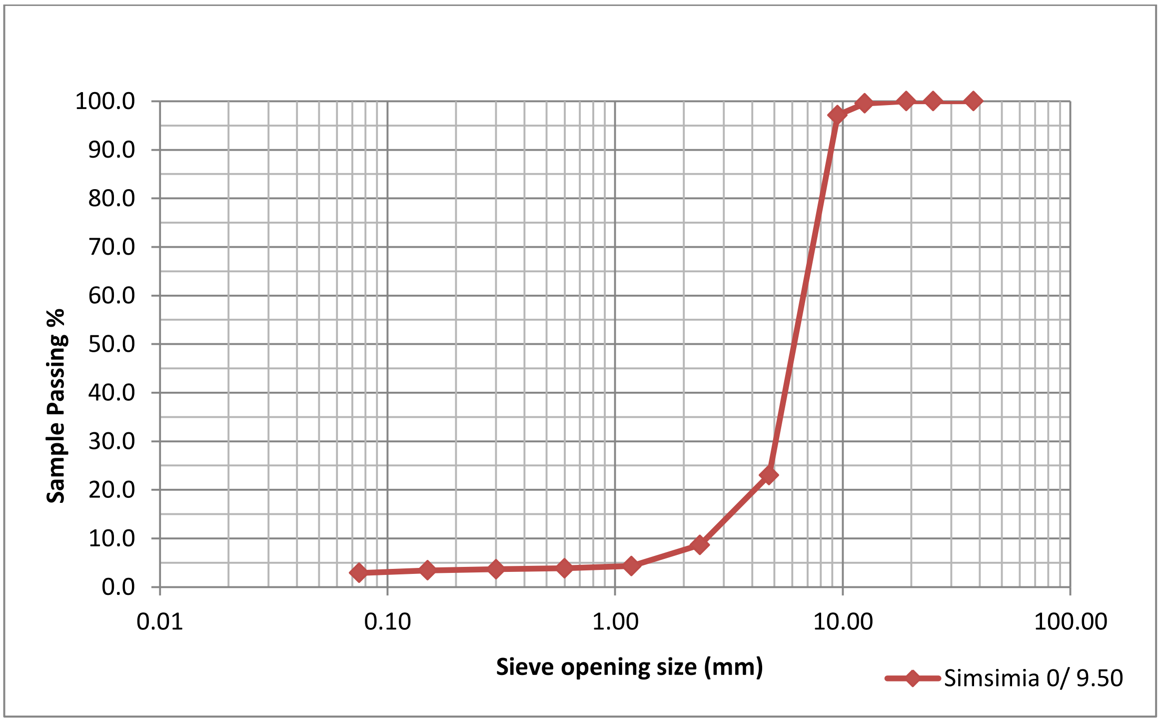


Figure (3.13): Gradation curve for used (Simsimia 0/ 9.5) aggregate

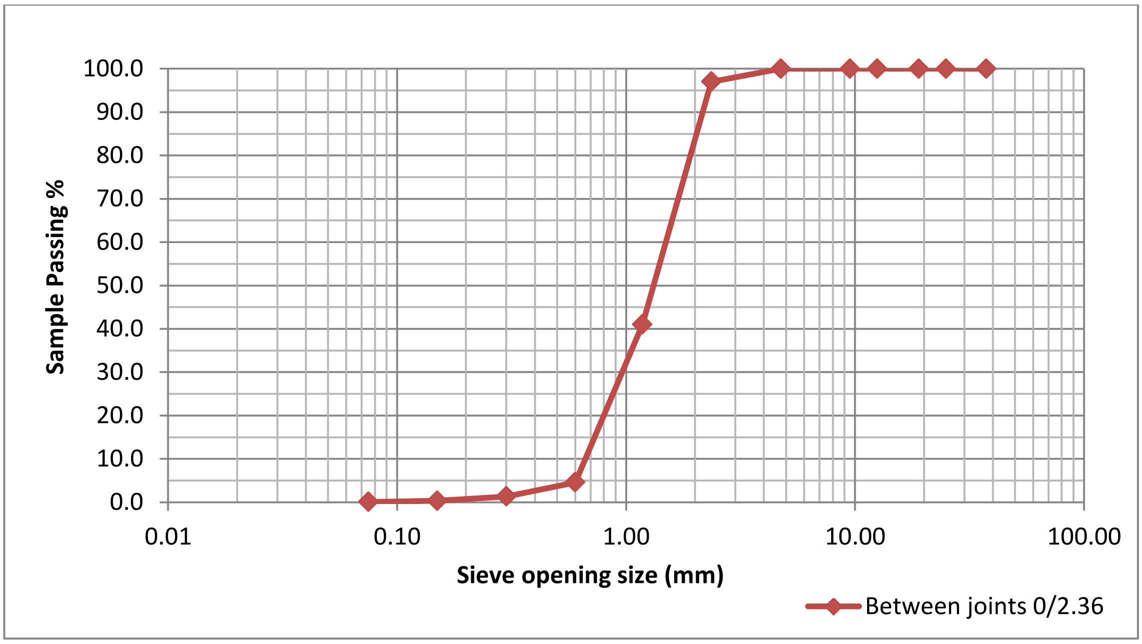


Figure (3.14): Gradation curve for used (Filling material between joints 0/2.36)

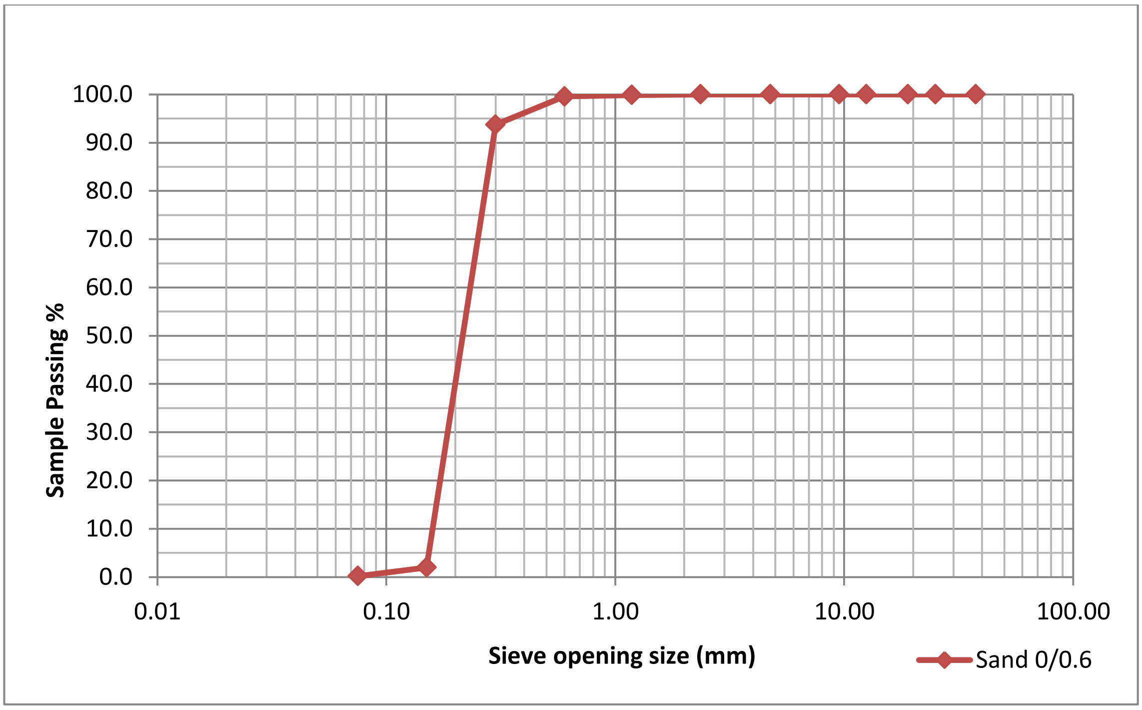


Figure (3.15): Gradation curve for used (Sand 0/ 0.6)

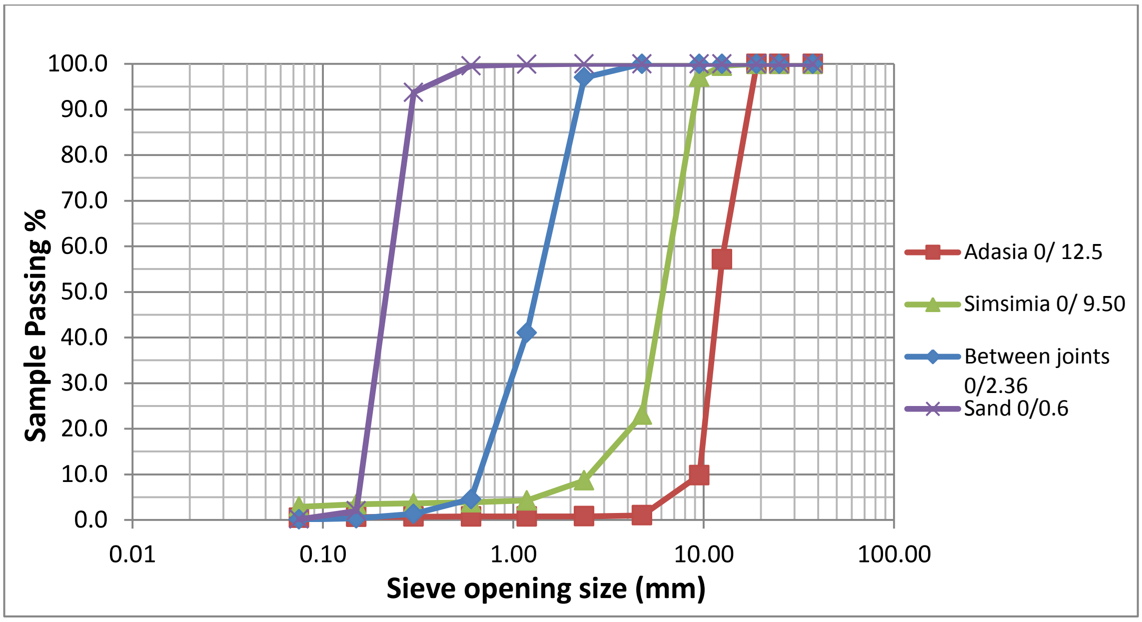


Figure (3.16): Used aggregates gradation curves

3.6 Infiltration tests

3.6.1 Pavement construction

Figure (3.17) shows the steel box that constructed for the experiment. This was constructed after completing the initial tests for interlock tiles and aggregate properties. Bedding and base course aggregates were washed to avoid clogging due to fine material, Section (3.3) details the pavement structure. A Steel frame followed by base-course materials placed on bottom of the box as geo-textile.

Figure (3.17): The experimental steel box of the permeable pavement

Figure (3.18) shows the interlock pavers sitting on top of the bedding layer. The joints between the blocks were filled with special aggregate that used for water well and it's gradation (0/2.36) was shown in Figure (3.14). It is important to compact the material until the maximum density is achieved. A vibrator was used to compact the material until the thickness of the material met the required height. The thickness of the base course layer in the range of 15cm and it is required to compact. Similar process was followed with the bedding layer, before the interlock pavers were placed Figure (3.19), and the material used for filling joints between interlock tiles is shown in Figure (3.20).

Figure (3.18): Interlock pavement and bedding material

Figure (3.19): Installed pavement surface

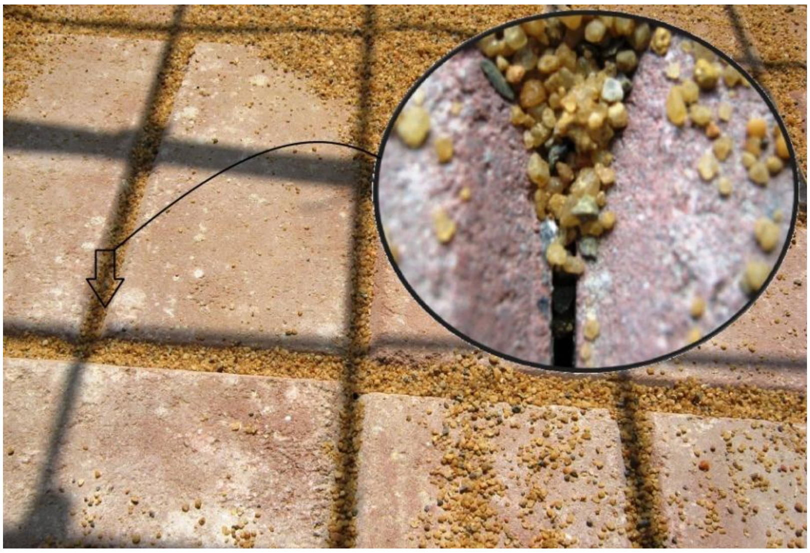


Figure (3.20): Filling joints between interlock tiles by fine aggregate

3.6.2 Different interlock types

Three types of interlock tiles were selected after calculating the largest value number of pieces per square meter and the size of joints, which is:

- Rectangular Tile 10 x 20 cm
- H Tile 16 x 20 cm
- Star Tile 18.20 x 19.60 cm, as shown in Table (3.6).

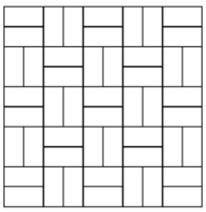
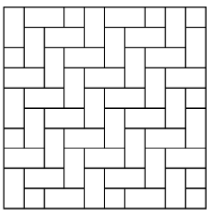
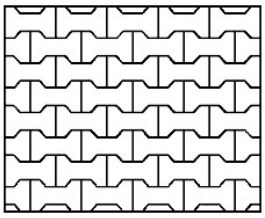
Table (3.6): Types of interlock tiles which used in pavement

	Rectangular Tile 10*20 cm	H Tile 16*20 cm	Star Tile 8.20*19.60 cm
Type			

3.6.3 Different interlock pattern type

The following patterns have been selected in experiments as shown in Table (3.7), they are commonly used.

Table (3.7): Pattern types of interlock tiles which used in pavement

	Rectangular 10*20 cm		H Tile 16*20 cm	Star18.20*19.60 cm
pattern Type	**Basket weave bond**	**Herringbone (bond (90) °)**	**bonded**	**bonded**
				

3.6.4 Base course layer

Three types of base course under interlock tiles were used:

- Coarse aggregate (Simsimia) 0/9.50 mm + (Sand) 0/0.6 mm
- Coarse aggregate (Adasia) 0/12.5 mm + (Sand) 0/0.6 mm
- Coarse aggregate (Adasia) 0/12.5 mm + Coarse aggregate (Simsimia) 0/9.50

Figure (3.21) shows the selected material in experiments under tiles.

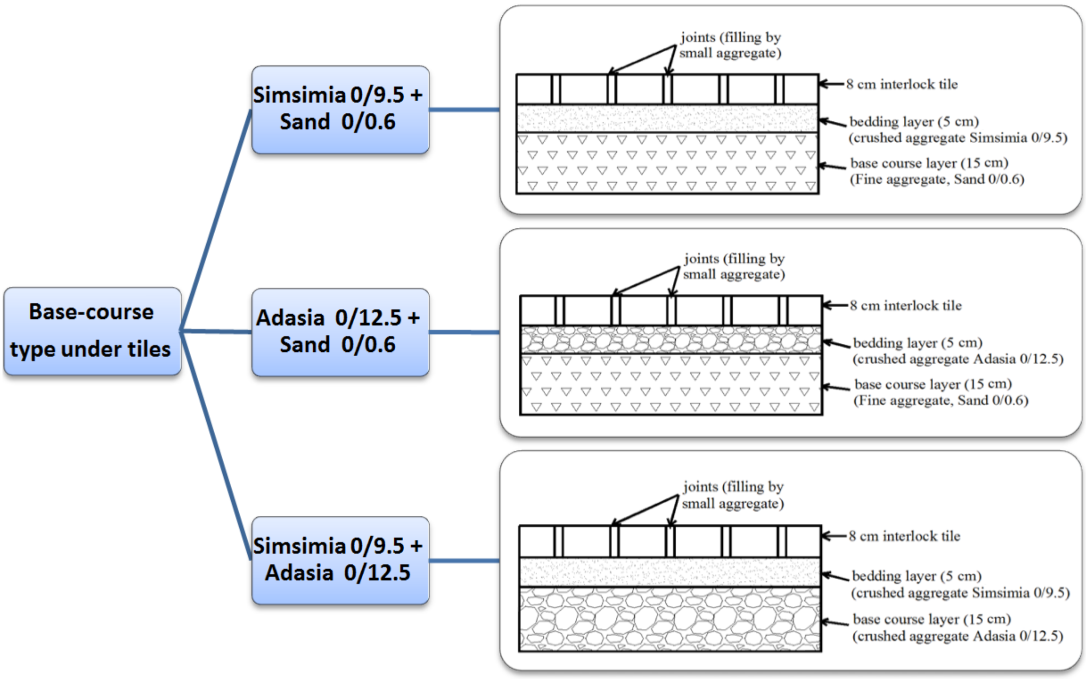


Figure (3.21): Types of base course layer used

3.6.5 Joints

Concerning the joints between the tiles, two types of joints were selected, 3 mm and 5 mm, as much as possible to keep the stability of the concrete pavement.

3.6.6 Rainfall simulator installation

The four legs Figure (3.22) of the steel box were installed after completing the construction of the pavement. Finally, the funnel was fixed under the steel box to collect the infiltrated water Figure (3.23). As mentioned previously, the rainfall simulator Figures (3.24) & (3.25) was placed with steel grid carrying the 25 nozzles installed at 80 cm from the surface of the pavement. The water flows through the joints of pavement was collected from underneath the pavement a funnel Figure (3.26).

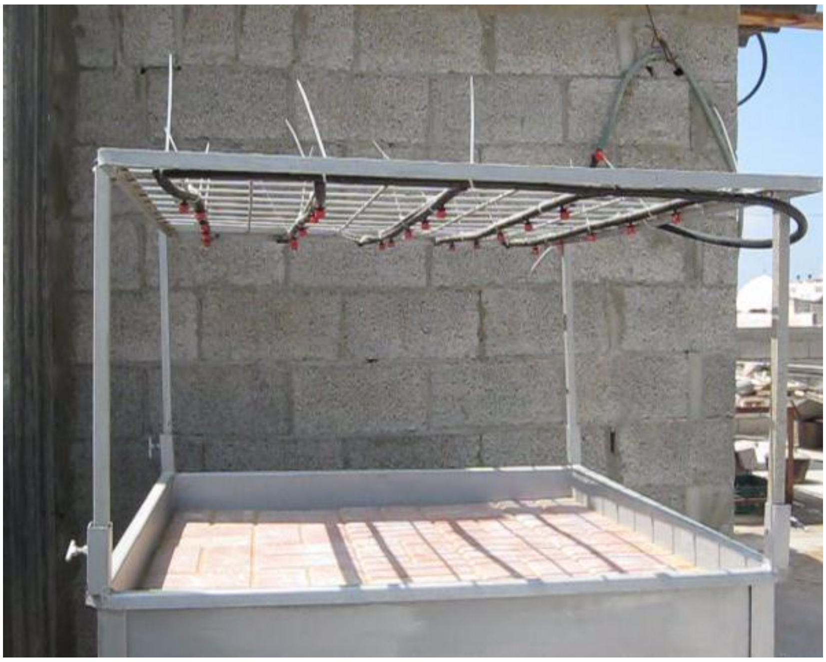


Figure (3.22): Rainfall simulator and laboratory pavement model box

Figure (3.23): Infiltrated water collecting funnel

Figure (3.24): The 25 evenly setup sprays

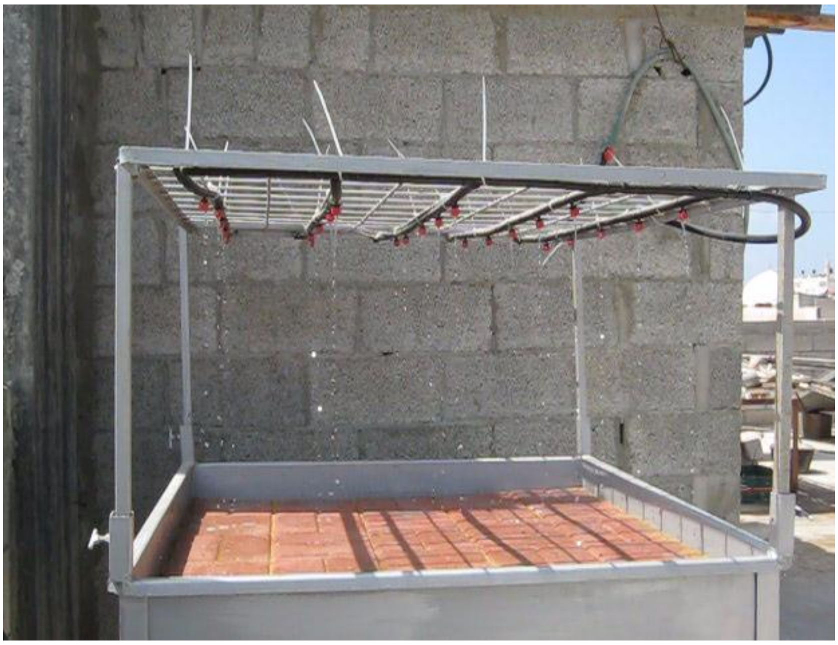


Figure (3.25): Infiltration test on the constructed permeable pavement

Figure (3.26): Infiltrated water out through permeable pavement

3.6.7 Rainfall simulator intensities

The RI simulation consist of five different rainfall storms of uniform intensities where the taken from curves of return period as: (15, 30, 45, 60, 120 mm/h), as shown in Figure (3.27).

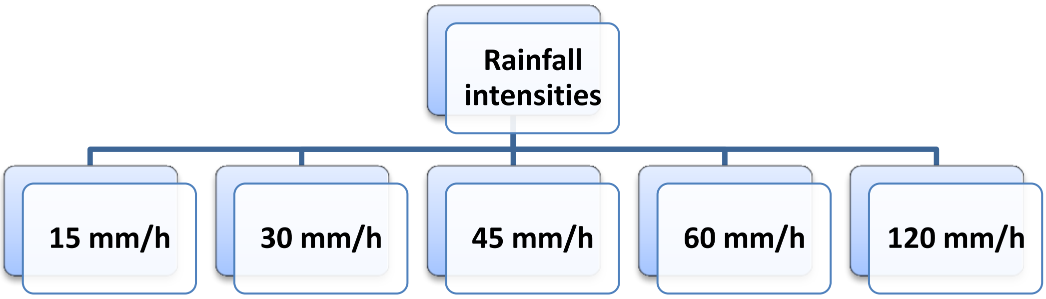


Figure (3.27): Infiltrated Intensity of water

3.6.8 Summary of all experimental scenarios

Figure (3.28) shows a summary of scenarios in the experimental work.

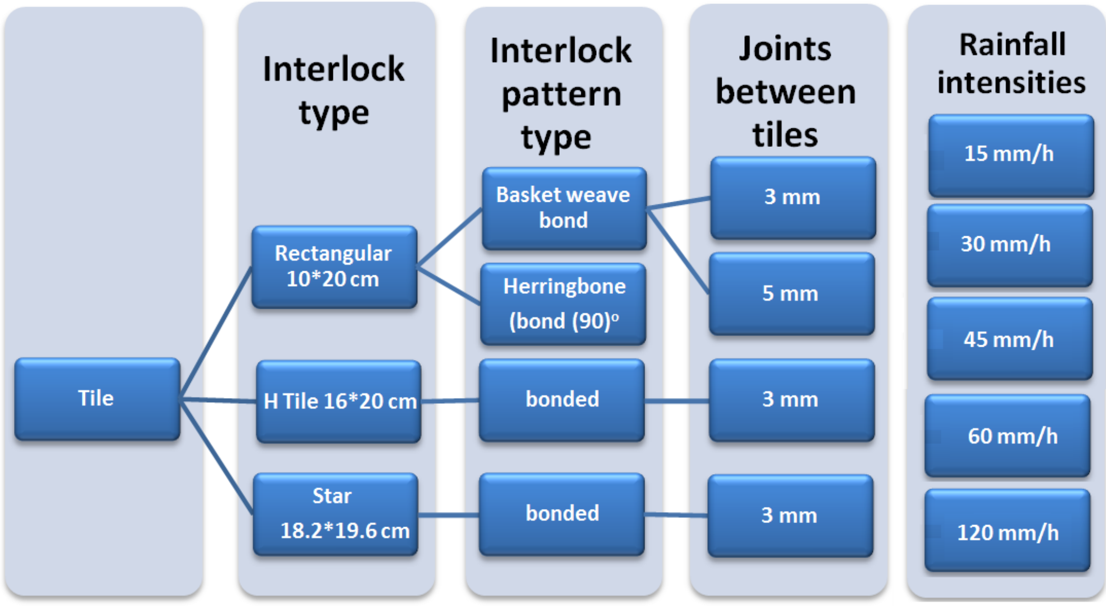


Figure (3.28): Summary of all experimental scenarios

Note: for each model has been used, three layers under tiles were used as shown in Figure (3.21) and five intensity's of water are described on Figure (3.27).

Chapter (4)
Results and discussion

4.1 Introduction

Results of experimental work were obtained and discussed to achieve study objectives, which include studying the effect of different joints, block shape, and pavement pattern on the permeability of water in concrete block pavement.

The results are presented in this chapter in four stages. First, recording all results of permeability percentage per minute for all five models that mentioned in Figure (4.1), which have all shapes of tiles used and scenarios of rainfall intensity. Second stage shows to the permeability percentage of water with different type of base course under pavement. Third stage is carried out the different percentages of permeability when using different joints which are 3and 5mm, finally the permeability when changing the patterns.

4.2 Experimental scenarios

The experimental work used the following scenarios to study the permeability of water as shown in Figure (4.1):

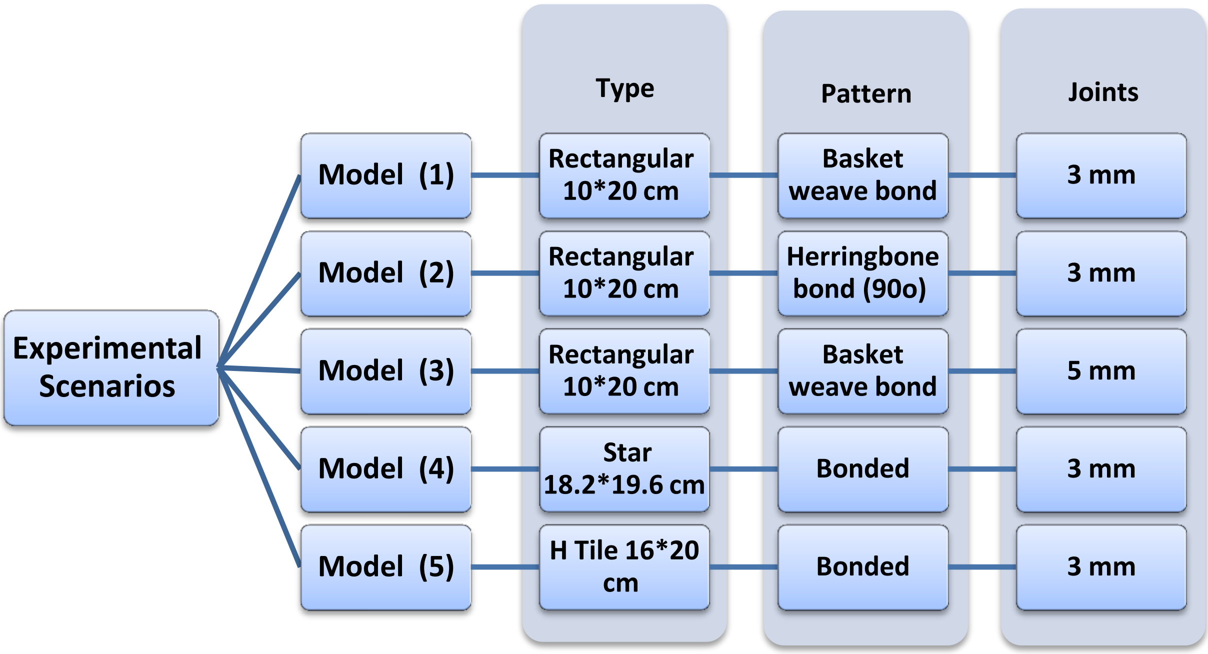


Figure (4.1): Experimental scenarios to study the permeability of water

For each model used, there are three types of base course layer under block tiles were used, and five intensity of storm water are used and described on Figure (4.2).

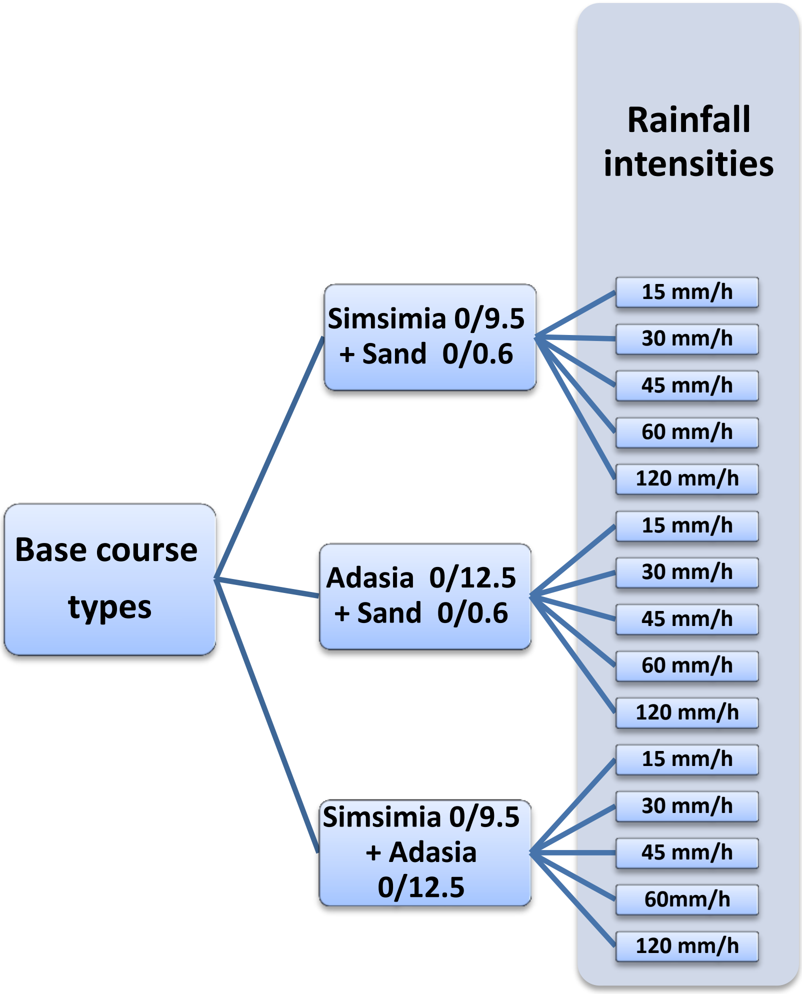


Figure (4.2): Types of base course layer and intensity of water

4.3 Result of experimental scenarios

The simulation consist of five different rainfall storms of uniform intensities to test the infiltration rate, through the rainfall simulator was varied between 15~120 mm/h. The flow rates lower than 15 mm/h were not considered as the flow through the nozzles were very low. The nozzles of the rainfall simulator were placed directly above the experimental area. The funnel underneath the pavement is also placed within the area to collect water.

In order to obtain the infiltration characteristics through the bedding layer and flow through the whole pavement structure for each rainfall event, the water flow through the bottom of the pavement was collected at 1 minute interval.

4.3.1 Result of permeability for Simsimia 0/9.5 and Sand 0/0.6 as Base course layer

The first type of base course layer under block tiles shown in Figure (4.3) for all models.

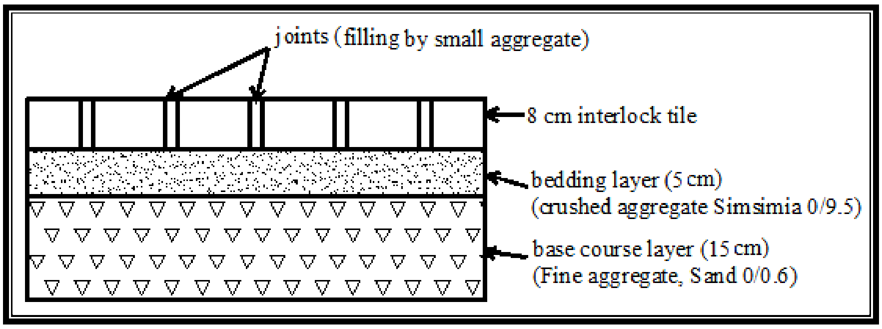


Figure (4.3): Base course Simsimia 0/9.5 and Sand 0/0.6 as base course layer

The result of cumulative out flow is shown in Table (4.1 - 4.5) respectively depending on the intensity of water.

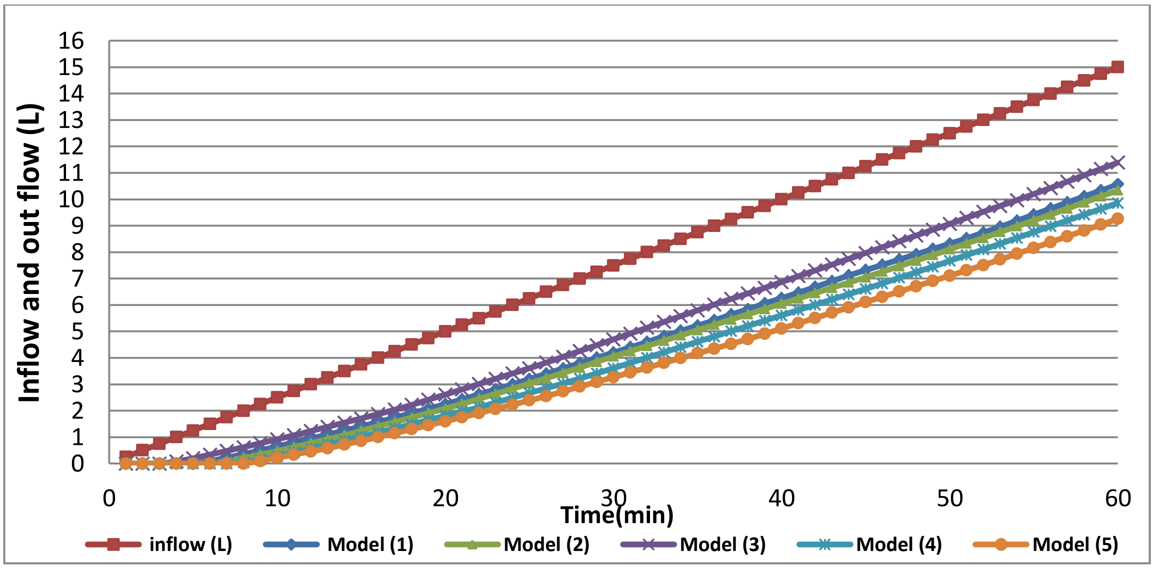
4.3.1.1 Result of cumulative outflow at rainfall intensity=15 mm/h

The result of cumulative outflow is record in Table (4.1) and permeability percentage % for all model was calculated.

Table (4.1): Cumulative outflow for all model at (RI=15 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
60	**15.00**	10.58	10.34	11.39	9.86	9.26
permeability percentage (%)		**70.53**	**68.93**	**75.93**	**65.73**	**61.73**

Figure (4.4) illustrates the comparison of results for all models during the intensity of water = 15 mm/h.



Figure(4.4): Comparison results for all models at intensity of water (15 mm/h)

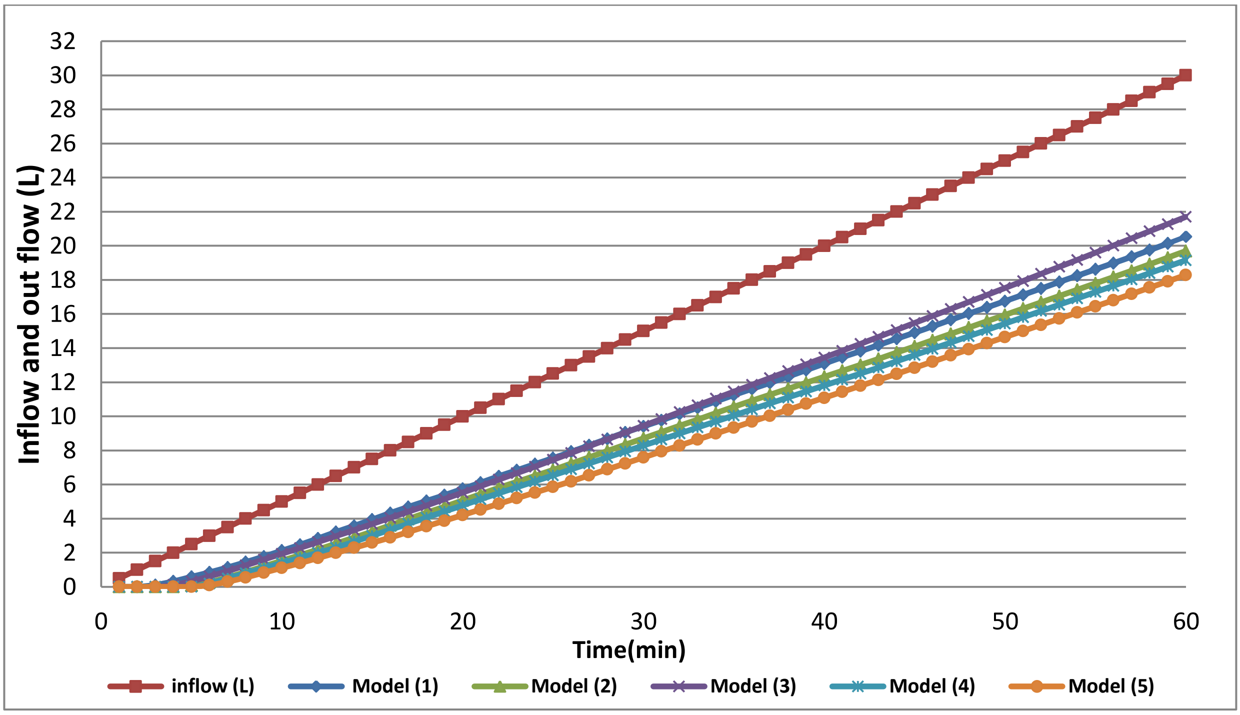
4.3.1.2 Result of outflow at rainfall intensity= 30 mm/h

The result of cumulative outflow is record in Table (4.2) and permeability percentage % for all model was calculated.

Table (4.2): Cumulative outflow for all model at (RI=30 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
60	**30.00**	20.54	19.7	21.7	19.16	18.29
permeability percentage (%)		**68.47**	**65.67**	**72.33**	**63.87**	**60.97**

Figure (4.5) illustrates the comparison of results for all models during the intensity of water = 30 mm/h.



Figure(4.5): Comparison results for all models at intensity of water (30 mm/h)

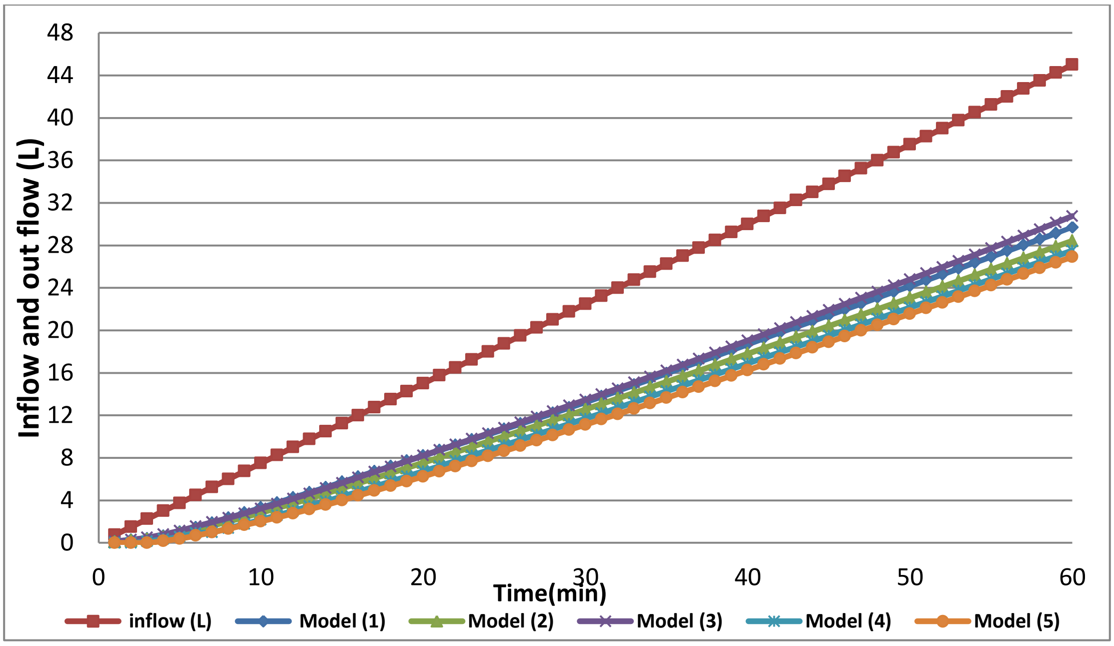
4.3.1.3 Result of outflow at rainfall intensity=45 mm/h

The result of cumulative outflow is record in Table (4.3) and permeability percentage % for all model was calculated.

Table (4.3): Cumulative outflow for all model at (RI=45 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
60	**45**	29.71	28.43	30.76	27.52	26.93
permeability percentage (%)		**66.02**	**63.18**	**68.36**	**61.16**	**59.84**

Figure (4.6) illustrates the comparison of results for all models during the intensity of water = 45 mm/h.



Figure(4.6): Comparison results for all models at intensity of water (45 mm/h)

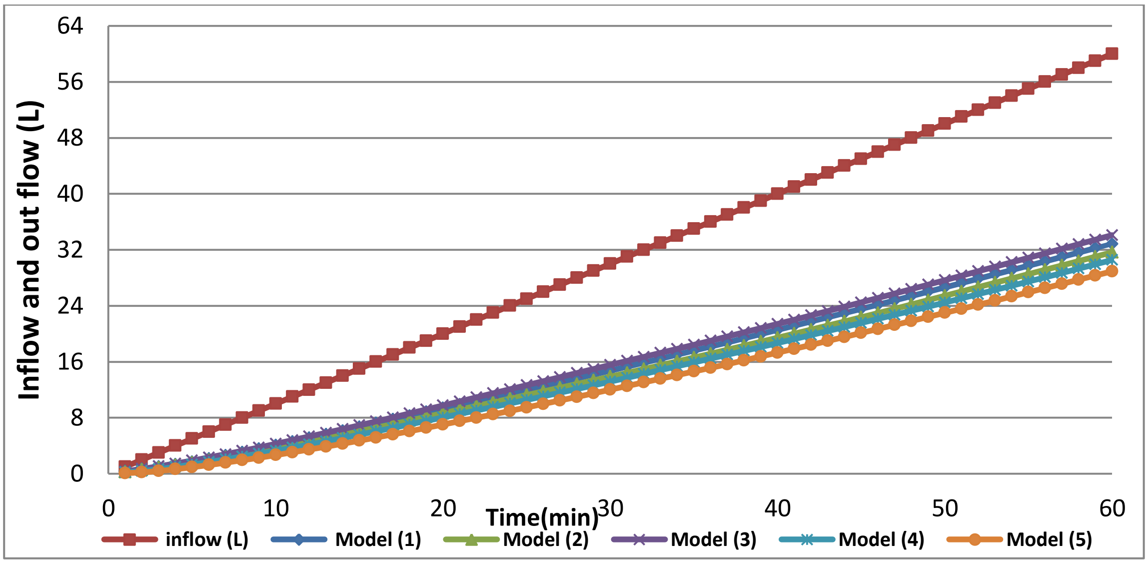
4.3.1.4 Result of outflow at rainfall intensity= 60 mm/h

The result of cumulative outflow is record in Table (4.4) and permeability percentage % for all model was calculated.

Table (4.4): Cumulative outflow for all model at (RI=60 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
60	**60**	32.87	31.65	34.1	30.55	28.93
permeability percentage (%)		**54.78**	**52.75**	**56.83**	**50.92**	**48.22**

Figure (4.7) illustrates the comparison of results for all models during the intensity of water = 60 mm/h.



Figure(4.7): Comparison results for all models at intensity of water (60 mm/h)

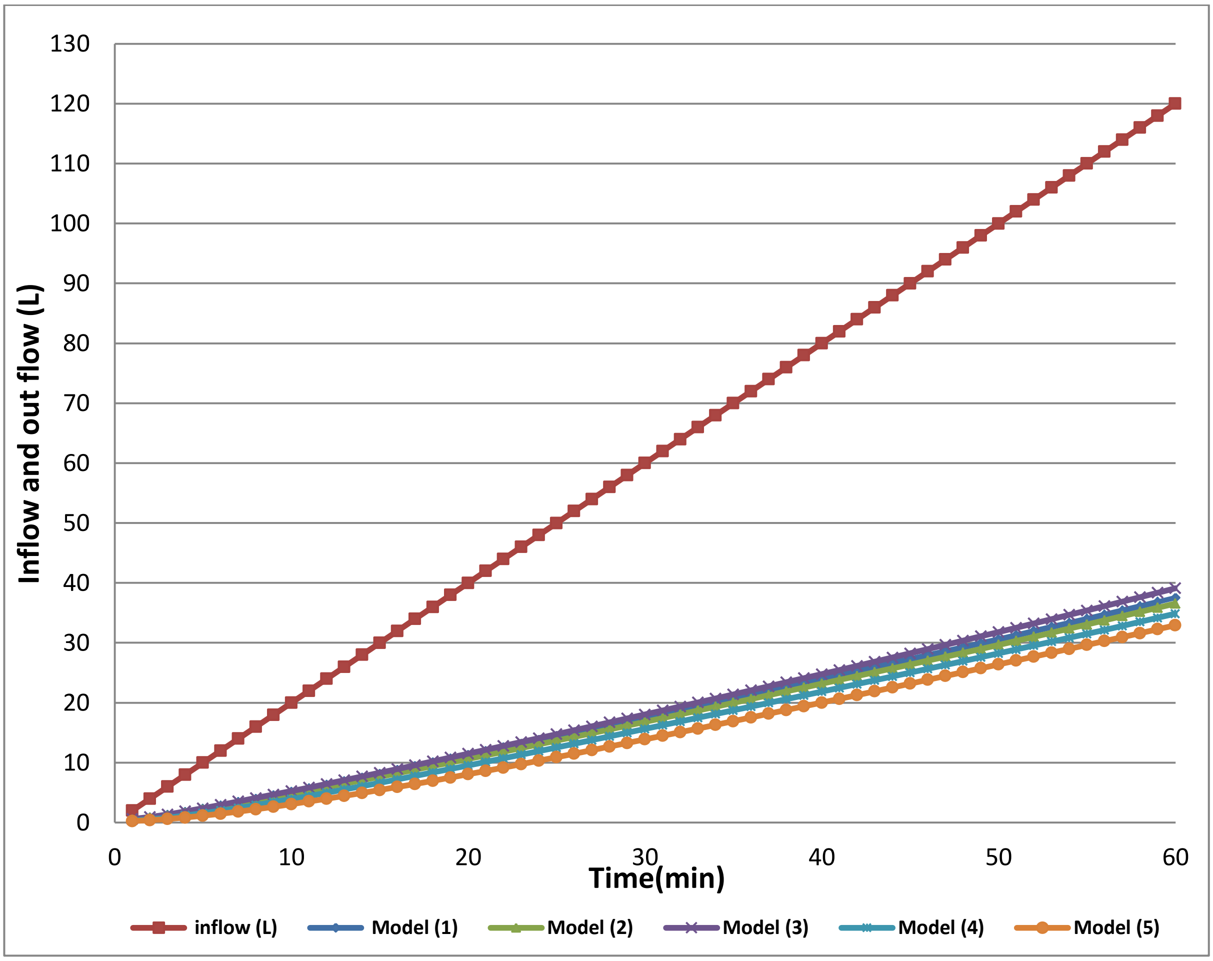
4.3.1.5 Result of outflow at rainfall intensity= 120 mm/h

The result of cumulative outflow is record in Table (4.5) and permeability percentage % for all model was calculated.

Table (4.5): Cumulative outflow for all model at (RI=120 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
60	**120**	37.54	36.56	39.11	34.87	32.93
permeability percentage (%)		**31.28**	**30.47**	**32.59**	**29.06**	**27.44**

Figure (4.8) illustrates the comparison of results for all models during the intensity of water = 120 mm/h.



Figure(4.8): Comparison results for all models at intensity of water (120 mm/h)

4.3.2 Result of Permeability for Adasia 0/12.5 and Sand 0/0.6 as Base course layer.

The second type of base course layer under block tiles shown in Figure (4.9) for all models.

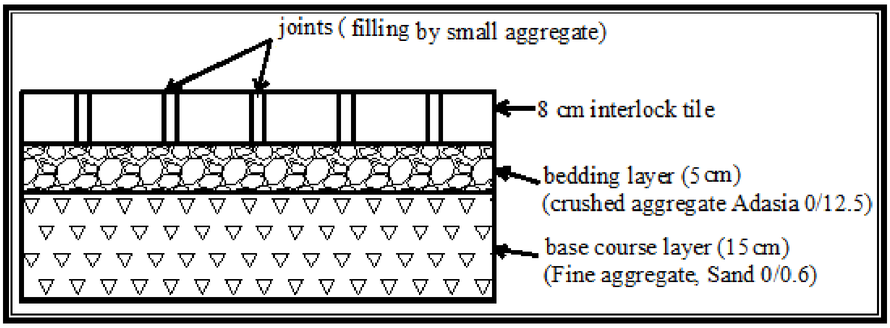


Figure (4.9): Base course Adasia 0/12.5 and Sand 0/0.6 on base course layer

The result of cumulative out flow is shown in Table (4.6 - 4.10) respectively depending on the intensity of water.

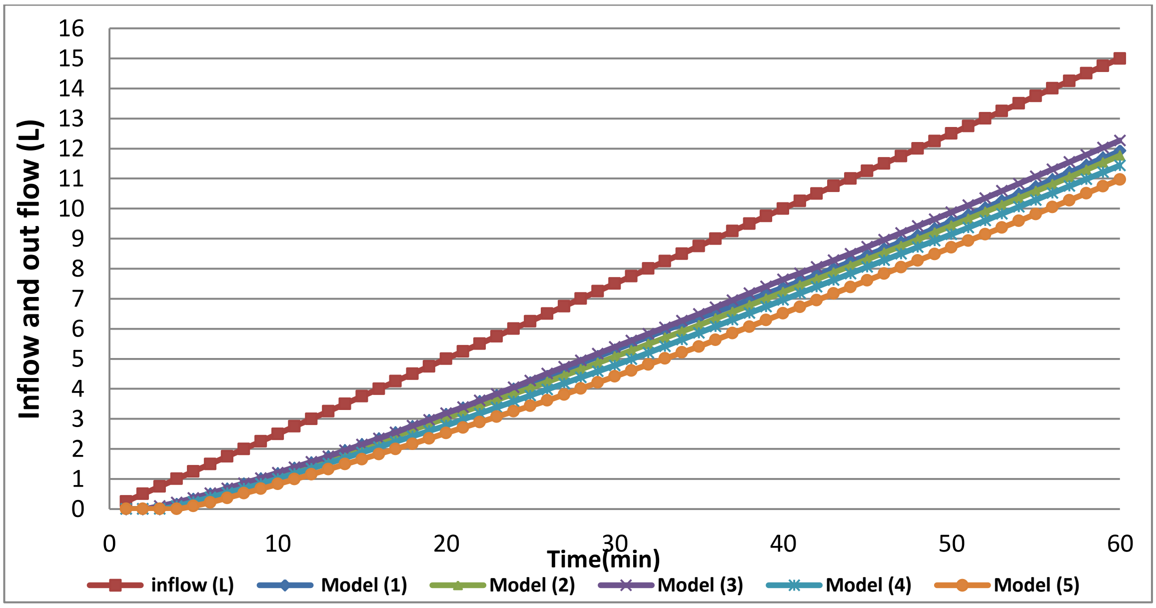
4.3.2.1 Result of outflow at rainfall intensity=15 mm/h

The result of cumulative outflow is record in Table (4.6) and permeability percentage % for all model was calculated.

Table (4.6): Cumulative outflow for all model at (RI=15 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
60	15	11.93	11.77	12.27	11.44	10.97
permeability percentage (%)		79.53	78.47	81.80	76.27	73.13

Figure (4.10) illustrates the comparison of results for all models during the intensity of water = 15 mm/h



Figure(4.10): Comparison results for all models at intensity of water (15 mm/h)

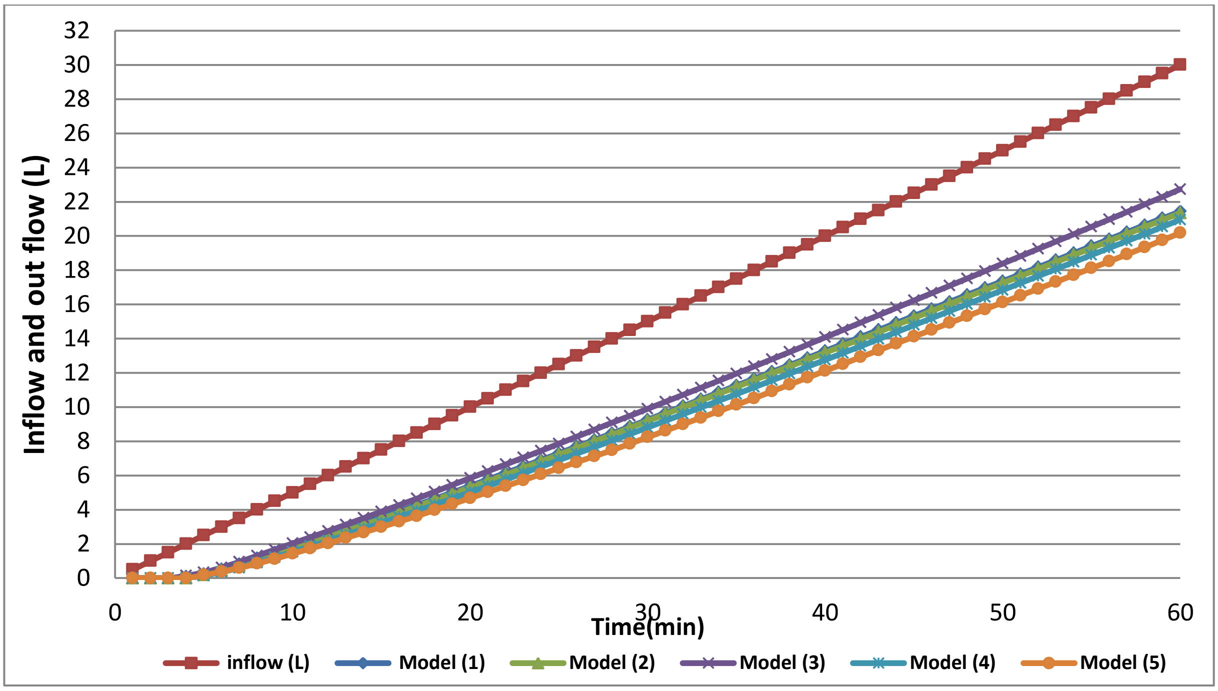
4.3.2.2 Result of outflow at rainfall intensity=30 mm/h

The result of cumulative outflow is record in Table (4.7) and permeability percentage % for all model was calculated.

Table (4.7): Cumulative outflow for all model at (RI=30 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
60	**30**	21.46	21.35	22.74	20.96	20.18
permeability percentage (%)		**71.53**	**71.17**	**75.80**	**69.87**	**67.27**

Figure (4.11) illustrates the comparison of results for all models during the intensity of water = 30 mm/h



Figure(4.11): Comparison results for all models at intensity of water (30 mm/h)

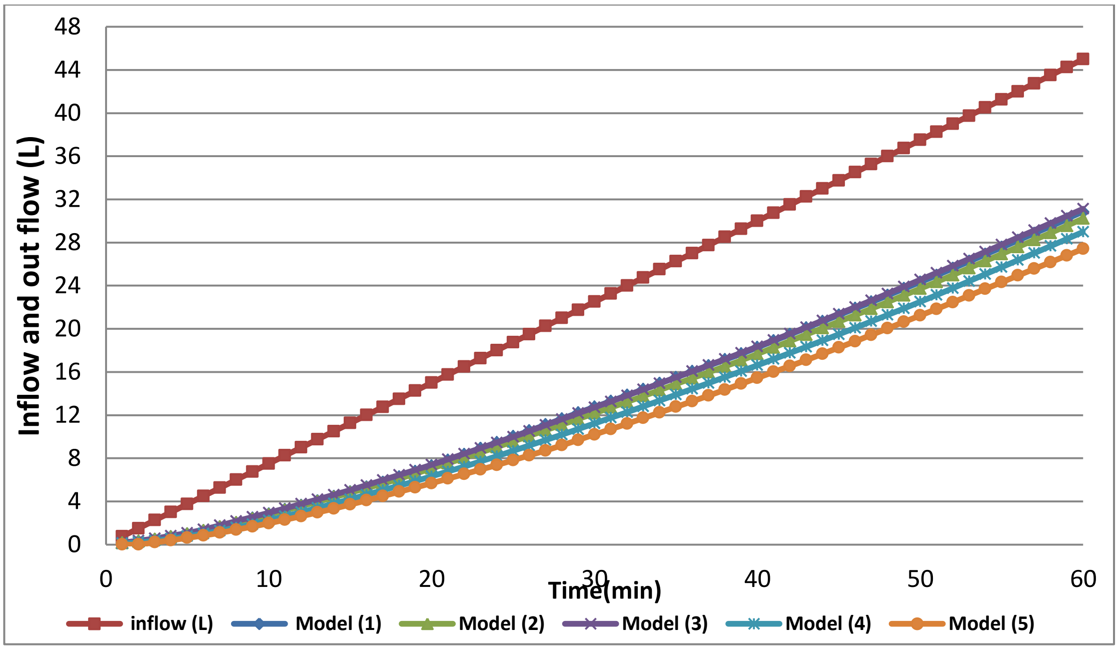
4.3.2.3 Result of outflow at rainfall intensity=45 mm/h

The result of cumulative outflow is record in Table (4.8) and permeability percentage % for all model was calculated.

Table (4.8): Cumulative outflow for all model at (RI=45 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
60	**45**	30.84	30.23	31.13	28.99	27.42
permeability percentage (%)		**68.53**	**67.18**	**69.18**	**64.42**	**60.93**

Figure (4.12) illustrates the comparison of results for all models during the intensity of water = 45 mm/h



Figure(4.12): Comparison results for all models at intensity of water (45 mm/h)

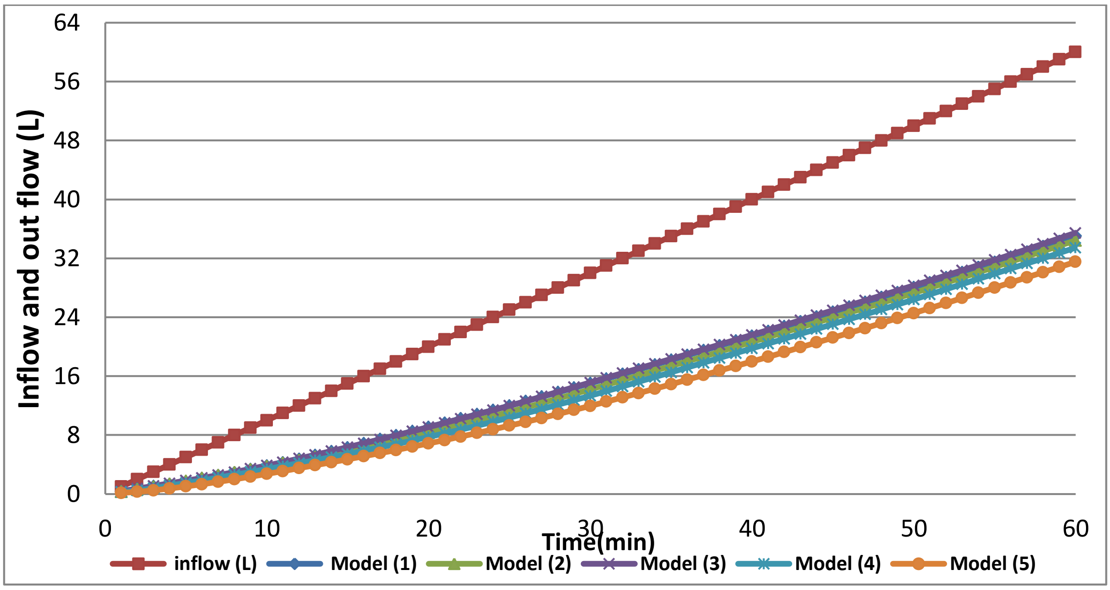
4.3.2.4 Result of outflow at rainfall intensity= 60 mm/h

The result of cumulative outflow is record in Table (4.9) and permeability percentage % for all model was calculated.

Table (4.9): Cumulative outflow for all model at (RI=60 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
60	60	35.04	34.43	35.46	33.45	31.52
permeability percentage (%)		58.40	57.38	59.10	55.75	52.53

Figure (4.13) illustrates the comparison of results for all models during the intensity of water = 60 mm/h.



Figure(4.13): Comparison results for all models at intensity of water (60 mm/h)

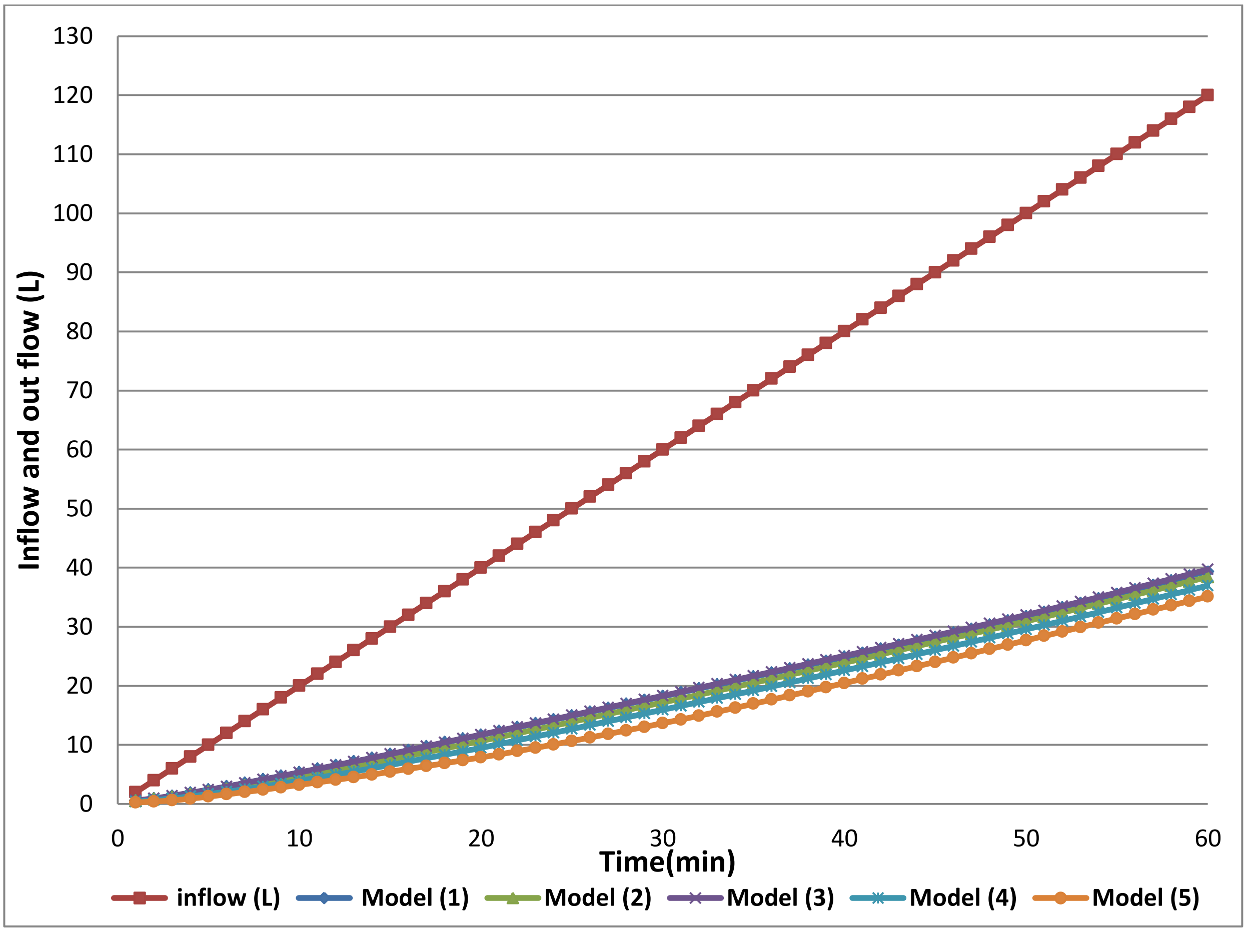
4.3.2.5 Result of outflow at rainfall intensity= 120 mm/h

The result of cumulative outflow is record in Table (4.10) and permeability percentage % for all model was calculated.

Table (4.10): Cumulative outflow for all model at (RI=120 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
60	**120**	39.37	38.43	39.7	36.98	35.1
permeability percentage (%)		**32.81**	**32.03**	**33.08**	**30.82**	**29.25**

Figure (4.14) illustrates the comparison of results for all models during the intensity of water = 120 mm/h.



Figure(4.14): Comparison results for all models at intensity of water (120 mm/h)

4.3.3 Result of Permeability for Adasia 0/12.5 and Simsimia 0/9.5 as Base course layer

The third type of base course layer under block tiles shown in Figure (4.15) for all models.

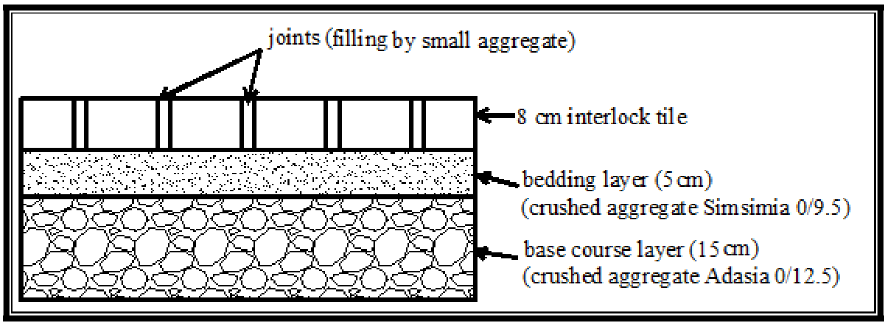


Figure (4.15): Base course Simsimia 0/9.5 and Adasia 0/12.5 on base course layer

The result of cumulative out flow is shown in Table (4.11 - 4.15) respectively depending on the intensity of water.

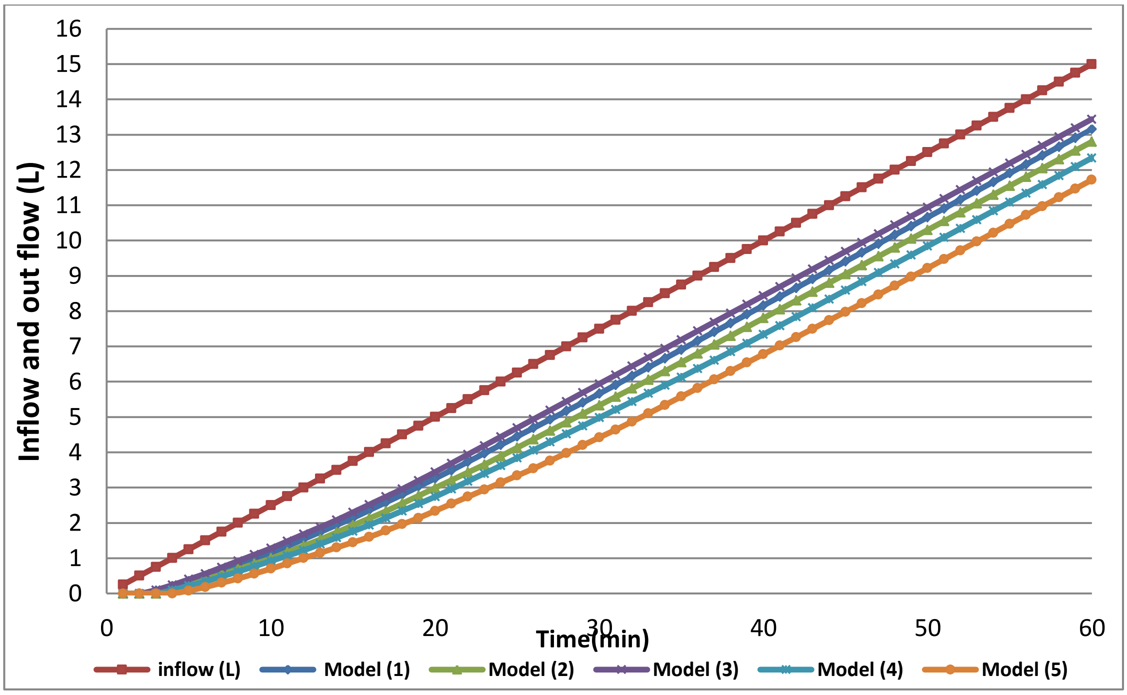
4.3.3.1 Result of outflow at rainfall intensity=15 mm/h

The result of cumulative outflow is record in Table (4.11) and permeability percentage % for all model was calculated.

Table (4.11): Cumulative outflow for all model at (RI=15 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
60	15	13.16	12.8	13.44	12.34	11.72
permeability percentage (%)		**87.73**	**85.33**	**89.60**	**82.27**	**78.13**

Figure (4.16) illustrates the comparison of results for all models during the intensity of water = 15 mm/h



Figure(4.16): Comparison results for all models at intensity of water (15 mm/h)

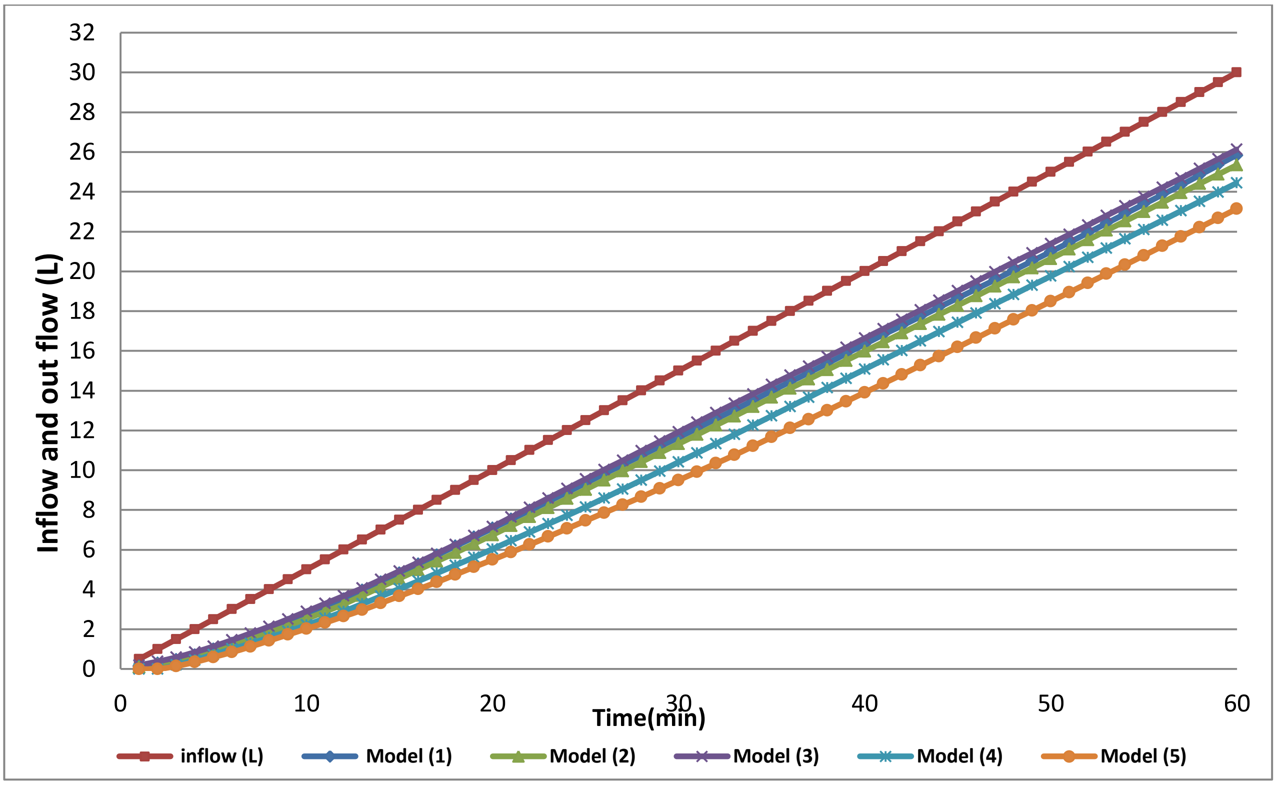
4.3.3.2 Result of outflow at rainfall intensity=30 mm/h

The result of cumulative outflow is record in Table (4.12) and permeability percentage % for all model was calculated.

Table (4.12): Cumulative outflow for all model at (RI=30 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
60	30	25.84	25.35	26.13	24.45	23.15
permeability percentage (%)		86.13	84.50	87.10	81.50	77.17

Figure (4.17) illustrates the comparison of results for all models during the intensity of water = 30 mm/h.



Figure(4.17): Comparison results for all models at intensity of water (30 mm/h)

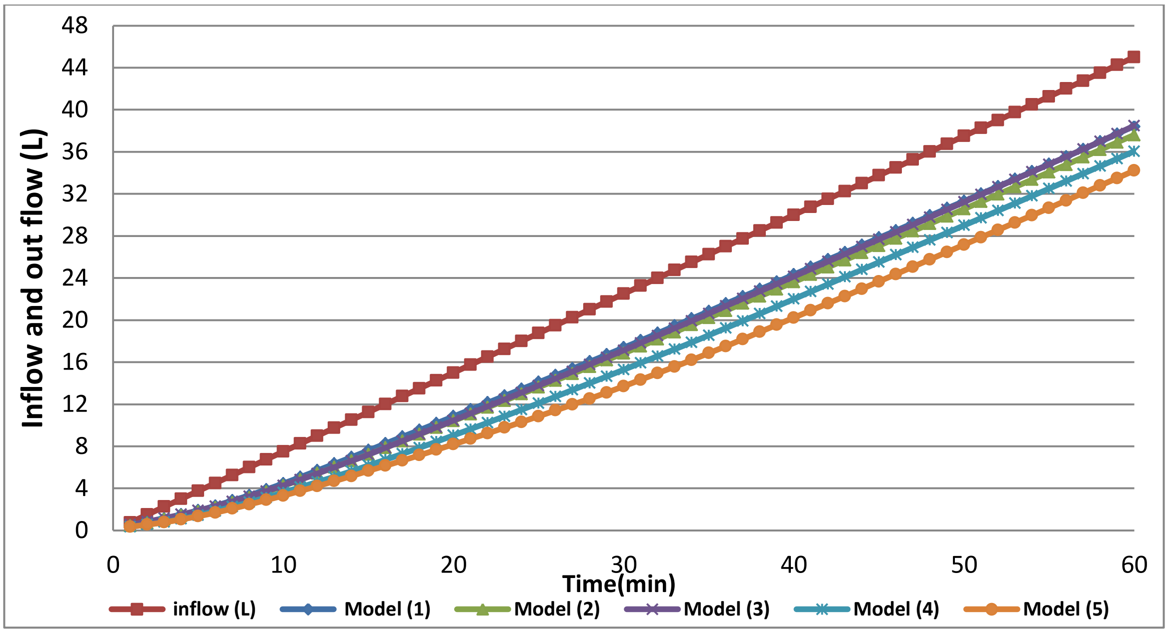
4.3.3.3 Result of outflow at rainfall intensity=45 mm/h

The result of cumulative outflow is record in Table (4.13) and permeability percentage % for all model was calculated.

Table (4.13): Cumulative outflow for all model at (RI=45 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
60	45	38.41	37.61	38.48	36.05	34.21
permeability percentage (%)		85.36	83.58	85.51	80.11	76.02

Figure (4.18) illustrates the comparison of results for all models during the intensity of water = 45 mm/h



Figure(4.18): Comparison results for all models at intensity of water (45 mm/h)

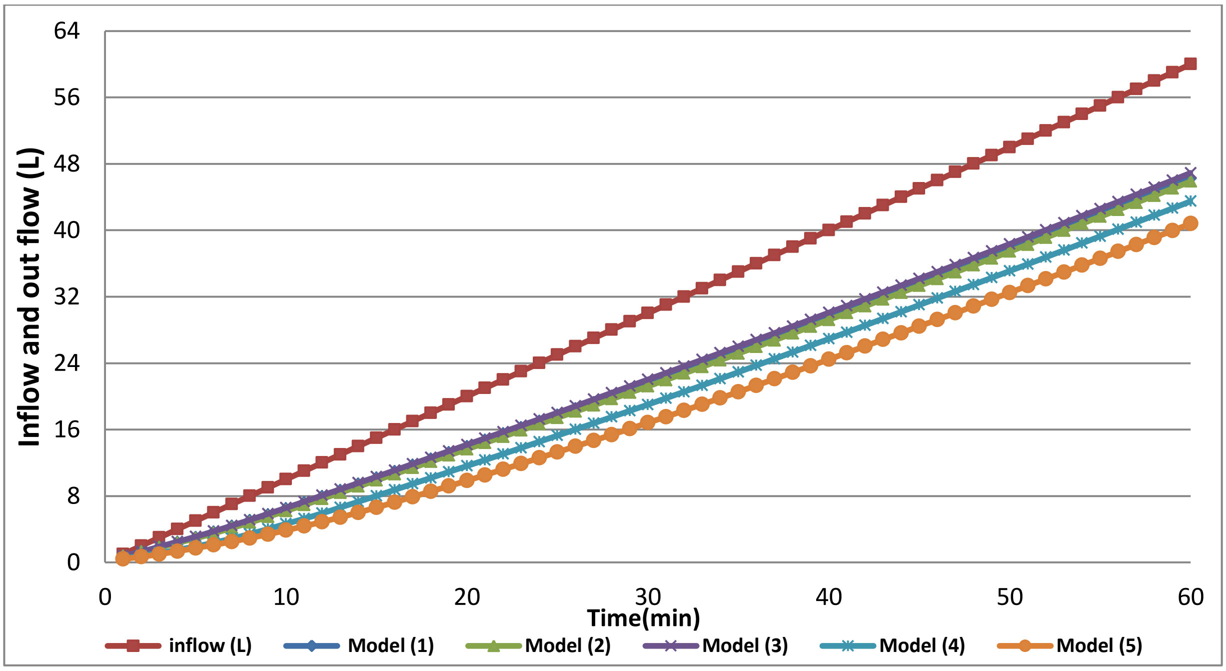
4.3.3.4 Result of outflow at rainfall intensity= 60 mm/h

The result of cumulative outflow is record in Table (4.14) and permeability percentage % for all model was calculated in the end of table.

Table (4.14): Cumulative outflow for all model at (RI=60 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
60	**60**	46.28	45.88	46.91	43.49	40.8
permeability percentage (%)		**77.13**	**76.47**	**78.18**	**72.48**	**68.00**

Figure (4.19) illustrates the comparison of results for all models during the intensity of water = 60 mm/h.



Figure(4.19): Comparison results for all models at intensity of water (60 mm/h)

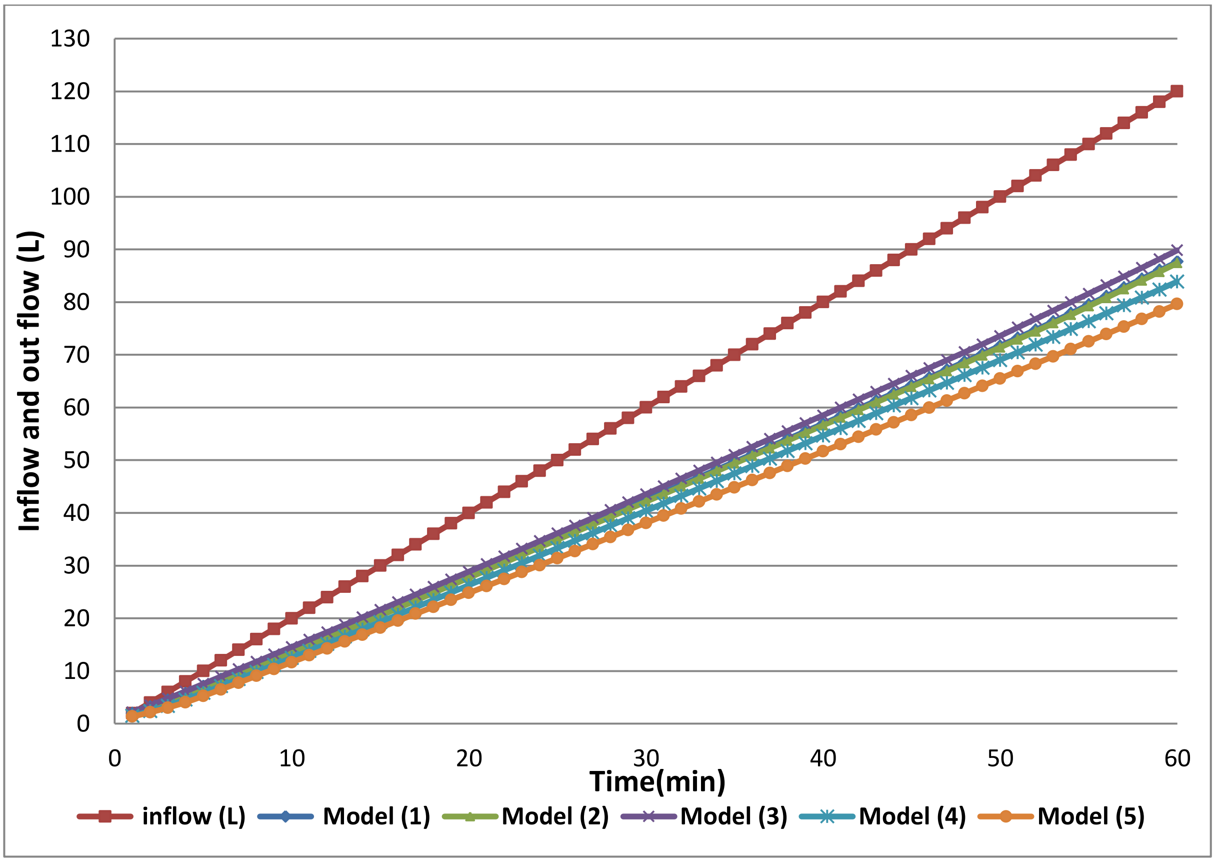
4.3.3.5 Result of outflow at rainfall intensity= 120 mm/h

The result of cumulative outflow is record in Table (4.15) and permeability percentage % for all model was calculated.

Table (4.15): Cumulative outflow for all model at (RI=120 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
60	**120**	87.72	87.41	89.84	83.9	79.63
permeability percentage (%)		**73.10**	**72.84**	**74.87**	**69.92**	**66.36**

Figure (4.20) illustrates the comparison of results for all models during the intensity of water = 120 mm/h.



Figure(4.20): Comparison results for all models at intensity of water (120 mm/h)

4.4 Permeability percentage Comparison

4.4.1 Permeability percentage for all models

All results have been recorded, which obtained from experiments that clarified earlier, where the table form designed in (Appendix A) to record the readings per 1 minute, Tables (4.16 - 4.20) below illustrates all the results.

Table (4.16): Results of permeability percentage for Model (1)

120 mm/h	60 mm/h	45 mm/h	30 mm/h	15 mm/h	Inflow				
					Base course	Type			
31.28	54.78	65.98	68.47	70.53	Simsimia 0/9.5 + Sand 0/0.6	Joints : 3mm	Pattern: Basket weave bond	Type(1) : Rectangular 10x20 cm	Model (1)
32.81	58.40	68.53	71.53	79.53	Adasia 0/12.5 + Sand 0/0.6				
73.10	77.13	85.36	86.13	87.73	Simsimia 0/9.5 + Adasia 0/12.5				

The result shown in Table (4.16) describes the permeability percentage of different rainfall intensities to rectangular block 10 x 20 cm with basket weave bond pattern and 3 mm joints, the result shows that no surface runoff generated from the pavement surface for the low intensities at 15 mm/h and the average percentage of inflow to outflow is 70.53 % in using Simsimia 0/9.5 and Sand 0/0.6 on base course layer and 87.73 % in using Simsimia 0/9.5 and Adasia 0/12.5 on base course layer, but at high intensities at 120 mm/h the surface runoff generated largely and average percentage of inflow to out flow not exceeded 31.28% in using Simsimia 0/9.5 and Sand 0/0.6 on base course layer and 73 % in using Simsimia 0/9.5 and Adasia 0/12.5 on base course layer.

The comparison of all results of permeability percentage for model (1) are shown in Figure (4.21).

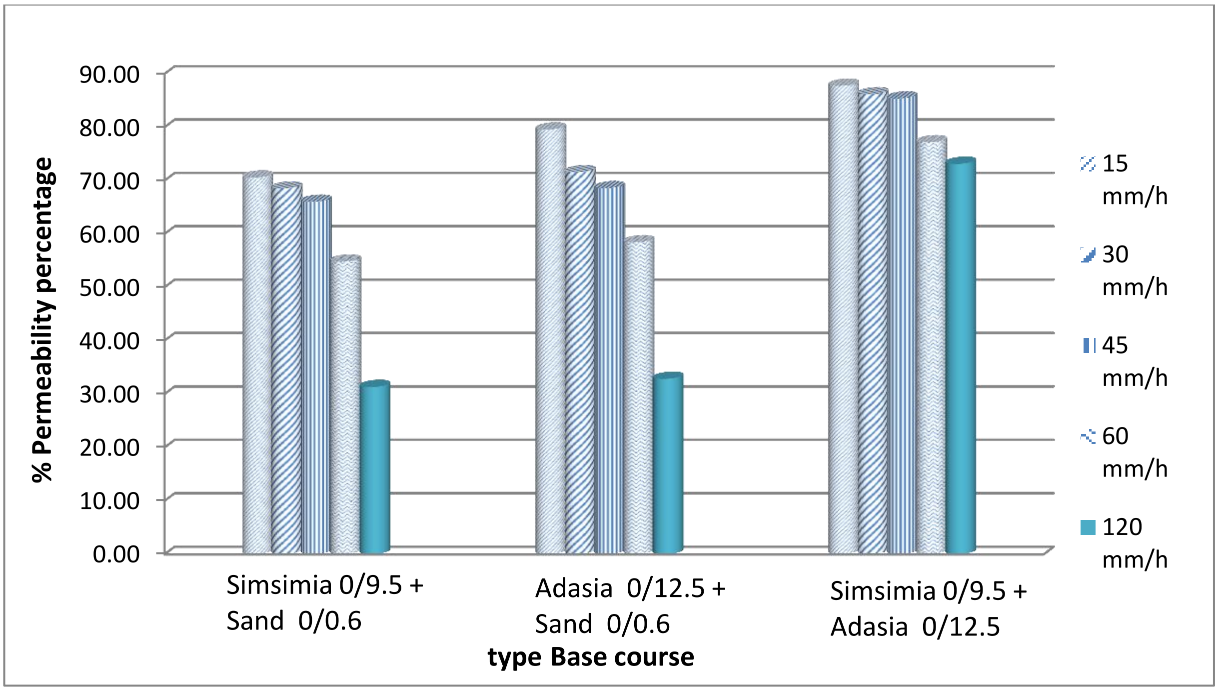


Figure (4.21): Comparison results of permeability percentage for model (1)

Table (4.17): Results of permeability percentage for model (2)

120 mm/h	60 mm/h	45 mm/h	30 mm/h	15 mm/h	Inflow				
					Base course	Type			
30.46	52.75	63.17	65.67	68.93	Simsimia 0/9.5 + Sand 0/0.6	Joints : 3mm	Pattern: Herringbone bond (90°)	Type(2) : Rectangular 10x20 cm	Model (2)
32.01	57.38	67.18	71.17	78.47	Adasia 0/12.5 + Sand 0/0.6				
72.84	76.47	83.58	84.50	85.33	Simsimia 0/9.5 + Adasia 0/12.5				

The result shown in Table (4.17) describes the permeability percentage of different rainfall intensities to rectangular block 10 x 20 cm with herringbone bond (90°) pattern and 3 mm joints, the result shows that no surface runoff generated from the pavement surface for the low intensities at 15 mm/h and the average percentage of inflow to outflow is 68.93 % in using Simsimia 0/9.5 and Sand 0/0.6 and 85.33 % in using Simsimia 0/9.5 and Adasia 0/12.5 on base course layer, but at high intensities at 120 mm/h the surface runoff generated largely and average percentage of permeability not exceeded 30.46 % in using Simsimia 0/9.5 and Sand 0/0.6 and 72.84 % in using Simsimia 0/9.5 and Adasia 0/12.5 on base course layer.

The comparison of all results of permeability percentage for model (2) are shown in Figure (4.22).

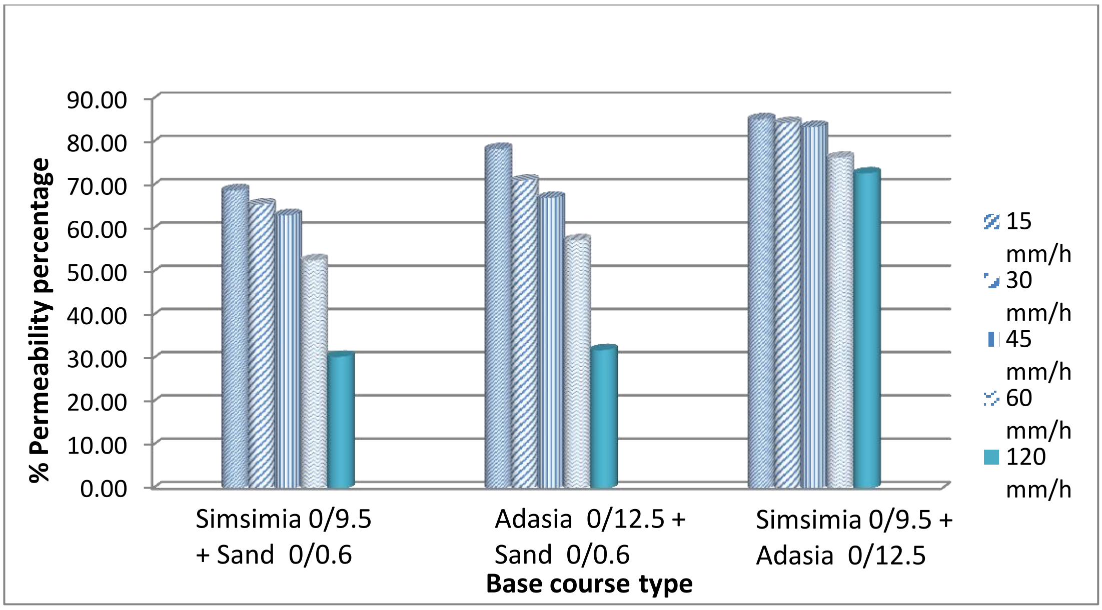


Figure (4.22): Comparison results of permeability percentage for model (2)

Table (4.18): Results of permeability percentage for model (3)

120 mm/h	60 mm/h	45 mm/h	30 mm/h	15 mm/h	Inflow: Base course	Type			
32.59	56.83	68.36	72.33	75.93	Simsimia 0/9.5 + Sand 0/0.6	Joints : 5mm	Pattern: Basket weave bond	Type(3):Rectangular 10x20 cm	Model (3)
33.08	59.10	69.18	75.80	81.80	Adasia 0/12.5 + Sand 0/0.6				
74.87	78.18	85.51	87.10	89.60	Simsimia 0/9.5 + Adasia 0/12.5				

The result shown in Table (4.18) describes the permeability percentage of different rainfall intensities to rectangular block 10 x 20 cm with basket weave bond pattern and 5 mm joints, the result shows that no surface runoff generated from the pavement surface for the low intensities at 15 mm/h and the average percentage of inflow to outflow is 75.93 % in using Simsimia 0/9.5 and Sand 0/0.6 and 89.60 % in using Simsimia 0/9.5 and Adasia 0/12.5 on base course layer, but at high intensities at 120 mm/h the surface runoff generated largely and average percentage of permeability not exceeded 32.59 % in using Simsimia 0/9.5 and Sand 0/0.6 and 74.87 % in using Simsimia 0/9.5 and Adasia 0/12.5 on base course layer.

The comparison of all results of permeability percentage for model (3) are shown in Figure (4.23).

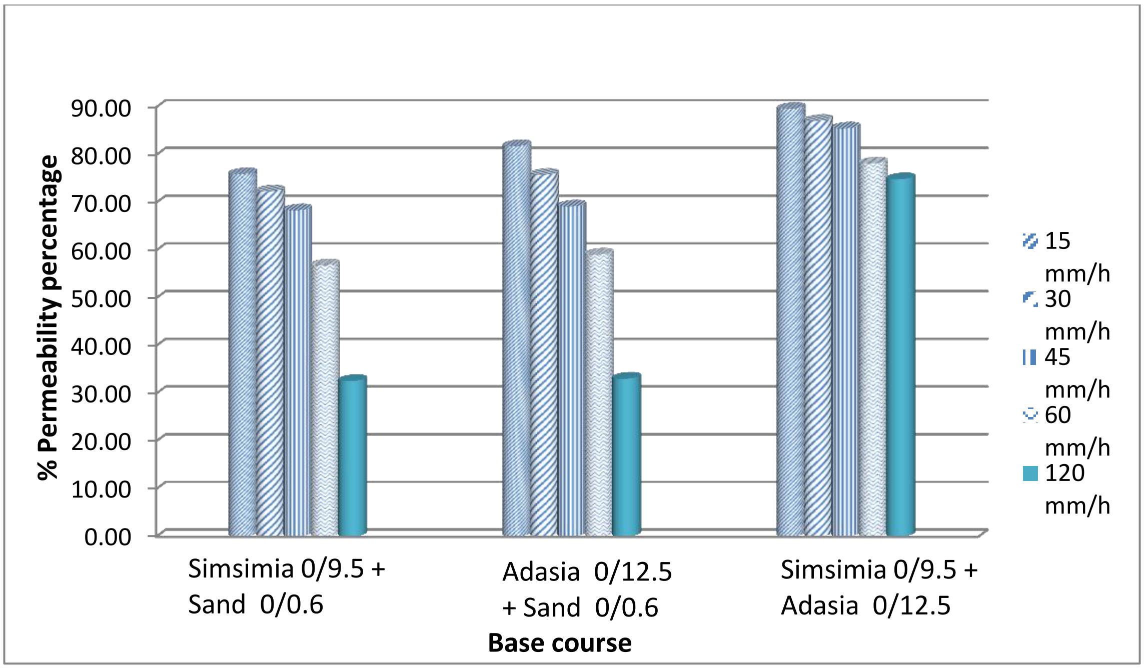


Figure (4.23): Comparison results of permeability percentage for model (3)

Table (4.19): Results of permeability percentage for model (4)

120 mm/h	60 mm/h	45 mm/h	30 mm/h	15 mm/h	Inflow				
					Base course	**Type**			
29.06	50.92	61.15	63.87	65.73	Simsimia 0/9.5 + Sand 0/0.6	**Joints : 3mm**	**Pattern: bonded**	**Type(4):Star 18.20x19.60 cm**	**Model (4)**
30.82	55.75	64.42	69.86	76.27	Adasia 0/12.5 + Sand 0/0.6				
69.92	72.48	80.11	81.51	82.27	Simsimia 0/9.5 + Adasia 0/12.5				

The result shown in Table (4.19) describes the permeability percentage for star 18.20x19.60 cm block with 3 mm joints, the result shows that no surface runoff generated from the pavement surface for the low intensities at 15 mm/h and the average percentage of inflow to outflow is 65.73 % in using Simsimia 0/9.5 and Sand 0/0.6 and 82.27 % in using Simsimia 0/9.5 and Adasia 0/12.5 on base course layer, but at high intensities at 120 mm/h the surface runoff generated largely and average percentage of permeability not exceeded 29.06 % in using Simsimia 0/9.5 and Sand 0/0.6 and 69.92 % in using Simsimia 0/9.5 and Adasia 0/12.5 on base course layer.

The comparison of all results of permeability percentage for model (4) are shown in Figure (4.24).

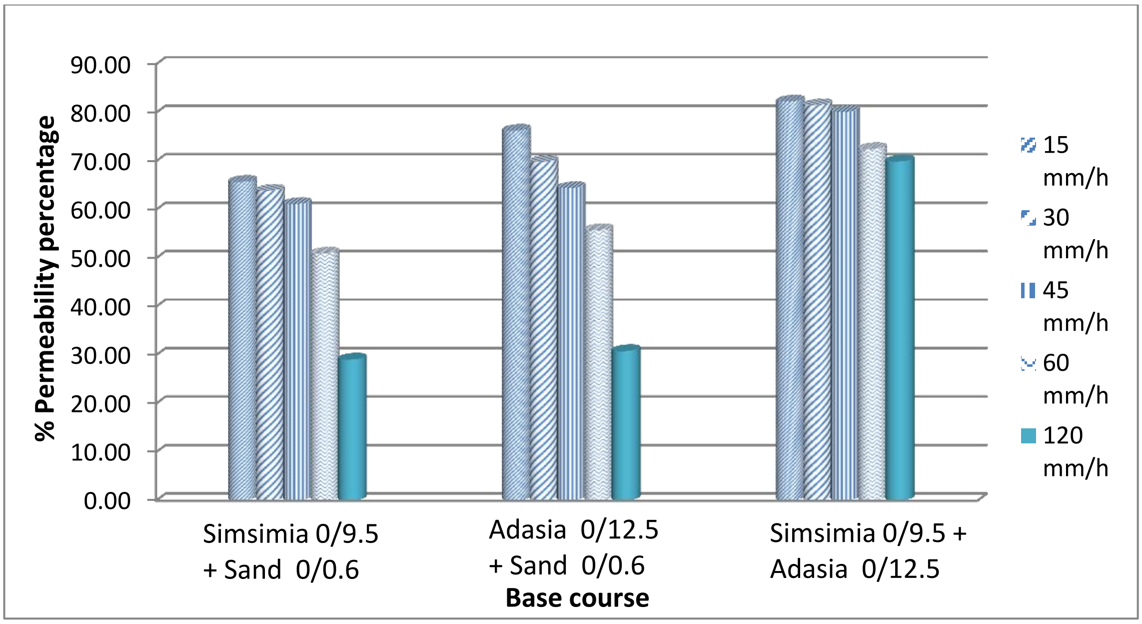


Figure (4.24): Comparison results of permeability percentage for model (4)

Table (4.20): Results of permeability percentage for model (5)

120 mm/h	60 mm/h	45 mm/h	30 mm/h	15 mm/h	Inflow				
					Base course	**Type**			
27.44	48.22	59.84	60.97	61.76	Simsimia 0/9.5 + Sand 0/0.6	**Joints : 3mm**	**Pattern: bonded**	**Type(5) : H Tile 16x20 cm**	**Model (5)**
29.25	52.53	60.93	67.27	73.13	Adasia 0/12.5 + Sand 0/0.6				
66.36	68.00	76.02	77.17	78.17	Simsimia 0/9.5 + Adasia 0/12.5				

The result shown in Table (4.20) describes the permeability percentage of different rainfall intensities to H 16 x 20 cm block with 3 mm joints, the result shows that no surface runoff generated from the pavement surface for the low intensities at 15 mm/h and the average percentage of inflow to outflow is 61.76 % in using Simsimia 0/9.5 and Sand 0/0.6 and 78.17 % in using Simsimia 0/9.5 and Adasia 0/12.5 on base course layer, but at high intensities at 120 mm/h the surface runoff generated largely and average percentage of permeability not exceeded 27.44 % in using Simsimia 0/9.5 and Sand 0/0.6 and 66.36 % in using Simsimia 0/9.5 and Adasia 0/12.5 on base course layer.

The comparison of all results of permeability percentage for model (5) are shown in Figure (4.25).

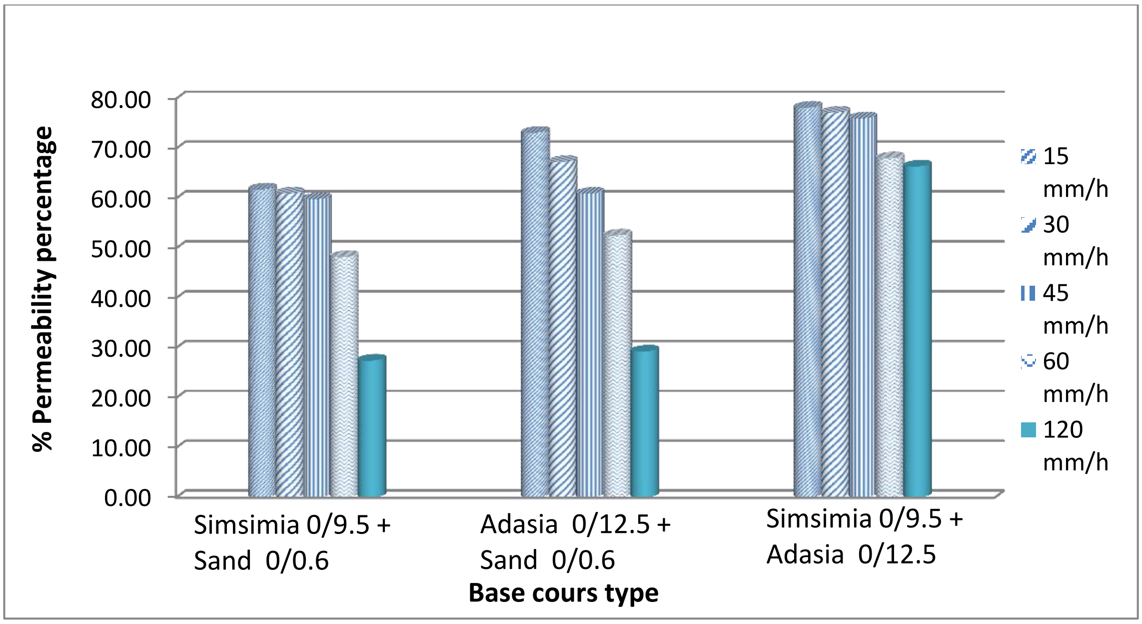


Figure (4.25): Comparison results of permeability percentage for model (5)

From all the results, the use of rectangular block 10 x 20 cm with basket weave bond pattern and 5 mm joints as describes in model (3) gives the best results of permeability.

4.4.2 Effect of using different types of base course on permeability

The comparison of all permeability results according to base course layer are shown in Figure (4.26 – 4.28), which show that the using coarse aggregate Adasia 0/12.5 and Sand 0/0.6 give slightly higher permeability percentage than the using of coarse aggregate Simsimia 0/9.5 and Sand 0/0.6 in the bottom of the tile layers, and using Simsimia 0/9.5 and Adasia 0/12.5 without using sand aggregates in the bottom layer gives very high permeability percentage.

When using Simsimia 0/9.5 and Sand 0/0.6 on base course layers the Comparison results of permeability percentage for all models are shown in Figure (4.26), result shows that the model (3) gives the best permeability.

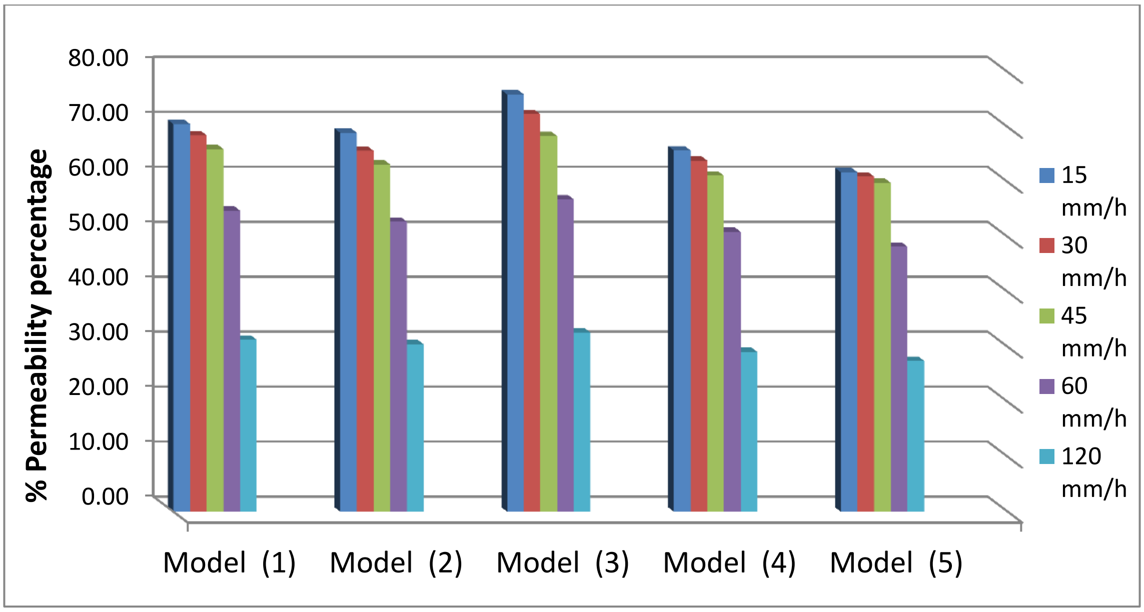


Figure (4.26): Comparison results of permeability percentage for all models when using Simsimia 0/9.5 and Sand 0/0.6 on base course layers

When using Adasia 0/12.5 and Sand 0/0.6 on base course layers the Comparison results of permeability percentage for all models are shown in Figure (4.27), results show that the model (3) gives the best permeability .

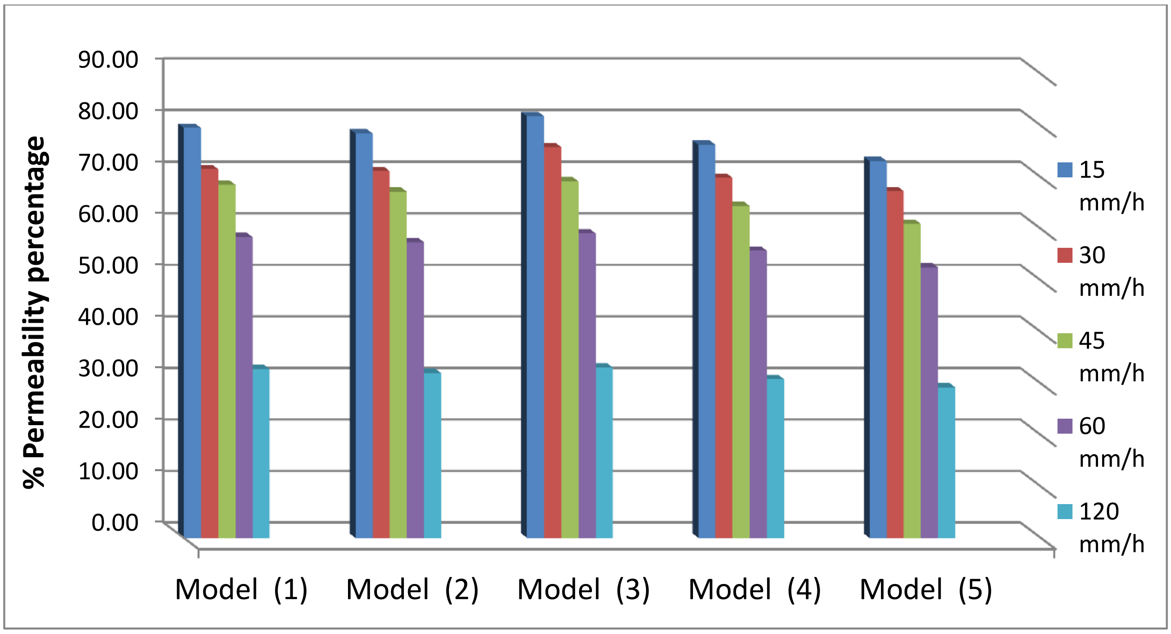


Figure (4.27): Comparison results of permeability percentage for all models when using Adasia 0/12.5 + Sand 0/0.6 on base course layers

When using Simsimia 0/9.5 and Adasia 0/12.5 on base course layers the Comparison results of permeability percentage for all models are shown in Figure (4.28), results show that the model (3) gives the best permeability percentage.

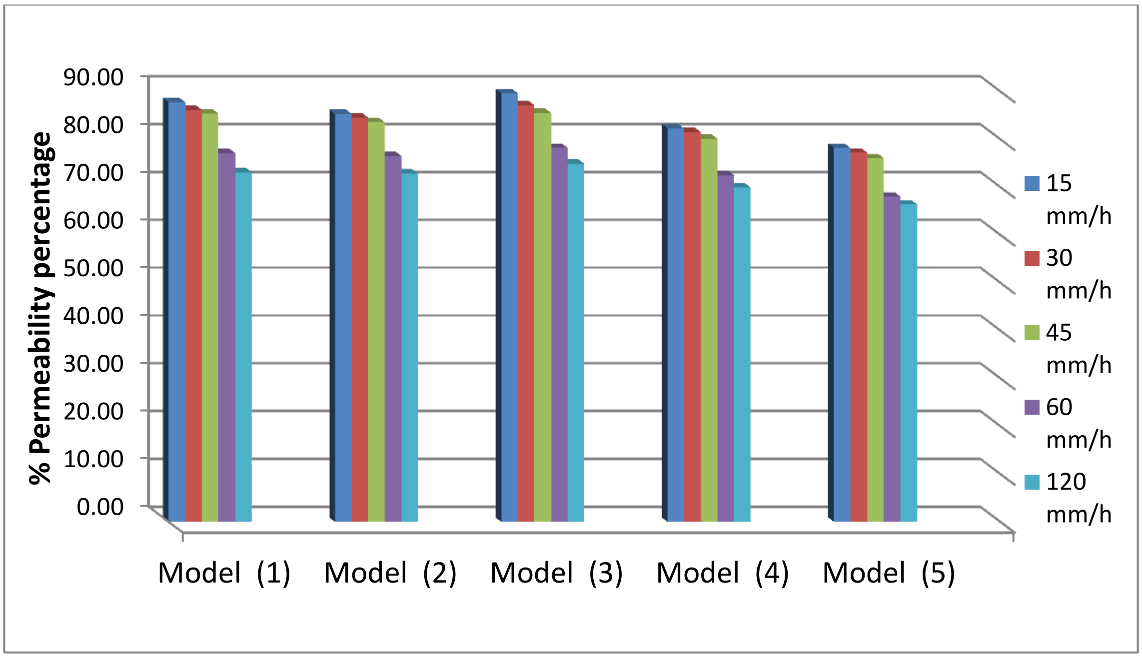


Figure (4.28): Comparison results of permeability percentage for all models when using Simsimia 0/9.5 and Adasia 0/12.5 on base course layers

4.4.3 Effect of using different joints between block on permeability

When using two types of joints, 3 mm and 5 mm the comparison of results are shown in Table (4.21).

Table (4.21): Results of permeability percentage for model (1&3) according to different joints

120 mm/h	60 mm/h	45 mm/h	30 mm/h	15 mm/h	Inflow				
					Base course	Type			
31.28	54.78	65.98	68.47	70.53	Simsimia 0/9.5 + Sand 0/0.6	Joints : 3mm	Pattern: Basket weave bond	Rectangular 10 x 20cm	Model (1)
32.81	58.40	68.53	71.53	79.53	Adasia 0/12.5 + Sand 0/0.6				
73.10	77.13	85.36	86.13	87.73	Simsimia 0/9.5 + Adasia 0/12.5				
32.59	56.83	68.36	72.33	75.93	Simsimia 0/9.5 + Sand 0/0.6	Joints : 5mm			Model (3)
33.08	59.10	69.18	75.80	81.80	Adasia 0/12.5 + Sand 0/0.6				
74.87	78.18	85.51	87.10	89.60	Simsimia 0/9.5 + Adasia 0/12.5				

Figure (4.29 - 4.31) below illustrates all the results, no large effect has been noticed in the percentage of water permeability during low intensity of water.

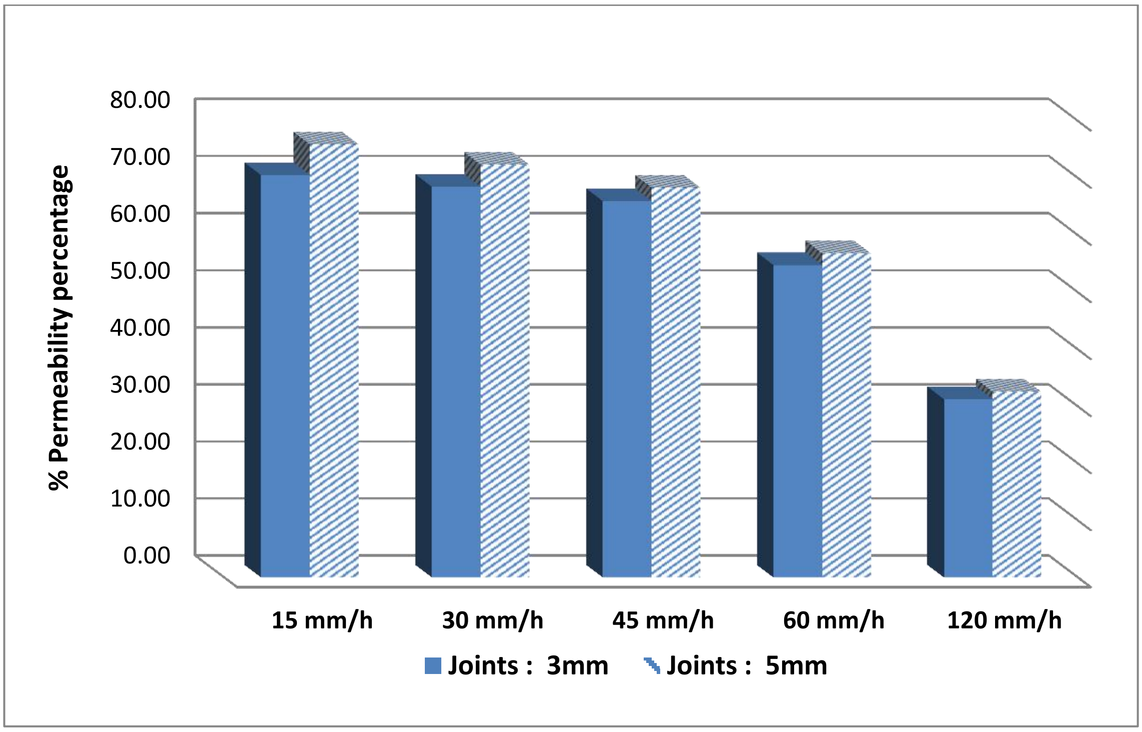


Figure (4.29): Comparison results of permeability percentage according to joints for Model (1 & 3) when using Simsimia 0/9.5 and Sand 0/0.6 as base course layer

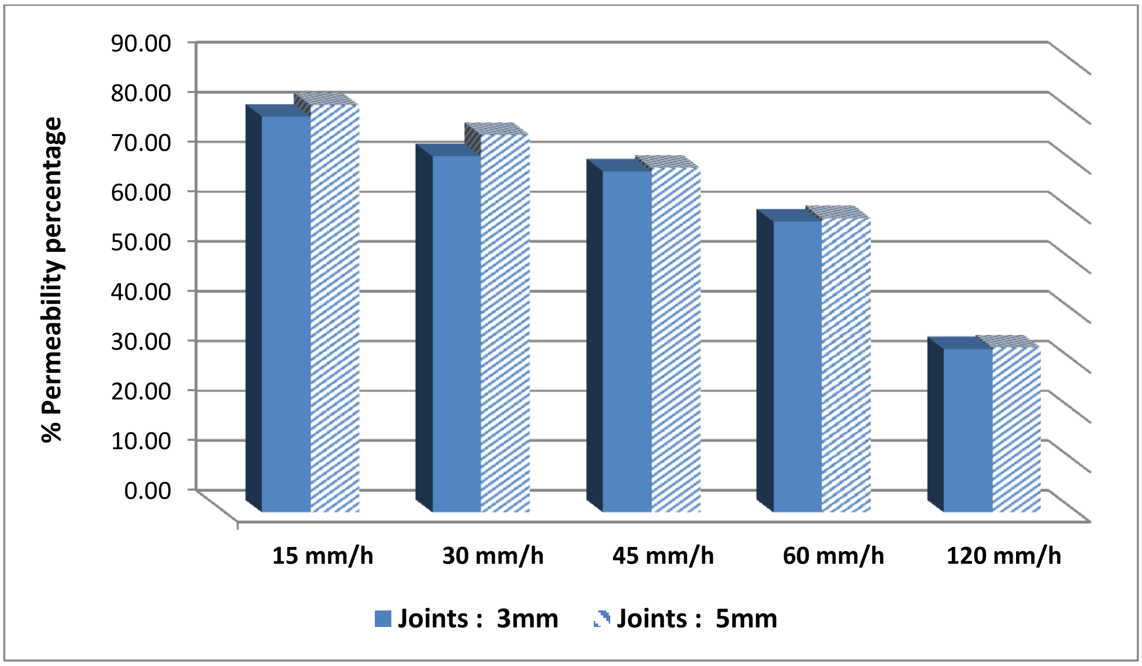


Figure (4.30): Comparison results of permeability percentage according to joints for Model (1 & 3) when using Adasia 0/12.5 and Sand 0/0.6 as base course layer

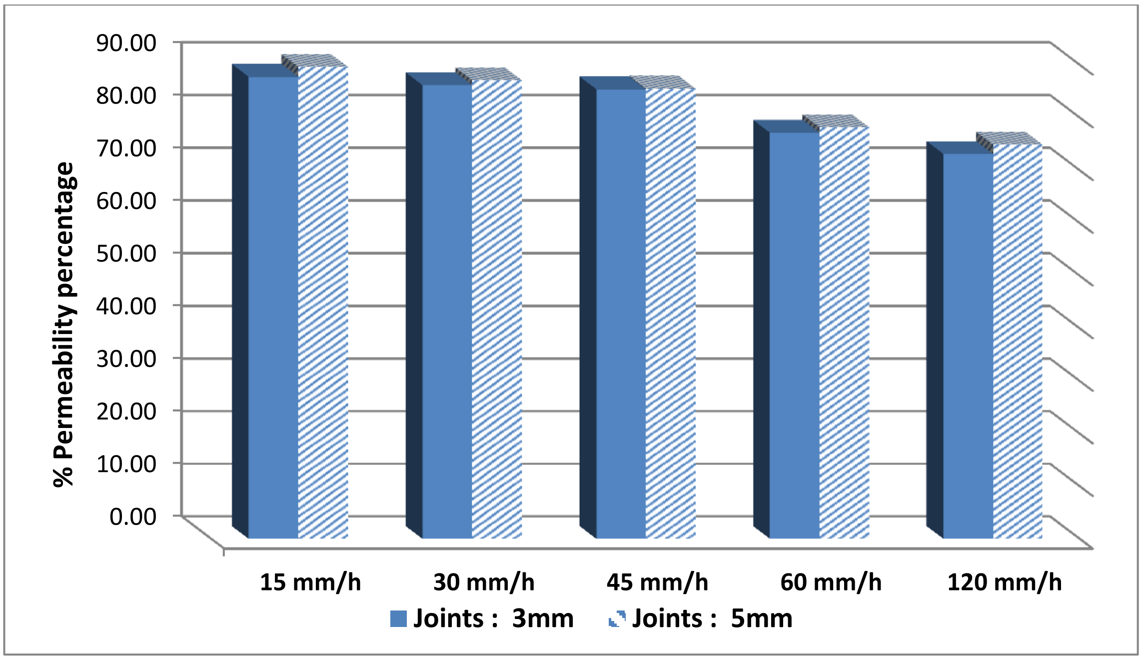


Figure (4.31): Comparison results of permeability percentage according to joints for Model (1 & 3) when using Simsimia 0/9.5 and Adasia 0/12.50 as base course layer

4.4.4 Effect of using different interlock pattern type on permeability

When changing patterns of tiles, the comparison of results are shown in Table (4.22).

Table (4.22): Results of permeability percentage for model (1&2) according to different pattern

120 mm/h	60 mm/h	45 mm/h	30 mm/h	15 mm/h	Inflow Base course	Type			
31.28	54.78	65.98	68.47	70.53	Simsimia 0/9.5 + Sand 0/0.6	Pattern: Basket weave bond	Joints : 3mm	Rectangular 10*20cm	Model (1)
32.81	58.40	68.53	71.53	79.53	Adasia 0/12.5 + Sand 0/0.6				
73.10	77.13	85.36	86.13	87.73	Simsimia 0/9.5 + Adasia 0/12.5				
30.46	52.75	63.17	65.67	68.93	Simsimia 0/9.5 + Sand 0/0.6	Pattern: Herringbone bond (90o)			Model (2)
32.01	57.38	67.18	71.17	78.47	Adasia 0/12.5 + Sand 0/0.6				
72.84	76.47	83.58	84.50	85.33	Simsimia 0/9.5 + Adasia 0/12.5				

Figure (4.32 - 4.34) below illustrates all the results, and the results didn't show significant effect on water permeability percentage through the intensity of water mentioned.

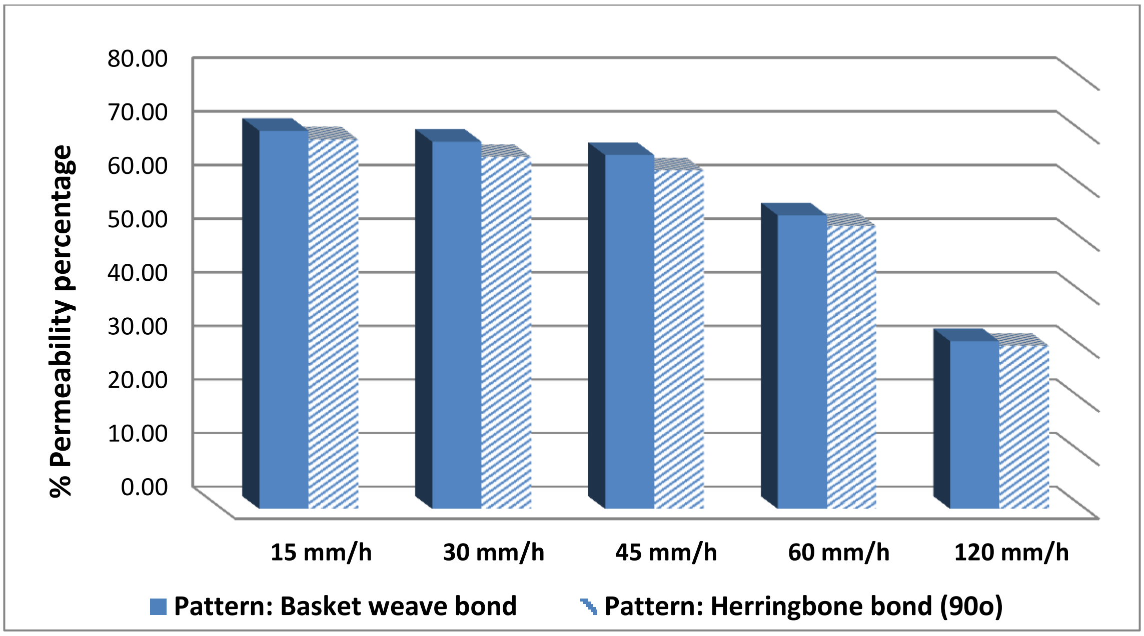


Figure (4.32): Comparison results of permeability percentage according to pattern for Model (1 & 2) when using Simsimia 0/9.5 and Sand 0/0.6 as base course layer

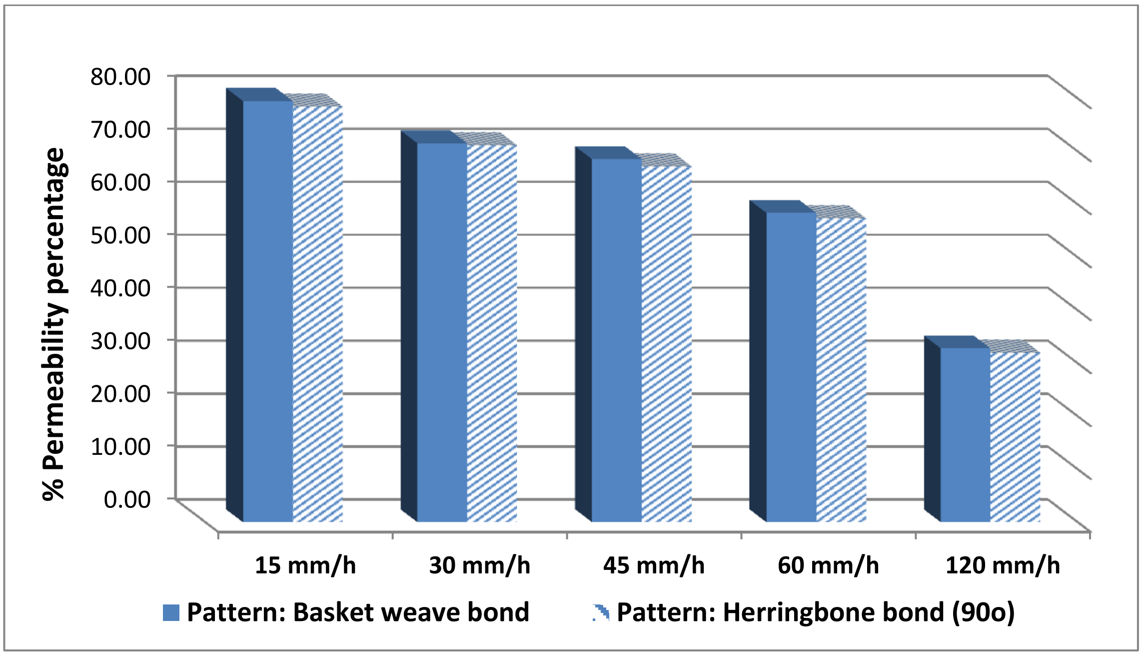


Figure (4.33): Comparison results of permeability percentage according to pattern for Model (1 & 2) when using Adasia 0/12.5 and Sand 0/0.6 as base course layer

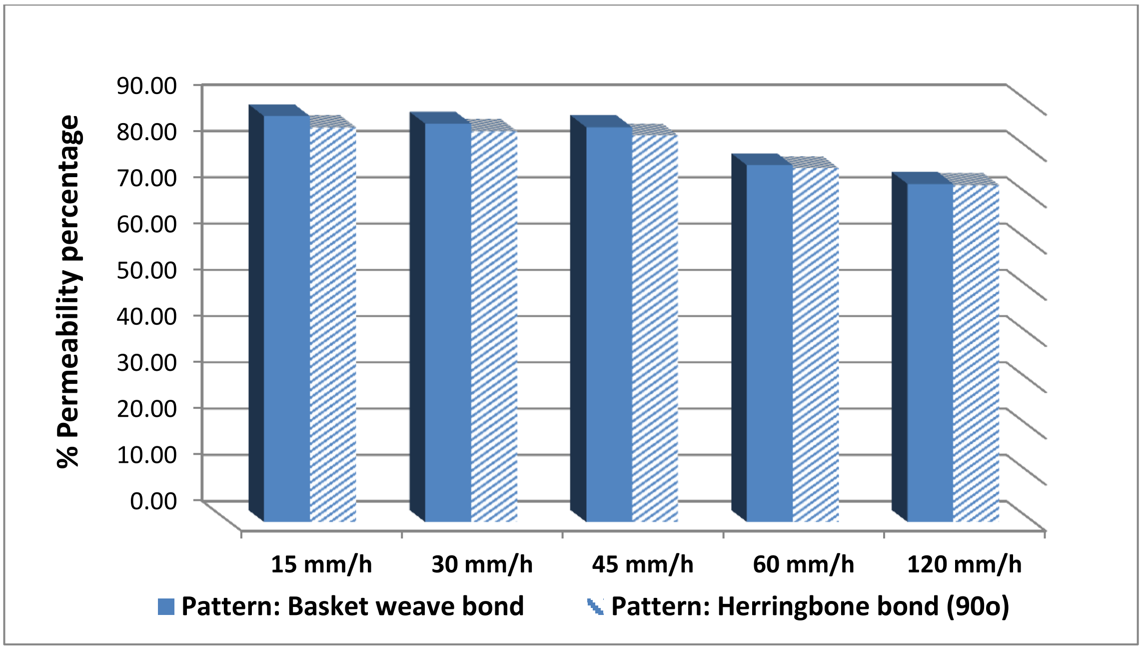


Figure (4.34): Comparison results of permeability percentage according to pattern for Model (1 & 2) when using Simsimia 0/9.5 and Adasia 0/12.50 as base course layer

Chapter (5)
Conclusions and Recommendations

5.1 Conclusions

The followings conclusions can be drawn:

a) The study has shown the possibility of infiltration the water through joints between Interlock and reduce the amount of water accumulated on the surface as runoff water as much as possible by using a variety of experiences.

b) Through experiments, the results show that the using rectangular block tile 10x20 cm gives the highest percentage of water permeability more than any other types of tiles as it was shown in Model (3).

c) In the existence of sand layer under the tiles the water permeability percentage for the intensity of rainfall at 15 mm/h amounted to about 76% without any surface water runoff, while at the intensity of rainfall 120 mm/h water permeability percentage did not exceed 32.5% with large surface runoff water.

d) When using coarse aggregate layer, the permeability percentage reached 89.6% in the low intensity of water and 75% in the largest intensity of water and less of surface water runoff was observed.

e) When changing patterns of tiles, the results didn't show significant effect on water permeability percentage through the intensity of water.

f) As for the increase of joints between interlock tiles, no large effect has been noticed in the percentage of water permeability during low intensity of water, while little increase was observed in the water permeability during the high water intensity but the increase in the continuity of water permeability grows with the increase of joints in cases of obstructive dust and dirt on the surface of the pavement.

5.2 Recommendations

a) The successful results obtained from the laboratory studies should be extended to a field based study to better understand issues related.

b) Through the results that have been obtained, the study recommends to take advantage and solve the problem of rain water accumulated in areas with light loads such as squares, car parking, stadiums and plazas.

c) It is important to get benefit from amounts of water that is collected and not neglected then, Re-injected into groundwater aquifer to reduce the water problem.

d) It is recommended to conduct similar studies about making mix concrete tile that has special specification to permeable water through the tiles and consist of compounds with water permeability properties.

e) Government, institutions , municipalities and researchers should integrate efforts toward preparing and implementing water management plan reinforcing the environmental sustainability by taking and support important issues to development the Infrastructure.

References

- Adams, M., 2006, 'Sustainable Site Design, Porous Pavement and Innovative Storm water Techniques', Cahill Associates, Inc., Environmental Consultants, American Public Works Association.
- American Association of State Highway and Transportation Officials (AASHTO), 2003, Standard Method of Test for 'Determining Dynamic Modulus of Hot-Mix Asphalt Concrete Mixtures', AASHTO Designation: TP 62-03.
- American Concrete Institute (ACI), 2006, Pervious Concrete, ACI Report 522R-2, Farmington Hills, Michigan.
- Bond P.C., Pratt C.J. and Newman A.P., 1999, A Review of Storm Water Quantity and Quality performance of permeable pavements in the UK. Proc. 8th International Conference on Urban Storm Drainage, Sydney, Australia, pp.248-255.
- Burak, R.J., 2004, 'Permeable Interlocking Concrete Pavements–Selection, Design, Construction and Maintenance', Transportation Association of Canada Annual Conference in Québec City.
- Cahill, T.H., Adams, M., Marm, C., 2003, 'Porous Asphalt', Hot Mix Asphalt Technology, Issue: SEPTEMBER/OCTOBER, http://www.asphaltalliance.com.
- Cement & Concrete Association of New Zealand (CCA), 1988, 'Interlocking concrete block road pavements ', A Guide to Design & Construction.
- Cement & Concrete Association of New Zealand website (CCANZ), 2013, [online], Available at: (http://www.ccanz.org.nz) [Accessed 8 May 2013]
- Concrete Masonry Association of Australia (CMAA), 2010, 'Permeable Interlocking Concrete Pavements'- A guide to permeable interlocking concrete pavements.
- Concrete Manufacturers Association (CMA), 2004, ' Concrete Block Paving: Book 2, Design Aspects, Concrete Manufacturers Association, pp. 20.
- Davies J.W., Pratt C.J. and Scott M.A., 2002. ' Laboratory study of permeable pavement systems to support hydraulic modeling'. 9th International Conference on Urban Storm Drainage, Portland, pp13.

- Environmental Protection Agency (EPA), 1999, ‘Storm Water Technology Fact Sheet Porous Pavement’, Environmental Protection Agency, Office of Water, Washington, D.C.
- Ferguson, B., 2005, ‘Porous Pavements’, Taylor and Francis Group, CRC Press, Boca Raton, FL, New York.
- Franklin Institute Research Laboratories (FIRL), 1972, ‘Investigation of Porous Pavements for Urban Runoff Control’. Washington, D. C.
- Hamdan, S., and Nassar, A., 2007, ‘Storm water availability in the Gaza Strip, Palestine. Int. J. Environment and Health, Vol. 1, No. 4.
- Interlocking Concrete Pavement Institute (ICPI), 2006, ‘Permeable Interlocking Concrete Pavements, Selection, Design, Construction, Maintenance’. Third Edition, Washington D.C.
- James, W. and von Langsdorff, H. , 2003, ‘The Use of Permeable Concrete Block Pavement in controlling environmental stressors in urban areas’ , Computational Hydraulics Intl. Canada.
- Khalaf, A., 2005, ‘Assessment of Rainwater Losses due to Urban Expansion of Gaza Strip’ , M.Sc Thesis, Islamic University of Gaza, Palestine.
- Kresin, Chris. , 1996, ‘Infiltration through aging permeable paving’, MSc. Thesis, School of Engineering, University of Guelph, Guelph, Ontario, Canada.
- Mississippi Concrete Industries Association (MCIA), 2002, ‘Pervious Concrete: The Pavement that Drinks’, http://www.mississippiconcrete.com/downloads/pervious.pdf.
- National Asphalt Pavement Association (NAPA), 2003, Design, Construction and Maintenance Guide for Porous Asphalt Pavement. Lanham, MD.
- National Asphalt Pavement Association, 2003, ‘Porous Asphalt Pavement’, National Asphalt Pavement Association, Lanham Maryland.
- Newton D., Jenkins G. and Phillips I. , 2003, ‘The Potential of Porous Pavement for Urban Storm Water Management’. 28th International Hydrology and Water Resources Symposium, Wollongong.
- Palestinian Standard Certificates (PSI and PSM) for block and tiles, Palestinian Standard PS 72, 1997.

- Pratt C.J., Mantle J.D.G. and Schofield P.A., 1989. 'Urban storm water reduction and quality improvement through the use of permeable pavements'. Water Science and Technology, 21,pp 769-778.
- Rabah F., 2008, 'Sanitary Engineering Lecturer- Design of Storm Water Drainge System in Gaza City'.
- Schaus, L. K., 2007, 'Porous Asphalt Pavement Designs: Proactive Design for Cold Climate Use' , M.Sc Thesis, Waterloo University at Ontario, Canada.
- Schueler, T. 1987, 'Controlling Urban Runoff: A practical manual for planning and Site of Interlocking Concrete Pavement Institute' (icpi.org) or the Low Impact Development Center.
- Schwab, G.O.; Fangmeier, D.D.; Elliot, W.J.; and Frevert, R.K. (1993). Soil and Water Conservation Engineering. 4th edition. John Wiley and Sons, Inc., New York.
- Shackel B. and Pearson A., 2004. 'Eco paving can help control road run-off, Erosion & Stormwater', pp32-35.
- Sharma, R. K. , 1983, 'A text Book of Hydrology and Water Resources'. 2nd. Eddition. J.C. Kapur for Dhanpat Rai and Sons, Delhi-Jultundur, India .
- Smith D.R., 1984, ' Evaluation of concrete grid pavements in the United States, Proc. 2nd Intl. Conf. on Concrete Block Paving, pp.809-814. Delft, the Netherlands.
- Tennis, P.D., 2004, 'Pervious Concrete Pavements', Portland Cement Association, Skokie Illinois.
- Thelen, E. and Howe, L.F., 'Porous Pavement', The Franklin Institute Press, Philadelphia Pennsylvania, 1978.
- Zhang, J B , 2006, 'A laboratory scale study of infiltration from pervious pavements' , M.Sc Thesis, Engineering and technology portfolio RMIT University.

Appendices

Appendix (A)
Results

Result of permeability for Simsimia 0/9.5 and Sand 0/0.6 as Base course layer at rainfall intensity=15 mm/h

Table (A.1): Cumulative outflow for all model at (RI=15 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
1 st	0.25	0	0	0	0	0
2 nd	0.50	0	0	0	0	0
3 rd	0.75	0	0	0	0	0
4 th	1.00	0	0	0.08	0	0
5 th	1.25	0	0	0.2	0	0
6 th	1.50	0.1	0	0.34	0	0
7 th	1.75	0.22	0.1	0.48	0	0
8 th	2.00	0.36	0.22	0.62	0.05	0
9 th	2.25	0.5	0.34	0.77	0.15	0.1
10 th	2.50	0.65	0.47	0.92	0.27	0.22
11 th	2.75	0.8	0.62	1.07	0.42	0.34
12 th	3.00	0.95	0.77	1.23	0.57	0.46
13 th	3.25	1.1	0.92	1.39	0.72	0.58
14 th	3.5.0	1.25	1.07	1.55	0.87	0.72
15 th	3.75	1.41	1.24	1.71	1.02	0.86
16 th	4.00	1.57	1.41	1.87	1.17	1
17 th	4.25	1.74	1.57	2.04	1.33	1.15
18 th	4.50	1.91	1.74	2.22	1.49	1.3
19 th	4.75	2.08	1.91	2.42	1.65	1.45
20 th	5.00	2.25	2.08	2.61	1.81	1.6
21 st	5.25	2.43	2.26	2.81	1.97	1.75
22 nd	5.50	2.62	2.45	3.01	2.13	1.91
23 rd	5.75	2.81	2.64	3.21	2.31	2.07
24 th	6.00	3	2.83	3.41	2.49	2.23
25 th	6.25	3.2	3.03	3.61	2.67	2.39
26 th	6.50	3.4	3.23	3.82	2.85	2.55
27 th	6.75	3.6	3.43	4.04	3.03	2.73
28 th	7.00	3.8	3.63	4.26	3.22	2.91
29 th	7.25	4	3.85	4.48	3.41	3.09
30 th	7.50	4.2	4.05	4.7	3.61	3.27
31 st	7.75	4.4	4.25	4.92	3.81	3.45
32 nd	8.00	4.6	4.45	5.14	4.01	3.63
33 rd	8.25	4.82	4.65	5.36	4.21	3.81
34 th	8.50	5.02	4.85	5.58	4.41	3.99
35 th	8.75	5.22	5.05	5.8	4.61	4.17
36 th	9.00	5.42	5.25	6.02	4.81	4.35
37 th	9.25	5.64	5.45	6.23	5.01	4.53
38 th	9.50	5.84	5.65	6.44	5.21	4.71
39 th	9.75	6.06	5.85	6.65	5.41	4.91
40 th	10.00	6.26	6.05	6.87	5.61	5.11
41 st	10.25	6.47	6.25	7.09	5.81	5.31
42 nd	10.50	6.68	6.45	7.31	6.01	5.51
43 rd	10.75	6.9	6.65	7.53	6.21	5.71

Cont. Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
44 th	**11.00**	7.12	6.85	7.75	6.41	5.91
45 th	**11.25**	7.32	7.05	7.97	6.61	6.11
46 th	**11.50**	7.52	7.26	8.19	6.82	6.31
47 th	**11.75**	7.72	7.47	8.41	7.03	6.51
48 th	**12.00**	7.92	7.68	8.63	7.24	6.71
49 th	**12.25**	8.12	7.89	8.85	7.45	6.91
50 th	**12.50**	8.32	8.11	9.07	7.67	7.11
51 st	**12.75**	8.52	8.33	9.3	7.89	7.31
52 nd	**13.00**	8.74	8.54	9.53	8.1	7.51
53 rd	**13.25**	8.96	8.76	9.75	8.32	7.72
54 th	**13.50**	9.19	8.98	9.97	8.54	7.94
55 th	**13.75**	9.42	9.2	10.2	8.76	8.16
56 th	**14.00**	9.65	9.42	10.43	8.98	8.38
57 th	**14.25**	9.88	9.65	10.67	9.2	8.6
58 th	**14.50**	10.11	9.88	10.91	9.42	8.82
59 th	**14.75**	10.34	10.11	11.15	9.64	9.04
60 th	**15.00**	10.58	10.34	11.39	9.86	9.26
permeability percentage (%)		**70.53**	**68.93**	**75.93**	**65.73**	**61.73**

Result of permeability for Simsimia 0/9.5 and Sand 0/0.6 as Base course layer at rainfall intensity=30 mm/h

Table (A.2): Cumulative outflow for all model at (RI=30 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
1 st	**0.5**	0	0	0	0	0
2 nd	**1.0**	0	0	0	0	0
3 rd	**1.5**	0.11	0	0	0	0
4 th	**2.0**	0.32	0	0.12	0	0
5 th	**2.5**	0.59	0.09	0.32	0	0
6 th	**3.0**	0.85	0.27	0.62	0.2	0.1
7 th	**3.5**	1.14	0.56	0.92	0.5	0.3
8 th	**4.0**	1.45	0.87	1.26	0.8	0.55
9 th	**4.5**	1.78	1.2	1.6	1.1	0.83
10 th	**5.0**	2.12	1.53	1.94	1.4	1.11
11 th	**5.5**	2.47	1.86	2.28	1.7	1.39
12 th	**6.0**	2.84	2.19	2.63	2	1.69
13 th	**6.5**	3.22	2.54	2.98	2.3	1.99
14 th	**7.0**	3.58	2.89	3.33	2.65	2.29
15 th	**7.5**	3.95	3.24	3.69	3	2.59
16 th	**8.0**	4.33	3.61	4.05	3.35	2.89
17 th	**8.5**	4.69	3.98	4.41	3.7	3.22
18 th	**9.0**	5.04	4.35	4.77	4.06	3.55
19 th	**9.5**	5.38	4.7	5.15	4.42	3.88
20 th	**10.0**	5.75	5.07	5.53	4.78	4.21
21 st	**10.5**	6.11	5.44	5.91	5.14	4.54

Cont. Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
22 nd	**11.0**	6.49	5.81	6.29	5.49	4.87
23 rd	**11.5**	6.84	6.16	6.67	5.84	5.2
24 th	**12.0**	7.2	6.51	7.05	6.19	5.53
25 th	**12.5**	7.55	6.86	7.45	6.54	5.86
26 th	**13.0**	7.92	7.23	7.85	6.89	6.19
27 th	**13.5**	8.3	7.6	8.25	7.24	6.54
28 th	**14.0**	8.68	7.97	8.65	7.59	6.89
29 th	**14.5**	9.06	8.34	9.05	7.94	7.24
30 th	**15.0**	9.41	8.71	9.45	8.29	7.59
31 st	**15.5**	9.77	9.08	9.85	8.64	7.94
32 nd	**16.0**	10.14	9.45	10.25	8.99	8.29
33 rd	**16.5**	10.5	9.81	10.65	9.35	8.64
34 th	**17.0**	10.87	10.19	11.05	9.7	8.99
35 th	**17.5**	11.25	10.56	11.45	10.05	9.34
36 th	**18.0**	11.61	10.92	11.85	10.41	9.69
37 th	**18.5**	11.96	11.27	12.25	10.76	10.04
38 th	**19.0**	12.33	11.62	12.65	11.11	10.39
39 th	**19.5**	12.71	11.97	13.05	11.46	10.74
40 th	**20.0**	13.09	12.32	13.45	11.81	11.09
41 st	**20.5**	13.47	12.67	13.85	12.16	11.44
42 nd	**21.0**	13.82	13.02	14.25	12.51	11.79
43 rd	**21.5**	14.18	13.37	14.66	12.86	12.14
44 th	**22.0**	14.55	13.74	15.07	13.23	12.49
45 th	**22.5**	14.91	14.1	15.48	13.59	12.85
46 th	**23.0**	15.28	14.47	15.89	13.96	13.21
47 th	**23.5**	15.66	14.84	16.3	14.33	13.57
48 th	**24.0**	16.03	15.21	16.71	14.7	13.93
49 th	**24.5**	16.39	15.58	17.12	15.07	14.29
50 th	**25.0**	16.76	15.95	17.53	15.44	14.65
51 st	**25.5**	17.13	16.32	17.94	15.81	15.01
52 nd	**26.0**	17.5	16.69	18.36	16.18	15.37
53 rd	**26.5**	17.88	17.06	18.77	16.55	15.73
54 th	**27.0**	18.25	17.43	19.18	16.92	16.09
55 th	**27.5**	18.62	17.8	19.6	17.29	16.45
56 th	**28.0**	18.99	18.17	20.02	17.66	16.81
57 th	**28.5**	19.36	18.54	20.44	18.03	17.18
58 th	**29.0**	19.75	18.92	20.86	18.4	17.55
59 th	**29.5**	20.14	19.31	21.28	18.78	17.92
60 th	**30.0**	20.54	19.7	21.7	19.16	18.29
permeability percentage (%)		**68.47**	**65.67**	**72.33**	**63.87**	**60.97**

Result of permeability for Simsimia 0/9.5 and Sand 0/0.6 as Base course layer at rainfall intensity=45 mm/h

Table (A.3): Cumulative outflow for all model at (RI=45 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
1 st	**0.75**	0.13	0.1	0.15	0	0
2 nd	**1.50**	0.26	0.2	0.3	0	0
3 rd	**2.25**	0.39	0.34	0.5	0.15	0
4 th	**3.00**	0.64	0.54	0.8	0.35	0.18
5 th	**3.75**	1.01	0.89	1.15	0.57	0.4
6 th	**4.50**	1.45	1.24	1.55	0.92	0.68
7 th	**5.25**	1.88	1.62	1.95	1	1
8 th	**6.00**	2.34	2.02	2.35	1.38	1.33
9 th	**6.75**	2.82	2.42	2.78	1.78	1.68
10 th	**7.50**	3.3	2.84	3.23	2.18	2.03
11 th	**8.25**	3.78	3.27	3.68	2.6	2.39
12 th	**9.00**	4.26	3.72	4.16	3.02	2.77
13 th	**9.75**	4.74	4.17	4.65	3.47	3.17
14 th	**10.50**	5.22	4.65	5.14	3.92	3.57
15 th	**11.25**	5.72	5.13	5.64	4.37	4
16 th	**12.00**	6.22	5.61	6.16	4.82	4.45
17 th	**12.75**	6.72	6.09	6.68	5.3	4.9
18 th	**13.50**	7.2	6.57	7.18	5.78	5.35
19 th	**14.25**	7.7	7.06	7.7	6.26	5.8
20 th	**15.00**	8.2	7.55	8.22	6.74	6.25
21 st	**15.75**	8.7	8.04	8.74	7.22	6.73
22 nd	**16.50**	9.2	8.54	9.26	7.72	7.21
23 rd	**17.25**	9.7	9.04	9.78	8.22	7.69
24 th	**18.00**	10.2	9.54	10.3	8.72	8.17
25 th	**18.75**	10.7	10.04	10.82	9.2	8.65
26 th	**19.50**	11.2	10.54	11.34	9.7	9.13
27 th	**20.25**	11.7	11.04	11.87	10.2	9.63
28 th	**21.00**	12.2	11.54	12.4	10.7	10.13
29 th	**21.75**	12.72	12.04	12.93	11.2	10.63
30 th	**22.50**	13.24	12.56	13.46	11.7	11.13
31 st	**23.25**	13.77	13.08	13.99	12.2	11.63
32 nd	**24.00**	14.31	13.6	14.54	12.72	12.13
33 rd	**24.75**	14.86	14.12	15.09	13.24	12.63
34 th	**25.50**	15.4	14.64	15.65	13.76	13.13
35 th	**26.25**	15.95	15.16	16.21	14.28	13.65
36 th	**27.00**	16.51	15.68	16.77	14.8	14.17
37 th	**27.75**	17.05	16.21	17.34	15.32	14.69
38 th	**28.50**	17.58	16.74	17.91	15.84	15.21
39 th	**29.25**	18.13	17.27	18.48	16.36	15.73
40 th	**30.00**	18.69	17.8	19.05	16.89	16.26
41 st	**30.75**	19.25	18.33	19.62	17.42	16.79
42 nd	**31.50**	19.81	18.85	20.19	17.94	17.32
43 rd	**32.25**	20.34	19.37	20.76	18.46	17.85
44 th	**33.00**	20.88	19.89	21.33	18.98	18.38

Cont. Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
45 th	**33.75**	21.43	20.41	21.91	19.5	18.91
46 th	**34.50**	21.97	20.94	22.49	20.03	19.44
47 th	**35.25**	22.52	21.47	23.07	20.56	19.97
48 th	**36.00**	23.08	22	23.64	21.09	20.5
49 th	**36.75**	23.63	22.53	24.22	21.62	21.03
50 th	**37.50**	24.17	23.06	24.8	22.15	21.56
51 st	**38.25**	24.72	23.59	25.38	22.68	22.09
52 nd	**39.00**	25.27	24.12	25.96	23.21	22.62
53 rd	**39.75**	25.82	24.65	26.54	23.74	23.15
54 th	**40.50**	26.38	25.19	27.12	24.28	23.69
55 th	**41.25**	26.93	25.73	27.72	24.82	24.23
56 th	**42.00**	27.48	26.27	28.32	25.36	24.77
57 th	**42.75**	28.03	26.81	28.92	25.9	25.31
58 th	**43.50**	28.58	27.35	29.52	26.44	25.85
59 th	**44.25**	29.14	27.89	30.14	26.98	26.39
60 th	**45.00**	29.71	28.43	30.76	27.52	26.93
permeability percentage (%)		**66.02**	**63.18**	**68.36**	**61.16**	**59.84**

Result of permeability for Simsimia 0/9.5 and Sand 0/0.6 as Base course layer at rainfall intensity=60 mm/h

Table (A.4): Cumulative outflow for all model at (RI=60 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
1 st	**1**	0.33	0.28	0.35	0.2	0.1
2 nd	**2**	0.66	0.56	0.7	0.4	0.2
3 rd	**3**	0.98	0.88	1.07	0.68	0.4
4 th	**4**	1.33	1.22	1.47	0.98	0.65
5 th	**5**	1.7	1.57	1.89	1.33	0.95
6 th	**6**	2.14	1.97	2.34	1.68	1.25
7 th	**7**	2.6	2.37	2.8	2.08	1.59
8 th	**8**	3.06	2.79	3.28	2.48	1.94
9 th	**9**	3.55	3.22	3.76	2.88	2.29
10 th	**10**	4.05	3.67	4.28	3.28	2.67
11 th	**11**	4.58	4.15	4.81	3.73	3.07
12 th	**12**	5.1	4.63	5.33	4.18	3.47
13 th	**13**	5.61	5.11	5.85	4.63	3.87
14 th	**14**	6.14	5.59	6.38	5.11	4.3
15 th	**15**	6.66	6.09	6.93	5.59	4.73
16 th	**16**	7.2	6.59	7.48	6.07	5.18
17 th	**17**	7.75	7.09	8.05	6.55	5.63
18 th	**18**	8.29	7.61	8.62	7.05	6.08
19 th	**19**	8.82	8.13	9.19	7.55	6.56
20 th	**20**	9.35	8.65	9.76	8.05	7.04
21 st	**21**	9.88	9.17	10.34	8.55	7.52

Cont. Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
22 nd	**22**	10.42	9.69	10.92	9.05	8
23 rd	**23**	10.96	10.21	11.5	9.55	8.48
24 th	**24**	11.5	10.73	12.08	10.05	8.98
25 th	**25**	12.03	11.25	12.66	10.55	9.48
26 th	**26**	12.56	11.77	13.23	11.07	9.98
27 th	**27**	13.09	12.29	13.81	11.59	10.48
28 th	**28**	13.63	12.82	14.39	12.11	10.98
29 th	**29**	14.18	13.35	14.97	12.63	11.5
30 th	**30**	14.73	13.88	15.55	13.17	12.02
31 st	**31**	15.3	14.41	16.13	13.71	12.54
32 nd	**32**	15.87	14.96	16.7	14.26	13.06
33 rd	**33**	16.44	15.51	17.27	14.81	13.58
34 th	**34**	17.02	16.06	17.85	15.36	14.1
35 th	**35**	17.6	16.61	18.43	15.91	14.62
36 th	**36**	18.18	17.16	19.01	16.46	15.14
37 th	**37**	18.76	17.73	19.61	17.01	15.66
38 th	**38**	19.36	18.3	20.21	17.56	16.21
39 th	**39**	19.96	18.87	20.81	18.11	16.76
40 th	**40**	20.56	19.44	21.41	18.68	17.31
41 st	**41**	21.16	20.02	22.01	19.25	17.86
42 nd	**42**	21.76	20.6	22.63	19.82	18.41
43 rd	**43**	22.36	21.18	23.25	20.39	18.98
44 th	**44**	22.96	21.76	23.87	20.97	19.55
45 th	**45**	23.56	22.36	24.49	21.55	20.12
46 th	**46**	24.16	22.96	25.12	22.13	20.69
47 th	**47**	24.77	23.57	25.75	22.71	21.26
48 th	**48**	25.39	24.19	26.38	23.29	21.83
49 th	**49**	26.01	24.81	27.02	23.87	22.41
50 th	**50**	26.63	25.43	27.66	24.47	22.99
51 st	**51**	27.25	26.05	28.3	25.07	23.57
52 nd	**52**	27.87	26.67	28.94	25.67	24.15
53 rd	**53**	28.49	27.29	29.58	26.27	24.73
54 th	**54**	29.11	27.91	30.22	26.87	25.33
55 th	**55**	29.73	28.53	30.86	27.47	25.93
56 th	**56**	30.35	29.15	31.5	28.07	26.53
57 th	**57**	30.98	29.77	32.15	28.69	27.13
58 th	**58**	31.61	30.39	32.8	29.31	27.73
59 th	**59**	32.24	31.02	33.45	29.93	28.33
60 th	**60**	32.87	31.65	34.1	30.55	28.93
permeability percentage (%)		**54.78**	**52.75**	**56.83**	**50.92**	**48.22**

Result of permeability for Simsimia 0/9.5 and Sand 0/0.6 as Base course layer at rainfall intensity=120 mm/h

Table (A.5): Cumulative outflow for all model at (RI=120 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
1 st	2	0.52	0.47	0.59	0.35	0.25
2 nd	4	0.84	0.77	0.94	0.55	0.4
3 rd	6	1.25	1.12	1.36	0.83	0.6
4 th	8	1.75	1.6	1.87	1.18	0.85
5 th	10	2.27	2.1	2.4	1.58	1.15
6 th	12	2.81	2.6	2.95	1.98	1.48
7 th	14	3.38	3.15	3.53	2.43	1.83
8 th	16	3.95	3.7	4.11	2.93	2.23
9 th	18	4.52	4.25	4.69	3.43	2.63
10 th	20	5.09	4.8	5.26	3.93	3.08
11 th	22	5.67	5.35	5.84	4.43	3.53
12 th	24	6.27	5.91	6.46	4.98	3.98
13 th	26	6.87	6.49	7.08	5.53	4.46
14 th	28	7.47	7.07	7.7	6.08	4.94
15 th	30	8.09	7.65	8.32	6.63	5.44
16 th	32	8.72	8.23	8.94	7.21	5.94
17 th	34	9.36	8.83	9.58	7.79	6.44
18 th	36	10.02	9.43	10.22	8.37	6.97
19 th	38	10.64	10.02	10.86	8.95	7.52
20 th	40	11.25	10.62	11.5	9.53	8.07
21 st	42	11.89	11.22	12.15	10.13	8.62
22 nd	44	12.51	11.82	12.8	10.73	9.17
23 rd	46	13.14	12.44	13.45	11.33	9.75
24 th	48	13.76	13.06	14.1	11.93	10.33
25 th	50	14.4	13.68	14.75	12.53	10.91
26 th	52	15.05	14.3	15.41	13.15	11.49
27 th	54	15.68	14.92	16.07	13.77	12.09
28 th	56	16.32	15.55	16.73	14.39	12.69
29 th	58	16.96	16.18	17.39	15.01	13.29
30 th	60	17.59	16.81	18.05	15.64	13.89
31 st	62	18.24	17.44	18.71	16.26	14.49
32 nd	64	18.88	18.07	19.38	16.88	15.09
33 rd	66	19.52	18.7	20.05	17.5	15.69
34 th	68	20.16	19.34	20.72	18.12	16.31
35 th	70	20.81	19.98	21.39	18.74	16.93
36 th	72	21.46	20.62	22.07	19.36	17.55
37 th	74	22.1	21.26	22.75	19.98	18.17
38 th	76	22.75	21.9	23.43	20.6	18.79
39 th	78	23.4	22.54	24.11	21.23	19.41
40 th	80	24.05	23.18	24.78	21.86	20.03
41 st	82	24.7	23.82	25.46	22.49	20.65
42 nd	84	25.35	24.46	26.16	23.12	21.27
43 rd	86	26	25.1	26.86	23.75	21.91

Cont. Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
44 th	**88**	26.65	25.74	27.56	24.39	22.55
45 th	**90**	27.29	26.38	28.26	25.03	23.19
46 th	**92**	27.94	27.03	28.96	25.67	23.83
47 th	**94**	28.59	27.68	29.66	26.31	24.47
48 th	**96**	29.26	28.33	30.38	26.95	25.11
49 th	**98**	29.93	28.98	31.1	27.6	25.75
50 th	**100**	30.59	29.65	31.8	28.25	26.4
51 st	**102**	31.26	30.32	32.52	28.9	27.05
52 nd	**104**	31.96	31	33.24	29.55	27.7
53 rd	**106**	32.65	31.69	33.96	30.2	28.35
54 th	**108**	33.32	32.38	34.68	30.85	29
55 th	**110**	34	33.06	35.4	31.5	29.65
56 th	**112**	34.7	33.76	36.14	32.15	30.3
57 th	**114**	35.41	34.46	36.88	32.83	30.95
58 th	**116**	36.11	35.16	37.62	33.51	31.61
59 th	**118**	36.83	35.86	38.36	34.19	32.27
60 th	**120**	37.54	36.56	39.11	34.87	32.93
permeability percentage (%)		**31.28**	**30.47**	**32.59**	**29.06**	**27.44**

Result of Permeability for Adasia 0/12.5 and Sand 0/0.6 as Base course layer at rainfall intensity=15 mm/h

Table (A.6): Cumulative outflow for all model at (RI=15 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
1 st	0.25	0	0	0	0	0
2 nd	0.5	0	0	0	0	0
3 rd	0.75	0	0	0.1	0	0
4 th	1.00	0.15	0.13	0.22	0.1	0
5 th	1.25	0.32	0.28	0.37	0.24	0.1
6 th	1.50	0.49	0.43	0.52	0.39	0.22
7 th	1.75	0.66	0.59	0.69	0.54	0.37
8 th	2.00	0.83	0.76	0.86	0.69	0.52
9 th	2.25	1	0.93	1.03	0.84	0.67
10 th	2.50	1.18	1.11	1.21	1.01	0.83
11 th	2.75	1.36	1.29	1.39	1.18	0.99
12 th	3.00	1.54	1.47	1.57	1.35	1.15
13 th	3.25	1.74	1.65	1.75	1.52	1.32
14 th	3.50	1.94	1.83	1.95	1.7	1.49
15 th	3.75	2.14	2.03	2.15	1.88	1.66
16 th	4.00	2.34	2.23	2.35	2.06	1.83
17 th	4.25	2.54	2.43	2.55	2.24	2
18 th	4.50	2.74	2.63	2.77	2.42	2.17
19 th	4.75	2.94	2.83	2.97	2.6	2.35
20 th	5.00	3.15	3.03	3.19	2.78	2.53
21 st	5.25	3.36	3.23	3.39	2.98	2.71
22 nd	5.50	3.57	3.43	3.61	3.18	2.89
23 rd	5.75	3.78	3.63	3.83	3.38	3.07
24 th	6.00	3.99	3.83	4.05	3.58	3.25
25 th	6.25	4.2	4.03	4.28	3.78	3.43
26 th	6.50	4.41	4.23	4.51	3.98	3.61
27 th	6.75	4.63	4.44	4.73	4.18	3.81
28 th	7.00	4.85	4.65	4.95	4.38	4.01
29 th	7.25	5.07	4.86	5.17	4.58	4.21
30 th	7.50	5.29	5.07	5.39	4.78	4.41
31 st	7.75	5.51	5.28	5.61	4.99	4.61
32 nd	8.00	5.73	5.49	5.83	5.2	4.81
33 rd	8.25	5.95	5.7	6.05	5.42	5.01
34 th	8.50	6.15	5.91	6.27	5.64	5.21
35 th	8.75	6.35	6.12	6.49	5.86	5.41
36 th	9.00	6.55	6.34	6.72	6.08	5.63
37 th	9.25	6.76	6.56	6.95	6.3	5.85
38 th	9.50	6.96	6.78	7.18	6.52	6.07
39 th	9.75	7.17	7	7.41	6.74	6.29
40 th	10.00	7.37	7.22	7.64	6.96	6.51
41 st	10.25	7.58	7.44	7.85	7.18	6.73
42 nd	10.50	7.79	7.65	8.06	7.4	6.95
43 rd	10.75	8.01	7.87	8.28	7.62	7.17

Cont. Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
44 th	**11.00**	8.23	8.09	8.5	7.84	7.39
45 th	**11.25**	8.45	8.31	8.73	8.06	7.61
46 th	**11.50**	8.67	8.53	8.96	8.28	7.83
47 th	**11.75**	8.89	8.75	9.19	8.5	8.05
48 th	**12.00**	9.11	8.97	9.42	8.72	8.27
49 th	**12.25**	9.34	9.2	9.65	8.93	8.49
50 th	**12.50**	9.57	9.43	9.88	9.15	8.71
51 st	**12.75**	9.8	9.66	10.11	9.37	8.93
52 nd	**13.00**	10.03	9.89	10.35	9.6	9.15
53 rd	**13.25**	10.26	10.12	10.59	9.83	9.37
54 th	**13.50**	10.49	10.35	10.83	10.06	9.59
55 th	**13.75**	10.73	10.58	11.07	10.29	9.82
56 th	**14.00**	10.97	10.81	11.31	10.52	10.05
57 th	**14.25**	11.21	11.05	11.55	10.75	10.28
58 th	**14.50**	11.45	11.29	11.79	10.98	10.51
59 th	**14.75**	11.69	11.53	12.03	11.21	10.74
60 th	**15.00**	11.93	11.77	12.27	11.44	10.97
permeability percentage (%)		**79.53**	**78.47**	**81.80**	**76.27**	**73.13**

Result of Permeability for Adasia 0/12.5 and Sand 0/0.6 as Base course layer at rainfall intensity=30 mm/h

Table (A.7): Cumulative outflow for all model at (RI=30 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
1 st	**0.5**	0	0	0	0	0
2 nd	**1.0**	0	0	0	0	0
3 rd	**1.5**	0	0	0	0	0
4 th	**2.0**	0.09	0	0.14	0	0
5 th	**2.5**	0.25	0.18	0.33	0.15	0.18
6 th	**3.0**	0.52	0.44	0.62	0.35	0.38
7 th	**3.5**	0.82	0.72	0.95	0.6	0.6
8 th	**4.0**	1.16	1.04	1.31	0.9	0.85
9 th	**4.5**	1.5	1.36	1.67	1.22	1.13
10 th	**5.0**	1.84	1.71	2.03	1.54	1.43
11 th	**5.5**	2.18	2.06	2.39	1.86	1.73
12 th	**6.0**	2.52	2.41	2.75	2.18	2.03
13 th	**6.5**	2.86	2.76	3.13	2.53	2.35
14 th	**7.0**	3.2	3.11	3.51	2.88	2.67
15 th	**7.5**	3.56	3.46	3.89	3.23	2.99
16 th	**8.0**	3.92	3.83	4.27	3.58	3.31
17 th	**8.5**	4.28	4.2	4.65	3.93	3.63
18 th	**9.0**	4.64	4.57	5.05	4.28	3.98
19 th	**9.5**	5.01	4.94	5.45	4.65	4.33
20 th	**10.0**	5.39	5.31	5.85	5.02	4.68

Cont. Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
21 st	**10.5**	5.77	5.68	6.25	5.39	5.03
22 nd	**11.0**	6.15	6.05	6.65	5.76	5.38
23 rd	**11.5**	6.53	6.44	7.05	6.14	5.73
24 th	**12.0**	6.91	6.83	7.45	6.52	6.08
25 th	**12.5**	7.3	7.22	7.86	6.9	6.43
26 th	**13.0**	7.69	7.61	8.27	7.28	6.78
27 th	**13.5**	8.08	8	8.68	7.66	7.13
28 th	**14.0**	8.47	8.39	9.09	8.04	7.48
29 th	**14.5**	8.86	8.79	9.49	8.42	7.86
30 th	**15.0**	9.26	9.19	9.9	8.81	8.24
31 st	**15.5**	9.66	9.59	10.31	9.2	8.62
32 nd	**16.0**	10.06	9.99	10.72	9.59	9
33 rd	**16.5**	10.46	10.39	11.13	9.98	9.38
34 th	**17.0**	10.86	10.78	11.54	10.37	9.76
35 th	**17.5**	11.26	11.18	11.96	10.76	10.14
36 th	**18.0**	11.66	11.58	12.38	11.16	10.52
37 th	**18.5**	12.06	11.98	12.8	11.56	10.92
38 th	**19.0**	12.46	12.38	13.22	11.96	11.32
39 th	**19.5**	12.87	12.78	13.65	12.36	11.72
40 th	**20.0**	13.28	13.18	14.08	12.76	12.12
41 st	**20.5**	13.69	13.58	14.51	13.16	12.52
42 nd	**21.0**	14.1	13.98	14.94	13.56	12.92
43 rd	**21.5**	14.51	14.39	15.37	13.97	13.32
44 th	**22.0**	14.92	14.8	15.8	14.38	13.72
45 th	**22.5**	15.33	15.21	16.23	14.79	14.12
46 th	**23.0**	15.74	15.62	16.66	15.2	14.52
47 th	**23.5**	16.15	16.03	17.09	15.61	14.92
48 th	**24.0**	16.56	16.44	17.52	16.02	15.32
49 th	**24.5**	16.97	16.85	17.95	16.43	15.72
50 th	**25.0**	17.36	17.25	18.39	16.84	16.12
51 st	**25.5**	17.77	17.66	18.82	17.25	16.52
52 nd	**26.0**	18.18	18.07	19.25	17.66	16.92
53 rd	**26.5**	18.59	18.48	19.68	18.07	17.32
54 th	**27.0**	19	18.89	20.11	18.48	17.72
55 th	**27.5**	19.41	19.3	20.54	18.89	18.12
56 th	**28.0**	19.82	19.71	20.97	19.3	18.52
57 th	**28.5**	20.23	20.12	21.41	19.71	18.93
58 th	**29.0**	20.64	20.53	21.85	20.12	19.34
59 th	**29.5**	21.05	20.94	22.29	20.54	19.76
60 th	**30.0**	21.46	21.35	22.74	20.96	20.18
permeability percentage (%)		**71.53**	**71.17**	**75.80**	**69.87**	**67.27**

Result of Permeability for Adasia 0/12.5 and Sand 0/0.6 as Base course layer at rainfall intensity=45 mm/h

Table (4.8): Cumulative outflow for all model at (RI=45 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
1 st	**0.75**	0.15	0.15	0.18	0.1	0
2 nd	**1.50**	0.3	0.3	0.36	0.2	0
3 rd	**2.25**	0.48	0.48	0.56	0.35	0.2
4 th	**3.00**	0.73	0.73	0.82	0.55	0.4
5 th	**3.75**	0.98	0.98	1.07	0.77	0.62
6 th	**4.50**	1.28	1.28	1.4	1.02	0.84
7 th	**5.25**	1.63	1.63	1.78	1.27	1.09
8 th	**6.00**	2.03	2.01	2.17	1.57	1.37
9 th	**6.75**	2.43	2.39	2.55	1.89	1.67
10 th	**7.50**	2.83	2.77	2.95	2.24	1.97
11 th	**8.25**	3.23	3.17	3.35	2.62	2.3
12 th	**9.00**	3.63	3.57	3.77	3	2.63
13 th	**9.75**	4.03	3.97	4.19	3.4	2.98
14 th	**10.50**	4.45	4.39	4.62	3.8	3.33
15 th	**11.25**	4.87	4.81	5.05	4.2	3.71
16 th	**12.00**	5.32	5.23	5.51	4.62	4.09
17 th	**12.75**	5.77	5.65	5.98	5.04	4.49
18 th	**13.50**	6.27	6.1	6.45	5.46	4.89
19 th	**14.25**	6.77	6.58	6.92	5.88	5.29
20 th	**15.00**	7.29	7.06	7.4	6.33	5.69
21 st	**15.75**	7.82	7.54	7.9	6.78	6.11
22 nd	**16.50**	8.36	8.04	8.42	7.23	6.53
23 rd	**17.25**	8.9	8.54	8.94	7.71	6.95
24 th	**18.00**	9.45	9.04	9.46	8.19	7.37
25 th	**18.75**	10	9.56	9.98	8.69	7.82
26 th	**19.50**	10.55	10.08	10.52	9.19	8.27
27 th	**20.25**	11.1	10.6	11.07	9.69	8.72
28 th	**21.00**	11.66	11.12	11.62	10.19	9.2
29 th	**21.75**	12.22	11.64	12.17	10.71	9.7
30 th	**22.50**	12.75	12.17	12.72	11.23	10.2
31 st	**23.25**	13.29	12.7	13.26	11.75	10.7
32 nd	**24.00**	13.84	13.23	13.82	12.27	11.2
33 rd	**24.75**	14.38	13.77	14.38	12.81	11.72
34 th	**25.50**	14.93	14.32	14.94	13.35	12.24
35 th	**26.25**	15.49	14.88	15.5	13.89	12.76
36 th	**27.00**	16.04	15.43	16.06	14.43	13.28
37 th	**27.75**	16.58	15.97	16.62	14.97	13.8
38 th	**28.50**	17.13	16.52	17.19	15.52	14.35
39 th	**29.25**	17.68	17.07	17.77	16.07	14.9
40 th	**30.00**	18.28	17.67	18.35	16.62	15.45
41 st	**30.75**	18.88	18.27	18.95	17.19	16
42 nd	**31.50**	19.48	18.87	19.55	17.76	16.55
43 rd	**32.25**	20.08	19.47	20.15	18.33	17.1

Cont. Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
44 th	**33.00**	20.68	20.07	20.77	18.91	17.68
45 th	**33.75**	21.28	20.67	21.39	19.49	18.26
46 th	**34.50**	21.88	21.27	22.01	20.09	18.84
47 th	**35.25**	22.48	21.87	22.63	20.69	19.44
48 th	**36.00**	23.1	22.49	23.27	21.29	20.04
49 th	**36.75**	23.72	23.11	23.91	21.89	20.64
50 th	**37.50**	24.34	23.73	24.55	22.51	21.24
51 st	**38.25**	24.96	24.35	25.19	23.13	21.84
52 nd	**39.00**	25.6	24.99	25.83	23.77	22.46
53 rd	**39.75**	26.25	25.64	26.49	24.42	23.08
54 th	**40.50**	26.9	26.29	27.15	25.07	23.7
55 th	**41.25**	27.55	26.94	27.81	25.72	24.32
56 th	**42.00**	28.2	27.59	28.47	26.37	24.94
57 th	**42.75**	28.85	28.24	29.13	27.02	25.56
58 th	**43.50**	29.5	28.89	29.79	27.67	26.18
59 th	**44.25**	30.17	29.56	30.46	28.33	26.8
60 th	**45.00**	30.84	30.23	31.13	28.99	27.42
permeability percentage (%)		**68.53**	**67.18**	**69.18**	**64.42**	**60.93**

Result of Permeability for Adasia 0/12.5 and Sand 0/0.6 as Base course layer at rainfall intensity=60 mm/h

Table (A.9): Cumulative outflow for all model at (RI=60 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
1 st	**1**	0.35	0.3	0.37	0.25	0.15
2 nd	**2**	0.7	0.6	0.74	0.5	0.3
3 rd	**3**	1.03	0.98	1.09	0.8	0.5
4 th	**4**	1.37	1.36	1.45	1.15	0.75
5 th	**5**	1.72	1.74	1.81	1.5	1.03
6 th	**6**	2.12	2.12	2.17	1.85	1.33
7 th	**7**	2.52	2.52	2.57	2.23	1.65
8 th	**8**	2.92	2.92	2.97	2.61	2
9 th	**9**	3.36	3.32	3.42	2.99	2.35
10 th	**10**	3.81	3.74	3.87	3.39	2.73
11 th	**11**	4.26	4.16	4.32	3.79	3.11
12 th	**12**	4.76	4.58	4.82	4.19	3.51
13 th	**13**	5.28	5	5.32	4.59	3.91
14 th	**14**	5.8	5.44	5.84	5.01	4.31
15 th	**15**	6.32	5.89	6.36	5.43	4.71
16 th	**16**	6.87	6.34	6.88	5.88	5.13
17 th	**17**	7.42	6.79	7.41	6.33	5.55
18 th	**18**	7.97	7.24	7.96	6.78	5.97
19 th	**19**	8.52	7.76	8.51	7.26	6.42
20 th	**20**	9.09	8.3	9.08	7.74	6.87

Cont. Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
21 st	**21**	9.66	8.87	9.65	8.24	7.32
22 nd	**22**	10.24	9.44	10.23	8.74	7.8
23 rd	**23**	10.82	10.01	10.81	9.27	8.28
24 th	**24**	11.4	10.58	11.39	9.82	8.78
25 th	**25**	11.98	11.15	11.99	10.37	9.28
26 th	**26**	12.58	11.75	12.59	10.95	9.78
27 th	**27**	13.2	12.35	13.23	11.53	10.32
28 th	**28**	13.8	12.97	13.87	12.13	10.86
29 th	**29**	14.42	13.59	14.51	12.73	11.41
30 th	**30**	15.04	14.21	15.14	13.35	11.96
31 st	**31**	15.66	14.83	15.78	13.97	12.54
32 nd	**32**	16.28	15.47	16.42	14.61	13.12
33 rd	**33**	16.92	16.11	17.06	15.25	13.7
34 th	**34**	17.56	16.75	17.7	15.89	14.3
35 th	**35**	18.2	17.39	18.34	16.53	14.9
36 th	**36**	18.84	18.03	18.98	17.18	15.52
37 th	**37**	19.49	18.67	19.63	17.83	16.14
38 th	**38**	20.14	19.33	20.29	18.48	16.76
39 th	**39**	20.79	19.99	20.95	19.13	17.38
40 th	**40**	21.44	20.65	21.61	19.78	18
41 st	**41**	22.09	21.31	22.27	20.43	18.62
42 nd	**42**	22.75	21.97	22.93	21.08	19.27
43 rd	**43**	23.41	22.63	23.6	21.74	19.92
44 th	**44**	24.07	23.29	24.27	22.4	20.57
45 th	**45**	24.73	23.96	24.94	23.07	21.22
46 th	**46**	25.39	24.62	25.61	23.73	21.87
47 th	**47**	26.05	25.28	26.28	24.39	22.52
48 th	**48**	26.71	25.94	26.96	25.05	23.2
49 th	**49**	27.37	26.62	27.64	25.73	23.88
50 th	**50**	28.05	27.3	28.32	26.41	24.56
51 st	**51**	28.73	28	29	27.11	25.24
52 nd	**52**	29.41	28.7	29.68	27.81	25.92
53 rd	**53**	30.1	29.41	30.38	28.51	26.62
54 th	**54**	30.78	30.11	31.08	29.21	27.32
55 th	**55**	31.48	30.83	31.78	29.91	28.02
56 th	**56**	32.18	31.55	32.51	30.61	28.72
57 th	**57**	32.88	32.27	33.24	31.31	29.42
58 th	**58**	33.6	32.99	33.98	32.01	30.12
59 th	**59**	34.32	33.71	34.72	32.73	30.82
60 th	**60**	35.04	34.43	35.46	33.45	31.52
permeability percentage (%)		**58.40**	**57.38**	**59.10**	**55.75**	**52.53**

Result of Permeability for Adasia 0/12.5 and Sand 0/0.6 as Base course layer at rainfall intensity= 120 mm/h

Table (4.10): Cumulative outflow for all model at (RI=120 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
1 st	2	0.56	0.52	0.6	0.4	0.25
2 nd	4	0.9	0.84	0.95	0.65	0.4
3 rd	6	1.33	1.19	1.4	0.95	0.6
4 th	8	1.85	1.59	1.9	1.3	0.9
5 th	10	2.39	2.04	2.42	1.68	1.25
6 th	12	2.95	2.54	2.94	2.08	1.63
7 th	14	3.54	3.04	3.54	2.51	2.01
8 th	16	4.13	3.56	4.14	2.96	2.41
9 th	18	4.72	4.08	4.74	3.44	2.81
10 th	20	5.31	4.6	5.34	3.94	3.23
11 th	22	5.91	5.15	5.94	4.44	3.65
12 th	24	6.53	5.73	6.56	4.94	4.07
13 th	26	7.15	6.31	7.18	5.49	4.52
14 th	28	7.77	6.91	7.8	6.04	4.97
15 th	30	8.41	7.53	8.45	6.59	5.45
16 th	32	9.06	8.15	9.1	7.17	5.93
17 th	34	9.72	8.77	9.76	7.75	6.41
18 th	36	10.4	9.39	10.44	8.33	6.89
19 th	38	11.04	10.03	11.09	8.91	7.39
20 th	40	11.67	10.67	11.74	9.49	7.89
21 st	42	12.33	11.31	12.4	10.13	8.39
22 nd	44	12.97	11.96	13.05	10.77	8.94
23 rd	46	13.62	12.61	13.7	11.41	9.49
24 th	48	14.26	13.25	14.35	12.05	10.07
25 th	50	14.92	13.9	15.01	12.69	10.65
26 th	52	15.59	14.58	15.68	13.34	11.25
27 th	54	16.24	15.23	16.34	13.99	11.85
28 th	56	16.9	15.88	17	14.64	12.45
29 th	58	17.56	16.54	17.66	15.3	13.05
30 th	60	18.21	17.19	18.31	15.95	13.67
31 st	62	18.88	17.84	18.99	16.6	14.29
32 nd	64	19.54	18.49	19.67	17.25	14.94
33 rd	66	20.2	19.16	20.35	17.9	15.6
34 th	68	20.86	19.83	21.02	18.55	16.28
35 th	70	21.53	20.51	21.69	19.2	16.96
36 th	72	22.2	21.19	22.36	19.88	17.66
37 th	74	22.86	21.87	23.04	20.56	18.36
38 th	76	23.53	22.55	23.72	21.24	19.06
39 th	78	24.2	23.23	24.4	21.92	19.76
40 th	80	24.87	23.91	25.08	22.6	20.46
41 st	82	25.55	24.61	25.76	23.28	21.18
42 nd	84	26.23	25.33	26.44	23.96	21.88
43 rd	86	26.91	26.03	27.12	24.64	22.6
44 th	88	27.59	26.73	27.8	25.34	23.32

Cont. Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
45 th	90	28.26	27.43	28.5	26.04	24.04
46 th	92	28.94	28.13	29.2	26.74	24.76
47 th	94	29.62	28.81	29.88	27.44	25.5
48 th	96	30.32	29.51	30.58	28.14	26.23
49 th	98	31.02	30.21	31.28	28.84	26.96
50 th	100	31.72	30.93	32	29.56	27.7
51 st	102	32.46	31.66	32.75	30.28	28.44
52 nd	104	33.23	32.41	33.5	31	29.18
53 rd	106	33.99	33.16	34.25	31.73	29.92
54 th	108	34.73	33.91	35.02	32.46	30.66
55 th	110	35.48	34.66	35.79	33.21	31.4
56 th	112	36.25	35.41	36.56	33.96	32.14
57 th	114	37.03	36.16	37.33	34.71	32.88
58 th	116	37.8	36.91	38.1	35.46	33.62
59 th	118	38.59	37.67	38.9	36.21	34.36
60 th	120	39.37	38.43	39.7	36.98	35.1
permeability percentage (%)		**32.81**	**32.03**	**33.08**	**30.82**	**29.25**

Result of Permeability for Adasia 0/12.5 and Simsimia 0/9.5 as Base course layer at rainfall intensity=15 mm/h

Table (A.11): Cumulative outflow for all model at (RI=15 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
1 st	0.25	0	0	0	0	0
2 nd	0.50	0	0	0	0	0
3 rd	0.75	0.08	0	0.1	0	0
4 th	1.00	0.2	0.12	0.24	0.1	0
5 th	1.25	0.34	0.26	0.4	0.22	0.08
6 th	1.50	0.48	0.4	0.56	0.34	0.18
7 th	1.75	0.63	0.54	0.74	0.48	0.3
8 th	2.00	0.79	0.69	0.92	0.62	0.42
9 th	2.25	0.97	0.84	1.1	0.77	0.56
10 th	2.50	1.15	0.99	1.28	0.92	0.7
11 th	2.75	1.34	1.17	1.48	1.07	0.85
12 th	3.00	1.54	1.35	1.68	1.22	1
13 th	3.25	1.74	1.53	1.88	1.4	1.15
14 th	3.50	1.94	1.73	2.08	1.58	1.3
15 th	3.75	2.14	1.93	2.3	1.76	1.45
16 th	4.00	2.36	2.13	2.52	1.94	1.6
17 th	4.25	2.58	2.33	2.74	2.14	1.78
18 th	4.50	2.8	2.55	2.96	2.34	1.96
19 th	4.75	3.03	2.77	3.2	2.54	2.14
20 th	5.00	3.26	2.99	3.44	2.74	2.34
21 st	5.25	3.49	3.21	3.69	2.96	2.54
22 nd	5.50	3.73	3.43	3.94	3.18	2.74
23 rd	5.75	3.97	3.65	4.19	3.4	2.94
24 th	6.00	4.21	3.89	4.44	3.62	3.14
25 th	6.25	4.45	4.13	4.69	3.84	3.34
26 th	6.50	4.69	4.37	4.94	4.06	3.54
27 th	6.75	4.93	4.61	5.19	4.29	3.76
28 th	7.00	5.17	4.85	5.44	4.52	3.98
29 th	7.25	5.41	5.09	5.69	4.75	4.2
30 th	7.50	5.66	5.33	5.94	4.98	4.42
31 st	7.75	5.91	5.57	6.19	5.21	4.64
32 nd	8.00	6.16	5.81	6.44	5.44	4.87
33 rd	8.25	6.41	6.05	6.69	5.67	5.1
34 th	8.50	6.66	6.3	6.94	5.9	5.34
35 th	8.75	6.91	6.55	7.19	6.13	5.58
36 th	9.00	7.16	6.8	7.44	6.37	5.82
37 th	9.25	7.41	7.05	7.69	6.61	6.06
38 th	9.50	7.66	7.3	7.94	6.85	6.3
39 th	9.75	7.91	7.55	8.19	7.09	6.54
40 th	10.00	8.16	7.8	8.44	7.34	6.78
41 st	10.25	8.41	8.05	8.69	7.59	7.02
42 nd	10.50	8.66	8.3	8.94	7.84	7.26
43 rd	10.75	8.91	8.55	9.19	8.09	7.5
44 th	11.00	9.16	8.8	9.44	8.34	7.74
45 th	11.25	9.41	9.05	9.69	8.59	7.98
46 th	11.50	9.66	9.3	9.94	8.84	8.22

Cont. Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
47 th	**11.75**	9.91	9.55	10.19	9.09	8.47
48 th	**12.00**	10.16	9.8	10.44	9.34	8.72
49 th	**12.25**	10.41	10.05	10.69	9.59	8.97
50 th	**12.50**	10.66	10.3	10.94	9.84	9.22
51 st	**12.75**	10.91	10.55	11.19	10.09	9.47
52 nd	**13.00**	11.16	10.8	11.44	10.34	9.72
53 rd	**13.25**	11.41	11.05	11.69	10.59	9.97
54 th	**13.50**	11.66	11.3	11.94	10.84	10.22
55 th	**13.75**	11.91	11.55	12.19	11.09	10.47
56 th	**14.00**	12.16	11.8	12.44	11.34	10.72
57 th	**14.25**	12.41	12.05	12.69	11.59	10.97
58 th	**14.50**	12.66	12.3	12.94	11.84	11.22
59 th	**14.75**	12.91	12.55	13.19	12.09	11.47
60 th	**15.00**	13.16	12.8	13.44	12.34	11.72
permeability percentage (%)		**87.73**	**85.33**	**89.60**	**82.27**	**78.13**

Result of Permeability for Adasia 0/12.5 and Simsimia 0/9.5 as Base course layer at rainfall intensity=30 mm/h

Table (A.12): Cumulative outflow for all model at (RI=30 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
1 st	**0.5**	0.14	0.1	0.19	0	0
2 nd	**1.0**	0.28	0.2	0.38	0	0
3 rd	**1.5**	0.46	0.39	0.59	0.2	0.15
4 th	**2.0**	0.7	0.63	0.85	0.45	0.35
5 th	**2.5**	0.99	0.92	1.14	0.73	0.6
6 th	**3.0**	1.29	1.21	1.46	1.01	0.85
7 th	**3.5**	1.61	1.51	1.8	1.29	1.13
8 th	**4.0**	1.95	1.84	2.14	1.59	1.43
9 th	**4.5**	2.33	2.17	2.51	1.89	1.73
10 th	**5.0**	2.71	2.53	2.9	2.22	2.03
11 th	**5.5**	3.09	2.89	3.29	2.55	2.33
12 th	**6.0**	3.52	3.27	3.68	2.9	2.65
13 th	**6.5**	3.95	3.7	4.07	3.28	2.97
14 th	**7.0**	4.38	4.13	4.5	3.66	3.32
15 th	**7.5**	4.83	4.56	4.93	4.04	3.67
16 th	**8.0**	5.28	4.99	5.36	4.42	4.02
17 th	**8.5**	5.73	5.42	5.81	4.82	4.37
18 th	**9.0**	6.18	5.85	6.26	5.22	4.75
19 th	**9.5**	6.63	6.3	6.71	5.62	5.13
20 th	**10.0**	7.08	6.75	7.16	6.04	5.5
21 st	**10.5**	7.53	7.21	7.64	6.46	5.88
22 nd	**11.0**	7.98	7.66	8.12	6.88	6.26
23 rd	**11.5**	8.43	8.11	8.6	7.3	6.66
24 th	**12.0**	8.89	8.57	9.08	7.72	7.06
25 th	**12.5**	9.35	9.03	9.56	8.15	7.46

Cont. Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
26 th	**13.0**	9.82	9.5	10.03	8.6	7.86
27 th	**13.5**	10.28	9.96	10.49	9.05	8.26
28 th	**14.0**	10.74	10.42	10.97	9.5	8.66
29 th	**14.5**	11.2	10.88	11.45	9.95	9.08
30 th	**15.0**	11.65	11.33	11.93	10.41	9.5
31 st	**15.5**	12.11	11.79	12.41	10.87	9.92
32 nd	**16.0**	12.58	12.26	12.89	11.33	10.34
33 rd	**16.5**	13.04	12.72	13.36	11.79	10.76
34 th	**17.0**	13.51	13.19	13.83	12.26	11.21
35 th	**17.5**	13.99	13.66	14.31	12.73	11.66
36 th	**18.0**	14.45	14.12	14.77	13.2	12.11
37 th	**18.5**	14.91	14.58	15.23	13.67	12.56
38 th	**19.0**	15.38	15.05	15.7	14.14	13.01
39 th	**19.5**	15.86	15.52	16.17	14.61	13.46
40 th	**20.0**	16.34	15.98	16.64	15.08	13.91
41 st	**20.5**	16.82	16.44	17.11	15.55	14.36
42 nd	**21.0**	17.27	16.9	17.58	16.02	14.81
43 rd	**21.5**	17.73	17.36	18.06	16.49	15.27
44 th	**22.0**	18.2	17.83	18.54	16.96	15.73
45 th	**22.5**	18.66	18.29	19.02	17.43	16.19
46 th	**23.0**	19.12	18.76	19.5	17.9	16.65
47 th	**23.5**	19.58	19.24	19.98	18.37	17.12
48 th	**24.0**	20.05	19.71	20.46	18.83	17.58
49 th	**24.5**	20.52	20.17	20.92	19.3	18.03
50 th	**25.0**	20.99	20.64	21.39	19.76	18.49
51 st	**25.5**	21.46	21.11	21.86	20.23	18.95
52 nd	**26.0**	21.94	21.58	22.33	20.7	19.41
53 rd	**26.5**	22.42	22.06	22.81	21.16	19.87
54 th	**27.0**	22.9	22.53	23.28	21.63	20.33
55 th	**27.5**	23.38	23	23.75	22.1	20.8
56 th	**28.0**	23.86	23.47	24.22	22.57	21.27
57 th	**28.5**	24.34	23.94	24.69	23.04	21.74
58 th	**29.0**	24.84	24.41	25.17	23.51	22.21
59 th	**29.5**	25.34	24.88	25.65	23.98	22.68
60 th	**30.0**	25.84	25.35	26.13	24.45	23.15
permeability percentage (%)		**86.13**	**84.50**	**87.10**	**81.50**	**77.17**

Result of Permeability for Adasia 0/12.5 and Simsimia 0/9.5 as Base course layer at rainfall intensity=45 mm/h

Table (A.13): Cumulative outflow for all model at (RI=45 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
1 st	**0.75**	0.48	0.43	0.55	0.36	0.35
2 nd	**1.50**	0.76	0.68	0.85	0.56	0.55
3 rd	**2.25**	1.11	1.05	1.17	0.8	0.77
4 th	**3.00**	1.49	1.42	1.52	1.1	1.05
5 th	**3.75**	1.89	1.79	1.9	1.45	1.35
6 th	**4.50**	2.34	2.18	2.3	1.85	1.69
7 th	**5.25**	2.84	2.62	2.75	2.26	2.07
8 th	**6.00**	3.34	3.11	3.23	2.68	2.47
9 th	**6.75**	3.89	3.65	3.73	3.13	2.89
10 th	**7.50**	4.47	4.24	4.28	3.61	3.31
11 th	**8.25**	5.07	4.83	4.83	4.11	3.76
12 th	**9.00**	5.7	5.42	5.41	4.61	4.21
13 th	**9.75**	6.33	6.01	6.01	5.11	4.69
14 th	**10.5**	6.96	6.62	6.61	5.63	5.17
15 th	**11.25**	7.61	7.23	7.21	6.18	5.67
16 th	**12.00**	8.26	7.87	7.86	6.73	6.15
17 th	**12.75**	8.91	8.51	8.51	7.28	6.65
18 th	**13.50**	9.54	9.13	9.16	7.86	7.15
19 th	**14.25**	10.19	9.78	9.81	8.44	7.67
20 th	**15.00**	10.84	10.42	10.46	9.04	8.19
21 st	**15.75**	11.49	11.06	11.13	9.64	8.71
22 nd	**16.50**	12.14	11.7	11.79	10.24	9.23
23 rd	**17.25**	12.79	12.34	12.45	10.86	9.77
24 th	**18.00**	13.44	12.98	13.11	11.48	10.31
25 th	**18.75**	14.09	13.62	13.78	12.1	10.86
26 th	**19.50**	14.74	14.26	14.44	12.72	11.41
27 th	**20.25**	15.39	14.9	15.11	13.36	11.97
28 th	**21.00**	16.04	15.55	15.79	14	12.53
29 th	**21.75**	16.71	16.2	16.46	14.64	13.11
30 th	**22.50**	17.38	16.85	17.13	15.28	13.71
31 st	**23.25**	18.06	17.5	17.83	15.93	14.33
32 nd	**24.00**	18.75	18.18	18.53	16.58	14.95
33 rd	**24.75**	19.45	18.86	19.23	17.23	15.57
34 th	**25.50**	20.14	19.54	19.92	17.88	16.21
35 th	**26.25**	20.84	20.22	20.62	18.56	16.86
36 th	**27.00**	21.55	20.9	21.34	19.24	17.51
37 th	**27.75**	22.24	21.58	22.04	19.92	18.19
38 th	**28.50**	22.92	22.26	22.74	20.6	18.87
39 th	**29.25**	23.62	22.94	23.44	21.3	19.55
40 th	**30.00**	24.33	23.62	24.15	22	20.23
41 st	**30.75**	25.04	24.32	24.86	22.7	20.91
42 nd	**31.50**	25.75	25.02	25.57	23.4	21.59
43 rd	**32.25**	26.43	25.71	26.27	24.1	22.27
44 th	**33.00**	27.12	26.39	26.97	24.8	22.97

Cont. Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
45 th	**33.75**	27.82	27.08	27.67	25.5	23.67
46 th	**34.50**	28.51	27.77	28.36	26.2	24.37
47 th	**35.25**	29.21	28.46	29.06	26.9	25.07
48 th	**36.00**	29.92	29.16	29.78	27.6	25.77
49 th	**36.75**	30.62	29.86	30.5	28.3	26.47
50 th	**37.50**	31.31	30.56	31.22	29	27.17
51 st	**38.25**	32.01	31.26	31.94	29.7	27.87
52 nd	**39.00**	32.71	31.96	32.66	30.4	28.57
53 rd	**39.75**	33.41	32.66	33.38	31.1	29.27
54 th	**40.50**	34.12	33.36	34.09	31.8	29.96
55 th	**41.25**	34.82	34.06	34.81	32.5	30.66
56 th	**42.00**	35.52	34.77	35.53	33.21	31.37
57 th	**42.75**	36.24	35.48	36.25	33.92	32.08
58 th	**43.50**	36.96	36.19	36.99	34.63	32.79
59 th	**44.25**	37.68	36.9	37.73	35.34	33.5
60 th	**45.00**	38.41	37.61	38.48	36.05	34.21
permeability percentage (%)		**85.36**	**83.58**	**85.51**	**80.11**	**76.02**

Result of Permeability for Adasia 0/12.5 and Simsimia 0/9.5 as Base course layer at rainfall intensity= 60 mm/h

Table (A.14): Cumulative outflow for all model at (RI=60 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
1 st	**1**	0.76	0.75	0.8	0.5	0.43
2 nd	**2**	1.3	1.25	1.3	0.8	0.68
3 rd	**3**	1.85	1.8	1.9	1.15	1
4 th	**4**	2.42	2.35	2.5	1.53	1.35
5 th	**5**	3.01	2.9	3.1	1.93	1.73
6 th	**6**	3.67	3.5	3.75	2.38	2.11
7 th	**7**	4.35	4.15	4.43	2.88	2.51
8 th	**8**	5.03	4.8	5.13	3.43	2.94
9 th	**9**	5.74	5.5	5.85	4.03	3.39
10 th	**10**	6.46	6.2	6.57	4.65	3.87
11 th	**11**	7.21	6.92	7.32	5.27	4.37
12 th	**12**	7.95	7.66	8.07	5.92	4.89
13 th	**13**	8.68	8.4	8.82	6.62	5.44
14 th	**14**	9.43	9.15	9.57	7.32	6.02
15 th	**15**	10.17	9.89	10.32	8.02	6.62
16 th	**16**	10.93	10.64	11.09	8.74	7.25
17 th	**17**	11.7	11.39	11.86	9.46	7.9
18 th	**18**	12.46	12.14	12.64	10.18	8.55
19 th	**19**	13.21	12.89	13.41	10.9	9.2
20 th	**20**	13.96	13.64	14.18	11.62	9.85
21 st	**21**	14.71	14.39	14.95	12.34	10.53
22 nd	**22**	15.47	15.15	15.72	13.06	11.21

Cont. Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
23 rd	23	16.23	15.91	16.49	13.8	11.89
24 th	24	16.99	16.67	17.26	14.54	12.59
25 th	25	17.74	17.42	18.03	15.28	13.29
26 th	26	18.49	18.17	18.83	16.02	13.98
27 th	27	19.24	18.92	19.63	16.76	14.68
28 th	28	20	19.67	20.43	17.51	15.38
29 th	29	20.77	20.44	21.23	18.26	16.1
30 th	30	21.54	21.21	22.03	19.01	16.82
31 st	31	22.33	21.98	22.82	19.78	17.54
32 nd	32	23.12	22.77	23.62	20.55	18.29
33 rd	33	23.91	23.56	24.42	21.32	19.04
34 th	34	24.71	24.36	25.22	22.12	19.79
35 th	35	25.51	25.16	26.02	22.92	20.54
36 th	36	26.31	25.96	26.82	23.72	21.32
37 th	37	27.11	26.76	27.62	24.52	22.1
38 th	38	27.93	27.58	28.44	25.32	22.88
39 th	39	28.75	28.4	29.26	26.12	23.66
40 th	40	29.57	29.22	30.08	26.92	24.45
41 st	41	30.39	30.04	30.9	27.72	25.24
42 nd	42	31.21	30.86	31.72	28.54	26.04
43 rd	43	32.03	31.68	32.54	29.36	26.84
44 th	44	32.85	32.5	33.36	30.18	27.64
45 th	45	33.67	33.32	34.18	31	28.44
46 th	46	34.49	34.14	35	31.82	29.24
47 th	47	35.32	34.96	35.83	32.64	30.04
48 th	48	36.16	35.78	36.67	33.46	30.86
49 th	49	37	36.6	37.51	34.28	31.68
50 th	50	37.84	37.44	38.35	35.1	32.5
51 st	51	38.68	38.28	39.19	35.92	33.32
52 nd	52	39.52	39.12	40.04	36.76	34.14
53 rd	53	40.36	39.96	40.89	37.6	34.96
54 th	54	41.2	40.8	41.74	38.44	35.78
55 th	55	42.04	41.64	42.59	39.28	36.6
56 th	56	42.88	42.48	43.44	40.12	37.44
57 th	57	43.73	43.33	44.3	40.96	38.28
58 th	58	44.58	44.18	45.16	41.8	39.12
59 th	59	45.43	45.03	46.03	42.64	39.96
60 th	60	46.28	45.88	46.91	43.49	40.8
permeability percentage (%)		**77.13**	**76.47**	**78.18**	**72.48**	**68.00**

Result of Permeability for Adasia 0/12.5 and Simsimia 0/9.5 as Base course layer at rainfall intensity= 120 mm/h

Table (A.15): Cumulative outflow for all model at (RI=120 mm/h)

Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
1 st	2	2	1.8	2.2	1.5	1.35
2 nd	4	3.2	2.8	3.5	2.4	2.15
3 rd	6	4.45	4	4.8	3.4	3.05
4 th	8	5.75	5.3	6.15	4.6	4.05
5 th	10	7.07	6.6	7.55	5.85	5.25
6 th	12	8.41	7.95	8.95	7.15	6.5
7 th	14	9.79	9.3	10.35	8.47	7.77
8 th	16	11.17	10.67	11.75	9.81	9.07
9 th	18	12.56	12.06	13.17	11.15	10.37
10 th	20	13.96	13.46	14.57	12.5	11.67
11 th	22	15.34	14.86	15.98	13.85	12.97
12 th	24	16.74	16.26	17.38	15.2	14.28
13 th	26	18.14	17.66	18.8	16.55	15.59
14 th	28	19.54	19.06	20.22	17.93	16.9
15 th	30	20.96	20.48	21.64	19.31	18.22
16 th	32	22.39	21.93	23.08	20.69	19.54
17 th	34	23.83	23.37	24.52	22.09	20.86
18 th	36	25.29	24.83	25.97	23.49	22.17
19 th	38	26.71	26.25	27.42	24.89	23.49
20 th	40	28.12	27.69	28.86	26.29	24.81
21 st	42	29.56	29.13	30.3	27.69	26.13
22 nd	44	30.98	30.57	31.75	29.09	27.45
23 rd	46	32.41	32.02	33.2	30.49	28.77
24 th	48	33.83	33.47	34.67	31.91	30.09
25 th	50	35.27	34.91	36.14	33.33	31.41
26 th	52	36.72	36.36	37.59	34.75	32.74
27 th	54	38.15	37.8	39.06	36.17	34.07
28 th	56	39.59	39.24	40.55	37.59	35.41
29 th	58	41.03	40.68	42.05	39.01	36.76
30 th	60	42.46	42.13	43.55	40.41	38.11
31 st	62	43.91	43.58	45.05	41.81	39.46
32 nd	64	45.35	45.03	46.55	43.23	40.81
33 rd	66	46.79	46.48	48.05	44.65	42.16
34 th	68	48.23	47.93	49.55	46.07	43.51
35 th	70	49.68	49.38	51.05	47.49	44.86
36 th	72	51.13	50.83	52.55	48.91	46.21
37 th	74	52.57	52.27	54.05	50.33	47.57
38 th	76	54.02	53.72	55.55	51.77	48.93
39 th	78	55.47	55.17	57.05	53.21	50.29
40 th	80	56.92	56.62	58.53	54.65	51.67
41 st	82	58.37	58.07	60.03	56.07	53.05
42 nd	84	59.82	59.52	61.53	57.49	54.43
43 rd	86	61.28	60.98	63.03	58.93	55.81
44 th	88	62.74	62.44	64.53	60.37	57.19

Cont. Time (min)	Inflow (L)	Cumulative outflow (L)				
		Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
45 th	**90**	64.21	63.91	66.03	61.81	58.57
46 th	**92**	65.69	65.39	67.51	63.25	59.95
47 th	**94**	67.19	66.89	69.01	64.69	61.33
48 th	**96**	68.7	68.39	70.52	66.14	62.71
49 th	**98**	70.2	69.89	72.02	67.59	64.11
50 th	**100**	71.72	71.41	73.6	69.04	65.51
51 st	**102**	73.23	72.92	75.2	70.49	66.91
52 nd	**104**	74.75	74.44	76.8	71.94	68.31
53 rd	**106**	76.3	75.99	78.4	73.42	69.71
54 th	**108**	77.9	77.59	80	74.9	71.11
55 th	**110**	79.52	79.21	81.62	76.4	72.53
56 th	**112**	81.14	80.83	83.24	77.9	73.95
57 th	**114**	82.78	82.47	84.88	79.4	75.37
58 th	**116**	84.42	84.11	86.52	80.9	76.79
59 th	**118**	86.07	85.76	88.18	82.4	78.21
60 th	**120**	87.72	87.41	89.84	83.9	79.63
permeability percentage (%)		**73.10**	**72.84**	**74.87**	**69.92**	**66.36**

Appendix (B)
Aggregate Tests

Sieve analysis Adasia (0/12.5)

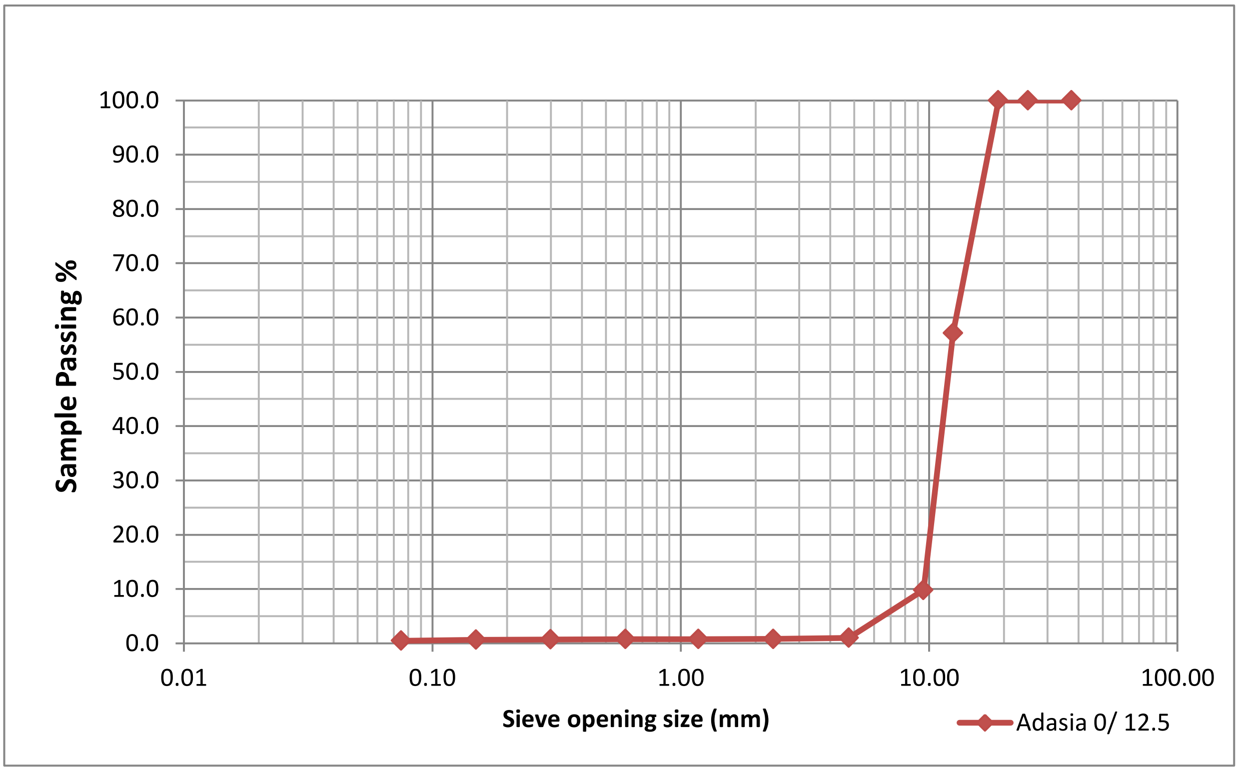
Adasia

حصمة عدسية

0/12.5

وزن العينة جافة قبل التنخيل 1390.5 جم

Sieve No.	Sieve Opening Size (mm)	Weight Retained (gm)	% Retained	Commulative % Retained	% Passing	Specifications		Notes
						Min	Max	
1 1/2"	37.50	0.0	0.0	0.0	100.0			
1"	25.00	0.0	0.0	0.0	100.0			
3/4"	19.00	0.0	0.0	0.0	100.0			
1/2"	12.50	595.5	42.8	42.8	57.2			
3/8"	9.50	658.5	47.4	90.2	9.8			
#4	4.75	122.5	8.8	99.0	1.0			
#8	2.36	3.0	0.2	99.2	0.8			
# 16	1.18	0.5	0.0	99.2	0.8			
# 30	0.60	0.0	0.0	99.2	0.8			
#50	0.30	0.5	0.0	99.3	0.7			
# 100	0.15	1.0	0.1	99.4	0.6			
# 200	0.08	2.5	0.2	99.5	0.5			
pan	0.00	6.5	0.5	100.0	0.0			
		1390.5						



Sieve analysis Simsimia (0/12.5)

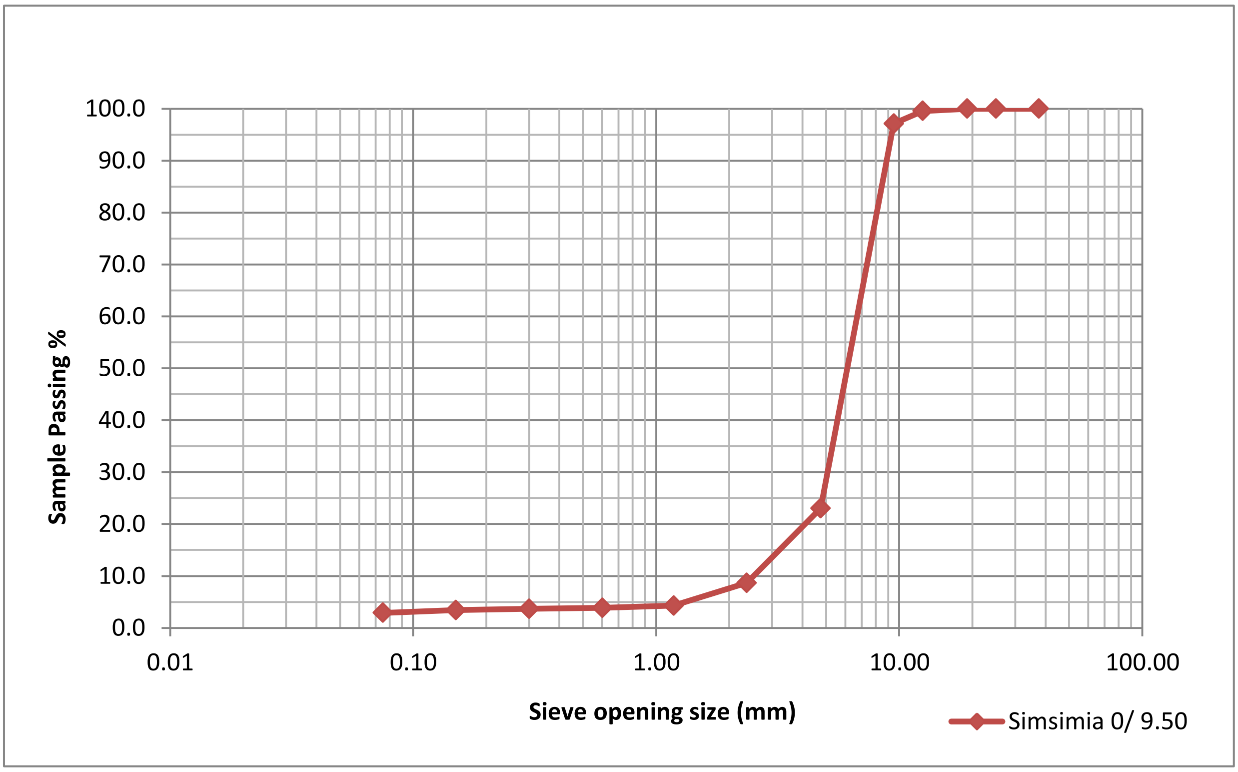
Simsimia

حصمة سمسمية

0/ 9.50

وزن العينة جافة قبل التنخيل 1503.5 جم

Sieve No.	Sieve Opening Size (mm)	Weight Retained (gm)	% Retained	Commulative % Retained	% Passing	Specifications		Notes
						Min	Max	
1 1/2"	37.50	0.0	0.0	0.0	100.0			
1"	25.00	0.0	0.0	0.0	100.0			
3/4"	19.00	0.0	0.0	0.0	100.0			
1/2"	12.50	6.5	0.4	0.4	99.6			
3/8"	9.50	36.5	2.4	2.9	97.1			
#4	4.75	1114.0	74.1	77.0	23.0			
#8	2.36	216.5	14.4	91.4	8.6			
# 16	1.18	65.5	4.4	95.7	4.3			
# 30	0.60	6.5	0.4	96.1	3.9			
#50	0.30	3.0	0.2	96.3	3.7			
# 100	0.15	3.5	0.2	96.6	3.4			
# 200	0.08	8.0	0.5	97.1	2.9			
pan	0.00	43.5	2.9	100.0	0.0			
		1503.5						



Sieve analysis Between joints (0/2.36)

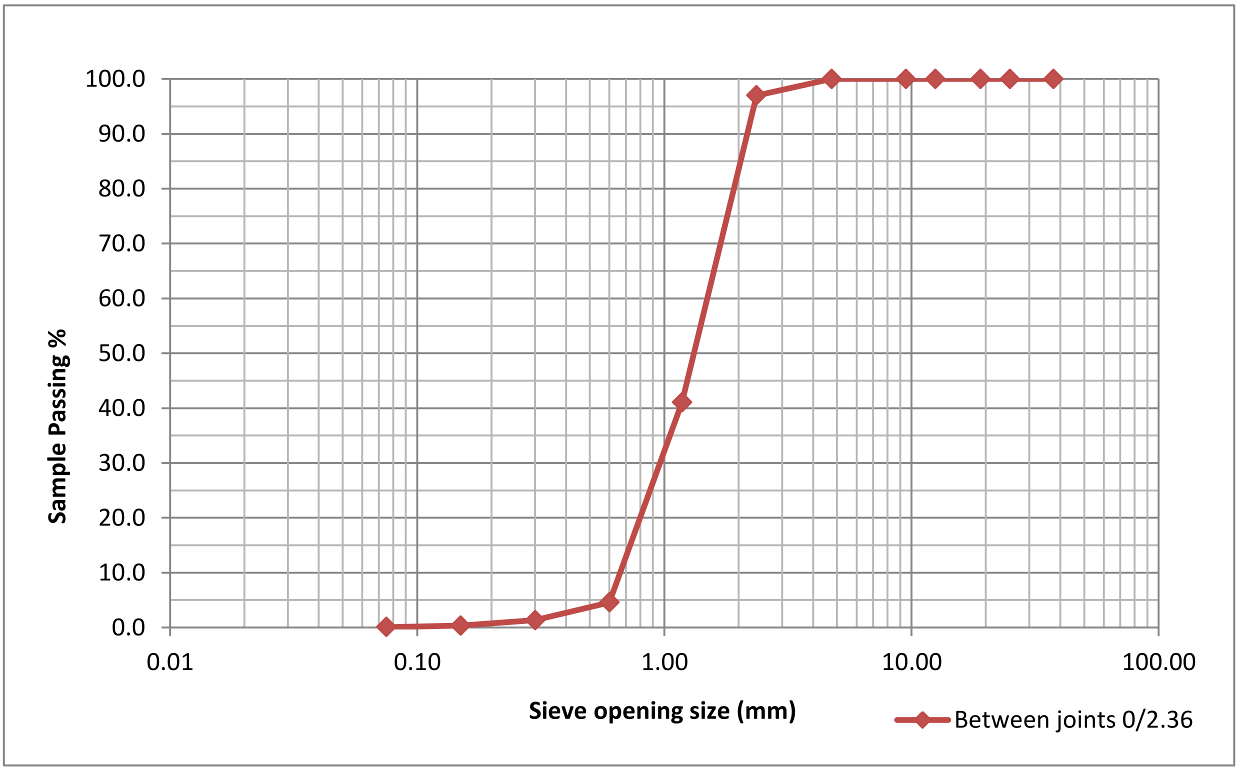
Between joints

0/2.36

حصمة الفلاتر

وزن العينة جافة قبل التنخيل 602 جم

Sieve No.	Sieve Opening Size (mm)	Weight Retained (gm)	% Retained	Commulative % Retained	% Passing	Specifications		Notes
						Min	Max	
1 1/2"	37.50	0.0	0.0	0.0	100.0			
1"	25.00	0.0	0.0	0.0	100.0			
3/4"	19.00	0.0	0.0	0.0	100.0			
1/2"	12.50	0.0	0.0	0.0	100.0			
3/8"	9.50	0.0	0.0	0.0	100.0			
#4	4.75	0.0	0.0	0.0	100.0			
#8	2.36	18.0	3.0	3.0	97.0			
# 16	1.18	337.0	56.0	59.0	41.0			
# 30	0.60	219.5	36.5	95.4	4.6			
#50	0.30	19.5	3.2	98.7	1.3			
# 100	0.15	6.0	1.0	99.7	0.3			
# 200	0.08	1.5	0.2	99.9	0.1			
pan	0.00	0.0	0.0	99.9	0.0			
		601.5						



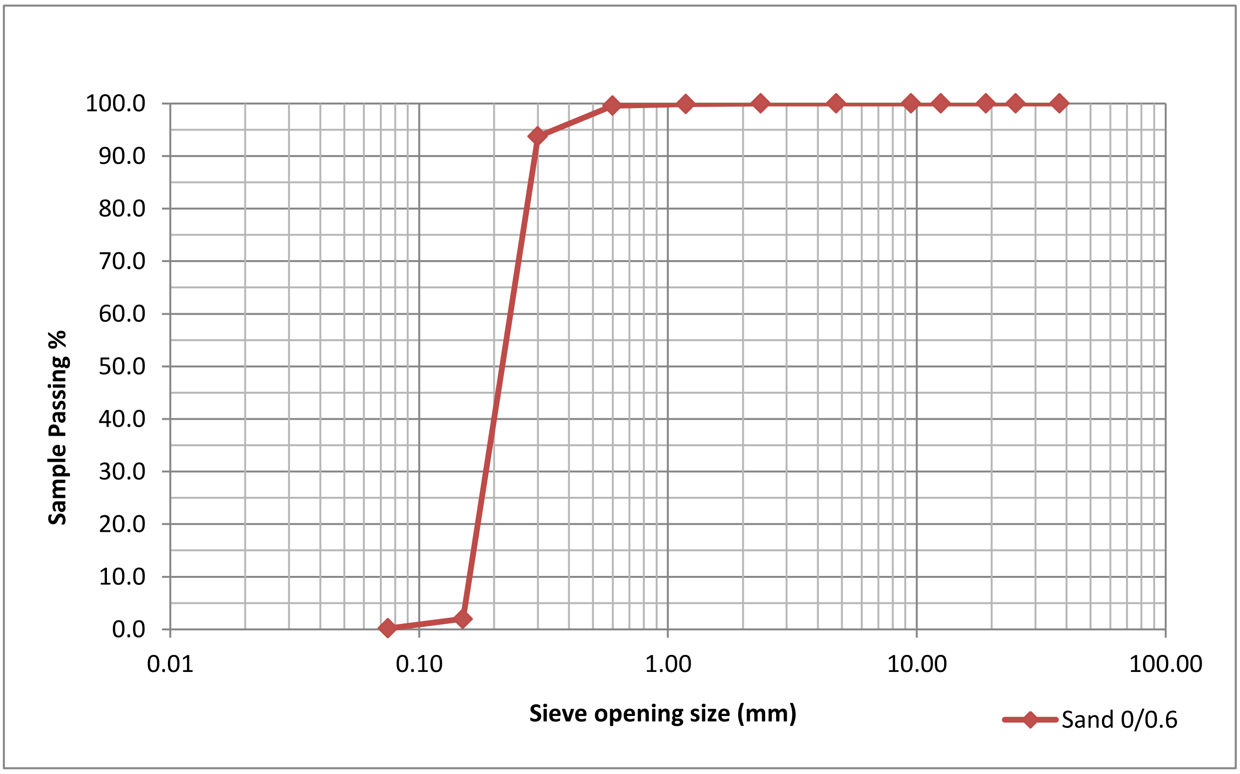
Sieve analysis for natural sand (0/0.6)

Sand **رمل 0.6**

0/0.6

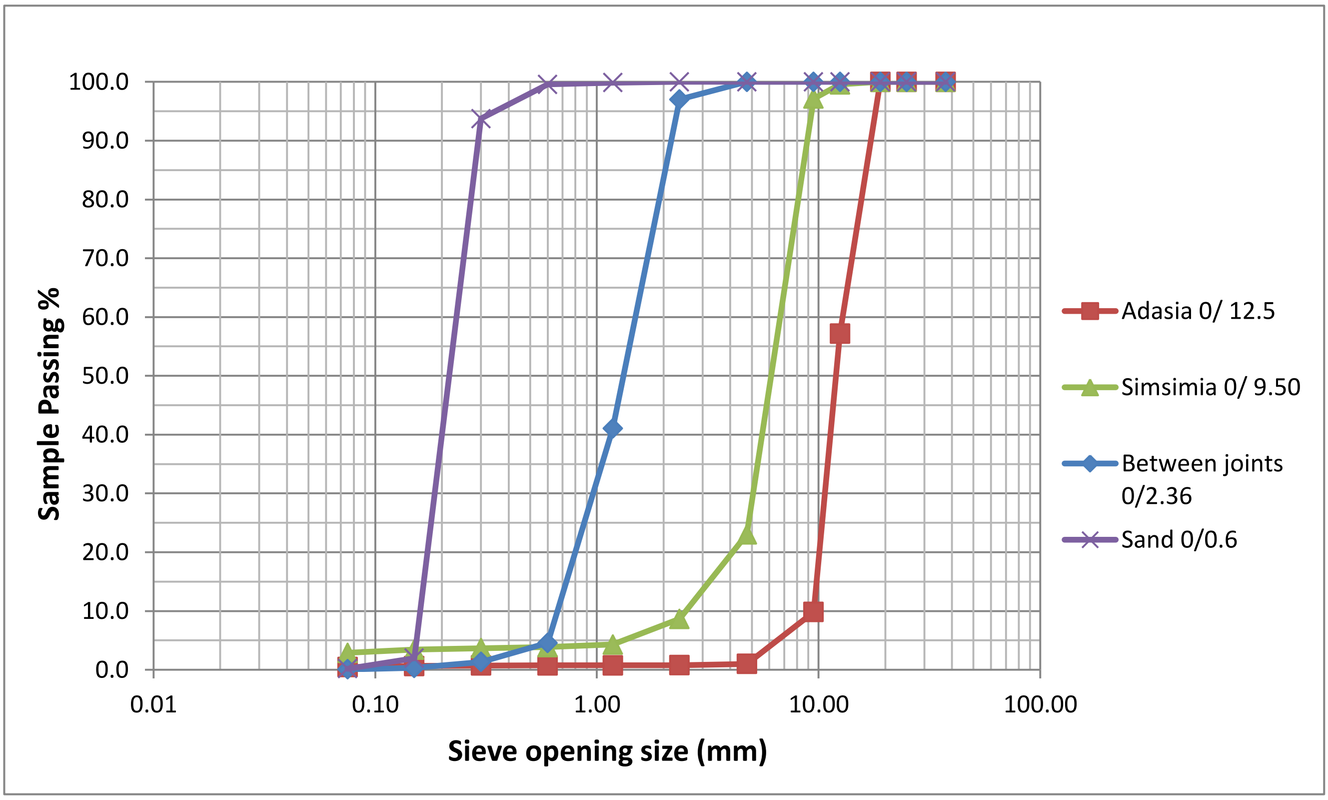
وزن العينة جافة قبل التنخيل 831 جم

Sieve No.	Sieve Opening Size (mm)	Weight Retained (gm)	% Retained	Commulative % Retained	% Passing	Specifications		Notes
						Min	Max	
1 1/2"	37.50	0.0	0.0	0.0	100.0			
1"	25.00	0.0	0.0	0.0	100.0			
3/4"	19.00	0.0	0.0	0.0	100.0			
1/2"	12.50	0.0	0.0	0.0	100.0			
3/8"	9.50	0.0	0.0	0.0	100.0			
#4	4.75	0.0	0.0	0.0	100.0			
#8	2.36	0.0	0.0	0.0	100.0			
# 16	1.18	1.0	0.1	0.1	99.9			
# 30	0.60	2.5	0.3	0.4	99.6			
#50	0.30	48.5	5.8	6.3	93.7			
# 100	0.15	762.5	91.8	98.0	2.0			
# 200	0.08	15.0	1.8	99.8	0.2			
pan	0.00	1.0	0.1	99.9	0.0			
		830.5						



Sieve analysis for all Aggregate

Sieve Opening Size (mm)	Sieve No. #	Sample Passing %			
		Adasia *0/ 12.5*	*Simsimia* *0/ 9.50*	*Between joints* *0/2.36*	*Sand* *0/0.6*
19	**3/4"**	100	100	100	100
12.5	**1/2"**	57.2	99.6	100	100
9.5	**3/8"**	9.8	97.1	100	100
4.75	**# 4**	1	23	100	100
2.36	**# 8**	0.8	8.6	97	100
1.18	**# 16**	0.8	4.3	41	99.9
0.6	**# 30**	0.8	3.9	4.6	99.6
0.3	**# 50**	0.7	3.7	1.3	93.7
0.15	**# 100**	0.6	3.4	0.3	2
0.075	**# 200**	0.5	2.9	0.1	0.2
pan		0.0	0.0	0.0	0.0



بسم الله الرحمن الرحيم

Association of Engineers - Gaza Governorates
Palestine
Materials Testing Laboratory

نقابة المهندسين - محافظات غزة
فلسطين
مختبر فحص المواد

فحوصات الركام

الكثافة النوعية			
	فولية	عدسية	سمسمية
وزن العينة مشبعة جافة السطح جم		556.0	226.0
وزن العينة في الماء جم		345	142.5
الحجم جم		211.0	83.5
الكثافة النوعية		2.635	2.707

فحص الامتصاص			
	فولية	عدسية	سمسمية
وزن العينة مشبعة جافة السطح جم		556	226
وزن العينة جافة جم		547	222
الامتصاص %		1.6	1.8

المدير الفني

مدير المختبر

Main Branch \ Gaza - Edrag - El Quse St.
Telefax: (+972) 8 2825065 ,Tel.: 2880085, Mobile: (+972) 599 247098
Rafah Branch \ Rafah-Othman ben Afan St.
Telefax : (+972) 8 2130035 , Mobile : (+972) 599 890883

المقر الرئيسي / غزة - الدرج - شارع القوس - مقابل مدرسة فهمي الجرجاوي
تليفاكس: ٢٨٢٥٠٦٥ ٨ (٩٧٢+)، تليفون: ٢٨٨٠٠٨٥، جوال: ٢٤٧٠٩٨ ٥٩٩(٩٧٢+)
فرع رفح / رفح - شارع عثمان بن عفان - عمارة زعرب
تليفاكس : ٢١٣٠٠٣٥ ٨ (٩٧٢+)، جوال : ٨٩٠٨٨٣ ٥٩٩(٩٧٢+)

98600

Appendix (C)
Interlock Tile Tests

بسم الله الرحمن الرحيم

Association of Engineers – Gaza Governorates
Palestine
Materials Testing Laboratory

نقابة المهندسين - محافظات غزة
فلسطين
مختبر فحص المواد

اختبار ضغط طوب الرصف الخرساني

Precast Concrete Paving Blocks- Compression Test

Client		طالب الفحص
Project		المشروع
Element	بلاط انترلوك 8 سم	العنصر
		أخذت العينة بمعرفة
Source		المصدر
Production I	04/01/2014	تاريخ الانتاج
Testing Date	01/02/2014	تاريخ الفحص
Age at Test	28يوم	عمر العينة عند الفحص
Sample Nun		رقم العينة

Test Results — النتائج

ملاحظات	الاجهاد kg/cm²	الكثافة g/cm³	الوزن g	الأبعاد الارتفاع(سم)	الأبعاد مساحة المقطع (سم²)	رقم النموذج
	682.3	2.320	5104.0	8.0	275.0	1
	657.9	2.341	5086.0	7.9	275.0	2
	566.4	2.343	5026.0	7.8	275.0	3
	600.1	2.284	5024.0	8.0	275.0	4

Average	627	Kg/cm²
Standard Deviation	52.9	Kg/cm²
Variation	18.5	%

ملاحظات:

* هذه النتائج تمثل العينات المفحوصة فقط
* لا يجوز اعادة اصدار هذا التقرير الا بموافقة خطية من المختبر
* تم الفحص حسب المواصفة BS 6717: Part 1:1993

مدير المختبر
Laboratory Manager

المدير الفني
Technical Manager

Main Branch \ Gaza - Edrag - El Quse St.
Telefax: (+972) 8 2825065 ,Tel.: 2880085, Mobile: (+972) 599 247098
Rafah Branch \ Rafah-Othman ben Afan St.
Telefax : (+972) 8 2130035 , Mobile : (+972) 599 890883

المقر الرئيسي / غزة - الدرج - شارع القوس - مقابل مدرسة فهمي الجرجاوي
تليفاكس: ٢٨٢٥٠٦٥ ٨ (٩٧٢+)، تليفون: ٢٨٨٠٠٨٥، جوال: ٢٤٧٠٩٨ ٥٩٩ (٩٧٢+)
فرع رفح / رفح - شارع عثمان بن عفان - عمارة زعرب
تليفاكس : ٢١٣٠٠٣٥ ٨ (٩٧٢+) ، جوال : ٨٩٠٨٨٣ ٥٩٩ (٩٧٢+)

100083--1/1

بسم الله الرحمن الرحيم

Association of Engineers - Gaza Governorates
Palestine
Materials Testing Laboratory

نقابة المهندسين - محافظات غزة
فلسطين
مختبر فحص المواد

فحص مقاومة التآكل(البري) للبلاط

Abrasion Resistence Test of Tiles

Client	0	طالب الفحص
Project	0	المشروع
Element	بلاط انترلوك 8 سم	العنصر
Source	0	المصدر
Production I	04/01/2014	تاريخ الانتاج
Testing Date	01/02/2014	تاريخ الفحص
Age at Test	28يوم	عمر العينة عند الفحص
Sample Nun	0	رقم العينة

Test Results **النتائج**

Required By Standard	Average		4	3	2	1	ITEM
ادنى للعينة 4 ملم	8.00		7	8	8	9	Thickness of wearing layer (mm)
أقصى للمعدل 5، أقصى للنموذج 7	2.83		2.90	3.00	2.30	3.10	Abrasion Resistance (mm)

ملاحظات:

* هذه النتائج تمثل العينات المفحوصة فقط
* لا يجوز اعادة اصدار هذا التقرير الا بموافقة خطية من المختبر
* تم الفحص حسب المواصفة م.ف 72: 1997

مدير المختبر
Laboratory Manager

المدير الفني
Technical Manager

Main Branch \ Gaza - Edrag - El Quse St.
Telefax: (+972) 8 2825065 ,Tel.: 2880085, Mobile: (+972) 599 247098
Rafah Branch \ Rafah-Othman ben Afan St.
Telefax : (+972) 8 2130035 , Mobile : (+972) 599 890883

المقر الرئيسي / غزة - الدرج - شارع القوس - مقابل مدرسة فهمي الجرجاوي
تليفاكس: ٢٨٢٥٠٦٥ ٨ (+٩٧٢)، تليفون: ٢٨٨٠٠٨٥، جوال: ٢٤٧٠٩٨ ٥٩٩(+٩٧٢)
فرع رفح / رفح - شارع عثمان بن عفان - عمارة زعرب
تليفاكس : ٢١٣٠٠٣٥ ٨ (+٩٧٢) ، جوال : ٨٩٠٨٨٣ ٥٩٩(+٩٧٢)

100083--1/1

بسم الله الرحمن الرحيم

Association of Engineers - Gaza Governorates
Palestine
Materials Testing Laboratory

نقابة المهندسين - محافظات غزة
فلسطين
مختبر فحص المواد

اختبار امتصاص

Absorption Test

Client	0	طالب الفحص
Project	0	المشروع
Element	بلاط انترلوك 8 سم	العنصر
Source	0	المصدر
Production I	04/01/2014	تاريخ الانتاج
Testing Date	01/02/2014	تاريخ الفحص
Age at Test	28يوم	عمر العينة عند الفحص
Sample num		رقم العينة

Test Results — **النتائج**

ملاحظات	الامتصاص %	الوزن الرطب g	الوزن الجاف g	الأبعاد الارتفاع(سم)	مساحة المقطع ($سم^2$)	رقم النموذج
	1.9	4999.0	4906.0	8.0	275.0	5
	1.8	5298.0	5204.0	8.1	275.0	6
	2.2	5206.0	5094.0	8.1	275.0	7
	2.8	5066.0	4928.0	7.8	275.0	8

Average Absorption 2.2 %

ملاحظات:

* هذه النتائج تمثل العينات المفحوصة فقط
* لا يجوز اعادة اصدار هذا التقرير الا بموافقة خطية من المختبر
* تم الفحص حسب المواصفة BS 1881: Part 122:1983

مدير المختبر
Laboratory Manager

المدير الفنـي
Technical Manager

Main Branch \ Gaza - Edrag - El Quse St.
Telefax: (+972) 8 2825065 ,Tel.: 2880085, Mobile: (+972) 599 247098
Rafah Branch \ Rafah-Othman ben Afan St.
Telefax : (+972) 8 2130035 , Mobile : (+972) 599 890883

المقر الرئيسي / غزة - الدرج - شارع القوس - مقابل مدرسة فهمي الجرجاوي
تليفاكس: ٠٨ ٢٨٢٥٠٦٥ (+٩٧٢) ،تليفون: ٢٨٨٠٠٨٥، جوال: ٢٤٧٠٩٨ ٥٩٩(+٩٧٢)
فرع رفح / رفح - شارع عثمان بن عفان - عمارة زعرب
تليفاكس : ٠٨ ٢١٣٠٠٣٥ (+٩٧٢) ، جوال : ٨٩٠٨٨٣ ٥٩٩(+٩٧٢)

100083--1/1

Appendix (D)
Photos Show the Method of the Work

Figure (D.1): *Construction of experimental steel box*

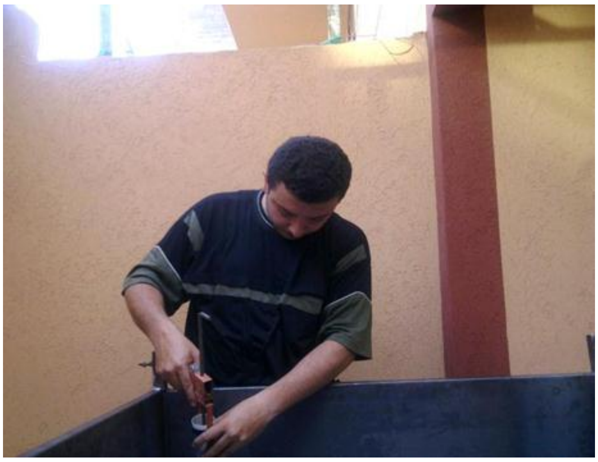


Figure (D.2): *Preparation of experimental steel box*

Figure (D.3): *Good closing to prevent leakage of the water*

Figure (D.4): *Experimental steel box with rainfall simulator*

Figure (D.5): *Experimental steel box before materials*

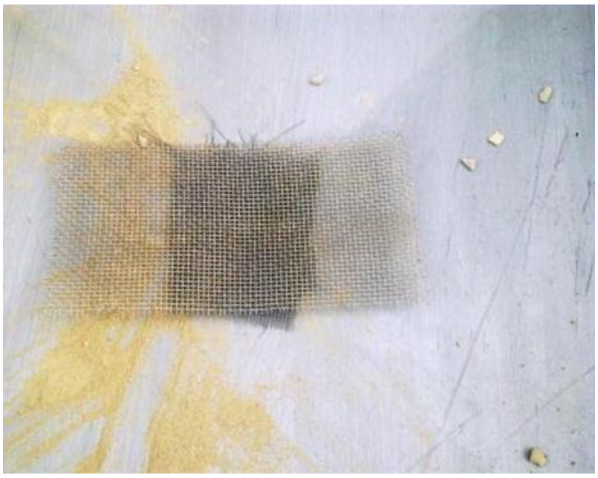


Figure (D.6): *Partial closing to prevent the entry of sand*

Figure (D.7): *Interlock tiles sitting on top of bedding layer*

Figure (D.8): *Aggregates preparing as base course material*

Figure (D.9): *Used Aggregates*

Figure (D.10): *Filling material between joints*

Figure (D.11): *Sieve analysis test*

Figure (D.12): *Weighting samples*

Figure (D.12): *Recording the results of Sieve analysis*

Figure (D.13): *Joints between interlock tiles*

Figure (D.14): *Calibration for nozzles to get uniform intensity of water*

Figure (D.15): *Water permeability at the surface of pavement*

Figure (D.16): *Measuring infiltrated water from pavement*