

Effect of the Type and Shape of Local Aggregate on the Hydraulic Property's Pervious Concrete Pavement

¹*Sabah Hamandoush, ²Fatima Alsaleh, ³Marwan Assi

¹Engineer, Department of Transportation's Engineering, Faculty of Civil Engineering, Aleppo University, Syrian Arab Republic

^{2,3}Professor, Department of Transportation's Engineering, Faculty of Civil Engineering, Aleppo University, Syrian Arab Republic

*Corresponding Author E-mail: sabahhm801@gmail.com

Abstract - Pervious concrete is considered as one of the sustainable solutions that has rapidly spread globally to urban areas, which encouraged engineers and researchers in the field of construction materials to adopt modern techniques to produce concrete mixtures according to the accepted standards for pavement design. The research aims to study the hydrological properties of the pervious concrete with different type and shape of local aggregate such as limestone, recycled, local metamorphic, natural river aggregate which available in Hasia city. This research was carried out through experimental study, by conducting the necessary tests on this aggregate to determine their suitability for use in the pervious concrete paving. The study concluded that, water permeability and porosity of the pervious concrete samples containing recycled and Limestone aggregate is higher than the rest of the types of aggregate while the use of river and local metamorphic aggregate may have porosity and permeability less.

Keywords: Pervious Concrete, Recycled Aggregate, River Aggregate, Metamorphic Aggregate.

I. INTRODUCTION

Concrete is one of the most common building materials in the world and can be easily mixed and poured to meet a variety of needs; it is used in paving operations for airstrips, some roads, and squares. But one of the disadvantages of paving with traditional concrete is that the break because of freeze and increases the flow of surface water and sometimes floods, in addition to the difficulty of exchanging heat and moisture between soil and air. So, pervious concrete paving was used consisting of cement, water, have Additives, coarse aggregate and little or no fine aggregate [1,2,4]. Cement content in the pervious concrete mixture's ranges from $(2.8 - 3) KN/m^3$ [7,16]. But in another research, cement content ranges $(2.7 \rightarrow 4.15) KN/m^3$ and aggregate content $(1190 \rightarrow 1480) kg/m^3$ and water-to-cement ratio $(0.27 \rightarrow 0.34) \%$ [2]. But the optimality water-to-cement ratio is 0.32 [4] and, in another research, $\left(\frac{w}{c}\right)$ was 0.36 [5,13]. Water Permeability for pervious concrete is calculated either by the

falling head permeability test [4,6,12,15] or by constant head method [9,10]. Pervious concrete permeability accepted ranges from $(1 \rightarrow 15) mm/sec$ [9], and in another research was $(81 \rightarrow 730) L/min/m^2$ [10,13], in addition to, researchers (Ali and Kareem, 2014) found that the water Permeability for pervious concrete usually ranges $(0.14 \rightarrow 1.2) cm/sec$, in addition to, pervious concrete paving can use in parking lots, low-load paving, corridors, glass house floors for plants, gardens, and many other uses [3,4,12]. It also contains a high percentage of voids ranging from 15% to 35% and pores of large dimensions are usually between $(2 \rightarrow 8) mm$ [1,2,5,10,13]. In other research, content of voids in the pervious concrete usually ranges from $(15 \rightarrow 30) \%$ [9]. Pervious concrete paving is characterized by reduced runoff, increased infiltration of rainwater into the soil and transport of water and air to tree roots[1,2], it is also an environmentally friendly paving material [2,3,8,9].

Many researchers conducted a generally experimental study on the hydraulic properties of pervious concrete[3,4,5,15], while other researchers have studied the impact of the size and type of aggregate on the hydraulic properties of the pervious concrete [7,8,9,10,13], as well as water Permeability for pervious concrete is influenced by the size of aggregate more than its type [9]. And other researchers have studied the impact of recycled aggregate on hydraulic properties [6,11,12,13], porosity is not significantly affected by use recycled aggregate [6], Additionally, a group of researchers (Wagih et al. 2013) proved that the optimal ratio for replacing natural aggregate with recycled aggregate ranges from $(25 \rightarrow 50)\%$ whereas strength for recycled aggregate is less than the natural aggregate about $(10 \rightarrow 20) MPa$ and its pores are higher, and it's also the falling occurs in the aggregate when recycled aggregate are used [11], in addition to, other researchers have studied the effect of silica fume on its properties also [3,13,14], the optimal ratio for replacing cement with silica fume to increase the strength of the pervious concrete ranges from $(15 \rightarrow 20)\%$ and when the percentage of silica fume increases from the optimal ratio, the viscosity of the mixture increases, the voids content increases and strength and durability decrease [14], and other researchers have studied the effect of partly replacing Portland

cement with fly ash[5,6,10], to reduce (CO₂) emissions from Portland cement, and replacing 30% of cement with fly ash increases compressive strength about 12.5%,but it doesn't affect Permeability very much[5], some of them have studied the impact of changing the ratio of water to cement on the properties of the pervious concrete [4,5,9,12], whereas the ratio of water to cement does not affect much on the properties of pervious concrete [9], but as (w/c) increases, the voids content increases, the permeability increases for pervious concrete [12].Compressive strength for the pervious concrete generally is low because of its high pores [3,5,6,7,8,9]. It is preferable to cover the pervious concrete samples with a plastic cover at the casting to maintain on moisture [3,13].

The components of the materials used in pervious concrete mixtures were compared to some reference studies mentioned in this paper as shown in Table 1, the hydraulic properties of the pervious concrete mixtures of this research and the mixtures shown in Table 1 respectively were also compared as shown in Table 2.

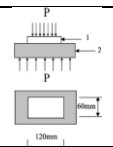


Table 1: Components of the materials used

Reference Number	aggregate Type	Size of coarse aggregate (mm)	Fine aggregate content (kg/m ³)	w/c (%)	SF (%)	Fly ash (%)	Cement quantity kg/m ³
[3]	Natural	15-30	15%	0.33	-	-	-
		10-20	15%	0.35			
		5-10	20%	0.35			
		5-10	20%	0.28			
[4]	River	9.5-12.5	-	0.27 0.30 0.32 0.36	-	-	420
[5]	River	10-20	-	0.3	-	-	-
				0.30			
				0.33			
				0.36			
				0.45			
				0.30			
				0.33			
				0.36			
				0.6			
				0.30			
0.33							
0.36							
[6]	Natural and recycled	13-20	-	-	-	-	-
[7]	Dolomite	0-4	-	0.33	-	-	350
		4-8	10%				
	8-16						
	4-8						
8-16	Slag Steel						
[8]	Basalt aggregate	2.36-4.75	-	0.31	-	-	378
		4.75-6					
		6-8					
		8-9.5					
		4.75-9.5					
		10-12.5					
		12.5-15					
		10-15					

Table 2 shows the size of the aggregates best to give high permeability and high porosity is (13 → 20 mm), and the ideal percentage of fly ash to give high porosity is (20%). In addition to, the ideal water-cement ratio for giving high

porosity is (0.30%), and the ideal amount of cement to give high porosity is 300 kg/m³.

Table 2: Results of some hydraulic properties

Reference Number	Porosity (%)	Water Permeability (mm/s)	Hardware	
[3]	-	7.8		
		8.3		
		8.9		
		1.9		
[4]	22	11		
	21	7.6		
	20	5		
	12	2		
[5]	7 days	28 days	(Coulombs)	
	30.98	31.12		4566
	21.25	23.1		3980
	12.92	13.01		3611
	29.2	30.1		4983
	16.87	17.09		3720
	8.28	8.31		1500
	30.98	31.23		4683
	14.69	15.12		3774
	3.507	3.78		1374
	12.92	13.01		-
	21.12	12.68		-
	20.56	11.55		-
19.71	9.85	-		
[6]	36	14.9		
	33	12.1		
	32	15.9		
[7]	6.3	-	-	
	21.29			
	14.24			
	22.2			
	19.27			
[8]	21.03	-	-	
	21.11			
	20.89			
	20.50			
	21.25			
	20.78			
	21.16			
20.56				

II. OBJECTIVE

The research aims to study the effect of different types and shapes of aggregates such as limestone, recycled, local metamorphism, and natural river aggregates available in the city of Hsia on the hydraulic properties of the pervious concrete, where a few research projects that studies pervious concrete in Syria.

III. EXPERIMENTAL INVESTIGATION

3.1 Materials and properties

Four different types of aggregate, limestone, natural river, recycled, and local metamorphic aggregate available in Hasia city, have been used with diameters reserved on the sieve of (9.5 mm) and passing by sieve diameter of (15 mm) to study the effect of the type and shape of local aggregate on some hydraulic properties such as porosity and water permeability for pervious concrete.

Ordinary Portland cement was used with compressive strength for cube after 28 days (32.5 N/mm²), and drinking water, and plasticizing was used according to (ASTMC – 494–83 compound of sulphonated naphthalene-formaldehyde condensate, where the plastics reduce the ratio of water to cement added to mixtures, as this type of plastics according to its specifications is used from (1 to 1.5) liters per cubic meter, and river sand and silica fume have been used as an additional material in the experimental mixtures of pervious concrete in this research. The apparent density, dry density, wear rate (Los Angeles factor), humidity, qualitative weight, absorption rate and surface moisture on the aggregate were performed to Determine their properties and was measured according to the method (ASTMC131) and the results were as shown in table 3.

Table 3: Aggregate properties

Aggregate materials	apparent density gr/cm ³ (γ)	dry density gr/cm ³ (γ _d)	Los Angeles factor (LA)	qualitative weight (Gs)	Humidity (w%)	Absorption rate (W%)
River	1,554	1,524	12,5	2,98	1,96	0,48
local metamorphic	1,434	1,403	15,3	2,96	2,24	0,87
Limestone	1,276	1,221	30,2	2,78	4,53	1,93
Recycled	1,179	1,086	40,8	2,42	8,56	6,24

3.2 Specimens Preparation and Mix Proportions

Was used (50%) of the content of coarse aggregate passing through the sieve diameter of (15 mm) and reserved on the sieve diameter of (12.5 mm) and (50%) of the coarse aggregate passing through the sieve diameter of (12.5 mm) and reserved on the sieve diameter of (9.5 mm) for each type of aggregate. A(300 kg/m³) cement was also used, and the percentage of plastic used in pervious concrete mixtures was constant and ratio (w/c) was changed according to the type of aggregate, where (2%) of the plastic was used from the amount of cement according to the specifications of the plastic used. And without the use of additives.

In the casting process, the cylindrical samples were used, where the materials used in the mixture were weighed and soaking the aggregate for half an hour for all types of

aggregate and the dry materials were mixed and then mixed with a small amount of water and plastic and then the water was added gradually in small quantities until the mixture smoothed without increasing or decreasing as show in figure 2, because increasing the amount of water leads to heterogeneity of the mixture and deposition of cement mortar below the sample and blockage of pores, and reduced amount of water needed leads to the mixture not sticking to each other and heterogeneity and reduced strength, then the molds were painted by oil and the mixture was poured into the molds on three layers and knocked each layer (25 times) with a wet metal rod, with attention to lack the increased of knocked that leads to the deposition of cement mortar down the sample and clogging pores, after filling the molds, the surface of the samples was settled, and (24 hours) later the molds were removed, and the samples were placed in the water to cure.

(6) cylindrical samples (15 cm) diameter and (30 cm) high were used for each type of aggregate to test the rate of permeability, porosity ratio.



Figure 1: A model of the homogeneity for the mixtures and pervious concrete samples floor

Permeability rate of cylindrical samples was calculated based on the fixed water head method of the following law:

$$K = \frac{Q * L}{A * H} \quad (mm/sec) ; Q = \frac{V}{t}$$

Where:

Q: flow (mm³/sec).

V: The volume of water leaking during time (mm³).

t: Water leak time (sec).

L: Length of cylindrical sample (300 mm).

H: height of water levels (mm).

A: Cylindrical sample section area (mm²).

Where the cylindrical samples were wrapped in a casing to prevent water from leaking from the sides and allowed to pass through the sample section only and was placed within the permeability device and start filling the bowl with water until the flow stabilized and the level of the water surface

above the cylindrical sample, and after the water head stabilized, the height the water level was measured by a graded ruler and the amount of water leaked began to be calculated within a time of (15 sec), where time was fixed for all cylindrical samples and for all types of aggregate in order to compare them, and the amount of water leaked during this time was weighed and compensated in the above-mentioned law to determine the rate of permeability of the pervious concrete.

Voids content is calculated as follows:

$$n = \frac{V_v}{V} * 100 \quad (\%) \quad ; \quad V_v = V - V_s$$

Where:

Vv: Voids size (cm³).

V: Total size of the cylindrical sample (cm³).

Vs: Aggregate size (cm³).

The bowl was fully filled with water and the cylindrical samples were slowly immersed in it and the weight of the floating water that equal to the weight of the aggregate was calculated and through compensation in the porosity law, voids content for the pervious concrete was calculated.

IV. RESULTS AND DISCUSSIONS

Experiments were conducted on different aggregate to compare them and find out what type of aggregate are best for use in pervious concrete mixtures, and the results were as follows:

4.1 Percentage of water needed for mixing

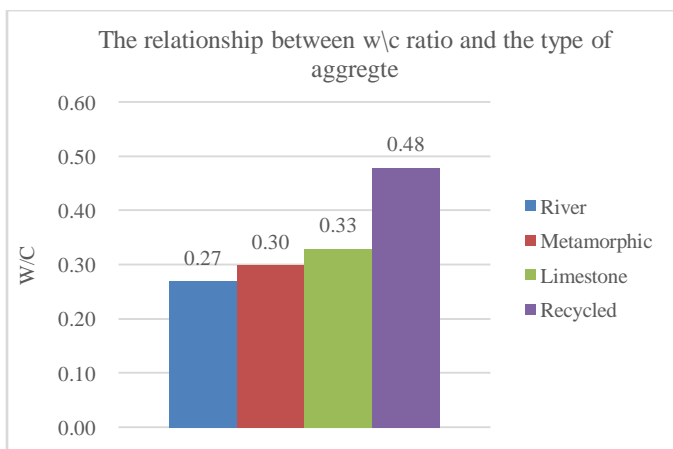


Figure 2: Ratio w/c for pervious concrete mixtures

Figure 2 shows that the water-to-cement ratio increases when the surface of the aggregate increases in roughness and

also increases further in recycled aggregate due to the many cracks in this aggregate.

4.2 Water Permeability

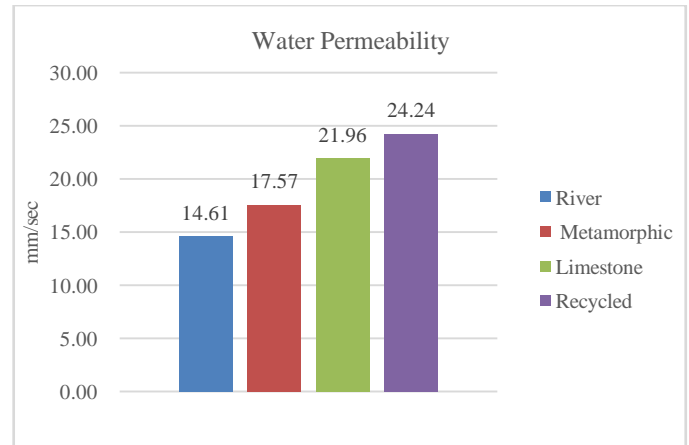


Figure 3: The relationship between water permeability and type aggregate

The Figure 3 shows the relationship between water permeability for final samples and type aggregate, where water permeability increases with the decrease in the hardness of the aggregate, where the great value is for samples containing recycled aggregate and then decreases slightly using limestone aggregate and then local metamorphic and is less valuable for samples containing river aggregate.

4.3 Voids content (Porosity)

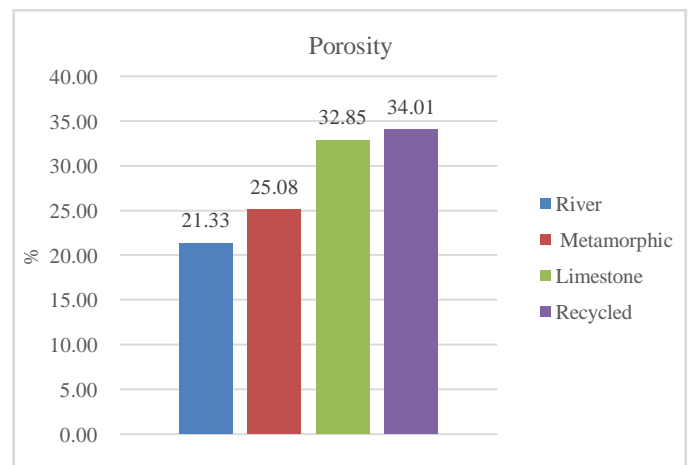


Figure 4: The relationship between voids content and type aggregate

The Figure 4 demonstration that voids content increases with the decrease in the hardness of the aggregate, where the great value is for samples containing recycled aggregate and then decreases slightly using limestone aggregate and then local metamorphic and is less valuable for samples containing river aggregate.

4.4 The relationship between the porosity and permeability

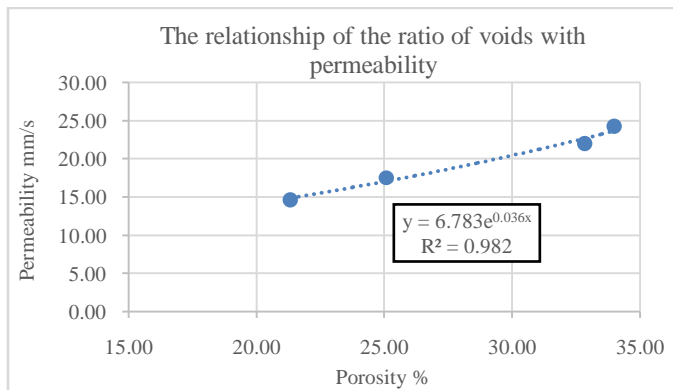


Figure 5: The relationship between voids content and permeability

Figure 5 shows that the permeability of the pervious concrete increases with the increase in the proportion of its voids and the relationship between the ratio of voids and permeability is achieved and corresponds to reference studies.

V. CONCLUSION

Permeability and voids content increase with increases the roughness of the surface of the samples. All the aggregate used have their permeability and the proportion of their spaces are usable in the pervious concrete paving works. Recycled aggregate is the best type of aggregate used in the pervious concrete paving work because their permeability and the proportion of their spaces are large.

REFERENCES

[1] Obla, K. H. (2010). Pervious concrete—An overview. *Indian Concrete Journal*, 84(8), 9.

[2] Tennis, P. D., Leming, M. L., & Akers, D. J. (2004). *Pervious concrete pavements* (No. PCA Serial No. 2828). Skokie, IL: Portland Cement Association.

[3] Yang, J., & Jiang, G. (2003). Experimental study on properties of pervious concrete pavement materials. *Cement and Concrete Research*, 33(3), 381-386.

[4] Ali, M. K., & Kareem, Q. M. S. (2014). Experimental Study on Mechanical and Hydrological Properties of Pervious Concrete with Different Water Cement Ratio. *Science Technology & Engineering*, 3(12), 107-113.

[5] Chopda, S.M., & Chhattani, B.M. (2015). Mechanical Properties of Pervious Concrete. *International Journal of Technology*, 5, 113-117.

[6] Sriravindrarajah, R., Wang, N. D. H., & Ervin, L. J. W. (2012). Mix design for pervious recycled aggregate concrete. *International Journal of Concrete Structures and Materials*, 6(4), 239-246.

[7] Ćosić, K., Korat, L., Ducman, V., & Netinger, I. (2015). Influence of aggregate type and size on properties of pervious concrete. *Construction and Building Materials*, 78, 69-76.

[8] Yu, F., Sun, D., Wang, J., & Hu, M. (2019). Influence of aggregate size on compressive strength of pervious concrete. *Construction and Building Materials*, 209, 463-475.

[9] Liu, H., Luo, G., Wei, H., & Yu, H. (2018). Strength, permeability, and freeze-thaw durability of pervious concrete with different aggregate sizes, porosities, and water-binder ratios. *Applied Sciences*, 8(8), 1217.

[10] Jain, A. K., & Chouhan, J. S. (2011). Effect of shape of aggregate on compressive strength and permeability properties of pervious concrete. *International journal of advanced engineering research and studies*, 1(1), 120-126.

[11] Zhu, X., Chen, X., Shen, N., Tian, H., Fan, X., & Lu, J. (2018). Mechanical properties of pervious concrete with recycled aggregate. *Computers and Concrete*, 21(6), 623-635.

[12] Zhang, W., & Gao, Y. (2019, May). Experimental Study of Pervious Concrete Using Recycled Coarse Aggregate. In *IOP Conference Series: Earth and Environmental Science* (Vol. 283, No. 1, p. 012006). IOP Publishing.

[13] Chinchillas Chinchillas, M. D. J., Corral Higuera, R., Gómez Soberón, J. M. V., Arredondo Rea, S. P., Almaral Sánchez, J. L., Acuña Agüero, O. H., & Rosas-Casarez, C. A. (2014). Influence of the shape of the natural aggregates, recycled and silica fume on the mechanical properties of pervious concrete. *International Journal of Advances in Computer Science and Its Applications*, 4(4), 216-220.

[14] Adil, G., Kevern, J. T., & Mann, D. (2020). Influence of silica fume on mechanical and durability of pervious concrete. *Construction and Building Materials*, 247, 118453.

[15] Costa, F. D., Lorenzi, A., Haselbach, L., & Silva Filho, L. D. (2018). Best practices for pervious concrete mix design and laboratory tests. *Revista IBRACON de Estruturas e Materiais*, 11(5), 1151-1159.

[16] AlShareedah, O., & Nassiri, S. (2019). Methodology for mechanistic design of pervious concrete pavements. *Journal of Transportation Engineering, Part B: Pavements*, 145(2), 04019012.

Citation of this Article:

Sabah Hamandoush, Fatima Alsaleh, Marwan Assi, “Effect of the Type and Shape of Local Aggregate on the Hydraulic Property’s Pervious Concrete Pavement” Published in *International Research Journal of Innovations in Engineering and Technology* - *IRJIET*, Volume 6, Issue 9, pp 69-74, September 2022. Article DOI <https://doi.org/10.47001/IRJIET/2022.609011>
