INFLUENCE OF MIX PROPORTIONS ON PERVIOUS CONCRETE USED IN PAVEMENTS

Ali Hussain Ali
Assistant Professor
Technical College/Mosul
Ali.hussain.ali22@gmail.com

Sarab Mohammed Esmaeel
M.Sc. Student
Technical College/Mosul
sarabali792@yahoo.com

Abstract:
In this research, the effect of using different water-cement ratios (w/c = 0.33, 0.35, and 0.4), different aggregate sizes (MAS = 40, 20, 14, 10 and 5.0) mm., adding different ratios of sand (5, 10, and 20)%, as well as, compaction on the strength and permeability of pervious concrete were studied. Test results indicated that, the best w/c ratio was 0.33 for MAS = 40, 20 and 14 mm., while the best w/c ratios were 0.35 and 0.4 for MAS = 10 mm. and 5.0 mm. respectively. In this research we considered a control mix (C:A = 1:6, w/c = 0.35 and MAS = 10 mm permeability = 2 sec) as the optimum mix proportions which it was obtained by trial mixes. It was clear that the best sand ratio was (10%). Results also indicated that, when adding 0.5% super-plastizer of cement weight, increase compressive strength. Finally adding sand with super-plastizer increase compressive strength but reduce permeability.

Keywords: Pervious concrete, Curing and Compaction, Mix Proportions, Sand, Green Concrete.

تأثير نسب الخلط على الخرسانة النفاذة المستخدمة في التبليط

الخلاصة:
في هذا البحث تم دراسة تأثير اضافه نسب مختلفة من الماء الى السمنت على الخرسانة النفاذة. حيث تم استخدام نسب ماء مختلفة (0.33,0.35 and 0.4) وتأثيرها على مقاسات مختلفة من الركام (40, 20, 14, 10, and 5.0) ملم. وايضا تم دراسة تأثير اضافة نسب مختلفة من الرمل (5%,10%,20%) والملدن بنسبة 0.5% من السمنت. واخيرا تم دراسة تأثير الرص على النفاذية ومقاومه الانضغاط. حيث وجدنا ان افضل نسبه ماء الى السمنت كانت 0.33 للمقاسات (40, 20 and 14) ملم بينما للمقاس 10 ملم كانت نسبة الماء المثلى 0.35 و0.4 للمقاس 5.0 ملم. في هذا البحث تم اعتبار الخلطة المرجعية (C:A=1:6, W/C = 0.35, MAS = 10 mm والنفاذية = 2 sec) باعتبارها كخلطة مثالية تم الوصول اليها بعد العديد من المحاولات. لقد بدا من الواضح ان افضل نسبة رمل مضافة كانت 10%. ايضا تم اضافة الملدن بنسبة 0.5% من السمنت حيث ارتفعت مقاومة الانضغاط. واخيرا بينت النتائج ان اضافة الرمل مع 0.5% من الملدن ادى الى زيادة في مقاومة انضغاط الخرسانة ولكن ادى الى نقصان في النفاذية.

الكلمات المفتاحية: الخرسانة المنفذة، المعالجة والرص، نسب المزج، الرمل، نسب الماء الى السمنت، الخرسانة الصديقة للبيئة.

Introduction:

What is pervious concrete: Pervious concrete is a special type of concrete with a high porosity used for concrete flatwork that allow water to pass through it, by reducing the runoff from a site and recharging ground level. ACI 522R defines pervious concrete as “a zero-slump, open-graded material consisting of: Portland cement, coarse aggregate, little or no fine aggregates, admixtures, and water.

Pervious concrete is a mixture of cement, water and a single-sized coarse aggregate combined to produce a porous structural material. It has a high volume of voids, which is the factor responsible for the lower strength and its lightweight nature. Pervious (porous or no-fines) concrete contains a narrowly graded coarse aggregate, little to no fine aggregate, and insufficient cement paste to fill voids in the coarse aggregate. This low water-cement ratio, low-slump concrete resembling popcorn is primarily held together by cement paste at the contact points of the coarse aggregate particles; this produces a concrete with a high volume of voids (20 – 35)% and a high permeability that allows water to flow through it easily**[1]**.

Pervious concrete pavement is a unique and effective means to meet growing environmental demands. By capturing rainwater and allowing it to seep into the ground, pervious concrete is instrumental in recharging groundwater, reducing storm water runoff, and meeting U.S. Environmental Protection Agency (EPA) storm water regulations. In fact, the use of pervious concrete is among the Best Management Practices (BMP) recommended by the EPA—and by other agencies and geotechnical engineers across the country—for the management of storm water runoff on a regional and local basis. This pavement technology creates more efficient land use by eliminating the need for retention ponds, swales, and other storm water management devices. The density of pervious concrete depends on the properties and proportions of the materials used, and on the compaction procedures used in placement. In-place densities on the order of (1600 to 2000) kg/m^3 are common, which is in the upper range of lightweight concretes. Pervious concrete mixtures can develop compressive strengths in the range of 500 to 4000 psi (3.5 to 28 MPa), which is suitable for a wide range of applications, typical values are about 2500 psi (17.0 MPa). Flexural strength in pervious concretes generally ranges between about 150 and 550 psi (1.0 and 3.8) MPa **[2]**.

[Emiko, Kiang Hwee, and Tien Fang] achieve high-strength, high porosity and permeability pervious concrete pavement was carried out. Mix proportions in terms of cement content, coarse aggregate/cement ratio (A/C) and water-cement (w/c) ratio were varied. Results showed that a water/cement ratio of 0.2 resulted in a dry and brittle mix that led to compressive strength less than 15.0 MPa but a high permeability rate of approximately 20 mm/s. A mix with w/c ratio of 0.3 and A/C ratio of 4.25 resulted in compressive strength of 13.9 MPa, flexural strength of 3.0 MPa and high porosity of more than 20%. The use of high cement content of 495 kg/m^3 in the mix resulted in high compressive strengths of 51.8 MPa, flexural strength of more than 4.0 MPa, however permeability was reduced to approximately 1.0 mm/s**[3]**.

[S. Hatanaka] studies cement paste characteristics and porous concrete properties. Good porous concretes with void ratio of (15 to 25)% and strength of (22 to 39) MPa are produced using paste with flow of (150 to 230) mm and top surface vibration of 10 s with vibrating energy of 90 $kN\text{-}m/m^2$. For low void ratio, high strength porous concrete of 39 MPa is obtained using paste with low flow. For high void ratio, porous concrete of 22 MPa is obtained using paste with high flow**[4]**.

[Vernon R. Schaefer, Keijin Wang, Muhannad T. Suleiman, and John T. Kevern] develop a Portland cement pervious concrete (PCPC) mix that not only has sufficient porosity for storm water infiltration, but also desirable strength and freeze-thaw durability. Results indicated that PCPC made with single-sized aggregate has high permeability but not adequate strength. Adding a small percent of sand to the mix improves its strength and freeze-thaw resistance, but lowers its permeability. Although adding sand and latex improved the strength of the mix when compared with single-sized mixes, the strength of mixes where only sand was added were higher. The freeze-thaw resistance of PCPC mixes with a small percentage of sand also showed 2% mass loss after 300 cycles of freeze-thaw. The preliminary results of the effects of compaction energy on PCPC properties show that compaction energy significantly affects the freeze-thaw durability of PCPC and, to a lesser extent, reduces compressive strength and split strength and increases permeability**[5]**.

[George N. McCain] examined the strength and hydraulic conductivity of porous concrete mix designs for pavements. It was found that the average values for compressive strength ranged between about (6.2 to 26.7) MPa depending on the mix design. The average values for hydraulic conductivity ranged between (0.18 and 1.22) cm/s (250 and 1730 in/hr) depending on the mix design. Therefore, specimens of at least 10.2 cm (4 in.) diameter are recommended for laboratory testing procedures**[6]**.

[Bradford M. Berry] using recycled concrete aggregate (RCA) in pervious concrete, specifically the effects on the density, strength and permeability. The coarse aggregate was substituted by (0, 10, 20, 30, 50, and 100)% RCA. As percent RCA increased both compressive strength and permeability generally decreased. The results indicated that up to

(50)% substitution of coarse aggregate can be used in pervious concrete without compromising strength and hydraulic conductivity significantly**[7]**.

[Anderson, Ian A.Suozzo, Mark Dewoolkar, and Mandar M.] evaluate the factors affecting the testing of strength and hydraulic parameters of pervious concrete pavement (PCP). Results indicated that, capping with rubber pads was found to provide more consistent compressive strength measurements compared to sulfur capping for both H:D ratios studied. H:D ratios less than the standard 2:1 were found to increase results of compressive strength measurements; however, a ratio of 1:1 was found to provide inconsistent results. Compressive strength specimens with H:D ratios less than 2:1 can be divided by 1.1 to estimate compressive strength of 2:1 H:D specimens. Results of laboratory hydraulic conductivity, single ring, double ring and falling head infiltrometer testing were found to correlate linearly to one another with a relation of 1.0 : 1.8 : 1.5 : 9.0 for 6 in. thick PCP. Sodium Chloride deicing salt at 8%, followed by 4 and 2% resulted in the greatest freeze-thaw damage**[8]**.

Significance and objectives of research:

In this research, studying the influence of different sizes of aggregate (MAS = 40, 20, 14, 10 and 5.0) mm., different water-cement ratios (w/c = 0.33, 0.35, and 0.4), adding different ratios of sand (5, 10, and 20)% of the total aggregate, as well as using (0.5%) superplasticizers by weight of cement on the compressive strength and permeability of pervious concrete. Also, the effect of compaction on compressive strength was investigated in this research for comparison purposes.

Practical Investigation:

Materials:

Five constituents (cement, coarse and fine aggregates, superplastizers and water) were discussed in order to use in preparing pervious concrete. Their descriptions were as follows:

1. Cement:

Ordinary Portland cement manufactured by Badoosh Factory in Mosul city, was used. The physical and chemical properties of the used cement were tested in accordance to Iraqi Specification No. 5, 1984**[9]**, and results were shown in Tables (1 and 2).

Table (1): Physical properties of the used cement

Properties	Test results	Iraqi Specification No. 5/1984**[9]**
Blain Fineness, (m^2/kg)	274	min. 230
Initial setting time, (minutes)	160	min. 45
Final setting time, (hrs)	3.67	max. 10
3-day compressive strength, MPa	24.68	min. 15
7-day compressive strength, MPa	33.32	min. 23
Soundness (%)	0.14	max. 0.8

Table (2): Chemical properties of the used cement

Basic components (%)	Test results (by weight)	Iraqi Specification No. 5/1984**[9]**
SiO_2	21.38	N. A.*
Al_2O_3	5.9	N. A.
Fe_2O_3	2.4	N. A.
CaO	62.31	N. A.
MgO	3.77	max. 5.0
SO_3	2.3	max. 2.8
L.O.I.**	1.22	max. 4.0
Insoluble residue	0.27	max. 1.5 %

* N. A.: Not Available.

** Loss on ignition.

2. Coarse aggregates:

The used coarse aggregates (rounded, uncrushed) are locally available. Five sizes of coarse aggregates (MAS = 40, 20, 14, 10 and 5) mm. were used.

Single-sized grading coarse aggregates were used, its grading test was done in accordance to the Iraqi specification No. 45, 1984**[10]**, its sieve analysis was shown in Table (3).

Table (3): Gradation of coarse aggregate used in pervious concrete[10]

Sieve size (mm)	Percentage passing for nominal sizes (by weight)				
	Single-sized aggregates				
	40 mm	20 mm	14 mm	10 mm	5 mm
50.0	100	--	--	--	--
37.5	85 – 100	100	--	--	--
20.0	0 – 25	85 – 100	100	--	--
14.0	–	0 – 70	85 – 100	100	--
10.0	0 – 5	0 – 25	0 – 50	85 – 100	100
5.0	--	0 – 5	0 – 10	0 – 25	45-100
2.36	--	--	--	0 – 5	0-30

3. Fine aggregates:

Sand from Kanhash region near Mosul city was used, its grading test was done in accordance to Iraqi specification No. 45, 1984**[10]**, its sieve analysis was shown in Table (4).

Table (4): Sieve analysis of the used fine aggregates

Sieve size (mm)	Percentage passing (%)	Iraqi specification No. 45, 1984**[10]** (Zone No. 2)
5	100	100
2.36	67	65-100
1.18	58	45-100
0.6	49	25-85
0.3	12	5-48
0.15	1	0-15
Fineness modulus	3.1	

Relative properties of the used coarse and fine aggregates were shown in Table (5).

Table (5): Relative properties of the used coarse and fine aggregates

Properties	Coarse aggregates test results	Specification
Dry sp. Gravity	2.63	ASTM C127**[11]**
S.S.D. sp. Gravity	2.64	
App. sp. Gravity	2.66	
Absorption capacity (%)	0.5	
Rodded unit weight (kg/m^3)	1716	ASTM C29**[12]**
Voids content (%)	33.26	

4. Super plastizers:

Super plasticizers type Sika Visco Crete -SF 18 was used; their technical date was shown in Table (6).

Table (6): Technical data for the used Superplasticizers type (Sika ViscoCrete -SF 18)

Product description	Sika ViscoCrete -SF 18 is a third generation superplasticiser for concrete and mortar.
Uses	(a) A wide range of applications where excellent workability and high strength development are required. (b) Concrete with ultra high water reduction (up to 30%). (c) High performance concretes. (d) Self-Compacting Concrete (SCC).
Chemical Base	Modified polycarboxylates based polymer.
Density	1.10 ± 0.02 g/cm^3 (at + 20°C).
pH Value	3 – 7

5. Water:

Tap water was used in preparing and curing all concrete specimens.

Concrete tests:

The tests that were conducted on concrete specimens to provide a complete picture of the compressive strength**[13]** and permeability**[14]** of the pervious concrete.

Results and Analysis:

In this research, different w/c ratios were used in order to find the best w/c ratio that enough for hydration of cement and the best mix proportion (C:A) for MAS = 10 mm. Results of the existing investigation were tabulated in Tables (7 to 12).

Table (7): Compressive strength of the trial mixes prepared with different MAS

Mix Proportions	MAS (mm)	w/c ratio	7-day compressive strength (MPa)	28-day compressive strength (MPa)
1:6	40	0.33	7.8	11.1
1:6	20	0.33	8.2	11.5
1:6	14	0.33	9.0	13.6
1:6	10	0.33	7.2	10.3
1:6	5.0	0.33	5.4	7.6

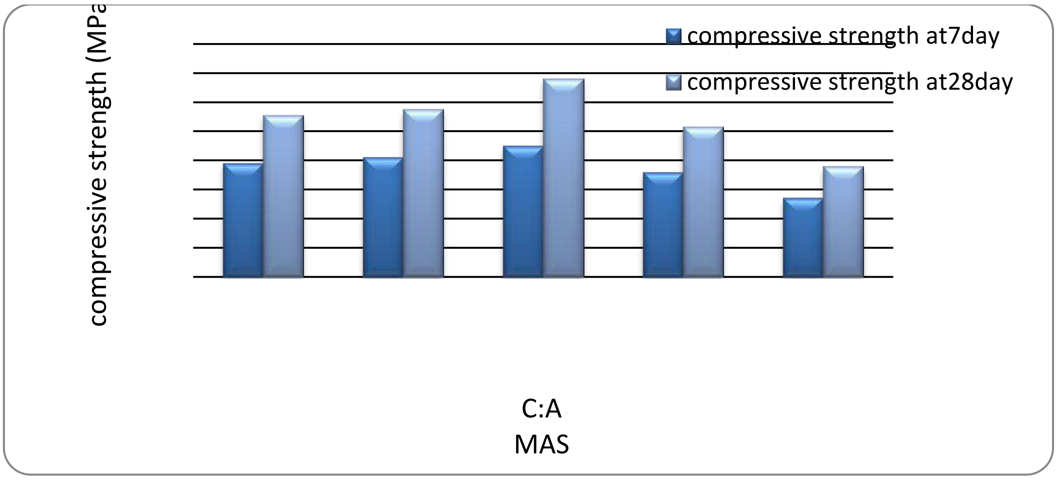

Fig. (1): Effect of C:A and MAS on the compressive strength for w/c = 0.33

In Table (7), different sizes of aggregates (MAS = 40, 20, 14, 10, and 5.0) mm. with w/c = 0.33 and mix proportions (C:A = 1:6) were used in preparing specimens of pervious concrete. Results indicated that, w/c = 0.33 was enough for specimens prepared with (MAS = 40, 20, and 14 mm) but it does not enough for specimens prepared with (MAS = 10, and 5.0 mm), since the smaller size of aggregate demands more water due to the higher surface area.

Table (8): Compressive strength of the trial mixes prepared with MAS = 10 mm., different C:A and different w/c ratios

Mix Proportions	MAS (mm)	w/c ratios	7-day compressive strength (MPa)	28-day compressive strength (MPa)
1:6	10	0.33	7.2	10.3
1:6	10	0.35	8.8	12.9
1:6	10	0.40	8.2	12.1
1:10	10	0.33	3.4	4.6
1:10	10	0.35	5.8	8.1
1:10	10	0.40	3.8	5.1

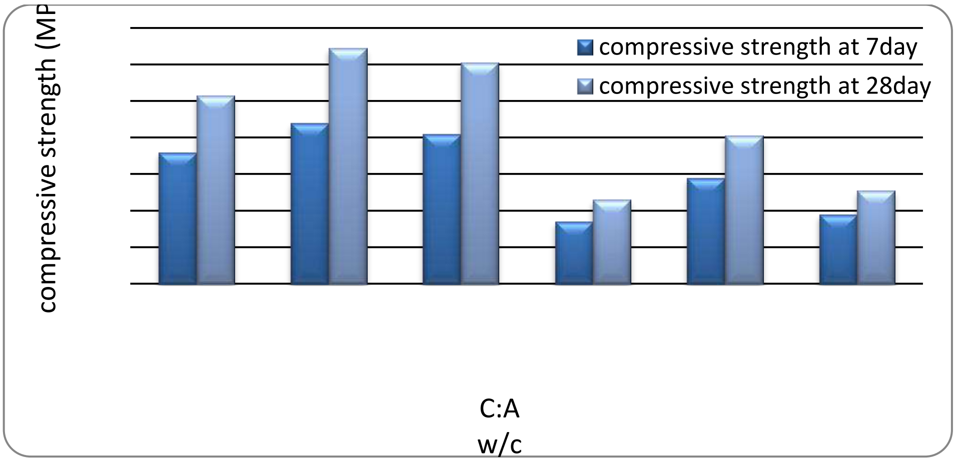

Fig. (2): Effect of C:A and w/c ratio on the compressive strength for MAS = 10 mm, with compaction

Discussing results of Table (8), it was found that the best mix proportions was C:A = 1:6 and w/c = 0.35, since w/c = 0.33 gave the minimum strength. This may be due to insufficient water that does not enough to complete the hydration of cement and also the smaller size of aggregate has larger surface area that made it demands higher amount of water.

Table (9): Compressive strength of the trial mixes prepared with different MAS (C:A = 1:6, and w/c = 0.35)

Mix Proportions	MAS (mm)	w/c ratio	7-day compressive strength (MPa)	28-day compressive strength (MPa)
1:6	40	0.35	7.6	10.5
1:6	20	0.35	7.8	11.3
1:6	14	0.35	8.2	12.0
1:6	10	0.35	8.8	12.9
1:6	5.0	0.35	6.5	9.1

From Table (9), it was found that the better concrete mix was prepared with MAS = 10 mm, C:A = 1:6 and w/c = 0.35, permeability (the time required for water to penetrate through concrete samples = 2 sec.), so that, this mix will be used as a control (reference) mix.

Table (10): Effect of sand content and compaction on the compressive strength and permeability of pervious concrete (MAS = 10 mm., and w/c = 0.35)

Mix Proportions	Sand content (%)	Without compaction			With compaction		
		7-day compressive strength (MPa)	28-day compressive strength (MPa)	Required time* (sec)	7-day compressive strength (MPa)	28-day compressive strength (MPa)	Required time* (sec)
1:6	5	10.8	13.7	3	13.8	17.25	4
1:6	10	12.0	15.3	6	15.2	19.1	7
1:6	20	7.6	9.4	10	10.4	13.0	12

***** The time required for water to penetrate through concrete samples.

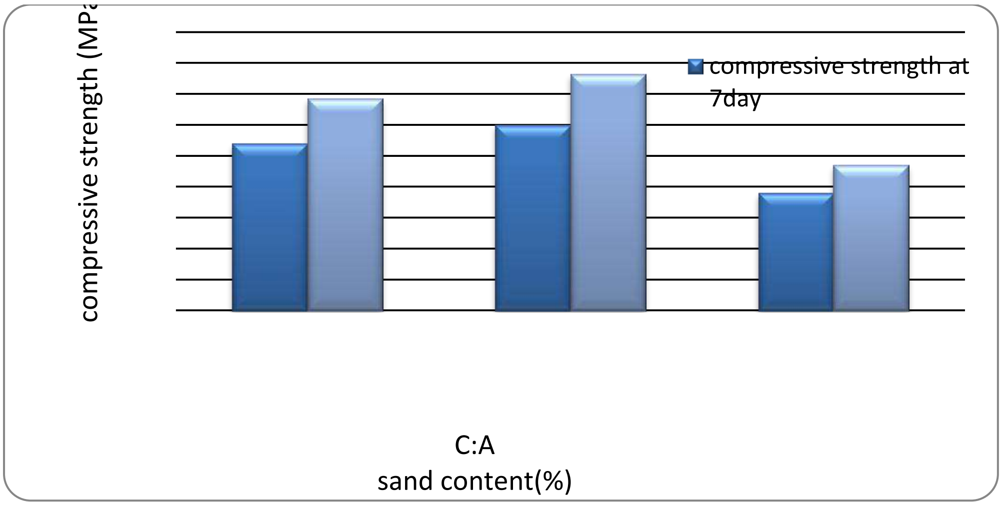

Fig. (3): Effect of C:A and sand content on the compressive strength for MAS = 10 mm, w/c = 0.35 and without compaction

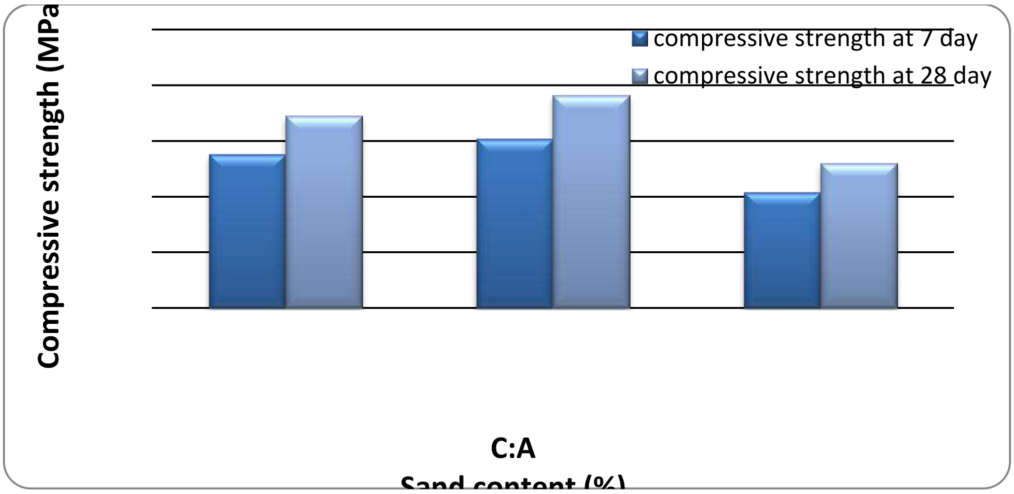

Fig. (4): Effect of C:A and sand content on the compressive strength for MAS = 10 mm, w/c = 0.35 with compaction

Discussing results shown in Table (10) and Figures (3 and 4), results indicated that:

1. Without compaction: it was clear that adding (5 and 10)% sand as a replacement of the total aggregate increases the 28-day compressive strength from (12.9 to 13.7) MPa and (12.9 to 15.3) MPa respectively, as compared with the control mix, permeability (the time required for water to penetrate through concrete samples increased from 3 to 6 sec.), while adding (20%) sand reduce the 28-day compressive strength from (12.9 to 9.4) MPa. This may be due to the mixing water was not enough to complete mixing and insufficient to complete the hydration of cement, and this may be the reason that some aggregate particles does not covered by the cement paste, while time required for water to penetrate through concrete samples increased to 10 sec. as compared with control mix = 2 sec. due to high sand ratio that effect on voids.

2. With compaction: compaction increases the 28-day compressive strength from (13.7 to 17.25) MPa with adding only (5%) of sand, but reduce permeability (time required for water to penetrate through concrete samples increased to 4 sec.), while adding 10% sand increases the 28-day compressive strength from (13.7 to 19.1) MPa, while permeability was reduced (time required for water to penetrate through concrete samples increased from 6 to 7 sec.), while adding 20% sand reduces permeability (10 to 12) sec. and increases the 28-day compressive strength from (9.4 to 13.0) MPa.

Table (11): Effect of super plasticizers and compaction on the compressive strength and permeability of pervious concrete

(MAS = 10 mm., w/c = 0. 35, and 0.5% super plasticizers)

Mix Proportions	Without compaction			With compaction		
	7-day compressive strength (MPa)	28-day compressive strength (MPa)	Required time* (sec)	7-day compressive strength (MPa)	28-day compressive strength (MPa)	Required time* (sec)
1:6	11.0	14.1	2	14.4	17.7	4

Discussing results shown in Table (11) indicated that:

1. Without compaction: it was clear that adding 0.5% superplastizers increase the 28-day compressive strength from (12.9 to 14.1) MPa as compared with the control mix (reference mix), while permeability = 2 sec.

2. With compaction: adding 0.5% superplastizers with compaction increase the 28-day compressive strength from (14.1 to 17.7) MPa as compared with specimen without compaction, but the time required for water to penetrate through concrete samples increase from (2 to 4) sec.

Table (12): Effect of sand and superplastcizers content on compressive strength and permeability of pervious concrete

(MAS = 10 mm, w/c = 0.35 and 0.5% superplastcizers)

Mix Proportions	Sand content (%)	Without compaction			With compaction		
		7-day compressive strength (MPa)	28-day compressive strength (MPa)	Required time* (sec)	7-day compressive strength (MPa)	28-day compressive strength (MPa)	Required time* (sec)
1:6	5.0	11.2	14.1	3	14.7	18.0	4
1:6	10.0	13.3	17.4	6	15.7	19.7	7
1:6	20.0	8.1	10.5	10	10.6	14.2	12

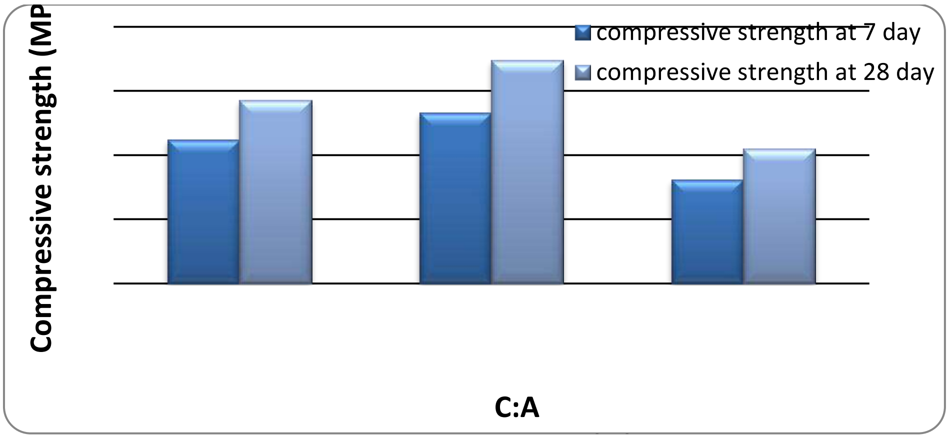

Fig. (5): Effect of C:A and sand content on the compressive strength for MAS = 10 mm, w/c = 0.35, and 0.5% superplastizers (without compaction)

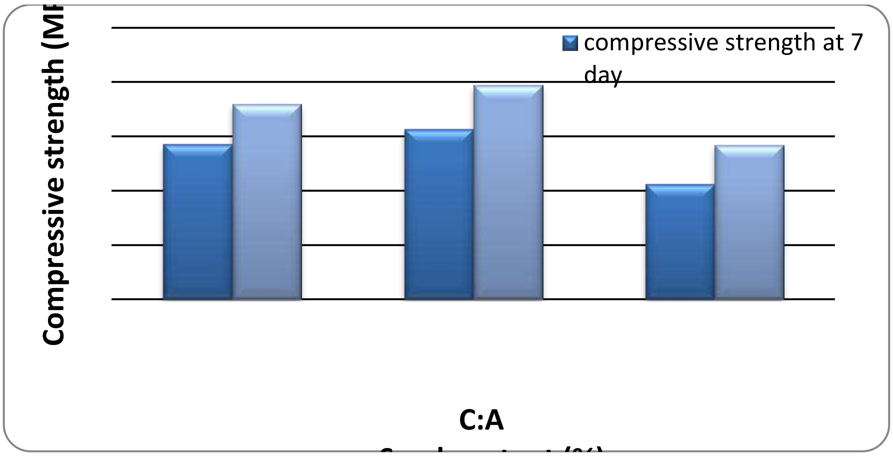

Fig. (6): Effect of C:A, sand content, and compaction on the compressive strength for MAS = 10 mm, w/c = 0.35, and 0.5% superplastizers

Discussing results shown in Table (12) and Figures (5 and 6), results indicated that:

1. Without compaction: adding 0.5% superplastizers and different ratios of sand together led to increase the 28-day compressive strength from (12.9 to 14.1) MPa as compared with the control mix prepared with sand ratio 5%, with permeability = 3 sec. while adding 10% sand led to increase the 28-day compressive strength from (12.9 to 17.4) MPa, with permeability = 6 sec. Finally adding 20% sand led to decrease the 28-day compressive strength from (12.9 to 10.5) MPa, and this may be due to the water doesn't enough to complete hydration of cement as noticed during mixing process, with permeability = 10 sec.

2. With compaction: adding 0.5% superplastizers and different ratios of sand together with compaction led to increase the 28-day compressive strength from (14.1 to 18) MPa as compared with the specimen without compaction with sand ratio 5%, and increase the time required for water to penetrate through concrete samples from (3 to 4) sec. while adding 10% sand led to increase the 28-day compressive strength from (17.4 to 19.7) MPa, with permeability = 7sec. Finally adding 20% sand led to increase the 28-day compressive strength from (10.5 to 14.2) MPa, with permeability = 12 sec.

3. On the other hand, results indicated that, the optimum sand ratio was (10)% which increases both compressive strength and permeability.

Conclusions:

Depending on the test results obtained from the existing investigation, the following conclusions may be drawn:

1. In this research, the optimum mix proportions (C:A = 1:6, w/c = 0.35 and MAS = 10 mm with permeability = 2 sec.), which obtained by trial mixes, was considered a control mix.

2. Test results indicated that, the best w/c ratio was 0.33 for MAS = 40, 20 and 14 mm., while w/c ratios 0.35 and 0.40 were the best for MAS = 10 mm. and 5.0 mm. respectively.

3. Adding 10% sand to pervious concrete enhance 28-day compressive strength from (12.9 to 19.1) MPa and (12.9 to 15.3) MPa with and without compaction as compared with control mix but reduce permeability (the time required for water to penetrate through the concrete increases from 2 to 6 sec. and from 2 to 7 sec. with and without compaction respectively as compared with the control mix.

4. Adding 20% sand to pervious concrete was too much and reduce both compressive strength and permeability. 28-day compressive strength (13.0 to 9.4) MPa, with and without

compaction. While increase time required for water to penetrate through concrete samples (permeability) from (12 to 10) sec. with and without compaction.

5.Compaction increases compressive strength from (12.9 to 15.6) MPa but reduce permeability (increase time required for water to penetrate through concrete samples) from (2 to 4) sec.

6. Adding 0.5% of superplastizers and 10% sand with compaction increases the compressive strength of pervious concrete up to 19.0 MPa and permeability to 7 sec.

7. Results also indicated that, when adding 0.5% super-plastizers, the 28-day compressive strength was increased to (17.7 and 14.1) MPa for mixes prepared with and without compaction respectively.

References:

[1] Neville, A.M., "Properties of Concrete", 4th. and Final Edition, John Wiley & Sons, Inc., New York, NY, Pitman Publishing Ltd., London, 844 pp, 2005.

[2] Paul D. Tennis, Michael L. Leming, and David J. Akers " Pervious Concrete Pavements" EB302.02, Portland Cement Association, Skokie, Illinois, and National Ready Mixed Concrete Association, Silver Spring, Maryland, USA, 2004, 36 pages

[3] Emiko LIMa, Kiang Hwee TANb, and Tien Fang FWAc, "*Effect of Mix Proportion on Strength and Permeability of Pervious Concrete for Use in Pavement*", Department of Civil and Environmental Engineering, National University of Singapore

[4] P. Chindaprasirta S. Hatanakab, T. Chareerata, N. Mishimab, Y. Yuasa "Cement paste characteristics and porous concrete properties", Construction and Building Materials Volume 22, Issue 5, May 2008, Pages 894–901 May 2008.

[5] Vernon R. Schaefer, Keijin Wang, Muhannad T. Suleiman, and John T. Kevern, "*Mix Design Development for Pervious Concrete In Cold Weather Climates*", Center for Transportation Research and Education, Iowa State University, 2901 South Loop Drive, Suite 3100, Ames, IA 50010-8634, February 2006.

[6] George N. McCain, Mandar M. Dewoolkar "*Porous Concrete Pavements: Mechanical and Hydraulic Properties*", Graduate Research Assistant, School of Engineering, University of Vermont, 114 Votey Hall, 33 Colchester Ave. Burlington, VT 05405, U.S.A., E-mail: george.mccain@gmail.com.

[7] Bradford M. Berry, "*Properties of Pervious Concrete Incorporating Recycled Concrete Aggregate*", Undergraduate Research Assistant, School of Engineering, University of Vermont, 116 Votey Hall, 33 Colchester Ave. Burlington, VT 05405

[8] Anderson, Ian A. Suozzo, Mark Dewoolkar, and Mandar M., "*Laboratory and Field Evaluations of Pervious Concrete*", University of Vermont, School of Engineering, August 2013, Website: www.uvm.edu/transportationcenter

[9] Iraqi Specification No.5, 1984, "*Portland Cement*".

[10] Iraqi Specification No. 45, 1984, "*Aggregates Used in Concrete*".

[11] ASTM C127–07, "*Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate*".

[12] ASTM C29/C29M–07, "*Standard Test Method for Bulk Density (Unit Weight) and Voids in Aggregate*".

[13] BS 1881: Part 116, "*Method for Determination of Compressive Strength of Concrete Cubes*", British Standard Institution.

[14] ASTM C1701 / C1701M – 09, "*Standard Test Method for Infiltration Rate of In Place Pervious Concrete*".