Use of Recycled Coarse Aggregate from Construction Waste Compared with Iraqi Natural Aggregate to Production of New Concrete

استخدام الركام الخشن المعاد تدويره من النفايات البنائية مقارنة بالركام الطبيعي العراقي لانتاج خرسانة جديدة

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Abstract:
The reuse of construction waste in the production of concrete achieves two goals; the first is the removal of large amounts of sources of environmental pollution resulting from these wastes and, the second objective is to provide cheap sources of concrete aggregate. This study included test properties for two types of concrete mixes: concrete made with natural aggregate (NAC) and, the other mixes was made with fine natural aggregate and recycled coarse aggregate (local waste). These wastes were used in the second mix after removing the large pieces of gravel and well washing and grading. The results showed that recycled aggregate has a lower specific gravity and higher water absorption compared to the natural aggregate. The results also revealed that the concrete produced using the recycled aggregate has acceptable compressive strength and water absorption ratio and it has a higher flexural strength and less density comparing with concrete made with natural aggregate. So it is appropriate to use the concrete made using recycled aggregate in the work of paving concrete roads, casting of cars carriages, casting sidewalks and road paths.
Keywords: concrete, recycled, coarse aggregate, environmental.

الخلاصة:
إعادة استخدام نفايات البناء في إنتاج الخرسانة يحقق هدفين؛ الأول هو إزالة كميات كبيرة من مصادر التلوث البيئي الناجم عن هذه النفايات، والهدف الثاني هو توفير مصادر رخيصة لركام الخرسانة. تضمنت هذه الدراسة فحص خصائص لنوعين من الخلطات الخرسانية: الاولى هي الخرسانة المصنوعة من الركام الطبيعي (NAC)، والخلطة الثانية خلطت باستخدام الركام الطبيعي الناعم (الرمل) والركام الخشن المعاد تدويره (النفايات المحلية). استخدمت هذه النفايات في الخليط الثاني بعد إزالة القطع الكبيرة من الحصى ومن ثم غسلها وتدريجها. أظهرت النتائج أن الركام المعاد تدويره له وزن نوعي اقل وامتصاص اعلى للماء مقارنة بالركام الطبيعي المستخدم في العراق. بينت النتائج ايضا أن الخرسانة المنتجة باستخدام الركام المعاد تدويره لها مقاومة ضغط ونسبة امتصاص للماء مقبولتين ومقاومة انثناء اعلى وأقل كثافة مقارنة مع الخرسانة المصنوعة من الركام الطبيعي. لذلك فمن المناسب استخدام الخرسانة المصنوعة باستخدام الركام المعاد تدويره في أعمال رصف الطرق الخرسانية، وصب مواقف السيارات، وصب الأرصفة وممرات الطرق.
الكلمات الدالة: الخرسانة، اعادة استخدام، الركام الخشن، البيئي

1. Introduction

Concrete waste is the debris resulting from the construction and demolition of different structures that is produced from repairs to existing structures or the demolition of the old ones or the construction of new buildings. These wastes are also produced from the production factories of ready-made concrete units such as Tiles, Block, flages, etc., as well as ready-made construction factories. It consists of pieces of stones or bricks or concrete or mortar of different sizes. These wastes are dumped in waste collection sites and accumulate annually in large quantities and, because they are highly durable and do not decay or decompose naturally, thus become a growing pollution problem annually around the world .

In the EU, for example, 850 million tons of construction and demolition waste is produced every year [1], In the USA, it produces 123 million tons per year, where only 5% of these wastes were reused, while the residue is dumped into landfills [2]. One of the ways in which this type of waste can be minimized is the reuse of concrete demolition products in the production of new concrete . Recycled concrete aggregate (RCA) produced by crushing the clean of demolished concrete that does not contain any pieces of wood or reinforcing bars or gypsum product residues, to sizes similar to the scale of the gravels, and then washing and sieving on different screeners sizes. It is, therefore, a cheap source of concrete aggregate, especially in countries that do not contain gravel or broken stones suitable for making concrete.

The use of this type of aggregate also reduces the extraction of gravel layers or cracking rocks to produce natural aggregate. Thus, these operations damage large areas of the natural environment in the world. The Concrete Produced in this Type of aggregate is called the recycled Aggregate Concrete (RAC) . This concrete carries the characteristics of the same old concrete and the same compounds. The mixture may consist of many types of concrete, this affects the concrete properties that produced from this aggregate, therefore, it is used for paving roads, paving sidewalks, or producing prefabricated concrete blocks that used in road and sidewalk borders. Thus, a little use to production for structural concrete, as it does not use more than 20% of the total aggregate used in this concrete. It is combined with the natural aggregate to produce this concrete if it is used [2]. The selection of a well-formed aggregate can improve the properties of the resulting concrete . In Finland, the production of concrete from the recycled aggregate giving resistance up to three times that of the local broken concrete [1].

The recycled aggregate is a less specific weight, greater absorption, and low workability because of its irregular surface, comparing with natural Iraqi aggregate. This requires more quantities of water to obtain concrete with workability equal to that produced by using natural aggregate. It absorbs water, during and after mixing, so it is best to mix it when it is saturated with water when producing the concrete.

2. Properties of Concrete with Recycled Aggregate

When demolished concrete is crushed, a certain percentage of cement mortar will remain attached to recycled aggregate from the original concrete. This attached mortar with recycled aggregate is the main reason for RCA is of lower quality when compared to natural aggregate (NA). There is a set of differences between RCA and NA Based on accessible investigational proofs, as follows :

- Increased water absorption, crushability, a quantity of powder particles and quantity of organic impurities, [3,4,5].
- Decreased specific gravity and, bulk density [3,6].

The results of the tests available for recycled aggregate concrete are a difference in wide limits, sometimes opposite. However, the general conclusions about the properties of concrete with recycled aggregate compared to natural concrete are:

- Increased creep, drying shrinkage and, absorption water up to 50% [7, 8, 9, 10].
- Decreased compressive strength up to 25% and, modulus of elasticity up to 45%.

The technique of RAC producing is different from the production of concrete with NA due to the presence of attached mortar. Recycled aggregate has higher absorption of water than a natural aggregate. For this reason, to obtain the required workability of recycled aggregate concrete, it is necessary to add another amount of water for the purpose of the saturation of the RA before or during the mixing process. Water Reducing and Set-Controlling Admixtures may be used if water is not added. The amount of water added is calculated based on the absorption of the recycled aggregate in a prescribed time .

3. Materials

3.1. Cement: Ordinay Portland cement was used from Karbala Cement Factory that corresponds to Iraqi standards [11]; the results of cement testing are shown in the Table (1).

3.2. Recycled and natural aggregate: The tested concrete cubes were used after crushing them and removed the large pieces of gravel, and then sieving it to conform to Iraqi specification standard [11], a maximum aggregate size of 20 mm. The used cubes represent different concrete mixtures that have been tested by the structural laboratory of the Department of Civil Techniques / Musayyib Institute for various types of structures executed by the private and state. The normal coarse aggregate was (5-20) mm and its source was from Al Nebaee area and it corresponds to Iraqi specification standard [11]. Table (2 and 3) shows the properties of recycled and normal aggregate respectively. Figures (1 and 2) show the graduation of recycled and normal aggregate compared to the specification limits respectively.

3.3. Fine aggregate (sand): The used sand was supplied from Al-Akheider reagion Karbala city. After washing, Sand sieving was performed, and the results showed that it is located in the second gradient zone according to the Iraqi specification standard [11], as shown in the Table (4). Figure (3) shows the gradation of sand compared to the specification limits.

3.4. Water: Drinking water (tap water) was used for mixing and curing the concrete.

4. Hardened concrete Test results

Two concrete mixes were made with normal and recycled aggregate. Materials used in concrete mixes were chosen by weight ratio (1:1.5:3) and water/cement (w/c) ratio equal to (0.50). The aggregate used in both mixes was in saturated dry surface condition. Tables (5) show the results of hardened concrete testing, which represents mean values for two concrete mixes. For each mix was used (15 cubes) three had tested at 7 days and the rest (12 cubes) at 28 days. Tests for the other properties of concrete, as in the table were obtained by examining three cubes for each property at the age of 28 days. Three prisms were also prepared and were tested at the age of 28 days for the purpose of obtaining flexural strength of concrete. All tests were done according to the British standards [12, 13, 14].

5. Discussion and conclusions

In this study, two concrete mixtures were compared, one of which used natural coarse aggregate and the other used the recycled aggregate obtained by crushing old tested cubes. These cubes represent different concrete mixtures with unknown compressive strength. According to the results, the following conclusions are made.

1. From the results obtaining shown in the table (4) and, figures (3 and 4) we can conclude that the difference in compressive strength is not significant. This conclusion indicates that the recycled coarse aggregate is of high quality if we know that the compressive strength of concrete mainly depends on the quality of aggregate. Therefore, and for the production of new concrete with good compressive strength, it is necessary to use the recycled aggregate obtained by crushing higher strength class concrete. However, in this work, the recycled aggregate was obtained from the crushing concrete cubes of unknown compressive strength .
2. According to the results of the flexural strength shown in Table (4) and figure (5), we can conclude that the flexural strength of concrete made with recycled aggregate is higher than the concrete produced by a natural aggregate. This high value is due to the roughness of the surface of the used recycled aggregate that leads to strong bonding with cement paste.
3. Based on the results, the water absorption of concrete produced by recycled aggregate is higher than the concrete produced by the natural aggregate as shown in the table (4) and, figure (6). Although, of this water absorption value of the concrete produced by using recycled aggregate, it can be considered acceptable according to the specifications for the concrete used to make concrete blocks, concrete curbs and channels and, precast concrete flags. The value of the water absorption in a table (4) is considered acceptable if it is compared with the Iraqi specifications [10] for the concrete products mentioned above which should not exceed 10% .

4. As shown in the tables (2 and 3), we note that the value of the specific gravity of recycled aggregate is less than of the natural aggregate. In the same tables, we can notice that the absorption value of the recycled aggregate is higher than in the natural aggregate. The water absorption value of the natural aggregate is usually (0.5 -1) %. This is because the percentage of porosity within the recycled aggregate is higher than of natural aggregate. This will reduce the specific gravity and increases the absorption ratio. This conclusion leads us to the need to adjust the mixing proportions based on the proportion of recycled aggregate to obtain the required workability .
5. Table (4) shows the results of concrete density, According to the results, it can be concluded that the density of the concrete produced by recycled aggregate is less than that produced by a natural aggregate. Although the results of compressive strength of concrete have not been affected much, there may be an impact on the durability of concrete in the future. So it is appropriate to use the concrete made using recycled aggregate in the work of paving concrete roads, casting of cars carriages, casting sidewalks and road paths, in Addition to what was mentioned earlier .

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Table (1) properties of cement used

Physical test				Notes
Item		Spec. limit	Test results	
Compressive strength (Mpa)	3 days (min)	15	15.9	Conformable
	7 days (min)	23	24.1	Conformable
Time setting	Initial (mint)	45 min	87.5	Conformable
	Final (hrs)	10 max	6.5	Conformable
Chemical test				Notes
Item		Spec. limit	Test results	
Sio_2 %			23.71	
AL_2O_3 %			3.92	
Fe_2O_3 %			4.12	
CaO %			62.97	
MgO %		5 max	2.77	Conformable
Free Cao			0.87	
So_3 % max	C_3A < 5 %	2.5	2.31	Conformable
	C_3A > 5 %	2.5		
Loss on ignition %		4 max	2.02	Conformable
Insoluble residue %		1.5 max	0.96	Conformable
C_{3S}			37.26	
C_2S			40.1	
C_3A		3.5 max	3.42	Conformable
C_4AF			12.52	
L.S.F %		0.66-1.02	0.88	Conformable

Table (2) properties of recycled aggregate

Sieve size mm	Percentage passing %	Standard limitation
37.5	100	100
20	97	100 – 95
10	42	60 – 30
5	5	10 – 0
Fines content through 75 micron sieve %	2.4	< 3
Percentage of So_3 %	0.076	< 0.1
Specific gravity		2.23
Water absorption %		3
Bulk density, compacted kg/m^3		1.31

Table (3) properties of normal aggregate

Sieve size mm	Percentage passing %	Standard limitation
37.5	100	100
20	99	100 – 95
10	59	60 – 30
5	3	10 – 0
Fines content through 75 micron sieve %	1.2	< 3
Percentage of So_3 %	0.04	< 0.1
Specific gravity		2.66
Water absorption %		0.4
Bulk density, compacted kg/m^3		1.57

Table 4. properties of fine aggregate

Sieve size mm	Percentage passing %	Standard limitation
4.75	94.8	90-100
2.36	87.7	75-100
1.18	74	55-90
0.6	51.9	35-59
0.3	23.8	8-30
0.15	5	0-10
Fines content through 75 micron sieve %	2.99	< 5
Percentage of So_3 %	0.398	< 0.5

Table 5. Results of hardened concrete testing.

Concrete type	Compressive strength (MPa)		Water absorption (%), 28 days	Concrete density (kg/m^3), 28 days	Flexural strength (MPa), 28 days
	7 days	28 days			
Normal concrete aggregate	17.54	23.87	4.3	2.395	5.1
Recycled concrete aggregate	15.51	21.3	7.6	2.210	7

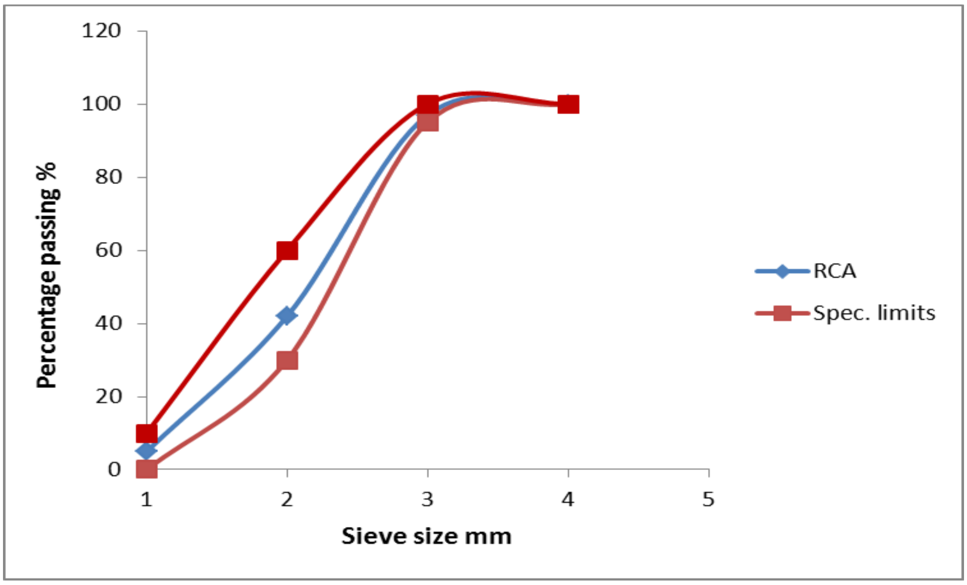

Figure 1. Graduation of recycled aggregate.

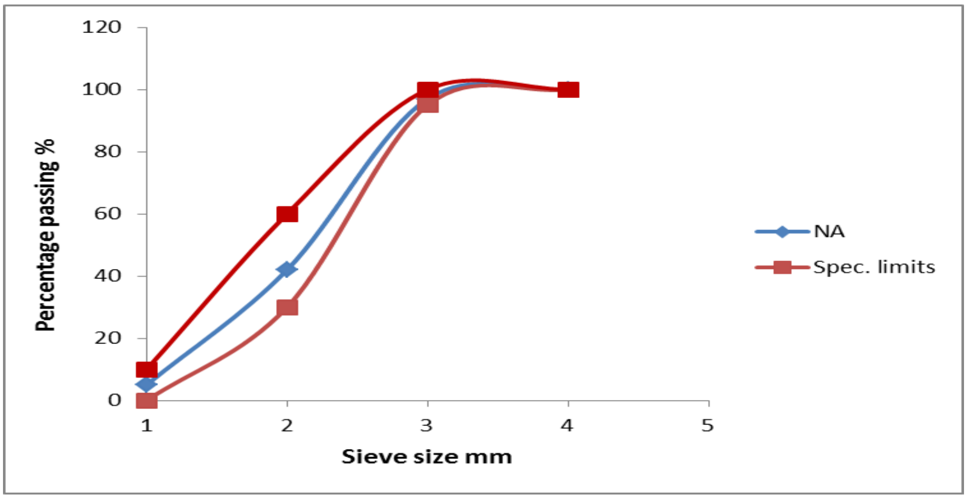

Figure 2. Graduation of normal aggregate.

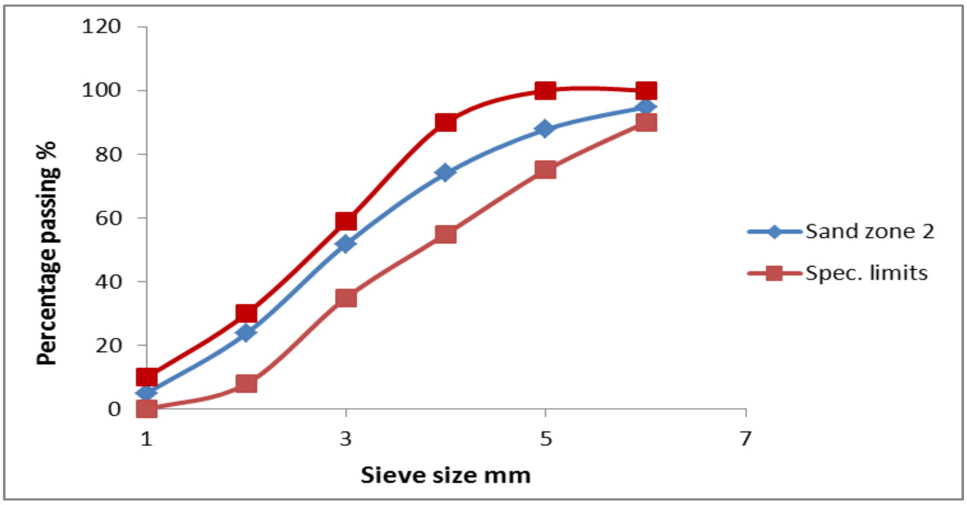

Figure 3. Graduation of sand.

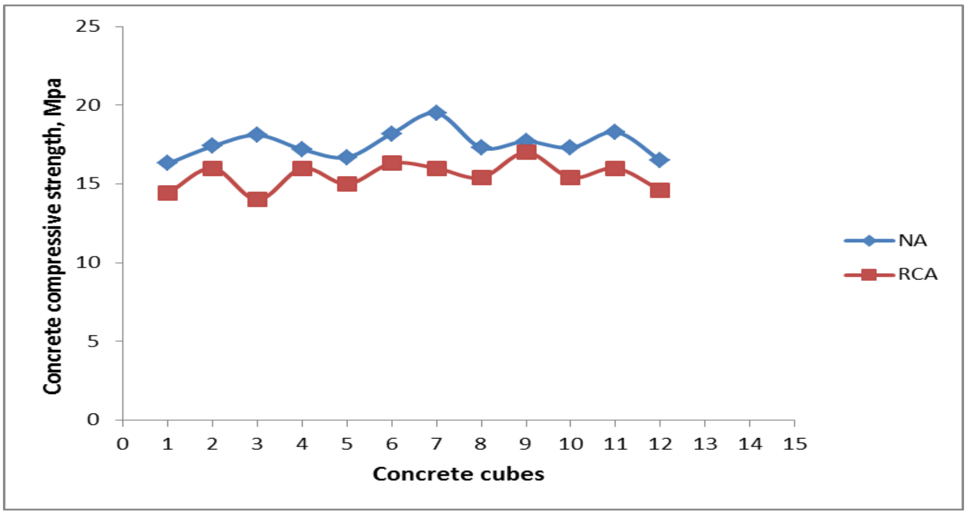

Figure 4.Compressive strength for concrete cubes at 7- days

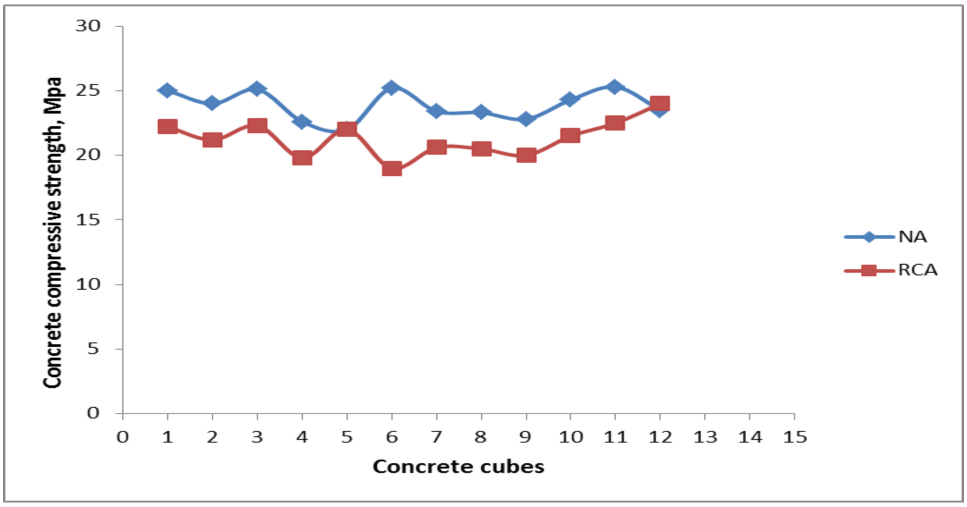

Figure 4. Compressive strength for concrete cubes at 28- days

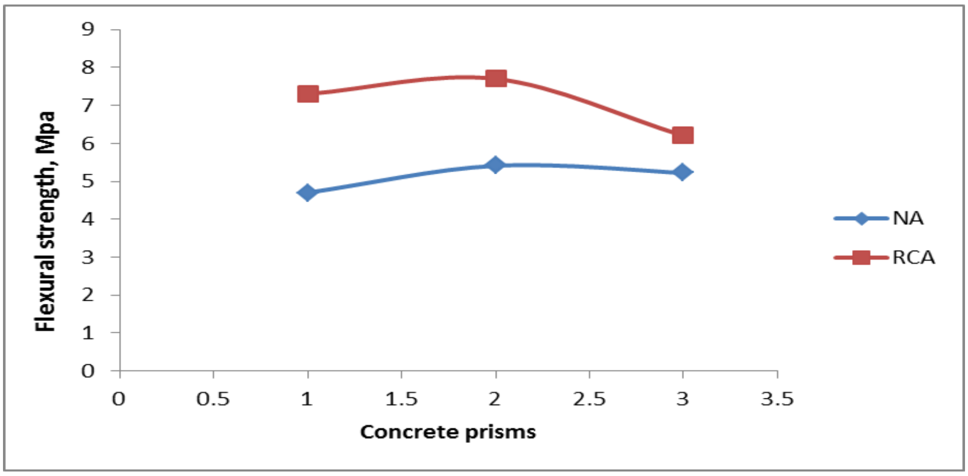

Figure 5. Results of concrete flexural strength.

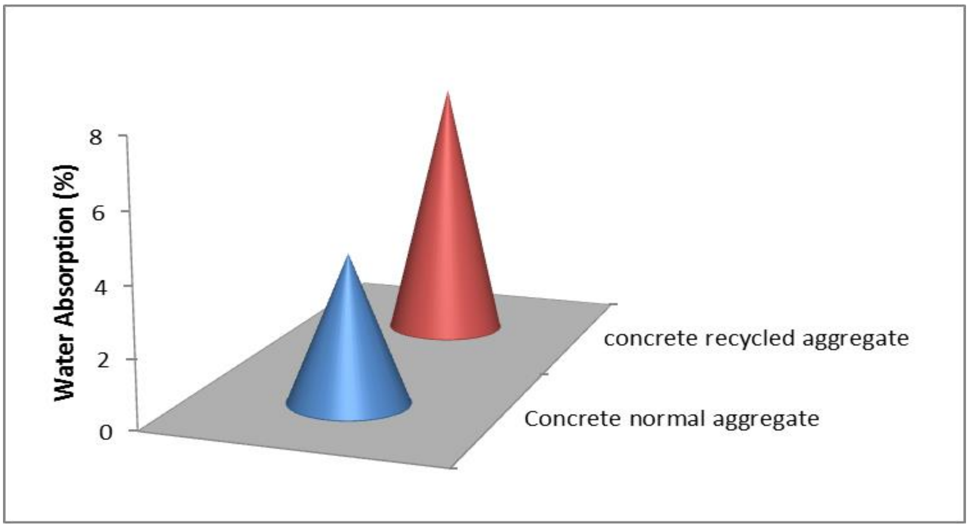

Figure 6. concrete water absorptions.