Al-Mustansiriyah Journal of Science
ISSN: 1814-635X (print), ISSN: 2521-3520 (online)
Volume 29, Issue 3, 2018
DOI: http://doi.org/10.23851/mjs.v29i3.623

Research Article
Open Access

Reusing Iraqi Construction and Aggregates Waste to Manufacturing Eco-Friendly Polymer Concrete

Awham M. Hameed*, Mohammad T. Hamza
Applied Sciences Department, University of Technology, Iraq.
**Correspondent author email: awham_m@yahoo.com*

Article Info

Received
06/10/2018

Accepted
21/10/2018

Published
10/03/2019

Abstract

The recycling and reusing of waste materials to produce suitable materials is very important subjects to scientific research in world now, because the decrease natural resources and create a hole or risk in future of the world. The aim of our research to produce polymer concrete (PC) has high mechanical and physical characteristic. This PC was prepared by using the waste of aggregates and demolitions to make PC have good mechanical and physical characteristic with low cost as compared as cement concrete. In this research different types of construction and demolition waste were used as aggregates replacement (i.e. waste of cement/concrete debris, waste of ceramics and the waste of blocks) while the type of polymer resins (i.e. Epoxy) as cement replacements. The weight percentages of resin were changed within (20, 25 and 30) % to manufacture this polymer concrete. The tests we done like physical such as density and mechanical such as compressive strength, flexural strength. Splitting tensile strength and Schmidt hammer rebound hardness.

Keywords: Polymer concrete, Reusing Aggregates, Construction Waste, Eco-Friendly.

Introduction

Portland Cement Concrete PCC is the very commonly used construction material in the world. Every year, the concrete industry generates near (12) billion tons of concrete and uses nearly (1.6) billion tons of Portland cement worldwide. Furthermore to overwhelming substantial amounts of nature materials limestone, sand and energy, manufacturing every one ton of Portland cement releases (1) ton of carbon dioxide (CO2) in to the environment. Concerns for the environmental development in the cement and concrete activities are more and more addressed [1, 2].

One of the immerging concrete technologies for environmental development is to use "Green" or "Eco - Friendly" materials. The "Green" or "Eco - Friendly" materials are measured as materials that use less natural resource and energy and produce less of (CO2). They are durable and recyclable and need less maintenance [3].

Polymer concrete (PC) is defining as a composite material which is composed of polymer resins that doing as binder materials of aggregates and micro fillers. After that enhance of atypical additives (catalysts and accelerators), binders experience polymerization resulting in a hardened composite [4].

The main difference, evaluated with cement-based concrete, separately from not containing hydrated cement, is that PC is more strong, more durable, and with less maintenance requirements [4, 5]. However, Portland cement can be used as micro-filler or aggregate [6] in PC. The advantages of this Polymer concrete (PC) such as mechanical strengths can reach 4 - 5 times higher than cement-based concrete [7] keeping the modulus of elasticity in similar values [8], has good chemical resistance and water impermeability [9, 10]. For these reasons, PC is commonly used in special applications of civil engineering [4, 11]. It has been used as a most important component for the construction of box culverts, underground pipes, trench lines, industrial floors, also as bridge deck overlays, and in reparation tasks of damaged cement based concrete structures [11].

Materials and Methods

Proposed Materials

Epoxy (EP)

Product Description: Sikadur®-52 is a two parts, solvent loose, little viscosity injection - liquids, based on high strengths epoxy resins.
Uses: The Epoxy resin with good adhesion to concrete, mortar, stone, steel and wood. Sikadur®-52 is used to fill and seal voids and cracks in the structures for example bridges and other civil engineering buildings, industrial and residential buildings, for instance columns, beams, foundations, walls, floors and water retentive structures. It not only forms an active barrier against water penetration and corrosion promoting media, but it also structurally bonds the concrete sections together. Table (1) show Mechanical and physical properties of (EP).
Fine aggregate

Table (1) Mechanical and physical properties of epoxy

	values	Units
Density	1.085	Kg/l
Compressive strength	52	N/mm^2
Flexural strength	61	N/mm^2
Tensile strength	37	N/mm^2
Bond strength	4	N/mm^2
E-Modules	1800	N/mm^2
Thermal expansion coefficient	$8.9 * 10^{-5}$	per ^{O}C
Color	Transparent	
Viscosity	~ 1200	mPa . s
	~ 430	mPa . s
	~ 220	mPa . s

The construction and demolition waste included:

- Waste of concrete debris. (CO)
- Waste of ceramic tiles. (CR)
- Waste of building blocks. (BL)
- Natural sand. (NS)
- River sand. (RS)

Some processes were made on this aggregate after collected. These are cracking, grinding, sieving, before mixing with polymeric resin as binder. Table (2) and (3) shows some properties of these five types of aggregates.

Table (2) Some properties of the used aggregates

Samples	bulk density g/cm^3	Specific gravity	Percentage of voids %
CO	1.209	1.522	0.205
CR	1.048	1.346	0.221
BL	0.995	1.255	0.207
NS	1.321	1.497	0.117
RS	1.316	1.527	0.138

Table (3) Some physical properties of aggregates.

Aggregates	Sulfate content %	Limit of Iraqi specification No.45/1984
CO	4.076	≤ 0.75 %
CR	0.297	
BL	0.663	
NS	0.333	
RS	0.424	
Aggregates	**Fine materials %**	**Limit of Iraqi specification No.45/1984**
CO	40.2	5 – 15 %
CR	36.3	
BL	28.5	
NS	4.3	
RS	8.2	

Tables (4) Grading of fine aggregate used throughout this work.

No.	NS	RS	CO	CR	BL	Limit of Iraqi No.45/1984
10	100	100	100	100	100	100
4.75	100	100	100	100	100	95-100
2.36	100	100	100	100	100	95-100
1.18	100	100	100	100	100	90-100
0.60	33	53	89	86	93	80-100
0.30	10	46	62	67	76	15-50
0.15	2	5	41	53	55	0-15

Preparation of specimens

Mixing of Concrete

At the first, It is important to mention that the manufacturing of PC requires care in the casting process, attention to curing temperature, composition, and careful to choose the type of resins and added aggregates. There are some factors effects on the propertied of the prepared PC. These factors can be summarized: specific area, interfaces with the matrix, strength and deformability, shape and size. Ten Mixtures of PC were prepared with different aggregate (concrete waste, ceramics waste, building blocks waste, natural sand and river sand). All aggregates were sieved with specified practical size distribution show in Table (4). And the three different contents of EPOXY resin of (20, 25 and 30%) were carried out, that show in Table (6). Then this resin was added to the aggregate after mixing it with the hardener with (2:1) ratio.

Mixing of Ordinary Portland cement Concrete

For normal concrete, a dry mixing had to be done for fine aggregate and then a proposed amount of cement was added to the fine aggregate and mixed for another 3 minutes by the manual mixing. The necessary amount of tap water was then additional and the whole elements were mixed for about other 5 minutes, and take up by 1 minute rest to avoid the forming of air bubbles as recommended in the ACI Committee. Show in table (5).

Casting and Curing of the Specimens

Before casting, the molds were carefully oiled to be ready for casting fresh concrete. The concrete was cast in layers (3 layers) for all specimens; each layer was compacted by a rod then all specimens were wet-cured by covering the finished surface and molds with polyethylene sheet for one day.

Tables (5) The mixture of Ordinary Portland cement mortars

2:1			W/C	
Aggregate g		Cement g	Water g	W/C
CO	800	400	200	50 %
CR	600	300	300	100 %
BL	600	300	300	100 %
NS	800	400	140	35 %
RS	800	400	140	35 %

Tables (6) The mixture of aggregates and EP resin.

Samples	Aggregate	Polymer risen		
		20% EP	25% EP	30% EP
EP+CO	Concrete debris	80%	75%	70%
EP+CR	Ceramic tiles	80%	75%	70%
EP+BL	Building block	80%	75%	70%
EP+NS	Natural Sand	80%	75%	70%
EP+RS	River Sand	80%	75%	70%

Test Procedures

Bulk density

This test was determined according to the ASTM C138 [16]. The bulk density was concluded by dividing the total mass of totally materials; (the sum of masses of the cement, the fine aggregate in the condition used, and any other solid or liquid materials used (Mass of concrete)), on the volume of the concrete.

$$\textbf{Bulk density } (g/cm^3) \quad \rho = m / v \quad ... (1)$$

Where: **ρ:** the density of concrete, **m:** mass of concrete, **v:** volume of the concrete

Compressive strength

The compressive strengths test was concluded according to B.S.1881, part 116 [12]. This test was made on 50 mm cubes using an electrical testing machine with a capacity of 2000 KN. The compressive strength of the sample was determined by dividing the maximum load applied on the samples during the test (to achieve the final failure) by the average cross - sectional area of the samples.

$$\textbf{Compressive } S = F / A \; ... (2)$$

Where: **F:** Force (N). **A:** Area (mm^2).

Splitting tensile strength

A concrete cylinder is placed with its horizontal axis between platens of a testing machine. The splitting tensile strength test was done according to ASTM C496-86 specification [13]. Cylinders were used and load was affected continuously up to failure using a standard testing machine of 2000 KN in capacity.

$$\textbf{Splitting } T\,S = 2P / \pi D L \; ... (3)$$

Where: **T:** splitting tensile strength (MPa). **P:** Max. Load (N). **D:** diameter (mm). **L:** length (mm).

Schmidt hammer test

This test was supplied out according to ASTM C 805 [14]. Cubic specimens with dimension of (50 mm) were used in this test. Compressive strength values of concrete were determined using the Schmidt hammer which is considered a non-destructive test. The major principle of this test is that it processes the re bound of anelastic mass when it collides with the concrete surface under the test. This rebound depends on the hardness of concrete and on the absorbed energy during the collision. The tested concrete specimen should be smooth and firmly supported. The hammer is pushed in contrast to the concrete, and then the mass indoor the hammer is rebounded since the plunger and takes a reading on the scale. This analysis is named rebound number which is the distance pass through by the mass stated as a percentage of the initial expansion of the spring. The rebound number is influenced by the energy lay up in the spring and on the size of the mass.

Flexural Strength

The flexural strength test was achieved on (40*40*160 mm) prism samples in agreement with ASTM C78-2003 [15] using SOIL TEST-VERSA tester hydraulic machine of 15 KN capacities. The prisms samples were exposed to center - point loading. Flexural strength can be determined by using the next equation:

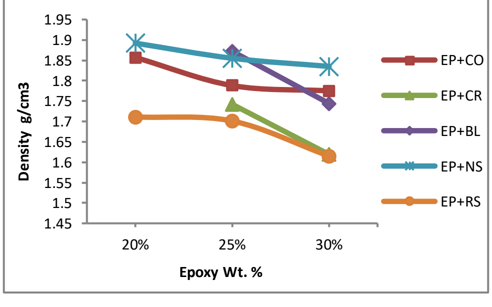
$$\textbf{Flexural S} = 3\,P\,L / 2\,b\,(d^2) \quad \ldots (4)$$

Where: **P:** applied load (N), **L:** span (mm), **b:** width of prism (mm), **d:** depth of prism (mm).

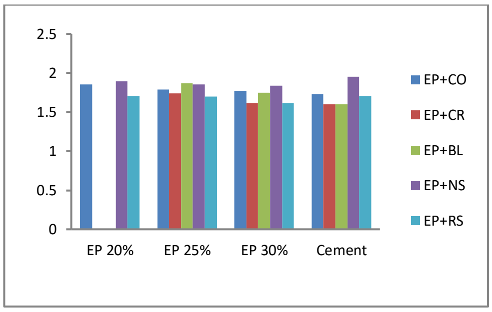
Results and Discussions

Bulk Density

Bulk density results are given in Figure (1A). This results show decreasing the values of bulk density with increasing the percentage of the added polymer resin to the all types of aggregates. It is observed that the minimum value of bulk density (1.615 g/cm^3) when the natural sand was used with weight ratio (70%). and epoxy resin of (30%), while the maximum value in the range of (1.892 g/cm^3). Due to increasing in the bonding material (epoxy resin), which is less dense than aggregates.



a



b

Figure 1 (A) Bulk density values as a function of weight percentages of EP polymer concrete and (B) the comparison of density values with Ordinary Portland cement (2:1) concrete.

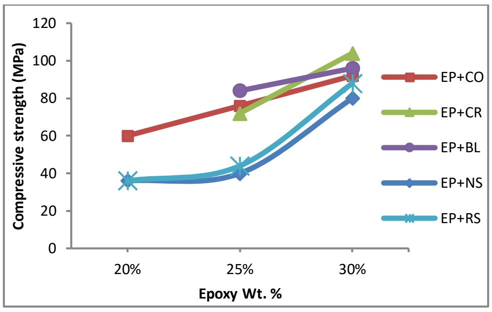
Compressive strength

Compressive strength results are given in Figure (2A). This results show increasing the values of Compressive strength with increasing the percentage of polymer resin were added to the all types of aggregates. It is clear that the maximum value of compressive strength equal to (104) MPa of (70%) ceramic waste and epoxy resin (30%). While the minimum value is (36) MPa when the river sand at (80%) was added. This minimum value can be considered high or good value compared with Portland cement concrete. The values of compressive strength are higher as compared as the samples prepared of ordinary Portland cement. It is found that the maximum value is (20) MPa when used natural sand by (2:1) ratio and (w/c) ratio is 35%. Figure (2B) illustrates this difference clearly.

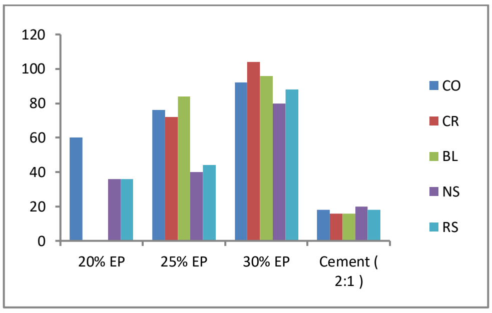
Splitting tensile strength

Splitting tensile strength results are given in Figure (3A). This results show increasing the values of splitting tensile strength with increasing the percentage of polymer resin added to the all types of aggregates.

It can be observed that the maximum value of splitting tensile strength at (30%) of epoxy and minimum value at (20%). This means that the increasing of added ratio of the polymer lead to increase the value of splitting tensile strength. Also, these values of splitting tensile strength are higher as compared as the samples made from ordinary Portland cement. It is observed that the maximum value is (0.3) MPa by mixing the cement with any of aggregate (concrete debris, ceramic tiles, and river sand) by (2:1) ratio and (w/c) ratio is 35%. Notice that in figure (3B).



a

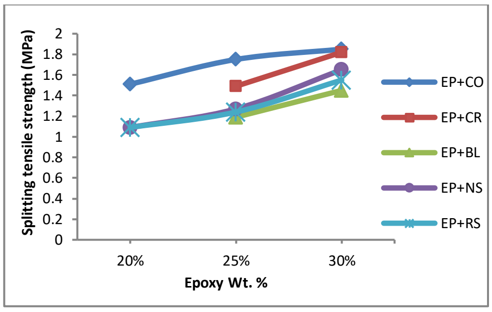


b

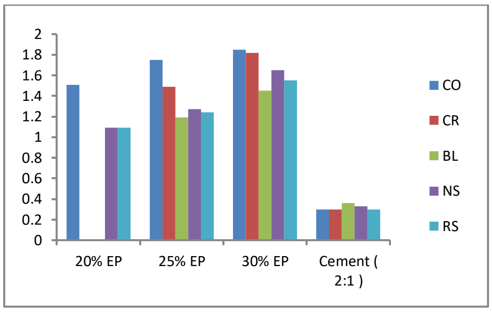
Figure 2 (A) Compressive strength values as a function of weight percentages of EP polymer concrete and (B) the comparison with ordinary Portland cement (2:1) concrete.

Flexural Strength

The flexural strength tests results are given in Figure (4A). This results show increasing the values of the flexural strength with increasing the percentage of polymer resins were added to the all types of aggregates, It is observed that the maximum value of flexural strength (29.288) MPa at (30%) of epoxy while minimum value at (20%). It can be noticed that these values of flexural strengths are high as compared as with samples are made of Ordinary Portland cement ware observed the maximum value is (7.82) MPa by mixing the cement with river sand by (2:1) ratio and (w/c) ratio is 35%. These values are distinguished in figure (4B).

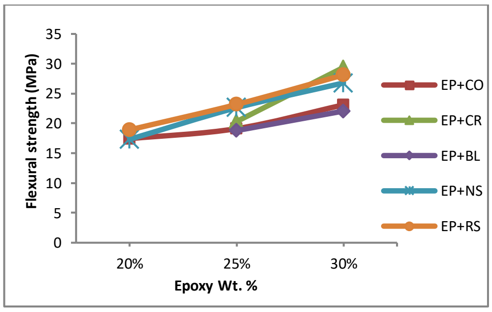


a

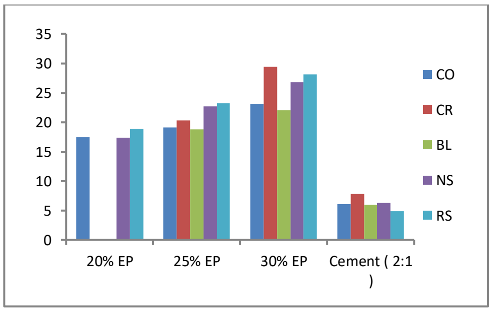


b

Figure 3 (A) Splitting tensile strength values as a function of weight percentages of EP polymer concrete and (B) the comparison with ordinary Portland cement (2:1) concrete.



a



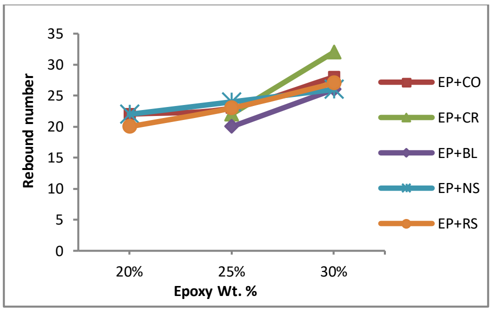
b

Figure 4 (A) Flexural strength values as a function of weight percentages of EP polymer concrete and (B) the comparison with ordinary Portland cement (2:1) concrete.

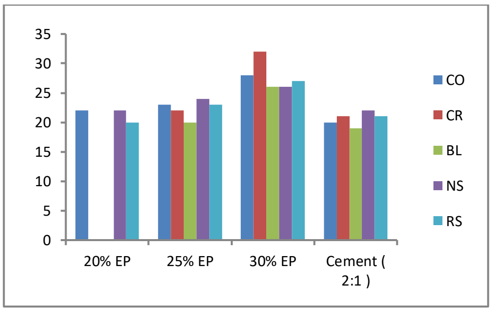
Schmidt hammer test

Schmidt hammer test results are given in Figure (5A). This results show increasing the val-

ues of the rebound number with increasing the percentage of polymer resin added to the all types of aggregates. It is obvious that in the maximum value of the rebound number is (32) at (30%) of epoxy while minimum value is (20) at (20%).
It can be noticed that the values of Schmidt hammer are high as compared as samples made of ordinary Portland cement as observed that the minimum value is (19) by mixing the cement with building blocks by (2:1) ratio and (w/c) ratio is 35%. Figure (5B) lists the rebound number of all samples.



a



b

Figure 5 (A) Schmidt hammer values (rebound No.) as a function of weight percentages of EP concrete and (B) the comparison with ordinary Portland cement (2:1) concrete.

In general, it can be concluded that all the properties of the specimens under work increasing with increase the weight percentage of added polymer. Because increasing in the bonding material, which make binds the aggregates with each other. And thus give greater strength.

Conclusions

In general, it is found that the polymer concrete (PC) produced from Epoxy (EP) has better properties than the other one which was prepared ordinary Portland cement. Bulk density results show decreasing the values with increasing the percentage of the added polymer resin for the all types of aggregates. The results of tests under work show increasing the values of these mechanical properties with increasing the percentage of polymer resin were added to the all types of aggregates. Also, it can be concluded that the prepared mortars could be used as precast have good properties with low cost.

References

[1] Methaa, P.K. “A Concrete Technology for Sustainable Development: An Overview of Essential Principles.” *CANMETs / ACI International Symposium on Concrete Technology for Sustainable Development*, Vancouver, 1999.
[2] Bjork, F. “Concrete Technology and Sustainable Development.” *CANMETs / ACI International Symposium on Concrete Technology for Sustainable Development*, Vancouver, 1999.
[3] Edvardsen, C., and K. Tollose. “Environmentally ‘Green’ Concrete Structures.” *Proceedings of the FIB Symposium: Concrete and Environment*, Berlin, October 2001.
[4] American Concrete Institutes Committee / 548, “Polymer concrete-structural applications. State-of-the-art report,” ACI Committee Report ACI / 548.6R-96, 1996.
[5] American Concrete Institute Committee, “Guide for the use of polymers in concrete,” ACI Committee Report ACI / 548 1R-09, 2009.
[6] American Concrete Institute Committee, “Guide for the use of polymers in concrete,” ACI Committee Report 548.1R-97, American Concrete Institute, 1997.
[7] M. Golestaneh, G. Amini, G. D. Najafpour, and M. A. Beygii, “Evaluation of mechanical strength of EP polymer concrete with silica powder as filler,”*World Applied Sciences Journal*, Vol. 9, No. 2, pp. 216–220, 2010.
[8] J. P. Gorninski, D. C. Dal Molin, and C. S. Kazmierczaki, “Study of the modulus of elasticity of polymer concrete compounds and comparative assessment of polymer concrete and portland cement concrete,” *Cement and Concrete Research*, vol. 34, no. 11, pp. 2091–2095, 2004.
[9] M. E. TawfikandS. B. Eskandeir, “Polymer concrete frommarble wastes and recycled poly(ethylene terephthalate),” *Journal of Elastomers and Plastics*, Vol. 38, No. 1, pp. 65–79, 2006.
[10] J. P. Gorninski, D. C. Dal Molin, and C. S. Kazmie rczak, “Strength degradation of polymer concrete in acidic environments,” *Cement and Concrete Composites*, Vol. 29, No. 8, pp. 637–645, 2007.
[11] J. T. San – Jos e, “Mechanical properties in resin polyester concrete, application to reinforced beams,” *Science and Engineering of Composite Materials*, Vol. 13, No. 4, pp. 271–282, 2006.

[12] B.S.1881, Part 116, "Method for Determination of Compressive Strength of Concrete Cubes", British Standard Institution, 1989, 3pp.
[13] ASTM C496 , “Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens“, Annual Book of ASTM Standard, Vol.04.02, 1989, pp., 259-262. USA
[14] ASTM C805–02,“Standard Test Method for Rebound Number of Hardened Concrete”, Annual Book of ASTM Standards, Vol. 04.02 Concrete and Aggregate, 2002, USA.
[15] ASTM C78 , “Standard Test Method for Flexural strength of Concrete (Using Simply Beam with Third point Loading,” Annual Book of ASTM Standard American Society for Testing and Materials, Vol. 04. 02, 2003. USA
[16] ASTM C138 , "Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete" Annual Book of ASTM Standards Vol. 04-02/2004. USA