Recycling the construction and demolition waste to produce polymer concrete

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Abstract. The sustainable management for solid wastes of the construction and demolition waste stimulates searching for safety applications for these wastes. The aim of this research is recycling of construction and demolition waste with some different types of polymeric resins to be used in manufacturing process of polymer mortar or polymer concrete, and studying their mechanical and physical properties, and also Specify how the values of compressive strength and the density are affected via the different parameters. In this research two types of construction and demolition waste were used as aggregates replacement (i.e. waste cement/concrete debris, and the waste blocks) while the two types of polymer resins (i.e. Unsaturated polyester and Epoxy) as cement replacements. The used weight percentages of the resins were changed within (1.5, 20, 25 and 30) % to manufacture this polymer concrete.

Keyword: polymer concrete, demolition waste, Unsaturated polyester, Epoxy.

1-Introduction
Concrete is a synthetic stone that is a mixture of water, admixture, binding material and additives. The world concrete commonly means Portland cement concrete (PCC), in that binder is Portland cement If the binder is synthetic resin of polymer, then we talk about synthetic resin polymer concrete (PC) (Now on the currently accepted term 'polymer concrete' is to be used) [1].

Polymer concrete (PC) is a comparatively young building material. It is primarily used for repairs, and for formation of sidewalks and wear-resistant stratum [2]. Research works in the literature [2] mostly test the properties of concrete purposed for given purposes. For enable the publishing of a new material, its mechanical and physical characteristics should be tested methodically. Many researches of several years aim to discover the characteristics of polymer concrete (PC) in detail, inclusive compressive strengths, flexural strengths, slow plasticity, fire resistance, and the relationship between concrete and concrete, and between polymer concrete and reinforcement rods.

The strengths and physical properties of polymer concrete mostly depend on the kinds of binder and admixture. In case of Portland cement concretes, standard strength is determined at 28 days [1]. It is also known that in case of cement concretes, strength is increasing continuously, and subsequent solidification can be observed even after 28 days of age. One of the most favorable properties of polymer concrete is extremely rapid strengthening, showing values approaching final strength as early at several days of age [4] [5]. However, there is no reference in the literature to long-term time-dependent rise in strength.
In situation of Portland cement concrete (PCC), the strength and physical characteristics of concrete are basically fixed by the state of affairs of production [1]. Decisive circumstances of production include temperature, and the duration of mixing and compaction. Previous study [3] to its the first objective is to get to know how the strength properties (compressive strength) of polymer concrete of a given composition change in function of time (from mixing to 90 days of age) while the second objective of it is to study how the strength properties (compressive strengths) of UP polymer concrete are influenced by the quality and duration of mixing and compaction. The current study aims to recycle the construction and demolition waste for using again to produce the polymer concrete after the mixing process with different polymeric resins in various weight ratios.

2-Materials

2.1. Epoxy

Sikadur-52 is a 2 parts, solvent free, low viscosity injection-liquids, based on high strength epoxy resins produced by (Sika yapim Kimyasallari A.S. Turkiye). Table (1) illustrates some mechanical and physical properties of epoxy resin.

This epoxy resin has kindly adhesion to the concrete, mortar, stone, steel and wood. Sikadur-52 is applied to fill and seal voids and cracks in structures, for example bridges and another civil engineering building, industrial and indoor buildings, e.g. columns, beams, ground, walls, floors and water keep structures. It not only forms an influential barrier against water sweating and corrosion strengthen media, but it also Structural aspect bonds the concrete Parts together.

| Mechanical & Physical prop. of epoxy |  |
|-------------------------------------|--|
| Density                             | 1.0850 g/cm$^3$ at 20 °C |
| Compressive strength                | 52 MPa after 7 days at 23°C |
| Flexural strength                   | 61 MPa After 7 days at 23°C |
| Tensile strength                    | 37 MPa After 7 days at 23°C |
| E-Modules                           | Flexural strength 1800 MPa after 7 days at 23°C |
| Thermal expansion coefficient       | 8.9×10^{-5} °C^{-1} from -20 °C to 40°C |

2.2. Polyester

Unsaturated polyester (UPE) resins are the most usually used for the composites industry. Polyester resins have a good equilibrium of mechanical, electrical and chemical characteristics. Unsaturated polyester resin it was used in this research is produced by K.S.A. Typical the properties of the unsaturated polyester resin are described in Table (2) and (3).

| physical properties of unsaturated polyester |  |
|---------------------------------------------|--|
| Density                                     | 1.9-2.0 kg/dm$^3$ At +25 °C |
| Percentage of Styrene                       | 22 % At +25 °C |
| Viscosity                                   | 1000 mPa . s At +25 °C |
| Color                                       | Purple At +25 °C |
| Specific weight                             | 1.15 At +25 °C |
| Hardener time                               | 6 minutes At +25 °C |
Table 3. Show mechanical properties of unsaturated polyester

| Mechanical properties of unsaturated polyester | Units       |
|----------------------------------------------|-------------|
| Dry value | Weigh value | UNITS |
| Tensile strength | 91.5 | 88.3 | N/mm² |
| Tensile modulus | 9.30 | 7.71 | KN/mm² |
| Flexural strength | 176 | 164 | N/mm² |
| Flexural modulus | 7.38 | 6.59 | KN/mm² |
| Glass contain | 27.4 | ------ | % |

The polyester resin has good chemical resistance characteristics. The chemical environment has to be well-known before polyester or vinylester resin can be selected. Polyester resins are suitable in weak alkalies and excellent in weak acid environments.

2.3. Sand

AL-Ukhaider natural sand was used throughout this work. The physical properties of aggregate according to Limits of the Iraqi Specification No.45/1984 illustrated in Table 4.

Table 4. Show Physical properties of sand.

| density | Sulfate content % | Absorption % | Thermal conductivity |
|---------|-------------------|--------------|----------------------|
| 2.65 g/cm³ | 0.2              | 0.6          | 0.7766 (W/m.K)       |

2.4. Construction and Demolition waste

- Waste cement/concrete debris
- Waste blocks. Show in figure (1).

Figure 1. Show Construction and Demolition waste (A) waste cement/concrete debris (B) waste blocks
Some processes were made on this aggregate such as crushing, grinding, sieving, before mixing with polymeric resin as binder. Table (5) shows some properties of these two types of aggregates.

| Samples         | Loose bulk density g/cm³ | Specific gravity | Percentage of voids % |
|-----------------|--------------------------|-----------------|-----------------------|
| Waste Blocks    | 0.995                    | 1.255           | 0.207                 |
| Waste Cement    | 1.209                    | 1.522           | 0.205                 |

3-Experimental Work

3.1. Mixing of Concrete
For preparing the polymer concrete (PC), a dry mixing had been done for both two types of aggregate for 3 minutes and then the unsaturated polyester resin (UP) or epoxy (EP) were added to the mixture after mixing with the hardener with weight ratio 0.01% for (UP) and (2:1) for (EP).

3.2. Casting and Curing of the Specimens
Before casting, the molds were carefully oiled to be ready for casting the fresh concrete. The polymer concrete was cast in 3 layers for all samples, respectively layer was compacted by a rod then all samples were wet-cured at room temperature and removed the molds after one day.

Figure 2. Show the samples
Table 6. Show the prepared samples (1)

| Samples | Aggregates                        | Polymer resin | Percentage of resin |
|---------|-----------------------------------|---------------|---------------------|
| SCEP    | N. sand + concrete Debris         | Epoxy         | 20 %                |
| SWEP    | N. sand + waste Blocks            | Epoxy         | 15 %                |

Table 7. Show the prepared samples (2)

| Samples | Aggregates                        | Polymer resin       | Percentage of resin |
|---------|-----------------------------------|---------------------|---------------------|
| SCUP    | N. sand + concrete Debris N: natural | Unsaturated polyester | 30 %                |
| SWUP    | N. sand + waste Blocks            | Unsaturated polyester | 25 %                |

4-Test Procedures

4.1. Compressive strength
The compressive strengths test was calculated consistent with B.S.1881, part 116 [6]. This test was made on 50 mm³ cubes using an electrical testing machine with measurements of 2000 kN. The compressive strengths of the samples were calculated by applying the equation 1.

\[
\text{Compressive strength} = \frac{F}{A} \quad (1)
\]

\(C\) = Compressive strengths in (MPa).
\(F\) = The maximum load up to failure in (N).
\(A\) = Initial cross sectional area of specimens in (mm²).

4.2. Bulk Density
This test was calculated consistent with the ASTM C138 [7]. Where the density was calculated by dividing the total mass of all materials. The bulk density was calculated by applying equation (2)

\[
\text{Bulk density} = \frac{M}{V} \quad (2)
\]

\(\rho\) = Bulk density in (g/cm³), \(M\) = Mass in (g) and \(V\) = Volume in (cm³).
5-Results and Discussions

5.1. Bulk Density
The density of case-hardened concrete is a responsibility of the densities of the initial components, mix quantities, initial and final water contented, air contented, degree of consolidation, degree of hydration, volume variations, and consequent gain or loss of water, amongst additional factors.

Dependence on these operators creates density an effective indicator of the homogeneousness of raw materials, mixing, batching, placing, sampling, and testing. Table (8) shows the bulk density values of various types of concrete before curing.

| Samples | Percentage of resin | Density | Unit |
|---------|---------------------|---------|------|
| SCUP    | 30 %                | 1.748   | g/cm³ |
| SWUP    | 25 %                | 1.854   | g/cm³ |
| SCEP    | 20 %                | 1.934   | g/cm³ |
| SWEP    | 15 %                | 1.642   | g/cm³ |

5.2. Compressive strength
Compressive strengths test the most important characteristic of concrete subsequently the first consideration in structural design, is that the structural components must be capable of transport the imposed loads. Table (9) shows the Compressive strength values of various types of concrete before curing.

| Sample | Percentage of resin | Compressive strength | Unit |
|--------|---------------------|----------------------|------|
| SCUP   | 30 %                | 80.48                | MPa  |
| SWUP   | 25 %                | 132.55               | MPa  |
| SCEP   | 20 %                | 121.93               | MPa  |
| SWEP   | 15 %                | 56.65                | MPa  |

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