

# **Mechanical properties of polymeric concrete produced by resin epoxy and light or natural aggregates**

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## **Abstract**

The use of lightweight concrete, beside benefits such as reducing the dead load and seismic force, has disadvantages such as high void and low compressive strength. One of the best ways to improve concrete strength is the use of epoxy polymer. In contrast with the positive properties of epoxy such as anti-abrasion, high adhesion, low slump, low processing time, resistance to moisture and high viscosity, negative properties such as fractures and low fracture strength, made this material to be used with fibers glass, plastic particles, etc. to increase the flexibility properties. This study compares the mechanical properties of lightweight concrete with the use of binder cement and polymeric concrete. Thus the addition of resin epoxy to improve the mechanical properties of concrete is investigated. The results show that among variables (resin, filler and aggregates), resin (up to 20% by weight of concrete) were more effective in increasing the compressive strength of concrete. Filler and aggregates also improve the compressive strength of concrete.

**Keywords:** epoxy, mixing design, compressive strength, specific gravity.

## ***1- Introduction***

However use of lightweight concrete made with portland cement is important because of good physical properties and low cost but it has so many defects including low bending strength, low failure strain, probability of freezing injury and low chemical resistance. These weaknesses of lightweight concrete can be raised by applying resin polymer. Polymers that are essentially synthetic plastic materials and are in organic category, can create an interconnected network within the concrete, fill the internal voids and reduce the concrete permeability greatly. Durability of such concrete is very good against environmental damaging factors, continuous freezing - melting and attack of chemical materials[1, 2, 3].

### ***1-1- Modification methods of concrete with polymer***

Polymeric materials can be used in concrete with three different methods, the concrete produced in each mode is called as follows:

#### **A - Polymeric impregnated concrete (pic)**

Usually polymeric impregnated concrete is a prefabricated concrete that after complete drying, is saturated with a low viscosity monomer. In situ polymerization of the monomers, fill concrete's voids and form an interconnected network. Saturating concrete with polymer improves the strength and durability of concrete significantly. For structural members of reinforced concrete and sizeable concrete members, sometimes polymer is sprayed onto the concrete surface.

The main application of PIC is in sewer pipes, sea water storage tanks, distillation workshops, wall panels, tunnel covering and swimming pools

#### **B - Polymeric cement concrete (PCC)**

Polymeric cement concrete is made of cement that polymeric materials has been added to it. Also this concrete has better mechanical properties and better resistance against penetration of water and salt and freezing -melting cycles. In addition this concrete has a very good adhesion to rebar and old concrete.

The main applications of concrete with polymeric cement is in structure floor, bridge deck road cover and repair of concrete structures. Also, due to the good adhesion properties it is appropriate for installation of prefabricated panels, porcelain stone and ceramic.

#### **C - Polymeric concrete (PC)**

Polymeric concrete that is called resin concrete plastic or resin concrete has been composed of an adhesive and mineral filler material such as sand or gravel. Since in this concrete a polymeric material replaces cement completely, it increases the concrete price considerably. Thus the application of this concrete will be appropriate where prices rise be justifiable because of its good qualities, a reduction in labor costs or reductions in required energy during the construction and maintenance of the concrete.

Polymeric concrete has a very good resistance against chemical ions attack and other corrosive factors and have very low water absorption property, abrasion resistance and good stability against freezing - melting cycles. Also high resistance of polymeric concrete compared with conventional concrete, sometimes leads to lower usage of materials about 50 %. It should be noted that in making up concrete with polymeric materials, different types of resins are used including polyester resins, vinyl ester resins, epoxy resins and phenolic resins. Polyester resin are made of reaction of one or more several criteria acids and alkali. These resins are dissolved in a solvent, such as styrene to reduce their viscosity and form three-dimensional networks.

Because of elastic cohesion of polymer that leads to the high creep values, polymeric concrete has no applications in structural work and its further use is for construction of prefabricated concrete components. Methods of polymeric concrete mixing and its required equipment, is similar to conventional concrete. Their catalysts are organic peroxides. Polyester resins has two general types, Iso and Ortho resins. High temperature and exposure to light reduces their life. Baking polyester resins with 2% catalyst is insensible, so add them catalyst. Vinyl ester resin is produced of reaction of unsaturated carboxylic and a unit of epoxy resin. These resins have a lot of epoxies' properties, but such as polyesters are processed. Double bonds were at the end of line leads polymers to be linear with high flexibility. Properties of epoxy resin are good mechanical and electrical properties, high heat resistance, excellent adhesion to many materials such as metal, wood, concrete, glass and ... Good resistance especially in the alkaline environment and low condensation after baking. Resin concrete comprises a cohesive polymer that may be thermoplastic, but more often is a thermosetting polymer and an mineral filler such as sand, gravel or broken stone. There are three types of polymer composite materials that are: injecting polymer, polymer - cement concrete, polymeric concrete. PC or polymeric concretes are composite materials that their all

coherency are synthetic polymers that their different forms such as synthetic resins concrete, plastic resin concrete, or simple resin concrete are known. Due to the use of polymers instead of portland cement, the price will increase considerably. There are other fillers for polymeric concrete that broken stones, limestone, gypsum, siLECA dust, granite, quartz, clay, foam glass (cellular glass), metal aggregates and generally any dry, solid and waterproof material can be used as filler. In PC production, a monomer with a polymer, a hardener and catalyst are mixed with fillers. Other added materials to the mixture include of plasticizers and fireproof, and sometimes increases additives for increasing bond resistance between polymeric mortar and fillers. To achieve full performance, polymeric concrete products for specific uses, various reinforcing fibers are used. These fibers include glass fibers, glass wool, steel fibers and wired networks. Charisma time and time of maximum strength in the PC can be changed from minutes to several hours by a small change in temperature or catalyst system. The amount of used cohesive polymer generally is low and usually is determined by size of filler, This amount in normal polymeric concrete is 5 to 15 percent of the total weight, but if filling were fine more than 30 percent may be necessary [1, 4] .

### ***1-2 - AppLECAtion of polymeric concrete:***

Most appLECAtions of polymeric concrete according to the cost is as follows:

Bridges and roads pavement, maintenance, building structures that are subjected to corrosion, industrial sport floor pavement, and producing artificial and decorative panels on residential and office spaces, concrete sealant, construction of underground structures such as industrial sewerage (corrosion resistant), making required trough in stables (resistant against ammonia materials and cheaper than ceramic products), making sculptures, vases and other decorative architectural forms similar to rock, making chemical storage tanks, marine environmental structures, overflow dam construction, wall sealing dams, tunnels' walls and ...

## ***2 - Research methods***

In this study, two types of polymeric concrete and lightweight concrete are maded that test methods, materials used and the results obtained are described in the following:

### ***2-1 - Materials used to make lightweight concrete***

- Cement: cement used in the production of samples is portland cement type I of Kerman Momtazan cement plant.
- Aggregate: consumed aggregate is kind of dark brown LECA manufactured in perlite plant with density of 0.6 grams per cubic centimeter.
- Water: Kerman. Drinkable water

### ***2-2 - Materials used for the production of polymeric concrete***

- Resin: epoxy resin used with a specific gravity of 1.15 grams per cubic centimeter and a charisma time of 1 hour was chosen.
- Aggregate, the same material used to make lightweight concrete.
- Filler: ash with density of 2.7 grams per cubic centimeter.
- Water: Kerman. Drinkable water

### 2-3 - Lab mixing design

Mixing design used in this study are divided into two part:

- mixing design of cement, LECA and water with volume ratios described in table 1
- mixing design of resin, LECA and filler volume ratios described in tables 2, 3 and 4

For production of lightweight concrete, in the first mixing design, amounts of water and cement volume were kept constant and changes were performed on the LECA volume. And for production of polymeric concrete in the second mixing design volume of filler and resin used LECA is changed.

Because resin concrete creep rate is higher compared to normal concrete curing, polymer saps used for resin hardening. Due to water absorption of aggregate, making them wet to be fully saturated after that let their surface to become dry then they will be used in making concrete. Specimens are processing in water at 24 ° At the age of 28 days compressive strength of concrete specimens were tested and polymeric concrete specimens according to ASTM were tested after 7 days.

In the following, the volume of used materials in the concrete is shown in the table and the compressive strength of related samples is shown in the graph.

Table 1: concrete mixing design style

Design code	Ratio of water to cement	Cement volume ratio	LECA volume ratio
Lc1	0.4	1	1
Lc2	0.4	1	1.5
Lc3	0.4	1	2

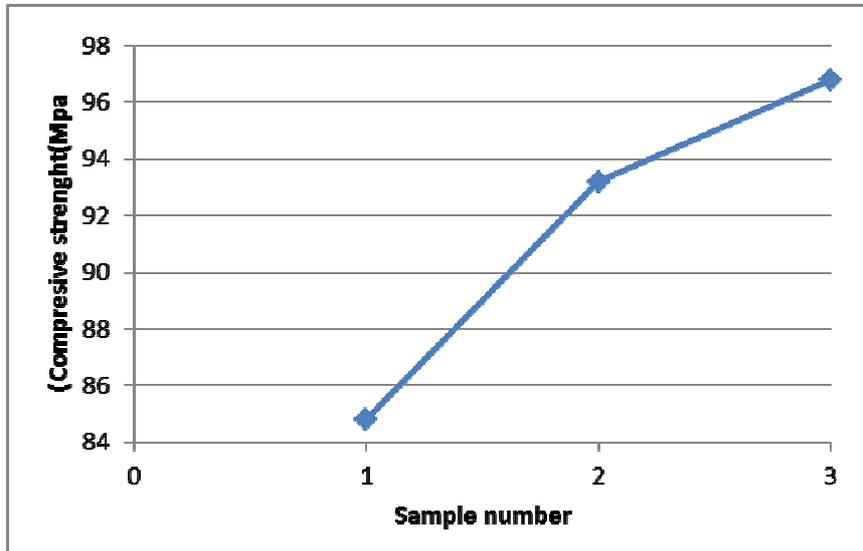


Figure 1: results of 28-day compressive strength testing of concrete samples

Table 2 - polymeric concrete mixing design pc (aggregates percentage change)

Design code	Filler volume ratio	LECA volume ratio	Resin
Pc1	1	1	10% concrete mass
Pc2	1	1.5	10% concrete mass
Pc3	1	2	10% concrete mass

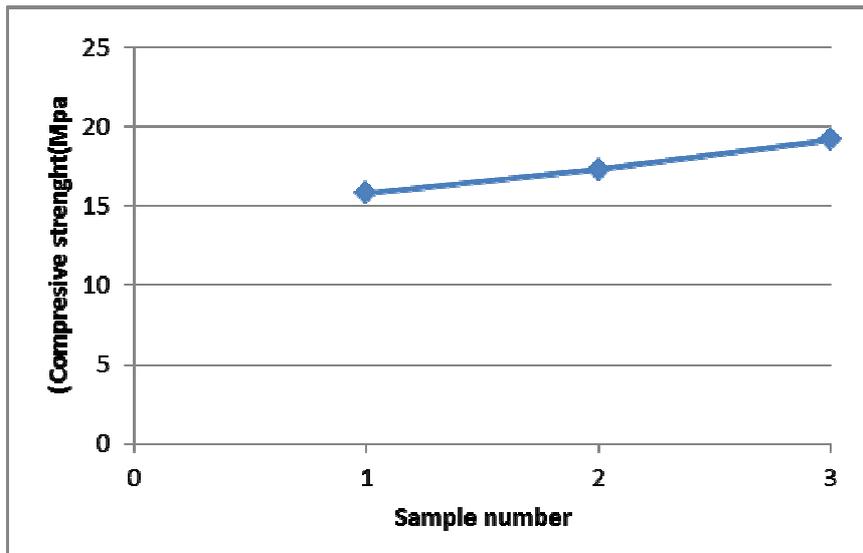


Figure 2 – 7 day compressive strength test results of polymeric concrete samples (aggregates percentage change)

Table 3 - polymer concrete mixing design pc (change of filler)

Design code	Filler volume ratio	LECA volume ratio	Resin
Pc10	1	1	10% concrete mass
Pc20	1.5	1	10% concrete mass
Pc30	2	1	10% concrete mass

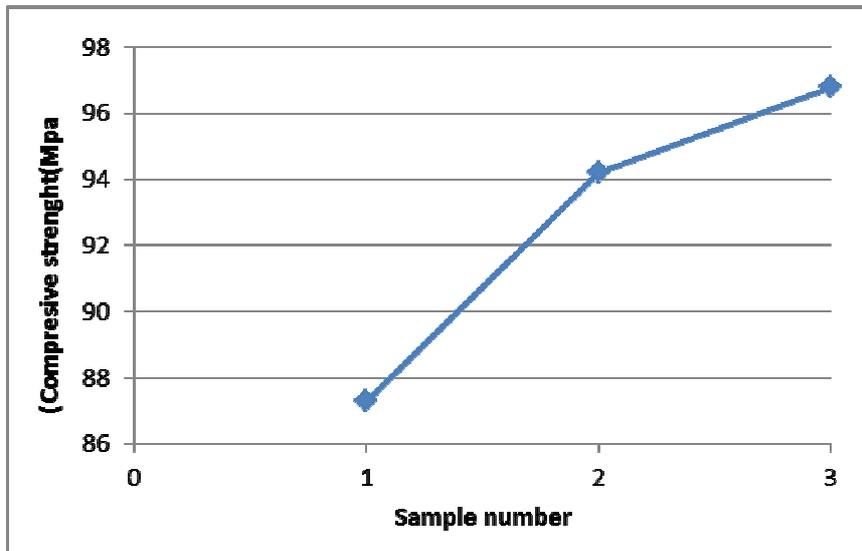


Figure 3 – 7 day compressive strength test results of polymeric concrete samples (change of filler)

Table 4: polymer concrete mix design pc (change in percent resin)

Design code	Filler volume ratio	LECA volume ratio	Resin
Pc100	1	1	10% concrete mass
Pc200	1	1	20% concrete mass
Pc300	1	1	30% concrete mass

Experiment of polymeric concrete with resin percentage changing is remarkable. Percentage changing of resin to about 20% cause increasing in compressive strength of concrete up to 114 MPA, but as resin increased concrete, compressive strength decreased more than 30% to about 95 MPA.

### 3- Conclusions

Comparison of mechanical properties (compressive strength) of two types of polymeric concrete (PC) shows that the addition of epoxy resin to concrete, after 7 days compressive strength, corresponds to 5 times the initial strength. With the addition of light aggregate to polymeric concrete, the compressive strength increases, and the effect of changing the amount of filler and fixing amount of resin and light aggregate is to increase the compressive strength further. In other words, the addition of filler is more effective in increasing the compressive strength than light aggregate. Polymeric concrete (resin) are more expensive than cement concrete with normal portland.

Thus polymer can be used only in exceptional cases where good properties, lower wage costs or lower energy during processing and transmission of the concrete be justifiable despite of high prices.

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