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Characterisation of polymer concrete with epoxy polyurethane acryl matrix

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HIGHLIGHTS

- Polymer concrete was obtained from resin type epoxy polyurethane acryl and aggregates.
- EPUAC is lightweight composite, with a high thermal and durability performances.
- Mechanical properties of EPUAC are comparable with that of polyester concrete.

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ABSTRACT

This paper studies a new type of polymer concrete obtained using epoxy polyurethane acryl and aggregates. Mechanical properties, such as: compressive strength, flexural strength, elasticity modulus, pull-out stress and adherence stress between cement concrete and polymer concrete were experimentally determined. Thermo-physical properties, such as: bulk density in natural and dry state, relative and absolute mass humidity, thermal conductivity, linear thermal dilatation, thermal shock strength, chemical resistance, frost-thaw resistance and water adsorption resistance were studied to establish the durability properties of the epoxy polyurethane acryl concrete. The experimental results have shown that epoxy polyurethane acryl concrete is a high performance, lightweight concrete with properties that recommend it as a possible replacement material for classical building materials.

1. Introduction

Polymer concrete is a relatively new high performance material, which has widespread applications due to its advantages in comparison with cement concrete [1–6]. Among the advantages offered by polymer concretes are: excellent mechanical strength, fast curing time, very good adhesion properties, resistance to abrasion and weathering, waterproofness and good sound and thermal insulation properties [7–13]. There are numerous domains for the use of polymer concrete, such as the production of precast members; in hydraulic structures, such as dams, dikes, reservoirs and piers; highway surfaces and bridge decks; as well as in the petrochemical industry, underground constructions, road surfaces and coating or repairs materials in the chemical and food industry [2,10,14]. In preparing mortars or concretes, different types of polymers are used, such as polyester, epoxy, furan, vinyl, rubber, phenol and acrylic resins [15–17]. Laws limiting styrene emissions will influence the developments in unsaturated polyesters [15]. High strength epoxy resin-based polymer concretes have the biggest cost and are used in limited domains. New types of polymer developed for the concrete industry are intended to optimise the ratio of cost and performance [18,19]. Epoxy-urethane acryl [20–23] is an important polymer with improved properties: high strength to abrasion, flexibility, elasticity, adsorption of shocks and good resistance in the environment. Polyurethanes have the advantage of low viscosity, good matrix bonding, a small reaction time and low cost. Polyurethane acryl adds the optical and durability properties of poly-acryl to polyurethane. The oligomer epoxy polyurethane acryl is 100% reactive and does not require solvent evaporation or special equipment for the recovery of solvent and thus, environment pollution and impact on the workers are minimised. The use of polyurethane acryl in the building material industry contributes in providing new advanced composites.

The objective of this study is to establish the performance of a new polymer composite using epoxy-polyurethane acryl and aggregate, in order to determine its applicability as a building material.

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2. Experimental program

2.1. Materials

2.1.1. Polymer

The polymer type epoxy polyurethane acryl and the hardener were obtained from the laboratory of "Petru Poni" Chemical Research Institute from Iasi, the methods of preparation are given in author's articles and are not presented in this paper [20–25].

For preparing epoxy polyurethane acryl concrete (EPUAC), a quantity of 70% aggregates and 30% polymer are necessary for the homogeneity of mix and workability. Previous studies on polyester resin concrete using the same type of aggregates established this mix [26].

2.1.2. Aggregate

The aggregate type was crushed granite from a quarry having a density of 2400 kg/m^3. In the mixture, the proportion of aggregates was 70% in equal dosages of two sorts: 0–1 mm and 1–3 mm.

2.2. Preparation of polymer concrete

The samples were prepared in two stages: first, the two sorts of aggregates were mixed, following which the aggregate mix was placed into moulds and the moulds filled with resin. A vibration table realised the compaction of the mixes. Different types of samples were used for testing according to the standards. After pouring, the samples of EPUAC were kept for 21 days until testing.

2.3. Experimental tests

2.3.1. Mechanical tests

- *Compressive strength.* Five 70 mm sized cubes were tested in axial compression according to SR EN 12390-3:2002 [27].
- *Flexural strength.* The tests were performed according to SR EN 12390-5:2002 [28], Fig. 1 on five prisms of 70 × 70 × 210 mm.
- *Elasticity modulus.* For determining the elasticity modulus, three samples of 25 × 25 × 80 mm were used (according to STAS 5585-71 [29]). The computational equation is:

$$E = \Delta_\sigma/\Delta_\varepsilon\ (N/mm2) \quad (1)$$

- *Maximum pull-out stress for a plain bar, Φ* = 16 mm. The tests were realised according to STAS 5511-1989 [30]. Three 70 mm cubic samples were tested, (Fig. 2a–c).
- *The adherence stress between cement concrete and polyurethane acryl concrete.* The tests were done according to a method conceived by the Research Institute in Construction INCD URBAN INCERC from Iasi–Romania, on three samples, Fig. 3a–d; the samples were simply supported and loaded with a concentrated load mid-span and tested in flexure. The cross section had the dimensions: width b = 70 mm and depth h = 60 mm. The failure is produced at the contact zone between the cement concrete and polyurethane acryl concrete.

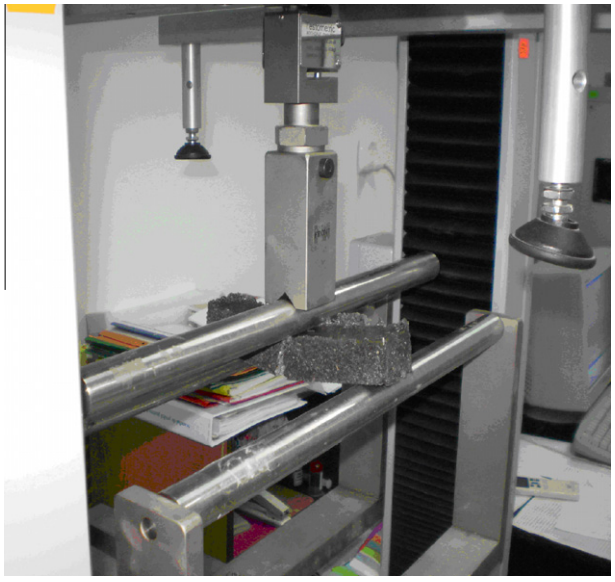

Fig. 1. Polyurethane acryl concrete sample tested in flexure.

2.3.2. Thermo-physical tests

- *Bulk density in natural and dry state.* The tests were done according to SR EN 771-3:2004 [31] and SR EN 772-13:2001 [32] on five samples with dimensions: L = 244.4–246.4 mm; l = 244.8–245.6 mm; d = 34.9–35.9 mm.
- *Relative and absolute mass humidity.* For testing according to SR EN 771-3:2004 [31], SR EN 772-10:2001 [32], five samples of the same size as in the case of density test were used.
- *Thermal conductivity.* The test was done according to STAS 5912-89 [34] using the method of one sample body. The samples had the same sizes as in the case of density test. According to standard, the sample was maintained at a temperature of 105 °C until constant mass. After that, the sample was introduced to a conductivity-device, equipped with measuring sensors that determine the thermal flux density, which crosses the sample from the top to the bottom in the central zone.
- *Linear thermal dilatation.* The experimental tests were done according to SR EN ISO 10545-8:2000 [35] on six samples with dimensions: L = 61.5–64.0 mm; $b \times h$ = 10 × 10 mm. The samples were dried at a constant temperature (110 ± 5 °C) until constant mass and then were introduced to a desiccator for cooling at ambient temperature. The initial length of the sample was measured and again at each temperature interval of 15 °C. The heating rate was 5 ± 1 °C/min.

The coefficient of linear thermal dilatation α_l was calculated according to the relation:

$$\alpha_l = (1/L + 0)x(\Delta L/\Delta t) \quad (2)$$

where L is the sample length at ambient temperature, mm; ΔL is the increase in length of sample between ambient temperature and 100 °C mm; and Δt is the increase of temperature, °C.

- *Thermal shock strength.* The test was done according to SR EN ISO 10545-9:2000 [36] using the method of immersion. Five samples were used having the dimensions: L = 11.95–12.00 mm; l = 3.32–3.52; h = 10 mm.
- *Chemical resistance.* The tests were done according to SR EN ISO 10545-13:2001 [37] on five prismatic samples, having an initial mass between: 26.716 and 45.842 g, Fig. 4.

For the tests the following solutions were used:

(a) Solution of hydrochloric acid 3% (volumetric percentage).
(b) Solution of hydrochloric acid 18% (volumetric percentage).
(c) Solution of potassium hydroxide (KOH), 30 g/L.
(d) Solution of potassium hydroxide (KOH), 100 g/L.

The samples were immersed in the solutions and kept in the laboratory for 12 days at a temperature of 20 ± 2°, Fig. 4. After that, the samples were exposed to stream for 5 days and were then boiled for 30 min. Following this, the samples were recovered, wiped and dried to a constant mass in an oven at 110 °C. Once dry, the samples were weighed and the loss of mass Δm, was determined. This then allowed the determination of the chemical resistance class- CRC-according to SR EN ISO 10545-13:2001 [37].

- *Frost-thaw resistance.* The tests were done according to SR EN ISO 772-18:2003 [38] on nine samples with dimensions: L = 34–38 mm; l = 32–34; h = 33–36 mm.
- *Water adsorption.* The tests were carried out according to SR EN ISO 10545-3:1999 [39] on three prismatic samples with an initial mass between: 124.123 and 137.552 g. The water adsorption of the samples by boiling in water at 100 °C for 2 h and then cooling in water for a further 2 h and 15 min was a hardness test for EPUAC.
- *Microstructure of polymer concrete.* A scanning electron microscope (SEM) Vega Tescan analysis running at 30 kV and selenium detectors were used to investigate the particle's morphology. An Ag sputter coating on the surface of the specimens provided a greater depth of image.

3. Results and discussion

The mechanical and thermo-physical properties determined on EPUAC are presented in the following tables. For a better characterisation of EPUAC, the results were compared with the experimental data obtained in previous studies on polyester concrete (PEC) [26], which has a similar composition to EPUAC.