

## Polimer concrete with dispersive reinforcement

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**Annotation:** Polymer concrete is a concrete that uses polybutadiene, a polymer from the liquid rubber family, as a binder, so that it has elastic properties and is extremely resistant to aggressive chemicals, high water repellency and high compressive strength. It does not reveal the destruction typical for ordinary concrete, such as cracking and peeling. It has a high electrical resistance, increased mechanical compressive and tensile strength. In addition, polymer concrete is a durable material with water-repellent properties and resistance to aggressive chemical environments.

The proposed polymer concrete uses a conventional aggregate, which is used to produce ordinary concrete, but a polymer is used as a binder. Also, the usage of non-metal composite reinforcement is proposed (APP patent No. 16983646).

Below are the results of testing samples with three types of dispersed reinforcement.

**Keywords:** polymer concrete, rubber concrete, composites, fittings, manufacturing methods, testing.

### What is polymer concrete and its main properties

The proposed polymer concrete does a US patent [1-3] protect a rubber concrete. Rubber concrete is the world's first polymer concrete, where not epoxy, polyester or furan resin is used as a binder, but liquid rubber (polybutadiene). Such concrete has a compressive strength of up to 90 MPa and a tensile strength of up to 30 MPa. (Which is especially important, since this tensile strength is significantly superior to the tensile strength of conventional Portland cement concrete).

Water absorption of polymer concrete does not exceed 0.06%. Polymer concrete has high chemical resistance, both in alkalis and in acids. Actually, the polymer concrete binder itself can be used as an independent, chemically highly resistant, protective coating with high adhesion to steel (up to 11.5 MPa at separation) and workable up to a temperature of 95° C (tables in the appendix).

For the first time, Acad. Oleg Figovsky in the USSR (USSR author's certificate 1025692 (1981) [4]) proposed polymer concrete based on liquid polybutadiene rubber.

Later research was carried out over the next 30 years at the Voronezh Technological State University [5-7]. Russian patent RU\_2135426, 07/08/1998 issued [8,9].

### **The main properties of rubber-polymer concrete in comparison with other concretes.**

- Modules of elasticity  $2,0-2,7 \text{ MPa} \cdot 10^4$  , which is about twice as low as regular concrete in the same circular.
- Will not crack in loads.
- Good adhesion.
- Small water absorption (about 0.05-0.06%)
- High coefficient of chemical resistance (based on 360 days of exposure): Salt water 1.00-1.05; about 0.95-0.98 for  $\text{H}_2\text{SO}_4$ , Lactic acid, Caustic potash.
- High electric resistance (more than  $10^9 \text{ Ohm/cm}$ )

### **Possible and existing uses**

Polymer concrete is more flexible, therefore also more stable to dynamic loads. So it allows the use of in buildings with dynamic loads. See below the results of the experiments from 2021. Polymer concrete sleepers (high dynamic loads and vibration) – see also results of testing.

Polymer concrete may be used for new construction or repairing of old concrete, nuclear industry, burial of nuclear sawdust, electrical construction. High chemical resistance makes it suitable for uses in sewage systems and structures in seawater

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(sewage pipes, communication channels etc.), coating floors and roads [10, 11]. In For example, in Israel Company BM GROUP used polymers for channels and pipes.

### **Composition of model materials for experiments**

The following materials were used in the work: rubber SKDN-N; technical sulfur; vulcanization accelerator - tetramethylthiuram disulfide (Thiuram-D); vulcanization activator - zinc oxide ZnO; calcium oxide CaO; finely ground mineral filler; metal or polypropylene fibers; sand; crushed granite.

For testing, samples-prisms  $40 \times 40 \times 160$  mm in size of three types of dispersed reinforcement with fibers were prepared: metal (40/0.8 mm), brass (15/0.3 mm), polypropylene (12/0.12 mm) and without reinforcement. When testing samples under compression and tension (on a machine certified in the established order), strain gauges were glued on opposite faces on the prism samples to remove longitudinal and transverse deformations that occur in the sample when a short-term compressive load is applied.

The figure shows the tensors on the samples installed before testing.

Samples were prepared before testing. It was checked that the surface of the samples was even, smooth, without pits, cracks and other defects, and the ends of the samples were perpendicular to their longitudinal axis.

The load was applied in steps of 10% of the expected breaking load, at a constant rate, not more than 1 MPa/s.

### **Bending tests**

The bending testing machine shall have a loading range up to 10 kN with an accuracy of  $\pm 1.0\%$  of the applied force and a specimen loading rate of  $50 \pm 10$  N/s.

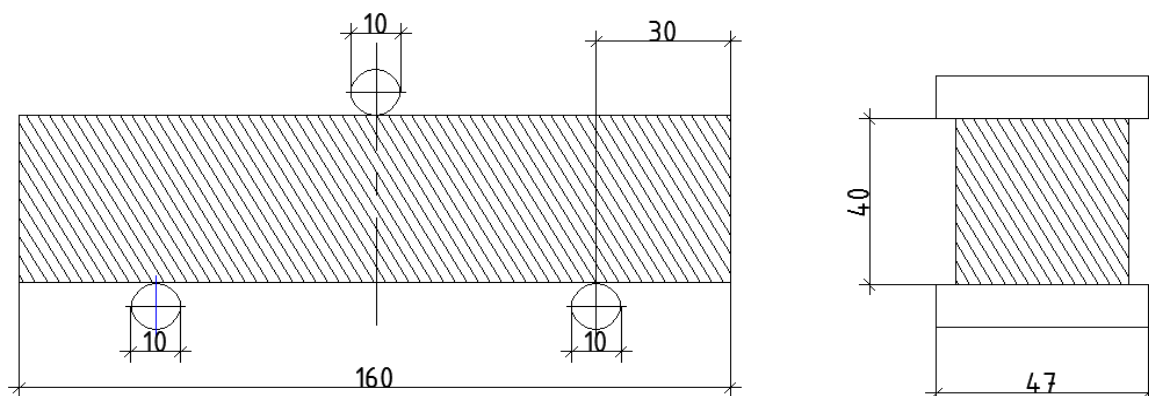
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**Figure 1** : Scheme of installation of strain gauges for testing specimens for compression

When loading the specimens, the supports and the upper part should have a round shape with a diameter of  $10.0 \pm 0.5$  mm, and the distance between the lower supports should be  $100 \pm 0.5$  mm. The length of the supporting elements is from 45 to 50 mm.

Schematically, the loading of the sample when determining the bending strength is carried out according to the above scheme (Figure 2):



**Figure 2** : Scheme of the sample on the supporting elements



**Figure 3:** General view of the test

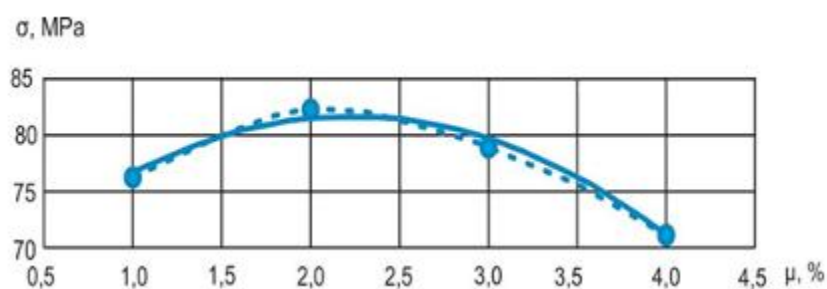
Sample beams were tested on a set of equipment for testing the mechanical properties of materials INSTRON 5982, certified in the prescribed manner. The load on the sample was applied uniformly until the destruction of the sample.

The maximum value of the press force at the moment of destruction of the sample, i.e. the force at which the yield strength of the reinforcement is reached was taken as the value of the breaking load on the sample. The loading was carried out in uniform steps. Each step was 10% of the expected breaking load. To measure longitudinal deformations in normal section, strain gauges with a base of 20 mm were glued onto the beam and reinforcement.

Strain gauges were used to determine the moment of crack formation.

For each series of experiments, experiments were carried out on 3 images. The dynamic load ranged from 0.6 to 0.9 breaking load.

### **Test results for Cauthon (RubCon).**



- Strength bond curve of polymer concrete with polymer fibers (theoretical)
- Strength bond curve of polymer concrete with polymer fibers (Experimental results)

**Figure 4:** Fibrocauton compressive strength depending on the percentage of dispersed reinforcement

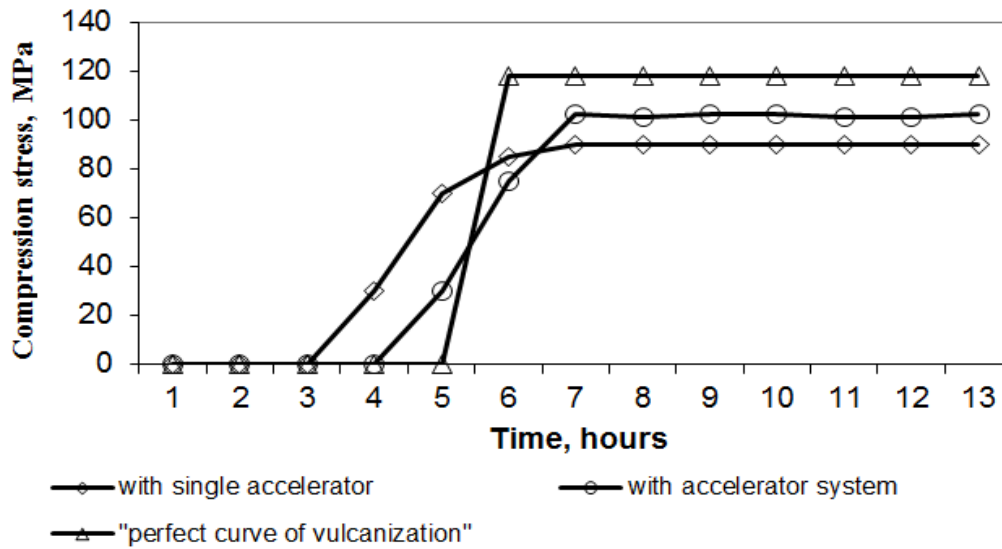


## Conclusions

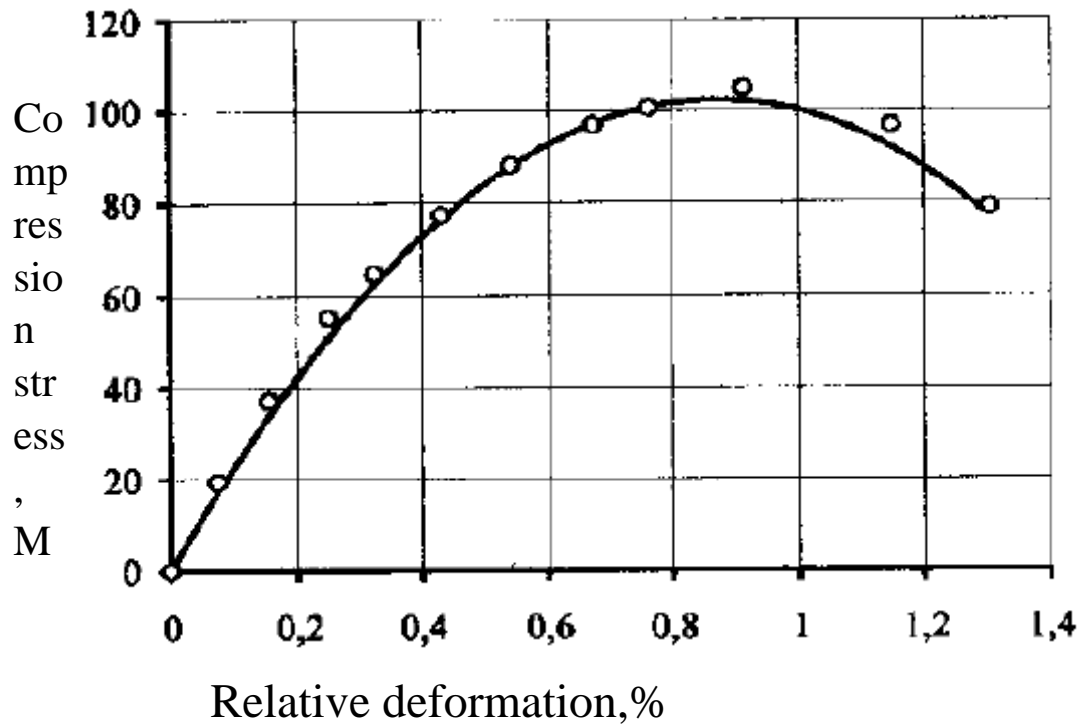
1. Experiments were carried out and the relative limits of endurance in compression were determined on the basis of  $2 \cdot 10^6$  cycles.
2. Endurance limit for fibrocement with dispersed reinforcement with polypropylene fiber 12/0.12 mm  $R_{pr,pul} = 62.91$  MPa.
3. Polymer concrete with dispersive reinforcement by polypropylene is resistant to dynamic loads and suitable for use in dynamic loads.
4. Because of its ability to insulate electricity, it can also be used as strong and stable insulating components

## Addendum: Cauthon Key Features (RubCon)

**Figure 5 : Consolidation time and accelerator system**

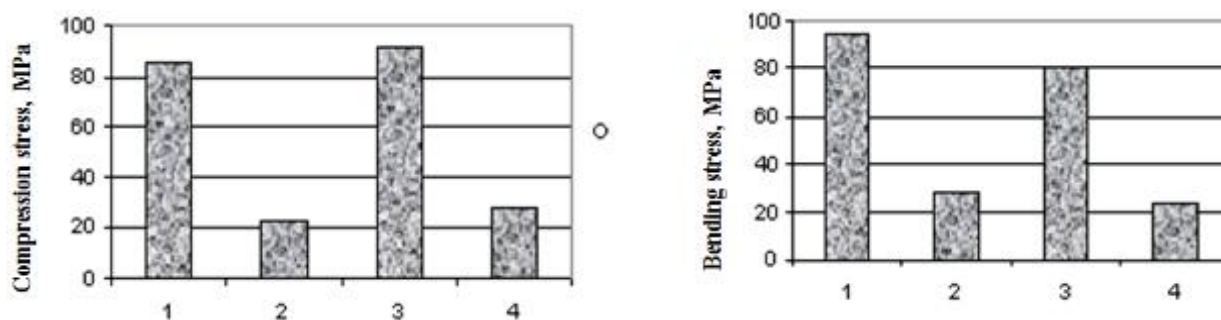


**Figure 6: Characteristic pressure - deformation relationship**





**Figure 7: Values of  $\sigma_{com}$  and  $\sigma_b$  of RubCon for various rubbers)**



1 - Potyoil®, 2 - PBN®, 3 - Ricon 130®, 4 - SKDN-N®

**Table 1 Basic physical-chemical and mechanical properties of RubCon**

| Indices  | Units                                | RubCon                  |
|--|--------------------------------------|-------------------------|
| 1  | 2                                    | 3                       |
| Density  | kg/m <sup>3</sup>                    | 2100-2300               |
| Strength at<br>- compression<br>- bending<br>- tension | MPa                                  | 80-95<br>25-30<br>12-15 |
| Modules of elasticity                                  | MPa10 <sup>4</sup>                   | 2.0-2.7                 |
| Poison's ratio   |                                      | 0.26-0.28               |
| Thermal conductivity<br>coefficient                    | W/m/°C                               | 0.3-0.5                 |
| Wear resistance  | (kg/m <sup>2</sup> )10 <sup>-3</sup> | 2-3                     |
| Specific toughness                                     | (J/m <sup>2</sup> )10 <sup>3</sup>   | 3.5-4.5                 |

| 1   | 2                                    | 3          |
|---|--------------------------------------|------------|
| Heat stability  | °C                                   | 80-100     |
| Water absorption  | %                                    | 0.05-0.06  |
| Coefficient of chemical resistance at 20 °C (based on 360 days of exposure) |                                      |            |
| - 20% H <sub>2</sub> SO <sub>4</sub>  |                                      | 0.97-0.98  |
| - 10% Lactic acid   |                                      | 0.95-0.96  |
| - 20% Caustic potash  |                                      | 0.97-0.98  |
| - 35% H <sub>3</sub> PO <sub>4</sub>  |                                      | 0.96-0.98  |
| - Water   |                                      | 0.99-0.995 |
| - Salt water  |                                      | 1.00-1.05  |
| Resistance to abrasion  | (kg/m <sup>2</sup> )10 <sup>-3</sup> | 2-3.5      |

**Table 2: Experimental values of load-carrying capacity averaged by test results for various stresses and temperatures levels**

| Normal stress, $\sigma$ (MPa) | Temperature, T (°C) | Time to failure, $\tau_f$ (min) |
|-------------------------------|---------------------|---------------------------------|
| $\sigma_1 = 5.65$             | 72                  | 527                             |
|                               | 77                  | 340                             |
|                               | 78                  | 132                             |
|                               | 86                  | 83                              |
|                               | 105                 | 3                               |
| $\sigma_2 = 6.07$             | 65                  | 552                             |
|                               | 66                  | 340                             |
|                               | 71                  | 215                             |
|                               | 72                  | 74                              |
|                               | 76                  | 56                              |
|                               | 84                  | 42                              |
| $\sigma_3 = 6.47$             | 60                  | 300                             |
|                               | 64                  | 265                             |
|                               | 67                  | 151                             |
|                               | 78                  | 21                              |

**Table 3. The main physical-mechanical characteristics of the new RubCon structure**

| Properties  | Value |
|---|-------|
| Average density, kg/m <sup>3</sup>                                  | 4.86  |
| Compression strength, MPa   | 2.05  |
| Bending strength, MPa   | 0.28  |
| Water absorption  | 0.23  |
| Maximal operation temperature, °C                                   | 0.80  |
| Linear attenuation coefficient. cm <sup>-1</sup>                    | 0.15  |
| Coefficient of radiation resistance at $\gamma$ -radiation dose MGy | 4.32  |

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