Effect of sand particles (50 wt%) on strength and resistance of epoxypolymer composite materials.

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Abstract: The sands of various dispersion&origin can watch as basic filler for tonnage build & industrial compounds. The work is devoted to the urgent topic of obtaining cheapened epoxy materials with a high content of natural and building sand. In the case of composite optimization, it is possible to obtain valuable competitive multi-tonnage composites, moreover, while maintaining the original performance properties or even improving them. In our work, the sand from Ukrainian mines & rivers were used. It is tree types of sand:

A) "Quarry" – from industrial carrier in nord of Ukraina;
B) "Bottom" – from bottom of big river (Desna);
C) "Fabric" – industrial sand TM Stark, Ukraina.

A number of practically important properties of composite materials based on epoxy resin and sand of various types and dispersions (50 wt%) have been established. It is shown that 50 wt% of all used sands leads to essential increasing of AbrasiveResistance and SwellingResistance, and microhardness. At same time, 50%-filling decreases investigated strength parameters (to compression & to bending). Is important that sands let reach a high esthetic characteristics of composites: in this simple method can obtain wood-, stone-, honey-like composite materials for building, design & décor.

The prospects for the implementation of these results are quite wide, since they cover both large-tonnage construction and repair, innovative industries, as well as small repair segments that are now developed (car service, museum restoration) and handmade. At the same time, this work only opens up these prospects and can become the basis for further scientific and practical research.

Keywords: Epoxy polymer, sands, strength at compression, bending, resistance, abrasion, swelling in acetone-ethylacetate, nitric acid.

Introduction

Filling of thermosetting resins with sand is a widespread and commercially demanded direction in applied materials technology. This is due to the availability of these additives (quarries, industrial waste, river beaches, sand spits, etc.). Sand of various dispersity fineness and purity can rightfully be considered one of the main fillers for polymer and inorganic composites. It is evidenced by its consumption in construction [1-4].

Since the discovery of epoxy resin by the great Russian chemist Dianin, and especially since the industrial use of epoxy resins, attempts have been made to mix this resin with cheap fillers [5]. This is facilitated by the unique ability of epoxy resin to perfectly combine with all dispersed powders.

Epoxy and acrylic polymer compositions with SiO_2 particles of different dispersion are used for the road-building, industrial and aerospace industries, as well as everywhere in handicraft production - handmade, restoration and repair [5-15]. Significant and long-term experience of detailed research has been accumulated in the laboratories of our team [8-11].

Defacto, sand is a quartz meso- and distorted microspheres, which are well embedded in most polymerizing matrices. In the applied and commercial literature, as well as on the Internet, there are many notes and recommendations for the creation and use of epoxy sand systems, mainly for self-leveling floors and countertops [1-7].

The obvious goal of filling epoxy and other polymer composites with sand is to - reduce the cost and impart some important properties, sometimes even to the detriment of others properties. In addition, polymer-sand composites can mimic a stone, wood, amber, and other natural materials.

Materials & methodics

The sands of various dispersion\cleaning\nature can watch as basic filler for tonnage build & industrial compounds. In many regions it is a cheap or free row material for many devices. De-facto, sand particles are natural meso-micro-dispersed spheres, that able to distribute well in many polymeric substances. An epoxy reins are one of their polymeric matrix for sand-filling.

The purpose of the work is a scientific and practical study of the effect of sand on the strength and chemical resistance of polymer composites. For the reliability of the experiment, three types of sand are taken, differing by dispersion and origin; they filled the standard epoxy type ED20 + PEPA.

In our work, the Sand from Ukrainian mines & rivers were used. It is tree types of sand:

A) "Quarry" - from industrial carrier in nord of Ukraine; Build carrier sand from lower layer of the Oster industrial quarry (Nord-Ost Ukraina region). Finely dispersed (P within 50 ± 30 microns).

B) “Bottom” - from deep of big flat river (Desna); Bottom river sand (from the flowing bank of the Desna River). Coarsely dispersed (P within 200 ± 100 microns), due to the abundance of inclusions of different rocks, it has a gray color.

C) “Fabric” - industrial sand, TM Stark, Ukraine. Industrial sand, produced by PE Stark (stark.ua). It is distinguished by a beautiful yellow color and relatively monodisperse (average particle size P within 100 ± 50 microns).

The polymer compositions were prepared as follows: sand was added\mixed to the resin, and then a hardener was added.

The following tests of the obtained composites were carried out.

A) Compression - (ISO 604: 2002; Soviet/Russian GOST 4651-2014), on cylindrical specimens with d = 6.5 mm and h = 11 ± 0.5 mm, made at 25 °C and heat-treated. To avoid sand settling, pouring into molds was carried out not after the beginning (gel-point) of the composition after adding the hardener.

B) Bending (ISO 178, DIN 53452, ASTM D790, GOST 56810-2015) plates with a size of 6 × 1 × 0.2 cm were made. Their fracture during bending was carried out on the basis of L = 3 cm.

The abrasion of the composites was measured by the change in the mass of the sample after wiping the sample with P180 sandpaper, 100-fold cycling with a cycling path diameter of 5 cm. The abrasion resistance T was calculated using the proposed empirical formula

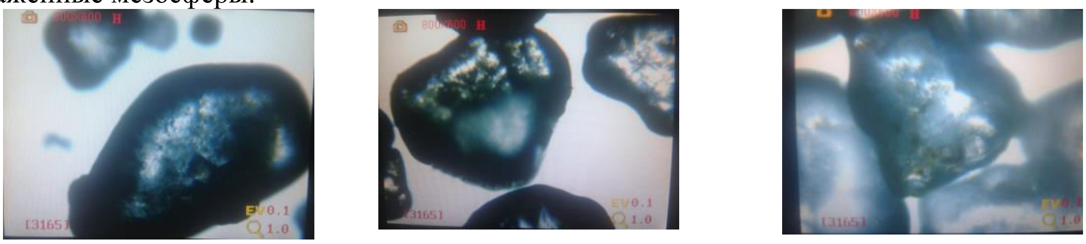
$$T = \frac{\rho}{X \cdot \rho_0},$$

$\frac{\rho}{\rho_0}$ – ratio of densities of filled and unfilled polymers, X is the amount of abrasion).

Tests on the resistance in liquids (ISO 62: 2008) were carried out - by measuring the weight gain of tablets 1 × 1 × 0.1 cm after removal from the liquid, wiping and short-term (5-10 min) drying at normal conditions Solutions of Acetone:Ethyl-acetate and 20% nitric acid concentration (produced in Ukraine and Russia) were used. The change in mass was recorded gravimetrically as% weight gain.

Experimental results

Из рис.1 видно, что средний размер частиц песков составляет 0,3-1 мм. По виду это силикатные искажённые мезосферы.



Quarry sand, ×100 — Bottom sand, ×100 — Fabric sand, ×100

Fig. 1. **Microscopy of fillers and compositions with them, ×100 (screen length is 700 microns).**

As can see from table 1, after filling, the compressive strength decreases significantly - by 20-22%. The least susceptible to weakening
is the composite with the high-dispersed sand (quarry, table 1), and the coarsest low-disperse(bottom sand) gives the lowest compression load. The same picture is observed for bending tests. This is understandable, since with an increase in the size of primary particles, the structuring ability of the inert filler decreases. These results do not confirm the assumptions about the possible structuring of the epoxy polymer by meso-micro-dispersed quartz (as occurs at optimal concentrations of nano-SiO_2 [8-10]).
On the other hand, the introduction of sand should have a clear positive effect in abrasion resistance (since sand is a clear abrasive). Indeed, after filling, the abrasion resistance increases noticeably - in 2-4 times (table 1). This is very important in the construction and self-leveling floors industry.

Table 1. **Mechanical indicators of composite samples.**

	Compression strength, load on cubic template 1×1×1,5 cm, MPa	Compression, load on cylinder d=7,5, h = 12^{+-1} mm	YoungModulus at compression, $\times 10^3$ kgf\cm^2
H (0%)	125 (100%)	275 ^{460}	12,5
Fabric	100 (80%)	290	12,8
Bottom	97 (78%)	250	12,8
Quarry	106 (85%)	265	13,7
MicroQuartz	-	260	
	Relative density (mass of cylindric template d=6.5 mm, h=12 mm)		
H (0%)	Fabric	Bottom	Quarry
40	58	55	56
Bending strength (kgf/mm^2, * - estimation)		Wear at abrasion by abrasive emery-paper P120 (W, mg & M, mm)	Resistance $w=100W_H/W$ to wear (H=100%)
H (0%)	12	W=8 mg & M=2.1 mm	100 %
Fabric	7	W=3 mg & M=0.8 mm	267 %
Bottom	-	W= 3 mg & 0.9 mm	267 %
Carrier	9	W=2 mg & 0.7 mm	400 %
MicroQuartz	7*	W=7 mg*	114 * %

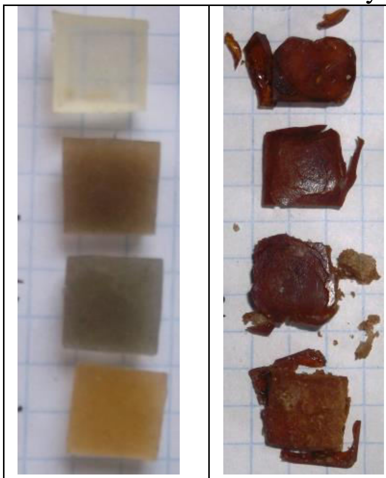
The effect of sand on the resistance of EpoxyComposite in aggressive environments also sometimes depends on the type of sand. In general, the filling results in increased resistance to swelling in acetone. In some cases (quarry sand, tab. 2), an increase in resistance to destruction is also observed.

Table 2. **Swelling and resistance in acetone of composites: unfilled and with 50 wt% sand of various types**

Days	H (Unfilled)	Quarry	Bottom	Fabric
0,17	12,7	10,0	5,4	4,0

1	25,9	14,2	7,4	5,1
3	destructed	26,5	destructed	destructed
9	-	26,5	-	-

From Table 2 and Figure 2 it can be seen that filling with sand gives a decrease in the activity of swelling at the initial stages. In some cases (quarry sand, Table 2), filling even completely eliminates the destruction of the sample, which is inevitable for unfilled and many filled epoxies.



a) b)

Fig. 2. Type of composites with 50 wt% of sand taken for experiments: a) - initial; b) - after 1 day exposure in acetone. sample marking, top to bottom: unfilled (up), carrier, bottom, fabric (lower).

In nitric acid, the effect of sand depends on its type and dispersion, however, no stable patterns are seen (Table 3). We can only say that such filling sometimes manages to increase the resistance to swelling in acid.

Table 3. Swelling in 20% nitric acid.

days	H (Unfilled)	Quarry	Bottom	Fabric
0	0,0	0,0	0,0	0,0
1	2,2	0,8	1,7	0,8
2	2,2	0,8	1,7	0,8
9	2,7	3,0	3,4	2,2
14	4,8	5,0	4,2	2,2
37	6,4	10,0	10,2	6,4

Conclusions

1. Filling of epoxy resin by sands let obtain an aesthetic (beautiful) and very abrasion-resistant composites. But epoxy-sand composites are less strong for compression and bending, comparative to unfilled polymer.
2. Filling with sand can increase the resistance of composites to aggressive influences - in particular, to acetone-ethylacetate and nitric acid.
3. These materials can be successfully used in the self-leveling flooring industry and industries requiring large volumes of cheaper polymer compounds.

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References

1. **Epoxy resin and quartz sand**./ KOLOLIT company website Self-leveling floors. - *https://skololit.ru/articles/epoksidnye-poly/epoksidnaya-smola-i-kvartsevyy-pesok/*

3. Kandyrin L.B., Surikov P. V., Kuleznev V.N. **Influence of the viscosity of filled epoxy resins on their spreading on a horizontal surface** // Inzhenerno-Fizicheskii Zhurnal. 2003.- *DOI: 10.1023 / A: 1024764829466*.

3A. **Heavy-duty colored quartz sand floors.** – available online at *https://polymerbeton.uaprom.net/p246462242-sverhprochnye-poly-tsvetnym.html*

4. Anoshkin V.S.**Physical and mechanical properties of biostable polymer composites filled with quartz sand. //** Ogarёv-Online. 2015. №18 (59). *-cyberleninka.ru/article/n/fiziko-mehanicheskie.-svoystva-biostoykih-polimernyh-kompozitov-napolnennyh-kvartsevym-peskom.*

5. D. Starokadomsky. **Long life of Epoxides**.// Science and Life J.(Наука и Жизнь), 2018. №1. pp.66-71. - *https://www.nkj.ru/archive/1030/32960/*

6. T.Ahmad, O.Mamat, R.Ahmad. **Studying the Effects of Adding Silica Sand Nanoparticles on Epoxy Based Composites**. J.Nanoparticles (Special issue) - Nano/Microstructured Materials: Rapid, Low-Cost, and Eco-Friendly Synthesis Methods (2013)- *https://doi.org/10.1155/2013/603069*

7. **Polymer composition for waterproofing sidewalks of bridges "Silol - sidewalk". -** *https://formasil.com.ua/p1019567951-polimernaya-kompozitsiya-dlya.html*

8. DL Starokadomsky**. Some features of swelling of photopolymer composites with different contents of highly dispersed silica** // Plastic.Massy (Пластические Массы), 2008, №7, pp.33-36

9. Starokadomskii, D.L., Solov'eva, T.N. **Effect of Silicon Oxide Fillers on Photochemical Curing of Compounds Based on Acrylic Monomers and Oligomers**. *Russian Journal of Applied Chemistry* **75,** 138–141 (2002). https://doi.org/10.1023/A:1015597713736

10. **Changes in the properties of the polyepoxide-nanosilica composite after modifying the filler surface with the original epoxy resin**
DL Starokadomsky, AA Tkachenko, AI Garashchenko,// Plastic.Massy (Пластические Массы), 2015, №10, pp.50-55

11. DL Starokadomskiy, I Telegeev, SV Golovan **Influence of Aerosil A-100 on strength, swelling and structure of epoxy polymer**. Plastic.Massy (Пластические Массы), 2010, 9, pp.35-40

12. Fatma Djouani, Carole Connan, Michel Delamar etc.. **Cement paste–epoxy adhesive interactions//** Construction and Building Materials. 2011, V.25. Iss.2. pp.411-423.- *https://doi.org/10.1016/j.conbuildmat.2010.02.035*.

13. Danchenko Y., Andronov V., Barabash E. и др. **Research of the intramolecular interactions and structure in epoxyamine composites with dispersed oxides** // Eastern European Journal of Enterprise Technologies. 2017. 6 (12). 4-12. https://doi.org/10.15587/1729-4061.2017.118565

14. Lee E.J., Lee J.H., Lim K.H. **Hybrid waterproofing polymer-modified asphalt filled with carbon fiber and inorganic materials** // Polymer (Korea). 2020. DOI:10.7317/pk.2020.44.1.1.

15. D.Rassokhin, **D.Starokadomsky**, A.Ischenko, O.Tkachenko, M.Reshetnyk, L.Kokhtych. **Determining the strength and thermal-, chemical resistance of the Epoxy polymer-composite filled with Basalt micronano fiber in the amount of 15–80 wt%** // Eastern European J. of Advanced Technologies . 1/12 (104). - 4. 2020. – p.55-63.- *DOI: 10.15587/1729-4061.2020.200491*