RESEARCH ON THE INFLUENCE OF THE TYPE OF MICROFILLER ON THE DAMPING CHARACTERISITCS OF POLYMER-CONCRETE COMPOSITES

Dr. Eng. Popov I.G.

Technical University Sofia, Plovdiv branch, Bulgaria

E-mail: ilgepo@abv.bg

Abstract: This research presents the experimental approach and methodics for quantification of the damping characteristics of two groups of polymer-concrete composites. By means of a comparative analysis here it is determined the influence of the type of fine filler material (microfiller) on the damping characteristics of the experimental polymer-concrete composites.

Keywords: polymer-concrete composites, units, body elements, damping characteristics, modal analysis.

1. *Introduction*

Known in the beginning in the construction industry, today polymer-concrete composite (PCC) materials gradually, but certainly replace the conventional construction materials in the machine building practice. The good tensile and deformation characteristics and especially their very good damping behavior are prerequisites for the alternative application of the PCC in the production of units and body details for machine tools (MT) and for other production equipment.

2. *Concise theoretical prerequisites*

PCC are non-metal, viscous-elastic, quasi-isotropic materials characterized with high density of mineral disperse fillers. In terms of physicochemical mechanics they are solid macrodispersed systems (structures) that possess phase composition and interfacial boundary. Usually PC composites consist of two solid phases (matrix and filler) and one or two fluid phases (gaseous or liquid). For interfacial boundary between the solid phases serves the surface of the filler, while between the solid and fluid phases – the surface of the pores and gaps.

As matrix (binding substance) in the PCC is used the thermoreactive or thermoplastic synthetic polymer (resin) that is filled in with mineral microfiller (fine filler) with considerable surface. Thus the cavities' volume of the filler, instead with resin, is filled with matrix that demonstrates improved elastic characteristics and reduced deformability. The size of the particles and the quantity of the fine filler inhibit the micro fissures and enhance the adhesive bonds, which ensures the achievement of a very compact "packaging" of the polydisperse solid granules of the filler. Thus a solid hard 3D (3-dimentional) framework of the PC conglomerate is formed.

3. *Expose*

The subject of research of this work – gamma thermoreactive (based on unsaturated polyester resin) PCC, are developed and tested in the Laboratory of testing and research of machine tools at the Technical University Sofia, Plovdiv Branch. They possess enough resilience, demanded from the structural materials used for units and body details and very good damping characteristics. From chemico-technological aspect the developed new different experimental PCC are in fact multi-component systems (mixtures), which components are interdependent and bilaterally restricted. Fig. 1 shows the theoretic geometric model of the PC structure [1].

Subject of this research are the damping characteristics of the above-mentioned PCC and particularly the influence of the type of fine filler (microfiller) on these characteristics.

The fine filler (microfiller) is one of the components of the polymer-concrete composites. The size of its particles is less than 125μm. In the course of the experimental work the following materials are used as fine filler:

A. Marble powder (classical version of the formulation);

B. Quartz powder.

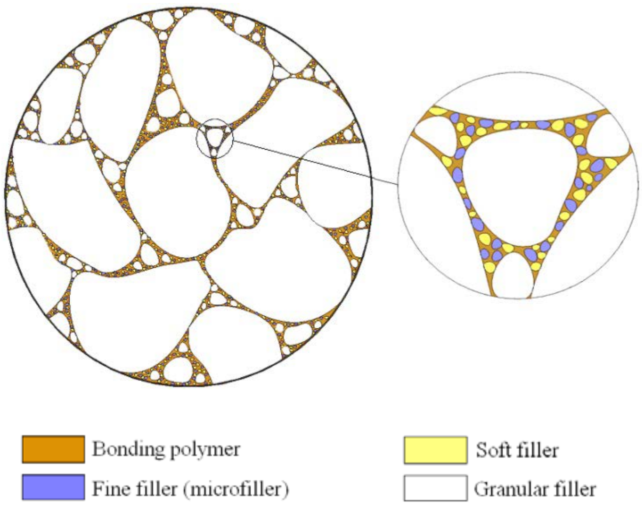


Fig.1. Theoretic geometric model of PC structure

3.1. *Methodics of the research*

In order to provide a solution for the task set in this research, here are presented the approach, ways and methods of conducting the experimental research. The influence of the type of fine filler on the damping characteristics of the PCC is determined according to the method of the similarity and comparison. For this purpose, two groups of polymer-concrete samples (test tubes) are used, respectively:

- First group: three polymer-concrete test tubes containing respectively ПБИП4, ПБИП8, ПБИП13, in which the microfiller is marble powder;
- Second group: three polymer-concrete test tubes containing respectively ПБИП4*, ПБИП8*, ПБИП13*, in which the microfiller is quartz powder.

The proportions of the respective PCC of both groups are the same. They differ only in the type of the microfiller in them. For the purpose of the comparative analysis it is accepted that the content of

the microfiller in the PCC of both groups to be the at maximum level, i.e. – 14%.
The sample units have rectangular parallelepiped form (a small bar) with dimensions 30×30×350 mm, Fig.2. In order to eliminate random errors, 3 sample test tubes of each composite are prepared.

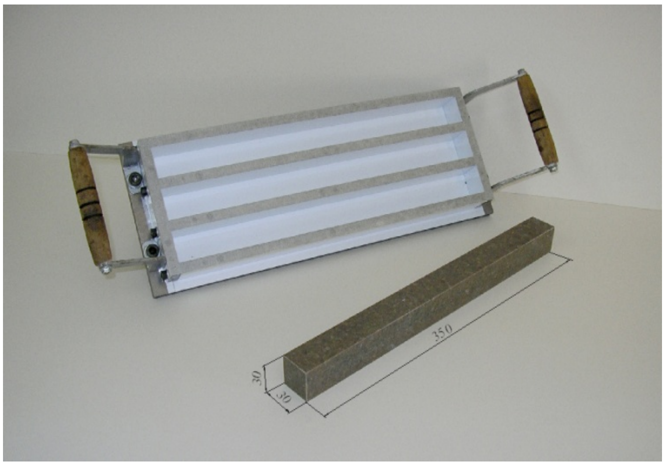


Fig.2. Sample unit and equipment for its making

The quantification of the damping characteristics of the PCC is difficult through direct measurement. Usually, in experimental conditions this happens on the basis of the parameters of the dynamic response of the tested samples, [2]. For the purpose of quantifying the damping characteristics the following experimental approach is applied: The tested sample unit is firmly fixed into a machine clamp, similarly to a bracket-fixed end of a bar. The machine clamp is fixed on a fundament or on a work table of a milling or other machine tool, with fixed vertical, transverse and longitudinal slides. Dynamic influence (excitation), in the form of forced mechanical vibrations, is applied on the free end of the bar. In this way the model of the multi-mass (with distributed parameters) vibrating dynamic system is implemented. The excitation of the forced vibrations in the dynamic system of the samples (test tubes) can be done by two methods:

- by means of variable sinusoidal (harmonic) excitation;
- by means of impulse (impact) excitation.

3.2. *Experimental setting*

The dynamic response of the tested unit, manifesting itself as transverse vibrations (in movement, speed or acceleration) is registered by vibration measurement and analysis equipment, by means of the accelerometer attached to the free end of the sample unit, Fig. 3 [1]. In the experimental setting shown on Fig. 3, the PC samples are excited through the impulse method, while the damping characteristics are determined through analysis of the damping forced oscillations.
The experimental determination of the damping characteristics of the PC samples is made according to the method of the modal analysis, [3]. The following damping characteristics are determined:

- damped (resonant) frequency - $f_d\,(\omega_d)$;
- 3dB bandwidth -Δf ($\Delta\omega$);
- dimensionless damping ratio -ξ;
- logarithmic decrement -δ;
- modal decay rate -σ;
- loss factor (absorption coefficient) -η;
- quality factor (resonant quality) -Q;
- 8,7dB decay time -τ_d.

Fig.3 *Experimental setting*

The functional relationships between the damping characteristics are shown with equation (1) and deduced in [1]:

$$\frac{\Delta\omega}{\omega_d} = 2\xi = \frac{1}{Q} = \eta = \frac{\delta}{\pi} = \frac{2\sigma}{\omega_d} = \frac{2}{\omega_d \tau_d} \quad , \qquad (1)$$

By analysis of (1) it can be seen that with increasing the values of the characteristics: Δf ($\Delta\omega$), ξ, δ, σ and η the damping capacity of the PCC proportionally increases, and vise versa: with increasing the values of the characteristics $f_d\,(\omega_d)$ and Q reduces the damping capacity of the PCC.
The vibration measurement and analysis equipment (complete equipment set by Brüel & Kjaer) directly reports: natural damping frequency - $f_d\,(\omega_d)$, 3dB bandwidth-Δf ($\Delta\omega$) and dimensionless damping ratio -ξ. The other damping characteristics are quantified according to (1).

3.3. *Results of the experiment*

On the basis of the so proposed methodics 2 groups of experimental results are obtained. The first group contains the results for the damping characteristics of PCC ПБИП4, ПБИП8, ПБИП13, in which the microfiller is marble powder, Table 1.

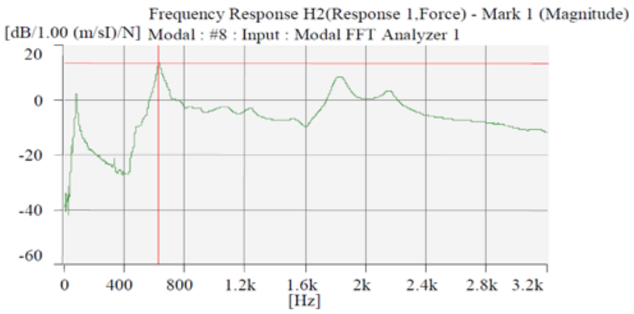
PCC with microfiller – Marble powder		Sample no.	Damping characteristics' values							
			Measured			Calculated				
No	Polymer concrete make		f_d	3dB Δf	ξ	δ	Q	η	σ	τ_d
4	ПБИП4	4.1	695.0	37.25	0.0268	0.1683	18.657	0.054	116.971	0.0085
		4.2	727.0	39.72	0.0273	0.1714	18.315	0.055	124.640	0.0080
		4.3	711.0	37.68	0.0265	0.1664	18.868	0.053	118.325	0.0085
8	ПБИП8	8.1	627.5	30.92	0.0248	0.1557	20.161	0.050	97.729	0.0102
		8.2	644.0	31.29	0.0243	0.1526	20.576	0.049	98.277	0.0102
		8.3	653.0	30.95	0.0237	0.1488	21.097	0.047	97.190	0.0103
13	ПБИП13	13.1	703.0	56.09	0.0399	0.2506	12.531	0.080	176.152	0.0057
		13.2	663.0	53.7	0.0405	0.2543	12.346	0.081	168.627	0.0059
		13.2	670.0	55.11	0.0411	0.2581	12.165	0.082	172.932	0.0058

Table 2

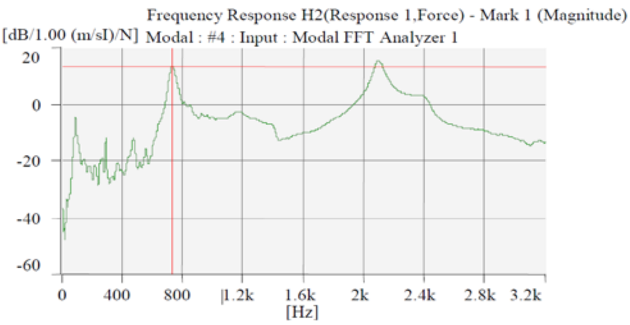
PCC with microfiller – quartz powder		Sample no.	Damping characteristics' values							
			Measured			Calculated				
No	Polymer concrete make		f_d	3dB Δf	ξ	δ	Q	η	σ	τ_d
4*	ПБИП4*	4.1*	721.0	40.23	0.0279	0.1752	17.921	0.056	126.33	0.0079
		4.2*	732.0	41.68	0.0285	0.1790	17.544	0.057	131.01	0.0076
		4.3*	707.5	38.77	0.0274	0.1721	18.248	0.055	121.74	0.0082
8*	ПБИП8*	8.1*	668.0	34.06	0.0255	0.1601	19.608	0.051	106.97	0.0093
		8.2*	671.0	33.01	0.0246	0.1545	20.325	0.049	103.66	0.0096
		8.3*	655.0	35.09	0.0267	0.1677	18.727	0.053	109.83	0.0091
13*	ПБИП13*	13.1*	595.5	48.23	0.0405	0.2543	12.346	0.081	151.46	0.0066
		13.2*	683.5	57.37	0.0419	0.2631	11.933	0.084	179.85	0.0056
		13.3*	645.0	51.34	0.0398	0.2499	12.563	0.080	161.21	0.0062

The second group contains the results for the damping characteristics of the PCC ПБИП4*, ПБИП8*, ПБИП13*, in which the microfiller is quartz powder, Table 2.

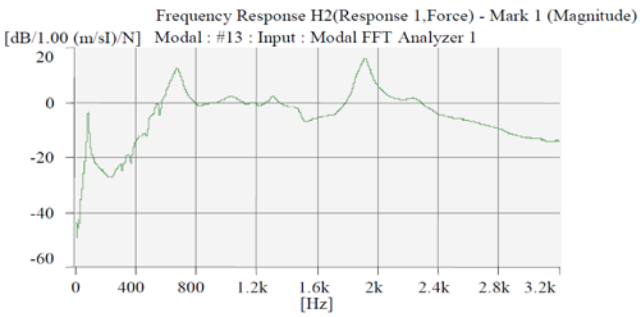
The obtained experimental results are based on reports that are automatically generated by the vibration measurement and analysis equipment, Fig. 4.



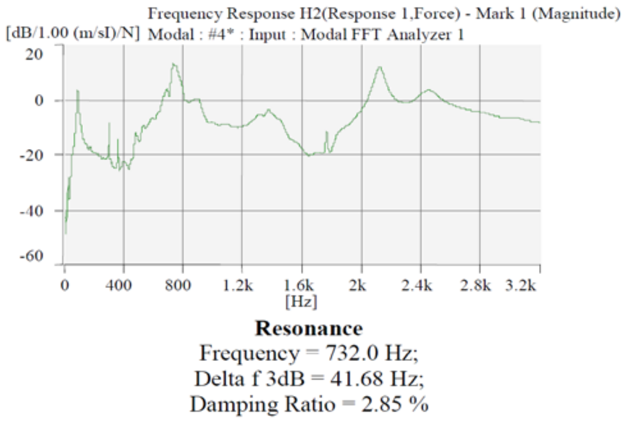
Resonance
Frequency = 627.5 Hz;
Delta f 3dB = 31.18 Hz;
Damping Ratio = 2.48 %

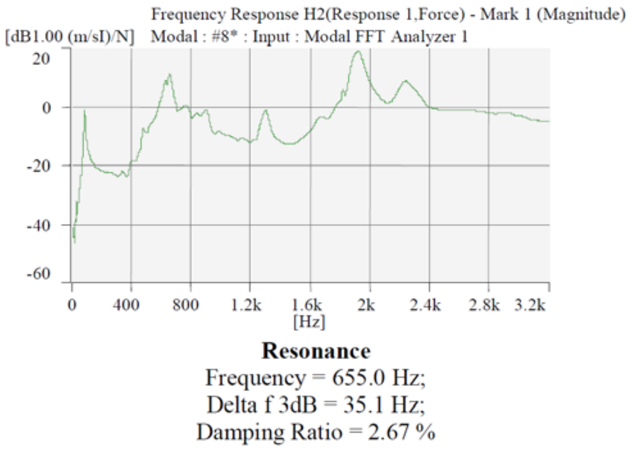


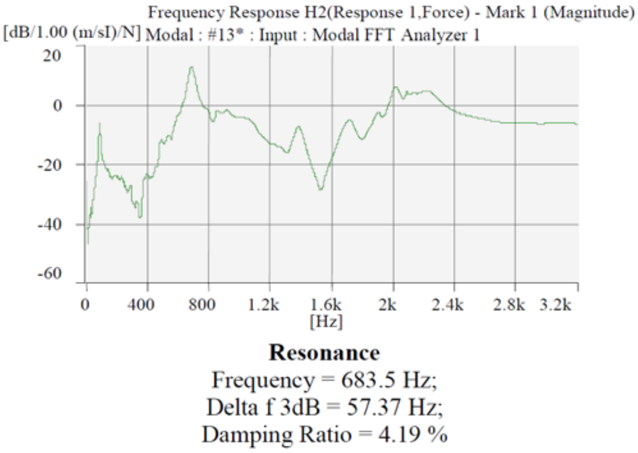
Resonance
Frequency = 727.0 Hz;
Delta f 3dB = 39.72 Hz;
Damping Ratio = 2.73 %



Resonance
Frequency = 670.0 Hz;
Delta f 3dB = 55.11 Hz;
Damping Ratio = 4.11 %







Фиг.4. *Reports of amplitude frequencies for determining the damping characteristics*

4. *Conclusion*

The choice of fillers and microfillers for the formation of polymer-concrete composites is dictated by the predetermined, desired characteristics of the material. By their type and quantity, the resilience, deformation, thermotechnical and damping characteristics of the polymer-concrete structure can be regulated. On the basis of the comparative analysis of the damping characteristics of the respective couples of experimental PCC from both groups, it can be seen that quartz powder used as microfiller in PCC improves damping (3,8 ÷ 9,7%) in the three experimental mixtures, marked with (*). This predetermines our preference for "quartz powder" as one of the components - fine filler (micro-filler) in PCC, applicable as structural material for the production of units and body details for machine tools and other production equipment.

5. *The results* of this work can be summarized in the following way:

- Original methodics is developed for the quantification of the damping characteristics of two groups of experimental polymer-concrete composites. In the first group, marble powder is used as microfiller, while in the second – quartz powder.
- Laboratory equipment is constructed and experimental setting is proposed, both ensuring the experimental work.
- On the grounds of the viscous damping concept and the viscous-elastic deformation hypothesis of Feucht, here is presented a relationship for the functional relationships between the damping characteristics of the experimental polymer-concrete composites.
- This work proposes, also, and experimentally proves, an original method for quantification of the damping characteristics of the polymer-concrete composites, i.e. the method of the experimental modal analysis.
- On the grounds of the obtained experimental results from the reports and the performed comparative analysis, it has been found out that quartz powder as a microfiller in polymer-concrete composites ПБИП4*, ПБИП8* and ПБИП13* improves their damping characteristics with 3,8 ÷ 9,7%.

References

1. Popov, I. Research and optimization of polymer-concrete composites in reference to their damping characteristics. PhD thesis, Sofia, 2013.
2. Zlatanov, V., Buchvarov, S., Atanasova, S. Vibration of a Load Elastic Suspended for Elastic Beam through Another Load. Machine Design, Vol.4, 2012, No.1, p.33-42.
3. Avitabile, P. Expetimental Modal Analysis. Sound and vibration, January 2001.