ACOUSTIC ABSORPTION OF GEOPOLYMER/SAND MIXTURE

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The article describes the acoustic absorption coefficient of material formed by geopolymer joining agent filled by sand. The geopolymer defined as a clay based inorganic poly-condensed 3D net was used as a substitute of epoxide resin, currently industrially used cementing material of granular media (generally quartz sand). The absorption coefficient α of conventionally used epoxide/sand sample was compared with studied geopolymer/sand mixtures. The main target was to find the alternative joining matter caused by permanently bumping costs of epoxide resin and its flammability. Presented paper deals with the influence of filling agent in geopolymer matrix (quantity of sand and its fractionation) on course of acoustic absorption coefficient and describes also the influence of thickness of geopolymer/sand mixture. The acoustic absorption coefficient α was defined within the range from 100 Hz to 2500 Hz. The results showed that both presented mixtures have specific sound absorbing properties – average value of coefficient with boarder range of effectiveness and high absorbing coefficient with narrow profile of effective frequencies.

INTRODUCTION

The noise is defined as undesirable sound, annoying and disturbing people in some cases even detrimental. Oversized noise negatively influences human beings and their life e.g. health, psyche, hearing and also performance in work. The occurrence of civilization diseases cast by noise was proved by research works and studies [1], which also accenting the necessity to decrease the unhealthy influence of noise.

Common sound decreasing method is, among others, the utilization of sound absorbing materials. The level of sound absorption could be characterized by the absorption coefficient (α) which corresponds to the amount of striking energy absorbed on the material surface. Values α strongly vary with frequency ranging from 0 to 1, where zero signs that material has no absorption and α = 1 means full sound absorption.

In the case of bonded granular media, the most important is managed distribution of homogenously spread graded grains in cementing media (e.g. epoxide resins). The granular structure has high open interconnected porosity which causes the transformation of sound waves into energy (sound absorption). Lot of articles documents the acoustic properties of mentioned sound absorbing materials and their behavior tested by different effects [2-5]. Many papers present the utilization of mathematical acoustic modeling [6-8], but only few of them describe the influence of filler particle sizes and used fractions on acoustic properties [9-12].

Commonly epoxide bounded sand joins the spherical grains among them by cervices, leaving enough free space in between sand particles, which finally defined the acoustic absorption coefficient. Industrially the epoxide content does not exceed 8 wt.% and even the formats 40 × 40 cm tiles (boards) with thickness of 20 mm only have sufficient flexible resistance allowing the application on the ceilings.

The main target of the presented paper was to find possible alternative joining agent of chosen and industrially used quartz grains and study its coefficient [α]. Instead of organic polymer–epoxide resin, the study presents inorganic, geopolymer binding agent joining the same grained sand.

Geopolymers are named by J. Davidovits in 1979 [13]. Geopolymer is based on alkali treated of thermally activated clay, which forms in ambient conditions 3D net capable encapsulate in its predominantly amorphous structure the high amount of different materials. The source of geopolymer is generally double layered clay material, e.g. kaolin. The thermal treatment adjust alumina ions to desirable position (Al^{3+} in IV-fold oxygen coordination) where is possible their hydration and progressive netting with silica ions. The four oxygen surrounding around the Al^{3+} ion result in negative charge of alumina tetrahedron, which is balanced by alkalis [13, 14]. The geopolymer is generally insoluble and stabile materials with compact microstructure. It has high early strengths, excellent mechanical properties comparable with other inorganic binder (Portland cement, gypsum, lime). Appreciable properties are also fire and heat resistance (up to 1200°C), absence of the hazardous combustion gasses and structure stability at high temperatures [14-18].

The investigation of the acoustic absorption coefficient of geopolymer/sand mixtures show alternative binder for industrials. The research results represent firm and long time collaboration with industrial producer of sound absorbing materials and than the specific requirements of application play inconsiderable role.

EXPERIMENTAL

The bounding properties of geopolymers are lower than these of epoxide binder. The amount of geopolymer has to reach as minimum 20 wt.% of final tested product; otherwise the flexible resistance is lower than comparable epoxide/sand sample. The presented paper study the acoustic properties of geopolymer/sand mixture but have to reflect on the second plan the industrially requirements as flexible resistance, costs and availability of sand fractions. Newly the very important is also fire resistance. The collaboration with first Czech producer - SONING A.S. also orientated the chose of raw material for geopolymer matrix production to the secondary sources of clayed materials [19].

According to the previous knowledge and experiments was used NW-Org. clay from the Kamenna Panna deposit, Central Bohemia, Czech Republic (highly kaoli-nitic refractory clay, containing about 3 wt.% of organic matter and due to this content refused by ceramic industry). To improve of geopolymer mixture properties (lowering the porosity) was added mica dust to the geopolymer matrix. Used mica dust was from the production of insulating mica materials (company Cogebi A.S., Tábor, Czech Republic). Chemical compositions are presented at Table 1. The quartz sand was delivered by Sklopísek Střeleč, a.s. company, Czech Republic, exploited from sedimentary sandstone deposit.

The 50 g of activated clay material were mixed by ordinary food kitchen processor with alkaline activator prepared from NaOH, soluble sodium silicate and water. Reaction starts during 25-30 minutes and than the mica and after next 5 minutes the sand were added. The amount of admixed materials presented in Table 2 is only recapitulation of the best results, which were accompanied by the set of samples with insufficient industrial requirements. The previous five years experiments with different type of geopolymer studies have assured the perfect homogenization when the food processor is used. The homogenized mixture was after next 10 minutes pulled to the standard cylinder moulds – diameter 62 mm. After 24 hours, samples were removed from moulds and cured at room temperature. The samples were left at laboratory temperature and pressure for 28 days, than tested, defining the acoustic absorption coefficient. The Table 2 presents the content of geopolymer base, mica and fraction of quartz sand in wt.%.

The parallel sample made from epoxide/sand mixture (8 wt.% of epoxide resin and mono-fraction of sand, diameter 0.3-0.6 mm) was a standard industrial production sample with thickness of 30 mm.

The chemical analyses were performed by an XRF analyzer (Spectro IQ, Kleve, Germany, where the target material is palladium, target angle 90° from the central ray and the focal spot a 1 mm × 1 mm square, the maximum Anode Dissipation 50 Watts with 10 cfm forced air cooling). The sound absorption coefficient was obtained by measurement on Brüel & Kjǽr, type 4206 impedance tube by the transfer-function method according the International Standard ISO 10534-2 [20]. The values were measured in the range from 100 Hz to 2500 Hz according to the most desirable interest of users of sound protecting panels and sheets (measurement level is considered as ± 3.0 % of presented value).

RESULTS AND DISCUSSION

The study presents the results of acoustic absorption coefficient of geopolymer/sand mixture and influence of its changes due to the thickness and sand fractionation of the samples. The presented Geo 1 mixture is a result of studies which as close as possible copied the parallel mixture of epoxide/sand. The official sound laboratory demands for sample testing their thickness of 10 and 30 mm.

Table 1. Chemical composition of used material (wt.%).

Material	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	L.O.I
NW org.	43.59	34.66	1.39	1.44	0.14	< 0.02	0.82	< 0.02	17.33*
Mica	46.02	34.35	2.83	0.42	< 0.002	4.74	10.91	< 0.11	0.1

** the value includes 3 % of organic matter*

Table 2. Composition of prepared geopolymer/sand mixtures.

Samples name	Geopolymer base (wt.%)	Mica* (wt.%)	Quartz sand with fraction: 0.3-0.6 mm (wt.%)	Quartz sand with fraction: 0.6-1.2 mm (wt.%)
Geo 1	20	3	77	0
Geo 2	20	3	19	58

** addition of waste mica dust lowered the porosity and is a result of previous experiments*

The Figure 1 presents the absorption coefficients (frequencies from 100 Hz to 2500 Hz) of samples Geo 1 in standard thicknesses 10 mm and 30 mm. The curve Geo 1 - thickness 30 mm showed rapid increase in low values of frequency and from 600 Hz is moderated. The maximum absorption coefficient α is 0.69 (1250 Hz).

The Geo 1 - thickness 10 mm line showed how the absorption properties could be modified by the change of thickness only. The increase is slower and the maximum moves to higher value - 2000 Hz (α = 0.74). According to the nature of curve, we could suppose that absorption coefficient could decrease very slowly and material could be used in sound protection for frequencies up to 1600 Hz.

The Geo 2 mixture is a result of experimental sets, where the proportions of bigger and smaller grains of sand were changed. The best result from the point of view sound absorption and mechanical property is presented. The low flexible resistance of the thickness of 10 mm samples claimed the necessity to prepare the sample thickness of 20 mm. The following Figure 2 than compares the 20 and 30 mm thickness of Geo 2 mixture. The use of two different fractions of quartz sand improves maximum absorption coefficients (α = 0.86-0.87) but at once sharpens courses of curves and limit the range of utilization. The maxima are in 1250 Hz and 2000 Hz for thicknesses 30 mm and 20 mm respectively.

Comparing the Geo 2 – thicknesses 30 mm and 20 mm we could find similar behavior as in case of Geo 1. The thickness of 30 mm composites have maximum absorption coefficient in same value of frequency – 1250 Hz.

The industrial requirements mentioned above excluded all mixtures with:

a) small amount of sand – then the final 77 wt. % is optimal,
b) higher quantity of geopolymer matrix then chosen 20 wt. % means lowering the porosity and in the mean time low sound absorption,
c) also lower quantity of geopolymer matrix then mentioned parameter means insufficient flexible resistance.

We found also that especially in case of higher quantities of geopolymer joining agent than mentioned 20 wt. %, that samples or final products are highly influenced by technique of preparation. The technology should exclude the vibration of products due to the thixotropic behavior of geopolymer composition with high content of sand.

The following Figure 3 shows courses of absorption coefficient α of the best data of chosen mixtures in range from 200-2600 Hz – each one (Geo 1 and Geo 2) as a result of separate series of mixtures and comparison with industrially prepared standard. The highest value of absorption coefficient has material Geo 2 with maximum α = 0.87 at frequency 1250 Hz. Comparing the absorption coefficient of Geo 2 and referenced epoxide/sand mixture at frequency of 1600 Hz we could reveal only very small difference. The peak of epoxide/sand mixture curve is at frequency 1600 Hz and its coefficient reaches value α = 0.83. The acoustic properties of material Geo 2 made from two different fractions of sand appear equivalent to epoxide/sand mixture.

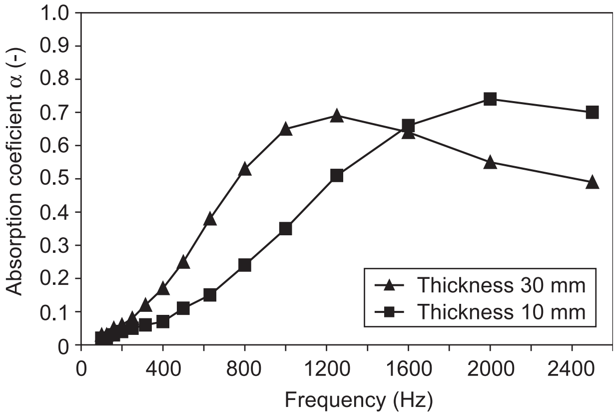

Figure 1. Absorption coefficient of geopolymer/sand mixture Geo 1 (fraction of quartz sand 0.3-0.6 mm).

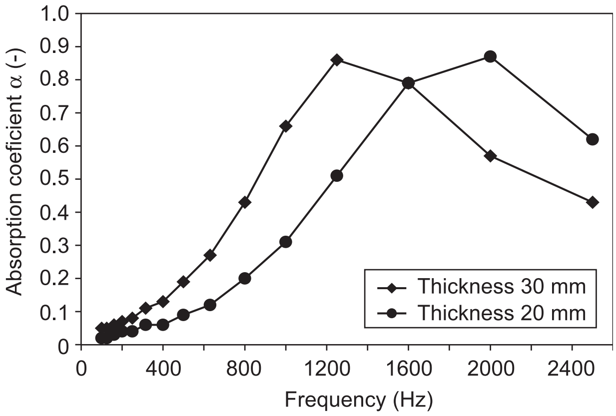

Figure 2. Absorption coefficient of geopolymer/sand mixture Geo 2 (fractions of quartz sand 0.3-0.6 mm and 0.6-1.2 mm).

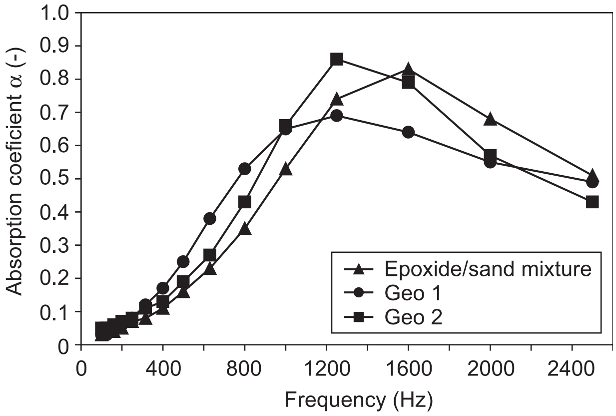

Figure 3. Overview of Geo 1, Geo 2 and epoxide/sand mixture results of absorption coefficient (thickness of 30 mm).

The Figure 3 summarizes the results of absorption coefficient of three samples (thickness of 30 mm). The geopolymer composites Geo1, Geo 2 are compared with standard 30 mm industrially obtained epoxide/sand mixture.

The curve of Geo 1 shows that mono-fractional sand material does not reach the values of absorption coefficient as Geo 2 does, and also the comparable epoxid/sand shows better value of α coefficient. The difference could be the reflex of porosity resulting from mono-fractioned quartz sand. The contact of small grains with minimum of inter-space vacancies results in lower acoustic resistance. Identical amount of joining agent in case of Geo 1 and Geo 2 mixtures differs by fractionation of sand (the influence of 3 wt.% of mica dust on porosity is minimal) in geopolymer surroundings. Important could be a fact that at low frequencies up to approx. 500 Hz the values α are comparable among all three samples.

The Geo 2 mixture presents better result at frequencies from 1000-1200 Hz but at higher frequencies values, over 1600 Hz, the epoxide/sand mixture shows better sound property. The necessary, 3 times higher, amount of joining agent (20 wt.%) is "equilibrated" by the combination of two sand fractions. The pores, their shape and quantity are decisive for the determination of acoustic property defined by absorption coefficient. We could imagine than the space among mentioned proportion (58 wt.%) of bigger concave grains (from 0.6-1.2 mm) is only partially filled by smaller grains (19 wt.%). The geopolymer joining agent homogenously spread among the grains left sufficient "free" space and than the porous structure. But experiments also showed that required flexible strength orders to double the thickness as mentioned above – from 10 to 20 mm.

The incomparable quality of geopolymer joining agent is its fire resistance. The purely inorganic basement of alumina–silicates was in presented experiment completed by use of powdered mica, but the resistance of geopolymer itself to high temperatures (up to 1200°C) is well known.

CONCLUSIONS

The results showed that geopolymer/sand mixtures have good absorption properties and confirm possibility to substitute the industrially used epoxide resin binder by geopolymer based matrix. Mono-fractional sand in combination with geopolymer creates broader range of effectiveness in point of frequencies but absorption coefficient reaches only average value (α = 0.69-0.74). The combination of two different sand particles causes improvement of absorption coefficient up to α = 0.87 but falls sharply down from 1600 Hz. In case of Geo 2 was found that combination of two quartz sand fractions bounded by 20 wt.% of geopolymer creates adequate open porosity, which finally reveals similar acoustic absorption as referenced epoxide/sand product.

The sand bonded by geopolymer resembles very porous natural sandstone but advantages of the technique of geopolymer allow the change and manage the porosity. Different fractions of quartz sand, their amount and quantity of geopolymer matrix could easily modified acoustic properties according to the various applications. The application of sound protective tiles and sheets in the interior of building the newly presents demand of fire resistance. The open flame and fire means fatal consequences (collapse and total destruction) on epoxide/sand products.

Besides confirming the acoustic property of geopolymer/sand mixtures we have acknowledged their fire resistance up to 1200°C. The industrials which have to resolve the problem of production costs could apply perspective technology of geopolymers.

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