PERLITE MORTARS WITH SYNTHETIC BINDER

By

K. Kovács

Department of Building Materials, Technical University, Budapest

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Presented by Associate Prof. Dr. Gy. Balázs, Head of Dept.

In our energy-conscious days, thermal insulating concretes made with different lightweight aggregates are of increasing importance. Perlite mortars with synthetic binder are distinguished by two features. Partly, perlite has the lowest bulk density among inorganic aggregates, thus, beside advantages of inorganic aggregates (e.g. refractoriness) it can be processed into mortar of the lowest solid density. Partly, synthetic resin, its binder, is fluid, of a behaviour different from usual, granular binders (cement, gypsum). Synthetic resin binders being by orders more expensive than conventional binders, their use is restricted to special cases, and the consumption has to be minimized.

Minimization of the quantity of a fluid binder is rather difficult, since perlite bubble walls are known to be permeable to fluids, much of the binder oozes into the bubble, and an important overdosage is necessary to have binder enough for sticking the bubbles together. Beside, binder filling out the bubbles impairs insulation properties. The absorption rate was found to depend on the binder viscosity.

To clear these problems, the quantity of resin or synthetic monomers mixed in fluid state to the perlite was investigated as a function of viscosity. Four model materials, each of a different viscosity, were chosen, such as:

Denomination	Viscosity at 20 °C
Furfuryl alcohol	45 mPa.s
Amikol 65 (carbamide-formaldehyde resin)	0.8–3 Pa.s
Polystyrene solved in xylol	5–500 Pa.s
Polystyrene melt	500 Pa.s

1. Experimental

Tests were made on commercial perlite PL.

1.1 *Effect of pressing on systems with various fluid contents*

A special device, schematically shown in Fig. 1, has been constructed, permitting measurement of the input pressure, that transmitted by the perlite system to the piston bottom, and to the dynamometer inside the bulk. Moisture contained in the perlite was varied.

Measurements have shown the perlite system to behave as a "dry" medium up to about 200% of moisture, that is, it absorbs the energy and transmits a slight part of pressure, thus particles get crushed. Over 200% of moisture, pressure transmittance tends to the ideal "hydraulic" condition, pressure losses are slight, tending to negligible. A mixture of 200% moisture showed the relation plotted in Fig. 2.

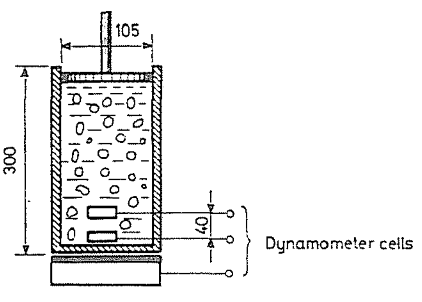

Fig. 1. Measurement of the pressing effect on the perlite bulk

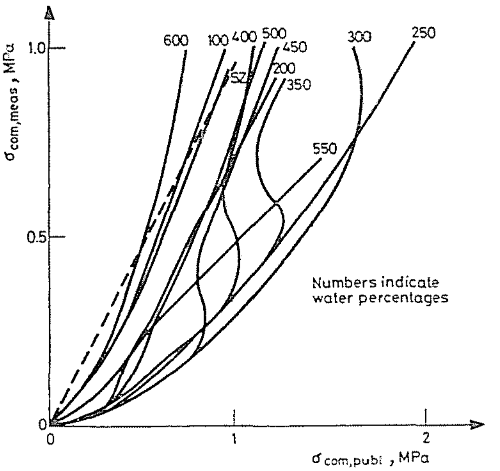

Fig. 2. Relationship of pressure transfer by a perlite-furfuryl-alcohol mix

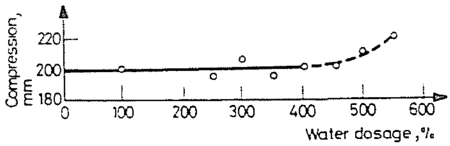

Fig. 3. Compressive strain under 1 MPa vs. water content

Thereafter compression due to 1 MPa vs. fluid content was determined. The result, namely that in the practically possible range of 100 to 400% of fluid, compression is inaffected by the fluid content, has been plotted in Fig. 3.

1.2 *Tests with furfuryl-alcohol* (FA)

Furfuryl-alcohol is transformed by acid condensation to very high strength furan resin. Reaction is advisably performed in two stages. First, an acid precondensate is made, mixed to the perlite, followed by thermal curing.

Perlite is eager to absorb FA, leading to a high consumption. Reduction was attempted by the following means: FA being compatible with water, perlite was wetted in advance, reducing, or better, unifying its absorptivity. Namely, a relatively small quantity of binder mixed to the dry perlite got there absorbed as a few lumps, without reaching other parts, and rather difficult to dissipate. Wetting was a good solution for the problem of binder dispersion.

The effect of water content on strength is seen in Fig. 4. For the applied 1 : 1 mix of perlite to FA, maximum is seen at 50% of water. This value is, of course, shifted for different FA dosages.

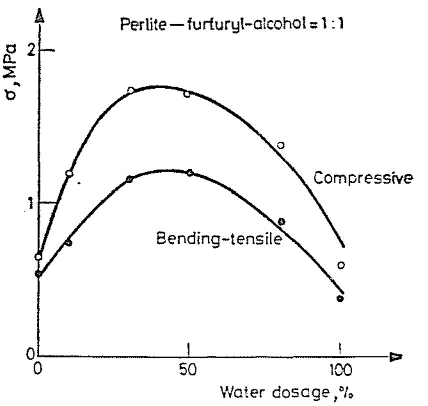

Fig. 4. Effect of water content on bending-tensile and compressive strengths

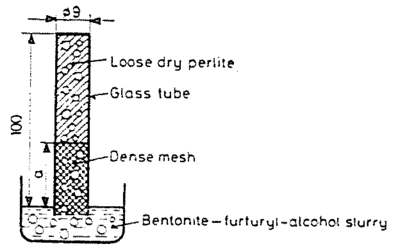

Fig. 5. Measurement of the perlite absorptivity to a bentonite-furfuryl-alcohol slurry

Thereby the problem of excessive absorption is partly solved. For other binders other liquids, irrelevant to the setting of the binder, may be selected.

To test the possibility of preventing an excessive absorption of such low-viscosity fluids by applying thyxotropized binder compounds, of them perlite absorbs only the fluid quantity needed for sticking, slurries have been made of FA and bentonite, of different proportions, and their thyxotropies determined in a rotation viscosimeter.

Thyxotropy was found for slurries made with 140 to 180 : 100 bentonite to FA proportions, worth to be experimented with.

24 h absorptivity tests of perlite to slurries were made according to the arrangement seen in Fig. 5.

Results compiled in Table 1 point out that the lowest absorption belongs to a 180 : 100 betonite to FA ratio, to be applied if possible.

Table 1

FA absorbed in perlite in 24 h, as a function of slurry composition

	Bentonite to FA ratio by mass					
	140 : 100	150 : 100	160 : 100	170 : 100	180 : 100	0 : 100
Absorption height, mm	78	41	29	20	11	100

Strength test results on 40×40×160 mm prisms made of 20 : 3 slurry to perlite ratios, with slurries of different compositions, have been compiled in Table 2.

Strengths are seen to fall short of expectations and to be lower than those for neat FA binder, thus, it is not a way to save binder. Increased solid densities are a special drawback.

1.3 *Tests with resin Amikol 65*

Also solution of this resin is compatible with water, its bond is accelerated by catalyst NH_4Cl.

Table 2

Strength values of perlite mortars made with bentonite-FA suspension binders

Characteristic	Unit	Bentonite to furfuryl alcohol ratio by mass				
		140 : 100	150 : 100	160 : 100	170 : 100	180 : 100
Green solid density	kg/m³	1120	1080	1160	1020	1060
Dry solid density	kg/m³	865	880	910	873	890
Bending-tensile strength	MPa	0.77	0.68	0.32	0.31	disintegrated
Compressive strength	MPa	1.51	1.42	0.89	0.77	disintegrated

Preliminary tests showed the perlite to absorb binders even in this range of viscosity. Considerations under 1.2 again motivated to wet the perlite. Specially determined water to resin ratio was found to be optimum for 1 : 1.

For a perlite dosage of about 270 kg/m³ and a moisture content of 100%, 140 to 220 kg/m³ of resin was found to give acceptable results.

Since the system contains the resin Amikol 65 in a low concentration because of the action of perlite as an inert filler, and of its dilution by water, its setting time is much prolonged. Therefore $40 \times 40 \times 160$ mm prisms have been made from mixes of different water dosages to test the timely process of setting of a mix (made with 189 kg/m³ of resin and 273 kg/m³ of perlite) from shrinkage and strength values. Shrinkage results are seen in Fig. 6. Setting of high-water mixes is seen to be delayed, starting with a flat limb, to be complete after 30 to 40 days when the resin can be considered as hardened.

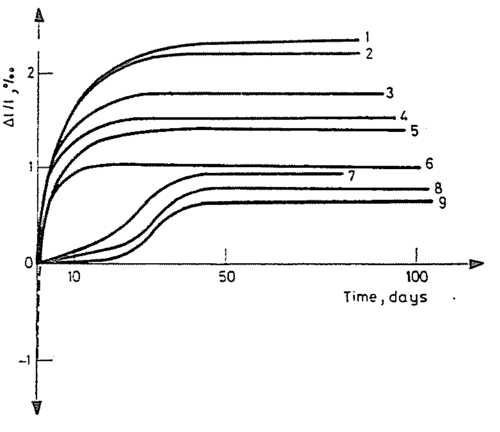

Fig. 6. Time-shrinkage relation vs. water content

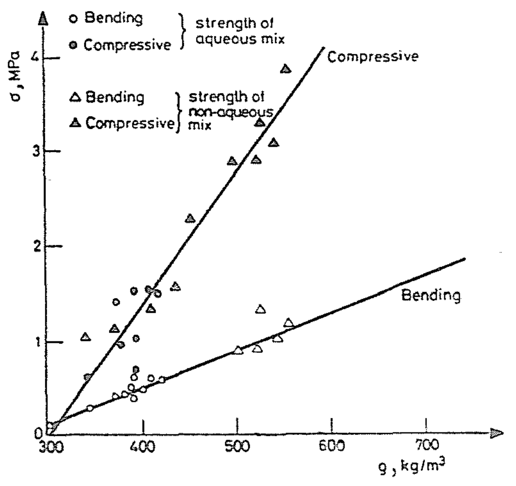

Fig. 7. Solid density vs. strength

The relation between solid density resulting from binder dosage, and compression (generally 4 MPa) and strength has been plotted in Fig. 7. The outlined method appears to result in mortar units of adequate strength under a compression of about 4 MPa, at a relatively low resin consumption.

1.4 *Tests on polystyrene solutions* (PS)

Solutions of different concentrations have been made to determine the viscosity permitting the solution to mix with perlite without being absorbed by the particles. Viscosity vs. concentration has been plotted in Fig. 8. PS

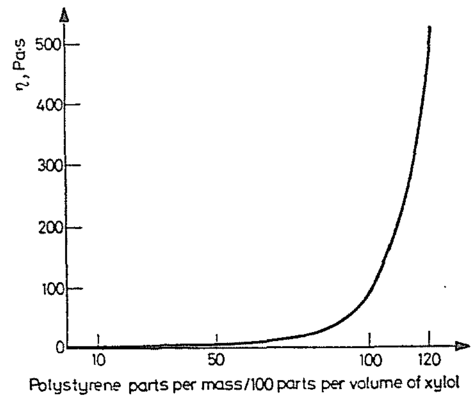

Fig. 8. Concentration vs. viscosity

to xylol concentrations of 90 to 120 : 100 are seen to be convenient. 24 h absorptions have been determined in the arrangement according to Fig. 5. Absorptions in this range were found to be minimum, of the 1 to 9 mm order. All solutions were made to specimens with solution to perlite ratios of 20 : 8. Difficulties arose from lumping. Besides, the solution loosing its fluid content got prone to fibrillation, also hampering mixing. At last, mixing the material by rubbing resulted in evenness. Specimens were cured by drying. 28-day strength results are seen in Table 3.

Table 3

Relationship between concentration and strength of polystyrene solution

Concentration	Unit $\frac{1}{100 \text{ tr.xylol}}$	90	100	110	120
Green solid density	kg/m^3	580	578	622	587
1-month solid density	kg/m^3	410	483	475	498
Tensile strength	MPa	0.960	1.044	1.065	1.00
Compressive strength	MPa	1.72	1.93	1.75	1.81

This method is seen to deliver rather acceptable results.

The solution to perlite ratio of 10 to 18 : 8 can be stated to much improve the strength for a PS to xylol ratio of 100 : 100. Beyond that, the strength increase is unsignificant. Microscopy showed solutions of a viscosity over 100 to 150 Pa.s practically not to penetrate into perlite particles, this being the viscosity range where the binder of syrupy consistency well mixes with perlite without an important proportion of inactive binder.

Of course, a polymer solution is not a suitable binder, evaporation of the solvent excessively prolonging the hardening, and acting as material loss impairing the economy.

The resulting perlite mortar is still plastic after a long time. Here it has only been used as a model material.

1.5 *Tests with polystyrene melt* (PS)

To test very high viscosities, melts of thermoplastic resins were used as models. Tests on PS melts will be presented below.

Tests were made on PS grains.

Molten PS has a very high viscosity, over 500 Pa.s, difficult to mix with perlite. It could only be done by mixing perlite with PS grains, then heated together. Although the material got lumped, a rather uniform mix has

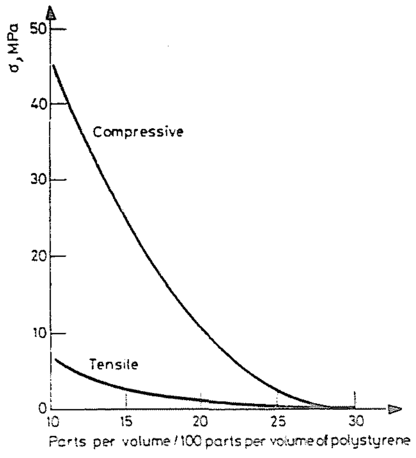

Fig. 9. Strength vs. perlite to polystyrene melt ratio

come about. This was made to specimens, cooled, and strength tested, with results plotted in Fig. 9. They are seen to be rather favourable.

Microscopy shows the sound perlite particles to be practically empty inside, the binder gets stuck outside the particles. The binder, of rather high viscosity, however, coats the particles in a thick layer, responsible for the high resin consumption.

Inasmuch as the binder costs are of no concern, this method suits perlite mortar production.

1.6 *Thermal conductivity tests*

Thermal conductivites of the specimens made according to the described four methods, from mixes considered to be the best, were tested in steady heat flow, in a Bock equipment.

Results have been compiled in Table 4.

Table 4

Thermal conductivity data

Material characteristics	Unit	Furan bond	Amikol 65 bond No. 9.	PS solution bond to a ratio 20 : 8	PS melt bond 25 ppm of perlite
Solid density	kg/m^3	0.279	444	392	495
Thermal conductivity	W/mK	0.079	0.111	0.095	0.123

Each is seen to have adequate thermal insulation.

Summary

Optimum state of binders for making perlite mortar has been tested on model materials of four different viscosities. *Furfuryl alcohol* was seen to be significantly absorbed in perlite bubbles.

Amikol 65, of a mean viscosity of 0.3 to 8 PA.s is vehemently absorbed in the bubbles, again to be reduced by wetting the perlite.

Mortar specimens made with *polystyrene* solved in xylol have a residual plasticity. No binder of a viscosity higher than 500 Pa.s enters perlite bubbles. This method is too complicated for perlite mortar making.

Plastic melts of viscosities over 500 Pa.s generally suit as binders, although the high viscosity results in thick coats around the particles, at a material wasting.

All in all, the best viscosity, for an otherwise adequate binder, is around 100 to 200 Pa.s

Senior Assistant Károly Kovács, H-1521, Budapest