MORTAR AND CONCRETE FROM ACTIVATED LIME PUMICITE

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Multiannual mechano-chemical research work at this Department aimed at determining the possibility of improving the latent hydraulicity of aqueous volcanic rocks (trasses) by mechanical activation. One achievement of this research was the possibility of producing "activated lime pumicite" from mechanically activated pumicite admixed with lime hydrate and a little portland cement, and pilot plant production of a few tons of this binder, according to principles specified in [1].

Hydraulic setting of the experimentally produced activated lime pumicite, a new binder, as well as mechanical characteristics of mortars and concretes made with them, have been subjected to great many tests, these were, however, rather informative of character, without striving to completeness. Primarily, utilization possibilities were of interest for us.

1. Activated lime pumicite mortars

Two different mortar test methods were applied. Partly, laboratory comparative tests were made on standard pumicite and cement mortars with sand and perlite aggregates. Partly — to test the durability primordial in practice — an experimental masonry wall has been erected to test weathering effects under natural conditions. These tests span four years.

1.1 *Laboratory tests*

Standard comparative mortar tests were made on mortar Hvb 7, with a composition complying with the Building Section Standard [2]:

1 cu.m of sand

125 kg of powdered lime hydrate

60 kg of portland cement C 450.

Sand grading is seen in Table 1.

Table 1

Mortar test aggregates

Lime pumicite grading mm	Sand 0 to 1 mm %	Expanded perlite %
5.0—2.0	1.45	0
2.0—1.0	5.55	2.0
1.0—0.5	17.40	14.0
0.5—0.25	50.00	28.0
0.25—0.125	24.50	30.0
0.125—0.063	1.00	18.0
Below 0.063	0.1	8.0
Bulk density	1530 kg/m^3	50 kg/m^3

Test results on activated lime pumicite have been compared to those on standard mortar. Mixtures were made where all the binder (both 125 kg of lime hydrate and 60 kg of cement) was replaced by activated lime pumicite (185 kg) but also mixes were made with different quantities of activated lime pumicite, as well as with or without plasticizer (Plastol).

Thermal insulating mortar was made with expanded perlite. In these mortars, all the sand volume was replaced by perlite.

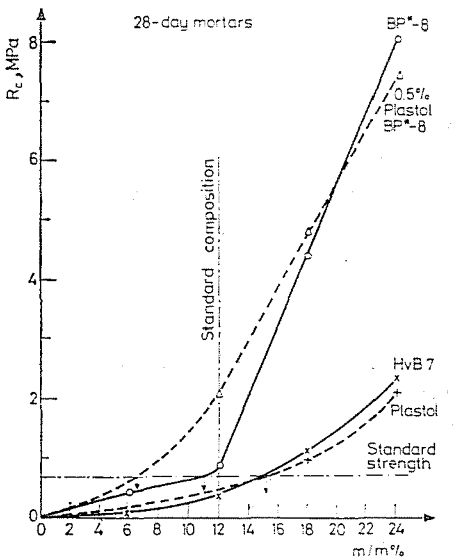


Fig. 1. Bond strength of plastering mortars vs. binder mass

Table 2

Standard test on mortar Hvb 7

Binder % by mass	w/c	Consistence (spread) cm	Water retention	Solid density kg/cu.m	28-day bending strength MPa	28-day compressive strength MPa
Sand + lime hydrate + cement (2.08 : 1 = m : c)						
6	4.3	14.5	0.69	—	—	0.10
12 (standard)	2.15	22.5	0.55	1800	0.28	0.36
18	1.48	24.5	0.59	1820	0.45	1.10
24	1.15	22.5	0.71	1840	0.90	2.37
Sand + lime hydrate + cement + 0.5% Plastol (cement % by mass)						
12 (standard)	2.15	23.5	0.47	1750	0.22	0.45
18	1.45	24.0	0.56	1810	0.52	0.90
24	1.11	23.5	0.72	1780	0.87	2.10
Sand + pumicite binder						
6	4.30	20.5	0.49	1770	0.28	0.40
12 (standard)	2.15	21.0	0.59	1970	1.07	1.86
18	1.48	24.5	0.57	1950	2.34	4.38
24	1.15	23.0	0.83	1910	—	8.04
Sand + pumicite binder + 5% Plastol (pumicite % by mass)						
12	2.15	24.0	0.57	1830	0.93	2.08
18	1.44	23.0	0.70	1990	2.25	4.82
24	1.08	22.0	0.81	1940	2.90	7.48
Perlite + lime hydrate + cement						
370 (standard)	2.06	25.0	0.50	700	0.19	0.36
Perlite + pumicite binder						
370	2.05	25.0	0.53	650	0.19	1.00

Table 2 and Fig. 1 compiling test data permit the following statements:

— The standard strength of 0.7 MPa needs much less of pumicite binder than of the usual lime hydrate + cement binder. Binder percentages needed to achieve the same standard strength are:

lime hydrate + cement	15 % by mass
lime hydrate + cement + Plastol	15 % by mass
activated lime pumicite	11 % by mass
activated lime pumicite with 0.5% of Plastol	7 % by mass

— For the same binder dosage the mortar strength is much higher than that of lime hydrate mortars. This is especially advantageous for very low-strength perlite plasterings. Also the solid density is lower — because of the lower solid density of pumicite — at an expected improvement of thermal insulation.

Complementary tests have been made on the frost and corrosion resistances as well as colour fastness of plasterings made with activated lime pumicite and pigments of different colours and types. These tests showed plasterings made with activated lime pumicite to exhibit resistances equivalent to those of cement-lime plasterings, namely:

- to support 24 freezing-thawing cycles without damage;
- not to affect staining qualities of various wall pigments exposed to light, CO_2 and water;
- to equal neat cement mortars by resistance to CO_2 and soft water.

1.2 *Plastering tests*

Both faces (E — W) of an experimental brick wall built in the Department yard were coated with three adjacent plasterings 1 m wide each, of two layers, 10 to 20 mm thick, made of mortars of different compositions such as:

East face:

a) 25 kg of standard sand 0 to 1 mm
10 kg of lime pumicite SP*-8
7.5 kg of water.

b) 25 kg of standard sand 0 to 1 mm
10 kg of lime pumicite BP*-8
7.5 kg of water.

c) 10 kg of blast furnace slag portland cement 350 from Lábatlan
10 kg of lime hydrate
10.5 kg of water
50 kg of sand 0 to 1 mm.

West face:

a) 50 kg of sand 0 to 1 mm
10 kg of lime pumicite SP*-8
8.5 kg of water.

b) 50 kg of sand 0 to 1 mm
10 kg of lime pumicite BP*-8
8.5 kg of water.

c) 10 kg of blast furnace slag portland cement 350 from Lábatlan
10 kg of lime hydrate
10.5 kg of water
50 kg of sand 0 to 1 mm.

(Symbols SP* and BP* indicate activated lime pumicite binders made of pumicite from *Szurdokpüspöki* and *Bodrogszegi*, resp. Numbers refer to the intensity of mechanical activation.)

Tests were made at 4 years of age using a mortar stripping device. Results have been compiled in Table 3.

Table 3

Bond strength test on 4-year mortars (MDa)

Masonry					
Facing east			Facing west		
SP*-8	BP*-8	350 pc	SP*-8	BP*-8	350 pc
0.34	0.43	0.39	0.35	0.32	0.33
0.14	0.31	0.20	0.19	0.13	0.18
0.50	0.60	0.56	0.57	0.50	0.41

Remark: Measurement results are averages from 12 measurements

The following conclusions have been made:

— Fresh mortars on the east face of the masonry, made with a high binder dosage (pumicite : sand = 1 : 2.5) are well spreadable, well adhering, thus good-consistency materials. Mortars on the west face were made with less binder (pumicite : sand = 1 : 5), of poorer consistence but still applicable.
— The plastered faces exposed to sunshine and frost effect for four years did not exhibit any change such as efflorescence, cracking, scaling etc.).
— Bond strength results were equal to, or better than, those of cement mortar. The effect of binder dosage could not be demonstrated unambiguously, since in 60 to 70 percent of all tests, the brick was torn out with the mortar.

2. Concrete tests

Laboratory tests concerned the compressive and bending-tensile strengths, modulus of elasticity and shrinkage of small concrete specimens, again making control specimens with portland cement binder beside those made with activated lime pumicite, and comparing test results. Since standard test results rank activated lime pumicite in the cement grade 25 (Fig. 2), blast furnace slag portland cement 35, the poorest binder made in Hungary, was chosen as

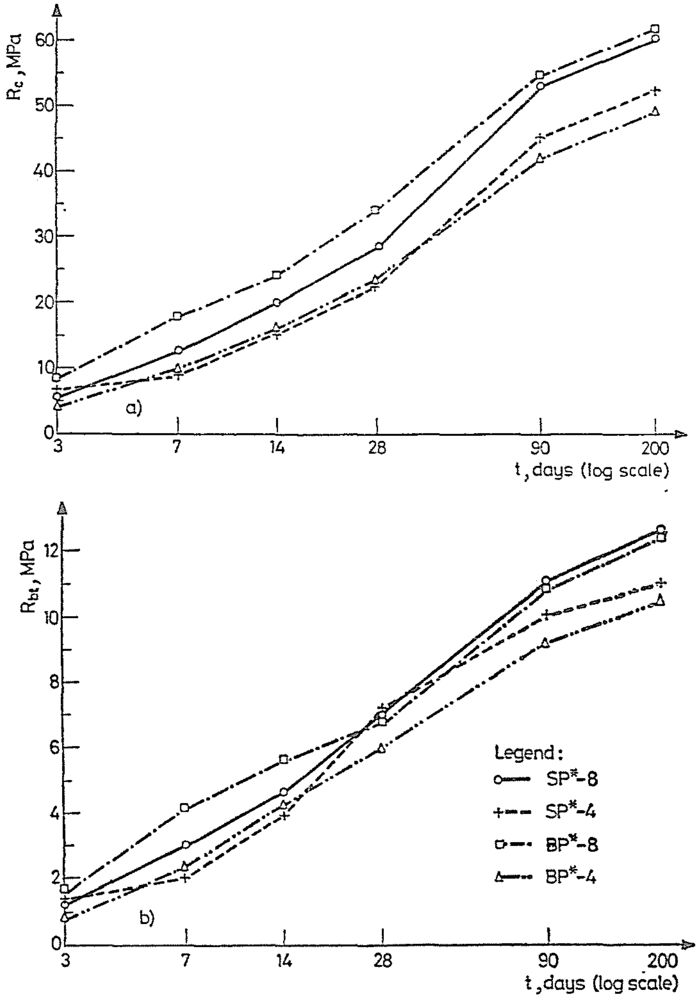


Fig. 2. *a)* Compressive, *b)* Bending-tensile } strength vs. specimen age
(water storage)

Composition:		
	binder:	450 g
	water:	225 g
	sand:	1350 g

reference material. Concrete compositions for the comparative concrete tests have been determined in preliminary tests.

Comparison relied on binder quantity referred to 1 cu.m. Water/binder ratio was the same in all tests. Notice that pumicite concrete has a higher paste volume than has cement concrete, because of the lower density of pumicite (2600 kg/cu.m). Therefore, theoretically the former ought to be more plastic than the latter. Nevertheless, pumicite concrete was found to be of stiffer consistence than cement concrete. From the aspect of placing, the two opposite effects (more paste and lower plasticity) balance each other.

2.1 *Strength tests*

This test series aimed at determining the effect of binder dosage on the concrete strength. Tests involved four different activated lime pumicite samples (BP*-8, BP*-4, SP*-8, SP*-4), and blast furnace slag portland cement 350 from Vác as reference. Design binder dosages were 200, 250, 300, 350, 400 kg/cu.m in every series.

Aggregate grading tended to limit curve B 16 and was composed of three fractions (Fig. 3).

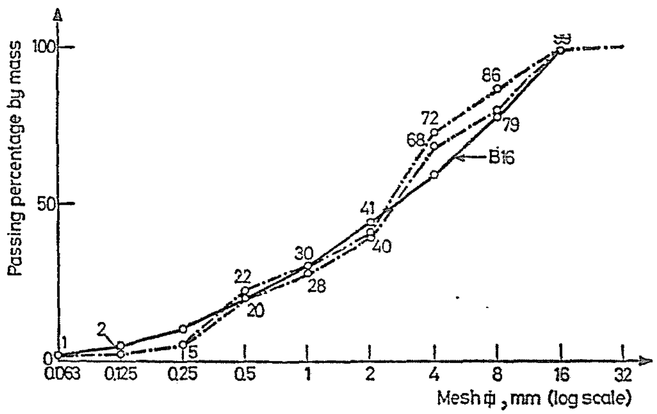


Fig. 3. Aggregate grading

2.1.1 *Concrete prism tests*

Test specimens 7.07 × 7.07 × 25 cm were made of concrete mixed manually and compacted on a vibrating table. Portland cement concretes were stripped at 1 day, pumicite concrete specimens at 2 or 3 days of age, then stored under wet burlap at 18—20 °C until 28 days of age. Thereafter the burlap was left unwetted. Prisms were first tested in bending over 21 cm span under third-point loading, then the compressive strength was determined on the two

Table 4

28-day concrete strength (MPa)

Binder type	Binder dosage kg/cu.m									
	200		250		300		350		400	
	Bending-tensile	Compressive	Bending-tensile	Compressive	Bending-tensile	Compressive	Bending-tensile	Compressive	Bending-tensile	Compressive
Portland c. 350 from Vác	2.07	11.40	3.20	14.75	4.07	22.28	4.15	21.92	4.44	24.27
SP*-4	2.77	8.17	3.72	14.13	3.81	15.22	4.01	17.97	4.32	22.22
SP*-8	3.92	15.25	3.94	19.48	4.19	20.83	4.78	25.75	4.69	28.23
BP*-4	2.87	11.60	3.46	16.40	4.01	15.73	4.04	19.48	4.30	25.17
BP*-8	1.74	10.60	2.86	15.47	2.88	20.33	3.28	24.33	3.21	27.65

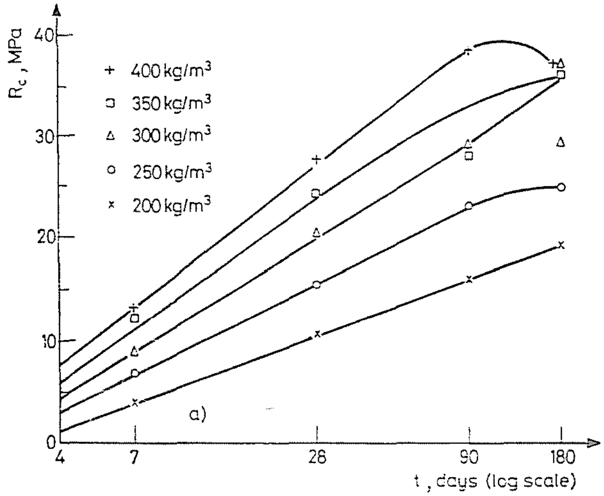
broken halves, compressed under a pressure plate of 5000 sq.cm. Test results have been compiled in Table 4, and results on pumicite BS*-8 have also been plotted in Fig. 4. The hardening process is illustrated by confronting 7-day and 90-day compressive strengths with that at 28 days of age. Ratios have been determined from fitting curves and compiled in Table 5.

2.1.2 *Concrete cube tests*

Concrete cubes 20 by 20 by 20 cm were made with blast furnace slag cement 350 from Vác, and activated lime pumicite. Specimens were moist cured in laboratory at 20 to 22 °C, or stored in the yard exposed to the weather, and tested at 1 year of age. Results have been compiled in Table 6.

Tests have led to the following conclusions:

— Concretes made with activated lime pumicite binder initially harden slower than do cement concretes.
— Standard strengths of the binders are rather different. This difference is, however, much less for concretes.
— Activated lime pumicite concretes are more sensitive to drying than are cement concretes, due to the slow hardening and to the increased shrinkage. Thus, concrete curing requires much care.
— According to tests to failure at 1 year of age, compressive strength of cured activated lime pumicite concretes is equal, and for those without curing, it is lower by 10 to 15 percent.
— Materials of lower activity are recommended since the energy consumption of higher activity is not rewarded by concrete properties, in particular, strength.



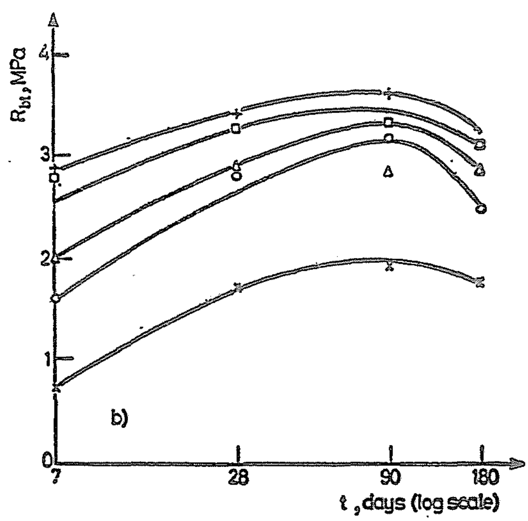


Fig. 4. a) Compressive } strength vs. concrete age and binder dosage
b) Bending-tensile }

— Activated lime pumicite concretes are exempt from bleeding, a hint to improved grouting properties.
— Activated lime pumicite concretes can be designed as blast furnace slag portland cement grade 350 concretes.

2.2 *Concrete shrinkage tests*

Concrete shrinkage was tested on prisms 10×10×50 cm in size of the following compositions:

Table 5

7 and 90-day compressive strengths referred to 28-day strength

Binder	Cement kg/m³	Percentage			
		7 days	avg.	90 days	avg.
P.c.V.350	200	59		136	
	250	53		140	
	300	55	57	127	131
	350	59		129	
	400	49		125	
SP*-8	200	35		150	
	250	40		140	
	300	43	43	140	149
	350	46		146	
	400	52		145	
SP*-4	200	32		160	
	250	33		157	
	300	36	35	158	156
	350	35		153	
	400	39		152	
BP*-8	200	38		152	
	250	42		148	
	300	45	44	148	146
	350	46		138	
	400	50		144	
BP*-4	200	43		152	
	250	39		148	
	300	39	43	150	148
	350	45		148	
	400	48		144	

Table 6

Compressive strength (MPa) of $20 \times 20 \times 20$ concrete cubes

Binder type	Cured specimens	Air-stored specimens without curing
P.c.350 from Vác	36.2	—
SP*-8	34.7	31.6
SP*-4	36.4	31.6
BP*-8	37.7	32.3
BP*-4	32.2	26.0

activated lime pumicite	300 kg/m³
water	165 kg/m³
aggregate	1775 kg/m³
	2240 kg/m³
cement	300 kg/m³
water	165 kg/m³
aggregate	1875 kg/m³
	2340 kg/m³.

Two prisms have been made from each concrete type and stored in laboratory at 30 to 45% r.h. and 20 to 24 °C, without moist curing. Shrinkage was determined by microscopy, by means of micrometer inserts stuck on the prisms. Mean results have been plotted in Fig. 5.

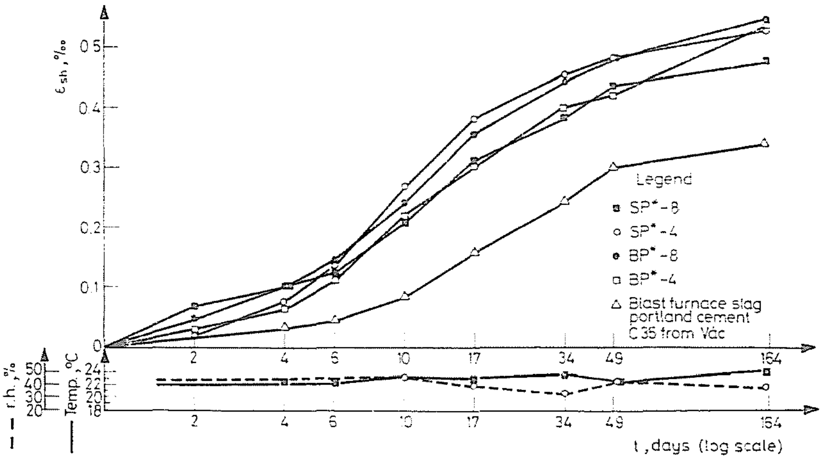


Fig. 5. Concrete shrinkage vs. age (binder dosage: 300 kg/cu.m)

Up to 164 days of age, the control specimen had a shrinkage of 0.34‰, and the pumicite concrete of 0.475 to 0.545‰. Shrinkage of the pumicite concrete was by 60% higher at maximum than that of the reference.

2.3 *Concrete deformability*

Prisms 12×12×36 cm were made with the same composition as the shrinkage specimens and stored under wet burlap in an air conditioned chamber at 10 °C. Measurement results compiled in Table 7 show the modulus of elasticity of activated lime pumicite concretes to be as low as 75 percent of the reference concrete.

Table 7

Modulus of elasticity (MPa)

Binder type	E_{z0}	$E_{zr}^{0,3}$	$E_{zr}^{0,6}$	$E_{\Delta}^{0,6}$
P.c.350 from Vác	36 000	—	—	—
	27 000	30 000	26 000	22 000
	30 000	30 000	28 000	24 000
SP*-8	21 000	—	—	—
	25 000	27 000	25 000	21 000
	24 000	28 000	22 000	18 000
SP*-4	20 000	—	—	—
	25 000	34 000	30 000	19 000
	22 000	26 000	24 000	17 000
BP*-8	21 000	—	—	—
	20 000	23 000	21 000	15 000
	23 000	24 000	22 000	16 000
BP*-4	29 000	—	—	—
	20 000	21 000	20 000	13 000
	24 000	26 000	24 000	17 000

Summary

Mortar and concrete technology tests were made on a new binder type (activated lime pumicite), with neat portland cement as reference.

Activated lime pumicite, with favourable consistency and binding properties, is suitable for plastering, since it can be made to a fairly workable mortar and a well adhering plastering of high strength, at a specific material consumption much lower than for conventional binders.

Again, it suits also as concrete binder in certain concrete technology problems. Its low modulus of elasticity recommends it mainly as binder for road foundations, inaffected by its disadvantageous sensitivity to drying, and high shrinkage.

References

1. Procedure for the production of high binding capacity hydraulic binders by mechanically activating volcanic glassy rocks. USA patent No. 4 188233.
2. Hungarian Building Section Standard ÉSz 54: Mortar quality requirements.*
3. Hungarian Standard MSz 523: Testing physical cement characteristics.*
4. Hungarian Standard MSz 4702/2: Cements. Portland, blast furnace slag portland, fly-ash portland cements.*
5. Hungarian Standard MSz 4713: Testing of concrete components.*
6. Hungarian Standard MSz 4715. Testing of hardened concrete.*

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* In Hungarian