

Aspects Concerning the Perlite Recovery in Addition with Polymeric Additives for Constructions Materials

DANIELA FIAT^{1*}, MIRELA LAZAR¹, VICTORIA BACIU¹, GHEORGHE HUBCA²

¹ Research Institute for Construction Equipment and Technology - ICECON SA, 26 Sos. Pantelimon, 021613, Bucharest, Romania

² Politehnica University of Bucharest, Applied Chemistry and Material Science, 1-3 Gh. Polizu, 011061, Bucharest, Romania

This study refers to the obtaining of mortar plasters using perlite and polymer additives additions. The performed study has outlined the influence of the polymeric additive nature and content as well as perlite addition on mortar plasters based on hydraulic binders characteristics.

Keywords: mortar plasters, polymeric additive, perlite, redispersabile powders, cellulose ethers

Mineral resources are natural accumulations likely to be exploited, incorporating mined products: metal ores, industrial minerals, building materials (sand, gravel, perlite, vermiculite), minerals and ornamental stones, solid mineral fuels (peat, coal), fluids (oil, gas) [1]. These resources are an important natural capital may be converted to raw materials.

Between natural resources with multiple applications, insufficiently exploited and used is perlitic rock.

The perlite is a volcanic rock, formed by lava cooled rapidly in contact with water or high pressure steam, light gray, presented in figure 1, with vitreous texture, from rhyolitic composition, with 2-5% constitution water. By heating, at temperatures 850-1110°C expands, increasing 10-20 times the volume, generating a light weight material, non-flammable, presented in figure 2 [2].

The perlite is an inorganic material with following chemical composition: 60-75% SiO₂, 12-16% Al₂O₃, 5-10% Na₂O, 2-5% K₂O, 0-2% CaO, 0-1% MgO, 0-1% Fe₂O₃, natural, ecological, granular, thermoinsulating ($\lambda = 0.040 - 0.060$ W/mK), very stable chemically, while non-degraded, with a water absorption of approx. 30-200 %, incombustible and can be used both under ordinary at temperatures and special conditions (maximal temperature of use approx. 1000°C).

Since perlite is a form of natural glass, it is classified as chemically inert and has pH of approximately 7.

The perlite is extracted from the mine and expanded in all countries of the world: Romania, United States, China, Greece, Japan, Hungary, Armenia, Italy, Mexico, Philippines and Turkey.

Gross deposits of perlite are extracted from quarry, crushed, dried in rotary dryers, sorted, sieved and sent to expand factories. To expanded perlite rotary kilns, fixed horizontal and vertical expansion were used.

In the expanding plants, the deposit is preheated or introduced directly in to the oven. Material preheated to about 430°C reduces fine fractions produced during the process of expansion, which increases productivity and controls product density uniformity. In the oven, perlite reaches temperatures of 760 - 980°C, at this point entering to the plastic state where the constitution water is evaporated. Because of this, hot perlite particles expand increasing 10-20 times the original size of the particle. From oven, the expanded perlite particles are released and transported pneumatically to a cyclone system.

The perlite has applications in steel industry, at casting melted materials, in ceramic industry (ceramic floor and wall tiles) and refractory materials (tiles, bricks) as a binder that induces pores, in food industry (drinks industry: vegetable oils, juice, beer, wine) at filtering material for liquids, chemical industry as adsorbent in the flotation of colloidal adsorption for the treatment of waste water containing heavy metals (Cu, Zn, Ni, Cd) [3, 4].

In agriculture the perlite is used as a mineral aggregate in horticultural crops. Mixed with soil, the perlite produces a favorable mineral environment which helps to develop plants, the soil with a higher capacity for water retention and an improved structural stability. For heavy airless soils (ex. clay), the perlite helps to drainage and aeration.

Due to many advantages low density, chemical and thermal stability, thermoinsulating properties, low humidity (<1%), in constructions the perlite is used for thermo-insulating and finishing materials ex. light concrete and plasters, refractory materials, light ceramic blocks, shaped composite materials and plates.

Increasing requirements in terms of construction quality, technological development, development of modern construction and chemical industry, emergence of new

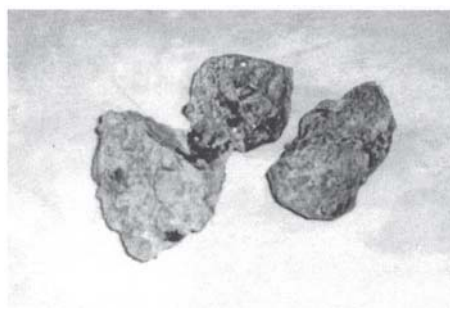


Fig. 1- Perlite rock



Fig. 2 - Expanded perlite

* Tel.: 0744470342

performance materials in constructions, diversification of building construction applications, imposed the change of traditional mortars, that can not meet current technical requirements (ex. adherence to non-absorbent surfaces, extruded PST, ceramic tiles with very low water absorption, wood panels, plates of natural stones or composites materials) with polymer additives.

Adding of polymer additives (aqueous dispersions of synthetic copolymers or redispersable powders) in traditional mortars based on mineral binders, improves considerably their properties: support adherence, workability time, capacity of water retention, flexibility, durability etc.

Nowadays, mixing technology on site for masonry mortars and plaster was also replaced by dry mortars. Dry mortars are produced in a special facility in which the process of mixing mineral binders, of aggregates (sand) and polymer additive is used to improve mortars performance. Dry mortars are delivered to building sites in bags or special bunkers, to be mixed only with water, before use. New technology for applying dry mortars, adequate equipment for efficient transport, mixing with water at the application, lead to an improvement in terms of productivity products applied as plaster and masonry mortars.

Redispersable powders are obtained by spraying aqueous dispersions of polymer, by special technologies, generally based on: ethylene/vinyl acetate copolymer, ethylene/vinyl laurate/vinyl chloride copolymers, versatile vinyl-vinyl acetate, acrylic copolymers.

After mixing (redispersion) in water, these powders binders polymer may form aqueous dispersions with all the typical features and functions of polymer binder. Furthermore, besides the advantages mentioned above because of waterproofing effect of redispersable powders it results a plaster with a strong rejecting water effect.

The additives are added generally in proportion of 1%-10% compared to mineral binders.

Methyl cellulose is water-soluble within a large temperature range. It is dispersed between binder and aggregate particles, avoids the formation of lumps, leading to obtaining a well mixed wet mortar. In pure solution and a wet mortar, methyl cellulose increases viscosity. Methyl cellulose also influences dry mortars adherence.

The water retention value of a mineral plaster is the percentage of water that remains in the plaster after capillary dewatering by absorbant substrate. Because cement-based mortars and plasters need water for setting, this must be retained in the mortar for a longer period of time. The high water retention in dry mortars is mainly made by the concentration and viscosity of the added methyl cellulose.

Another important dry mortar feature is consistency, which is added to the amount of water needed to achieve an effective product, property that is also controlled by the methyl cellulose content.

Cellulosic additives - cellulose ethers are used as thickening and water retaining agents in dry mortars, in very small quantities 0.02-0.7%. The mainly used cellulose ethers in dry mortars are methyl hydroxy ethyl cellulose (MHEC) and methyl hydroxy ethyl cellulose (MHPC) [5].

Other additives used in dry mortars are:

- starch ethers: to increase the viscosity of dry mortars containing cellulose ether hydroxypropyl starches are added, in addition rates of 0.01-0.04% in cement-based renders and 0.02 -0.06 % in gypsum-based plasters. At the optimal dosage, workability is improved.

Air-entraining agents act by entraining air micropores in the mortar, to obtain a decreased wet mortar density, a

better wet mortar workability and a higher efficiency. Air-entraining agents are mainly in powder form (sodium salts of fatty acid sulfonates and sulfates). The addition rate in masonry and plaster mortar is 0.01-0.06%;

- accelerators: are used to adjust setting time. Calcium formate (> 0.07%) or lithium carbonate (> 0.2%) are mainly used;

- retarders: the main applications are in gypsum plasters. Without these additives the setting of gypsum is too fast. Tartaric and citric acids or synthetic acids, in addition of 0.05 - 0.25% are thus mainly used.

Hydrophobic agents prevent water from penetrating in to the mortar, but allow mortar „to breathe” i.e. there takes place water vapour diffusion by mortar for external applications. There are two groups of hydrophobic agents: metal salts of fatty acids (addition 0.1-1%) and redispersable polymeric powders with hydrophobic properties. The first group has the advantage of lower addition but the second group presents the advantage of better durability, because hydrophobic redispersable powders are not eliminated from mortar during rain and it also improves the mortar substrate adhesion over the years;

- superplasticisers: have a strong influence on the water mortar demand. A mortar containing superplasticisers needs smaller water quantities than usual to reach the same consistency. Superplasticisers (ex. casein, naphthalene, melamine etc.) are used mainly in mortars which need strength. Usual amount of addition is 0.2-1%.

Fibres, can be divided into two groups: long fibres used mainly to influence wet mortars properties and water demand;

- defoamers - reduce the air content into wet mortars. Defoamer powders used are, for ex. hydrocarbons, polyglycoles or polysiloxanes.

Experimental part

This work was aimed at studying the influence of nature and polymer additive content, cellulosic additives and content of perlite on the mortar plasters.

The research was made on mortars based on Portland cement, hydrated lime and sand, to which have been added fixed quantities of polymer additives, cellulosic additives and perlite.

Due to perlite high absorption of water of about 30%-200%, for waterproofing redispersable powders were added.

As polymer additives (redispersable powders and cellulose ether) were used additives made by WACKER - Polymer Systems GmbH&Co.KG Germany: Vinnapas RI 551 Z, Vinnapas RI 554 Z and Walocel MKX 45000 PP 10, made by WOLFF Cellulosics GmbH&Co.KG Germany, available by SC BRENNTAG ROMANIA SRL [6-8]. Technical characteristics of additives are presented in table 1.

There was used expanded perlite made by Bentonita SA, Medieșu Aurit, whose characteristics are presented in table 2, perlite type P2 of fine granulation [9].

The obtained mortar was characterized by determining the density of fresh and hardened mortar, mechanical strengths, mortar support adhesion and water penetration.

Density of fresh mortar was determined by the ratio between the mass and volume occupied when introduced into a measuring container with indicated capacity, according to SR EN 1015-6:2001 [10]. The measuring container is filled with mortar prepared according to recipe, so the mortar flows from the container center to the outer surface. The excess of mortar is removed by smoothing with a palette so to obtain a smooth mortar surface. The container filled with mortar is weighed and related to the known volume of the container (approx. 1 liter).

Characteristics	Value	Fields of application
Vinnapas RI 551 Z (a)		
Appearance	powder, cream coloured	<ul style="list-style-type: none"> - adhesives mortars for ceramic tiles; - adhesives for external insulation and finishing systems; - plastering mortars; - sealing slurries and putties; - sole binder for adhesives plastering mortar
Chemical composition	Ethylene/vinylaurate/vinyl chloride copolymer	
Stabilizer system	Polyvinyl alcohol	
Particle size > 400 µm	< 2%	
Particle size, predominant	0.3-9 µm	
Solids content	98-100 %	
Ash content (1000°C, 30 min.)	11-15 %	
Apparent density	400-500 g/l	
Minimum film-forming temperature	0°C	
Vinnapas RI 554 Z, hydrophobic properties (b)		
Characteristics	Value	Fields of application
Appearance	powder, cream coloured	<ul style="list-style-type: none"> - adhesives mortars for ceramic tiles; - adhesives for external insulation and finishing systems; - plastering mortars; - gypsum plaster - sole binder for adhesives plastering mortar
Chemical composition	Ethylene/vinylaurate/vinyl chloride copolymer	
Stabilizer system	Polyvinyl alcohol	
Particle size > 400 µm	< 2%	
Particle size, predominant	0.3-9 µm	
Solids content	98-100 %	
Ash content (1000°C, 30 min.)	11-15 %	
Apparent density	400-500 g/l	
Minimum film-forming temperature	0°C	
Walocel MKX 45000 PP 10 (c)		
Appearance	powder, white coloured	<ul style="list-style-type: none"> - plastering mortars; - adhesives mortars for ceramic tiles; - adhesives for external insulation and finishing systems
Chemical composition	modified methyl hydroxy ethyl cellulose	
Solubility	water	
Viscosity	45000-52000 mPa	
pH	neutral (2%)	
Moisture content	max. 7%	

Table 1
TECHNICAL
CHARACTERISTICS

Characteristics	U.M.	Perlite type P2
Thermal conductivity	W/mK	0,040
Specific weight	kg/m ³	60 -80
Particle size, predominant	mm	0 - 1
Particle size, under 0,32 mm	%	< 60
Content in sterile	%	< 5
Moisture	%	< 2

Table 2
PHYSICAL AND CHEMICAL
PROPERTIES PERLITE TYPE P2-P

The density of hardened mortar was determined by the ratio between sample mass in dry state and displaced volume when immersed in water, according to SR EN 1015-10:2001 [11]. Prismatic specimens were used 40 x 40 x 160 mm. Saturated test-piece volume is determined by hydrostatic weighing, weighed by balance collar plate immersed in water tank and wet test-piece weighed by balance collar plate, outside water tank. Specimen mortar density is calculated as the ratio between mass and displaced volume.

Flexural strength of hardened mortar is determined by applying a load in three points, to the breaking, on hardened prismatic 40 x 40 x 160 mm samples of freshly cast mortar prepared according to recipe and 28 days conditioned. Compressive strength is determined on prismatic heads by applying a progressive load perpendicular to the sample. Flexural and compressive strength of hardened mortar was determined according to SR EN 1015-11:2002 [12]. Tests were performed 28 days after casting.

The adhesive strength of mortars applied on substrate is expressed as maximal necessary load to separate the mortars by traction and it was determined according to SR EN 1015-12:2001 [13]. Fresh prepared mortar according

to recipe, is applied to substrates (rectangular slabs). It is conditioned 7 days, covered with PE film at temperature 20±2°C, the test-specimens are removed and stored at a constant temperature of 20±2°C and 65±5% air relative humidity, about 21 days. The tensile pieces are fixed (mettalic pieces 50x 50 mm with devices for direct connection to a tensile machine). Samples are tested 28 days after preparation, immediately after being removed from storage site. A force perpendicular to the test surface is applied with a tensile machine, at a uniform speed. Adhesion force is measured as the maximum tensile effort on the mortar plastering surface. Adhesion force is the ratio between the breaking force and test surface.

Water penetration test (p) consists in measuring the quantity of water required to maintaining constant water column level with known diameter and height for a certain time and it was determined according to the described method in NE 001-96 [14]. On cement mortar specimens (200 x 200 x 20 mm) plaster mortar prepared according to recipe is applied. 28 days after applications, on the finished surface samples it is fixed a graduated glass cylinder and it is sealed with paraffin. 24 h after drying, the glass cylinder fills with distilled water to the indicated level. Every 24 h

Table 3
MORTAR TESTED PHYSICAL-MECHANICAL PROPERTIES

No.	Characteristics	U.M	Recipes composition:								
			Recipe 1 (standard mortar*)	R 2	R 3	R 4	R 5	R 6	R 7	R 8	R 9
			-	-	1% (a) 0.05% (c)	2% (b) 0.05% (c)	1% (a) 0.05% (c) 16.5% P	1% (b) 0.05% (c) 8.5% P	1% (b) 0.05% (c) 7% P	1% (b) 0.05% (c) 5% P	2% (b) 0.05% (c) 5% P
1.	Density (fresh mortar)	kg/m ³	2108	1190	1790	1700	979	1320	1310	1453	1438
2.	Proportion of water added	%	24	84	23	12	83	45	43	39	38
3.	Density (hardener mortar)	kg/m ³	1490	850	1510	1490	630	838	761	1062	1012
4.	Flexural strength:	N/mm ²	- 7 days	-	1.79	1.85	0.25	0.55	0.63	0.52	0.79
			- 28 days	-	2.80	2.87	0.31	0.67	0.72	0.74	1.14
5.	Compressive strength:	N/mm ²	- 7 days	-	5.15	4.52	0.31	1.37	1.43	1.54	2.10
			- 28 days	-	7.40	7.63	0.62	1.43	1.69	1.85	2.34
6.	Substrate adhesion:	N/mm ²	- 7 days	0.22	0.36	0.27	0.10	0.14	0.15	0.18	0.20
			- 28 days	0.38	0.51	0.51	0.12	0.17	0.18	0.20	0.24
7.	Water penetration (p)	g/dm ² zi	140.12	140.12	140.12	70	140.12	118.6	110.50	107.10	75.70
8.	Specific consumption	kg/m ³	4.01	2.30	3.79	3.57	2.23	2.23	2.32	1.69	1.7

* traditional plaster mortar: cement, hydrated lime, sand

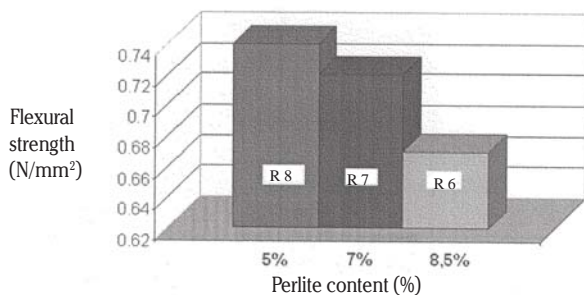


Fig. 3. Flexural strength variation in accordance with perlite content

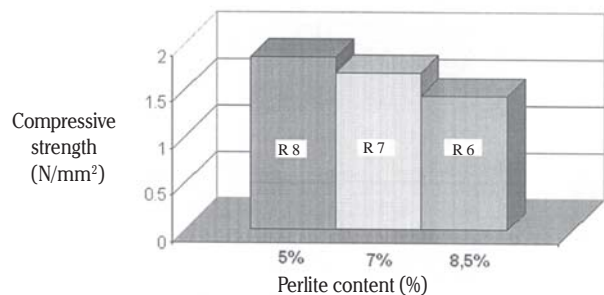


Fig. 5. Compressive strength variation in accordance with perlite content

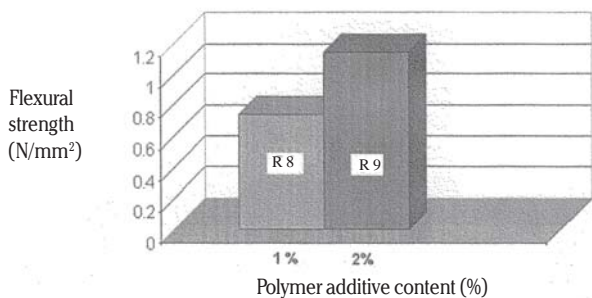


Fig. 4. Flexural strength variation in accordance with polymer additive content (at constant perlite content 5%)

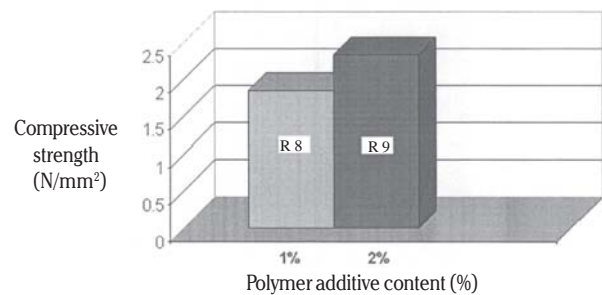


Fig. 6. Compressive strength variation in accordance with polymer additive content (at constant perlite content 5%)

water level in cylinder is completed, measuring the amount of water added. This operation is repeated for 8 days.

Results and discussion

In table 3 there are presented the obtained results regarding the mortar properties depending on their composition.

Initially a classical mortar plaster recipe was elaborated (cement CEM II/A-S 32,5; sand with granulation 0.2 - 0.5 mm; hydrated lime), recipe R1.

The constant cement content and hydrated lime and cellulosic ether were maintained. The perlite content and redispersable powder content were varied.

By the addition of polymeric additives: redispersable powders (a) - 1% and cellulosic ether (c) - 0.05%, recipe R3 were observed, a better workability and an improvement of mortar substrate of adhesion about 34%, mortar being permeable to water.

By adding a polymeric additive with hydrophobic properties (b) - 2%, recipe R4, it results an increase of mortar substrate adhesion of about 34% and an important water penetration (p) decrease of about 50%, over recipe R1.

In R2, the recipe with 16% perlite addition (light aggregate), without polymeric additives it is observed a considerable decrease of mortar density of about 43%, a large amount of water added for obtaining a normal consistency of application (standard cone = 9 cm), insignificant mechanical strength, can not be determined because the mortar is brittle and with a very low support adhesion, decreased with about 60% over the plaster mortar recipe R1, without additives. The mortar is also permeable to water ($p > 100 \text{ g/dm}^2 \times \text{day}$). It results that without polymeric additives addition, the mortar with 16% perlite can not be used.

By decreasing perlite content (8.5%-R6, 7%-R7, 5%-R8) and in the presence of redispersable powders (a), (b) and

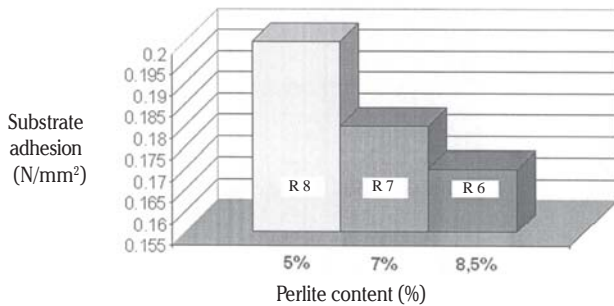


Fig. 7 - Substrate adhesion variation in accordance with perlite content

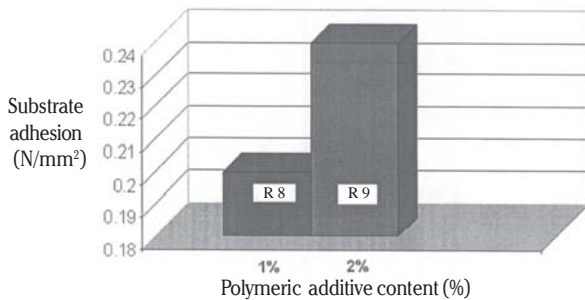


Fig. 8. Substrate adhesion variation in accordance with polymer additive content (at constant perlite content 5%)

cellulosic ether (c) it is observed, a slight increase of mechanical strength (figs. 3, 5), the increase of substrate adhesion (fig. 7) of about 30% and a decrease of water penetration (fig. 9), over recipe R2.

At a perlite content of 5%, with addition of 2% polymeric additive (b), 0,05% cellulosic ether, recipe R9, it results an improvement of the adhesion (fig. 8) about 20% over recipe R8-1% polymeric additive (a), an increase of mechanical strength (figs. 4, 6) and a decrease of water penetration (fig. 10) of about 30% ($p < 100 \text{ g/m}^2 \times \text{day}$).

Conclusions

The perlite represents important natural resources, not polluting the atmosphere, water and soil with dangerous toxic emissions (heavy metals powders and polycyclic aromatic hydrocarbons).

Generally, at all recipes with perlite addition, it is noted a considerable decrease for dry density which leads to classification in class LW, plastering and rendering light mortars ($\rho_a \leq 1300 \text{ kg/m}^3$), according to SR EN 998-1:2004 [15].

High perlite content, even with polymer addition, leads to the decrease of mechanical strength and substrate adhesion as well as the increase of water permeability expressed by water penetration "p". For this reason, the optimal perlite dosage is 5%.

The polymer addition (redispersable powder and cellulosic ethers) leads to the improvement of the characteristics: water retention, workability, substrate adhesion.

The increase of polymer additive amount in recipe leads to the decrease of water penetration. The same result is obtained by using a polymer additive with hydrophobic properties (Vinnapas RI 554 Z - b).

Specific consumption of perlite mortars (R9) considerably decreased with about 58% over the classic mortar (R1), leads to much lower execution costs.

Lower mechanical strengths with 5% perlite can be improved by using complex cements, with high mechanical strength, considering the uniformity of granulometric degree of cement, a number of correlations between mechanical strength of cement and mechanical strength

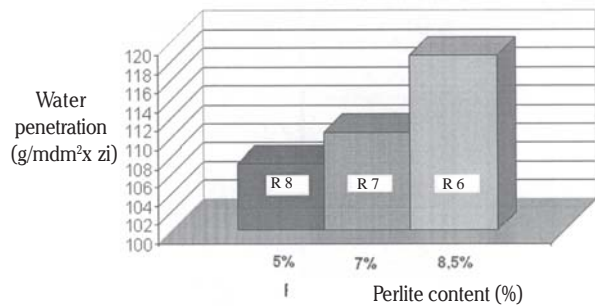


Fig. 9. Water penetration variation in accordance with perlite content

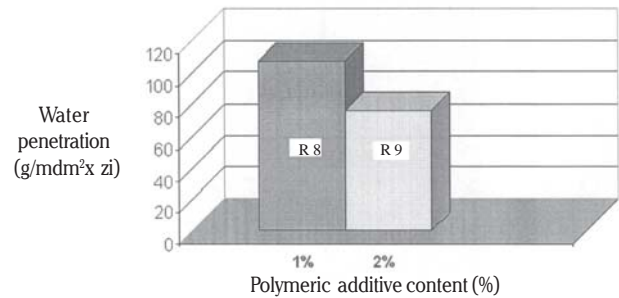


Fig. 10. Water penetration variation in accordance with polymer additive content (at constant perlite content 5%)

(initial and final) occurring in mortars [16, 17]. Fibre (glass, polymeric) addition may be used, which makes a disperse reinforcement.

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