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MASTER FLOOR®: The New Application of Pumice Stone as Lightweight Floor Filling Material †

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Abstract: Pumice quarried by LAVA MINING & QUARRYING SA from Yali island, Dodecanese, is used, domestically and abroad, in applications such as concrete lightweight aggregate, masonry units constituent, road substrate, and loose soil stabilization. It is a porous natural volcanic rock with low density, low thermal and noise transmission, and higher strength among all the natural or artificial lightweight materials of mineral origin. Nowadays, pumice is of additional interest, as it has a reduced CO_2 footprint because thermal energy is not required for its expansion compared with artificial lightweight aggregates. In this context, HERACLES Group is launching a new product in the market under the brand name MASTER FLOOR®, a commercial bagged product for floor or wall fillings with lightweight and insulating properties.

Keywords: pumice stone; lightweight floor filling; CO_2 footprint

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1. Introduction

Pumice quarried by LAVA MINING & QUARRYING SA from Yali island, Dodecanese, is a porous natural volcanic rock with low density, low thermal and noise transmission, and higher strength among all the natural or artificial lightweight materials of mineral origin. Nowadays, pumice is of additional interest, as it has a reduced CO_2 footprint because thermal energy is not needed for its expansion compared with the artificial lightweight aggregates.

Pumice has been extensively used, domestically and abroad, for infrastructure works, lightweight concrete, lightweight masonry blocks, and horticultural applications. In recent years, HERACLES Group aims at the applied research on the upgraded commercial use of pumice. Pumice-concrete, as a filling material for floors and masonry, has been used for many years successfully by builders and contractors. In these cases, the proportions of concrete materials (pumice, cement, sand, water) are determined by the experience, habits, and equipment of the builders. HERACLES Group aims to create a lightweight aggregate with a defined composition and properties of the resulting lightweight concrete, which led to launching the bagged lightweight aggregate MASTER FLOOR®.

2. Laboratory Data

Composition of MASTER FLOOR® is a result of experimentation in Hellenic Concrete Technology Center (Heracles Group) and interaction with builders and contractors in application trials. Laboratory mixtures included, as raw materials, pumice of granular grade 0/3 mm, pumice 0/8 mm, sand and commercial expanded perlite for lightweight filling concrete applications. Properties of lightweight aggregates are presented in Table 1, and the representative laboratory data which were used as a guide for MASTER FLOOR® formulation are presented in Table 2.

Table 1. Particle size distribution and loose bulk density of lightweight aggregates.

	Pumice 0/3	**Pumice 0/8**	**Expanded Perlite**
Sieve, mm		**Passing, % *w*/*w***	
8		99	
4		78	
3.15	99	70	99
2	86	54	79
1	60	38	50
0.5	40	27	32
0.25	23	20	17
0.125	17	15	11
		Loose bulk density dry aggregate, kg/m^3	
	830	860	86

Table 2. Representative laboratory data.

Lab Mix Design Code		**8478**	**8479**	**8480**	**8489**	**8481**	**8482**	**8484**	**8485**	**8483**
cement CEM II 32.5	kg/m^3	213	168	182	161	202	235	216	195	396
pumice 0/3 dry mass	kg/m^3	870	687	743	656.7	660	766	0	0	0
pumice 0/8 dry mass	kg/m^3	0	0	0	0	0	0	922.1	828.7	0
expanded perlite	kg/m^3	0	0	0	0	0	0	0	0	114.5
sand dry mass	kg/m^3	0	0	0	0	162.6	188.6	0	0	0
water of moisture	kg/m^3	51.3	40.5	43.8	38.7	51.2	59.3	13.8	12.4	0.0
water added	kg/m^3	355.2	208.0	260.6	213.0	245.9	310.5	333.4	257.6	481.5
air enrainment agent	kg/m^3	0	0.91	0.39	1.22	0.39	0	0	0.42	0
air content	v/v%	14.8	39.9	31.5	41.1	29.0	15.1	18.4	30.8	33.2
density fresh	kg/m^3	1490	1105	1230	1071	1323	1559	1486	1294	999
slump	cm	7	14	14	19	15	6	16	9	19
		compressive strength								
24 h	MPa	0.83	0.21	0.54	0.06	0.52	1.46	1.51	1.18	0.76
2 days	MPa	1.71	0.61	1.14	0.34	1.40	2.51	2.99	2.51	1.33
7 days	MPa	3.09	1.25	2.24	0.82	2.61	4.46	5.27	4.47	2.49
28 days	MPa	5.63	2.48	4.10	1.71	5.12	7.79	8.85	7.50	3.16

Particle size distribution of pumice 0/3 is similar with that of expanded perlite. Its loose bulk density is tenfold higher than that of the expanded perlite.

In mix designs 8479, 8480, 8489, 8481 and 8485, the use of air entrainment results in the reduction of the fresh density of pumice concrete and reduction of cement content. In general, the fresh density of pumice concrete is in the range 1105 to 1559 kg/m^3, the cement content from 161 to 235 kg/m^3, and compressive strength at 28 days (cubes 150 mm); from 1.71 to 8.85 MPa. Mix design 8483 with expanded perlite presents a fresh density of 999 kg/m^3, strength at 8 days 3.16 MPa, with cement content 396 kg/m^3.

A diagram of strength vs. cement content is presented in Figure 1. Lightweight concrete with pumice 0/3 mm exhibits a liner relation of strength vs. cement content. The use of pumice 0/8 has higher strength due to the different packing of aggregates in the mixture.

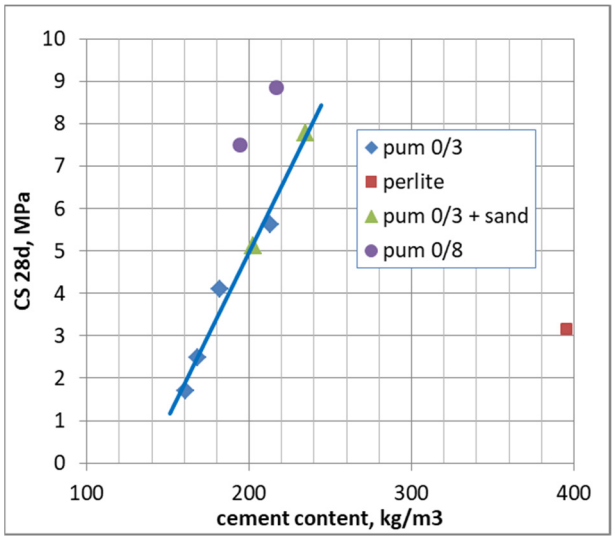

Figure 1. Strength of lightweight concrete vs. the applied pumice concrete vs. cement content.

3. Components and Application

MASTER FLOOR® is a mixture of pumice and limestone sand of defined particle size and proportions, containing polypropylene fibers. Pumice moisture is kept within controlled limits.

MASTER FLOOR® is mixed at the jobsite with cement and water to produce a high-strength lightweight concrete for filling applications:

- Floor leveling before applying tiles, granite etc.
- Undercoating for rooftop layering (drainage slopes, insulation)
- Vertical masonry fillings

4. Usage Quality

Usage quality of MASTER FLOOR® includes properties desirable from the builders and contractors during and after the application of the product:

- Polypropylene fibers enhance the resistance against early cracks
- Low apparent weight resulting in a reduction of building loads
- It is inert in contact with the reinforcement
- It has thermal and sound insulating properties
- The selected granulometry and specific ratio of pumice and sand gives:
    - No emission of dust at jobsite ensuring health, safety, and tidiness
    - No segregation when moving/transporting the bags
    - No additional surface treatment is required for coating with tiles
    - A surface suitable for increased tile adhesion and glue saving
    - Pumpability of the fresh mixture (MASTER FLOOR®, cement and water) with typical mortar equipment over a wide range of water and cement ratio.

5. Technical Properties

A concrete mixture with 1 m^3 MASTER FLOOR and 200 kg/m^3 cement CEM II32.5 develops sufficient strength already from the second day, typically as

2 days strength: 1.5 MPa
7 days strength: 2.8 MPa
28 days strength: 5.0 MPa
Bulk density of pumice concrete
Fresh: 1550–1650 kg/m^3
Equilibrium with ambient: 1500–1600 kg/m^3
Dry oven (reference): 1450–1550 kg/m^3

The strength of the applied pumice concrete depends on cement content, as in Figure 2.

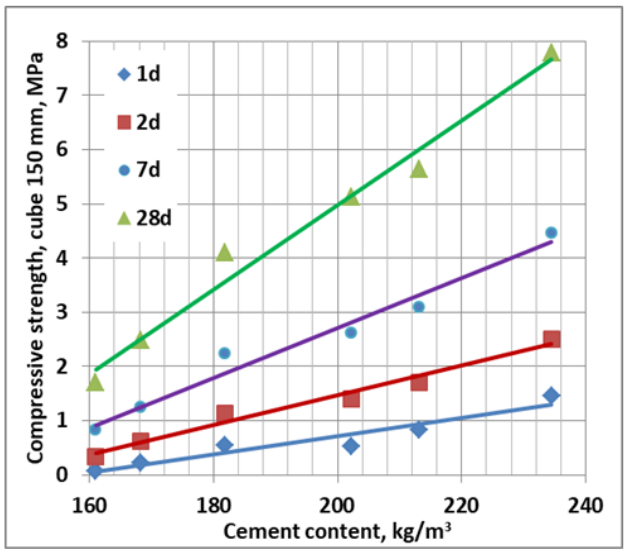

Figure 2. Strength of the applied pumice concrete vs. cement content.

The thermal conductivity coefficient of dry oven pumice concrete is λ_{10dry}= 0.5–0.7 W/(m K).

Use of Air Entrainment Agent

The addition of the air entrainment agent during mixing at the jobsite results in a further decrease in fresh bulk density, down to 1380 kg/m^3, saving the MASTER FLOOR®, cement and water per unit surface of floor.

6. CO_2 Footprint

The use of MASTER FLOOR® as lightweight concrete aggregate leads to significant CO_2 savings:

In comparison, the expanded perlite CO_2 saving is estimated to be around 55%.

- Due to less cement being required, the CO_2 saving in the mix is 50%. The cement content of expanded perlite concrete is double aiming to reach the same strength at the ages of 1 and 2 days.
- Pumice is naturally expanded, in contrast with perlite, which is processed in high temperature-requiring additional energy. During processing, 0.25–0.30 kg CO_2/kg perlite is emitted, resulting in an extra 5% of CO_2 saving using pumice.

In comparison with conventional cement mortars, the CO_2 saving is estimated to be around 9%.

In addition, CO_2 savings occur during the operation of the building. Mixes with MASTER FLOOR® have a thermal conductivity coefficient λ = 0.5–0.7 W/(m K), compared with that of 0.7–1.0 of conventional mixes.

Data Availability Statement: Experimental results of Tables 1 and 2 are primary data given without intermediate calculation as exactly contained in the experimental files of Hellenic Concrete Technology Center (Heracles Group).