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Thermal and Sound Insulation Properties of Recycled Expanded Polystyrene Granule and Gypsum Composites

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Abstract: Up to now, primary resources have been the main choice of raw material selection for production. Now, global market tendencies have brought significant attention to secondary resources as the price has been raised for primary materials, and there is a shortage of their delivery. This could bring an additional effort to increase the recycling level of construction and demolition waste, including expanded polystyrene (EPS). Efforts have been made to develop new efficient building materials with a high content of recycled EPS. In this paper, composite insulation material made of gypsum hemihydrate and recycled EPS beads by casting and compression methods were evaluated, and properties were compared. Thermal and sound insulation properties were characterized. Density from 48 to 793 kg/m^3 was obtained and the thermal conductivity coefficient from 0.039 to 0.246 W/(m·K) was measured. Compression strength was from 18 kPa to 2.5 MPa. Composites produced with the compression method have a sound absorption coefficient $\alpha > 0.9$ in the range from 600 to 700 Hz, while the samples produced by casting showed poor sound absorption with wide deviation. Compression methods had an advantage over the casting method as more homogenous and lightweight materials were produced with improved insulation properties.

Keywords: insulation; EPS granules; gypsum; sound absorption

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1. Introduction

Expanded polystyrene (EPS) boards have been widely applied in the fields of energy-efficient buildings due to their low density, high durability, and superior thermal performance. Historically, EPS is a very economical insulating material that is easily available globally and is also extensively researched in concrete composites [1]. Tendencies are shifting lately due to the epidemiological situation around the world, which is summarized as the increasing demand for EPS from the packaging sector and the fluctuating crude oil prices that hamper market growth and change prices [2]. This boosts the market for secondary EPS granules, and more advanced materials are expected from the building sector with the use of secondary EPS. Up to now, EPS waste has been a large problem in the modern world. Not only is EPS generated as waste in construction and demolition, but it is also largely wasted as packaging material. As effective and sustainable recycling of EPS has not yet been developed, large volumes of it are landfilled. EPS is mostly air, up to 98%, and in landfills, EPS is flying around and polluting the surrounding environment. In the past, EPS/XPS installation waste was primarily recycled due to its cleaner conditions if the material was intact. In 2018, EPS/XPS construction waste recovery accounted for almost 77%, including 10% recycling and 67% energy recovery. Still, about 23% of post-consumer EPS/XPS construction waste is disposed. The reasons for the lower recycling quotas of EPS/XPS demolition waste are the bad quality of EPS/XPS materials from demolition (high impurities, contamination, etc.) and the lack of separate collection [3]. Several recycling processes have been developed for EPS [4], but these often require the use of hazardous solvents [5]. Previously, EPS dispersion in ethyl acetate was evaluated to obtain extrudable composite, and gypsum was used as a flame retardant. It was concluded that gypsum incorporation did not extinguish the flame, and the entire test body was consumed by the combustion of the material [6]. However, like other organic foaming insulation materials, its application is seriously limited by inherent combustibility that tends to cause fire accidents. Since Kan and Demirboga in 2009 found a method to process waste EPS as aggregates, the use of the material has increased significantly since then [7]. Previous research has indicated that lightweight composites with incombustibility and low thermal conductivity can be prepared by combining EPS with inorganic cementitious materials. The advantage of EPS is its ability to be mechanically ground into tiny beads or larger granules called "peanuts", which occupy a smaller volume for the same weight. A conclusion has been drawn from these studies that the density, mechanical properties, and thermal conductivity of lightweight composites show a downward trend with the increase in EPS content, which is attributed to the low strength and high porosity of EPS. It is universally acknowledged that OPC is the most widely used building material in the world and it is often used as a cementitious material in thermal insulation composites with EPS beads as a lightweight aggregate. However, an increasing interest in the construction industry is a tendency to reduce the usage of OPC or look for an alternative for OPC due to the large amount of energy consumption and greenhouse gas emissions with the production of OPC. EPS CDW has been evaluated as a component of gypsum matrix to manufacture plaster for interior coatings or for prefabricated hollow core gypsum block with dimensions up to $40 \times 20 \times 10$ cm. Still, the density of this material remains high at >1.0 g/cm^3 [8]. Bicer et al. studied the density, water absorption, mechanical strength, and thermal conductivity of new lightweight gypsum plaster mixed with the waste EPS and obtained a low density (451–1088 kg/m^3) thermal insulation material for building energy efficiency [9]. EPS waste has been incorporated in foamed concrete to obtain low density and improved heat insulation properties. In this way, densities between 331 and 356 kg/m^3 have been reached with thermal conductivity of 0.093 W/(m·K) [10]. Different reinforcements of lightweight gypsum–EPS composites have been tested by incorporating different additives (latex, binding additive, or plasticizers) and fibers (glass fiber and polypropylene fiber) and it was concluded that the use of coarse EPS waste has a negative effect on the Shore C surface hardness, especially with latex and fibers [11]. To prepare a flowable mixture, it requires abundant binders to fill the gap space between EPS beads to meet the needs of forming for the casting method. It is difficult to reduce density further and improve insulation performance due to the binder factor, which results in the inability to meet the growing demand of building energy savings [12]. Waste EPS and resin in gypsum plaster with a density of 451 kg/m^3 and thermal conductivity of 0.047 W/(m·K) have been used to prepare panels for decoration work. Waste EPS granulate has been used in a geopolymer matrix, and density as low as 516 ± 43 kg/m^3 and thermal conductivity of 0.121 W/(m·K) have been obtained. The properties of lightweight plaster materials made with EPS had significant property differences just by changing the compositions' water-to-binder ratio (W/B). W/B increase from 0.6 to 1.2 with 2 wt.% EPS addition reduced the density from 1.13 to 0.48 g/cm^3. It has been concluded that the maximum EPS ratio is 2% due to the workability of mortar [13]. EPS with a gypsum-to-water-to-EPS granulate ratio of 1:2:0.081 had a thermal conductivity of 0.065 W/(m·K), which is almost 2× higher than pure EPS foams, and a reaction to fire rate of C,s1,d0 [14]. Previously mentioned studies have mostly focused on the preparation of thermal insulation materials with EPS beads as lightweight aggregates by the casting method [1]. Little research is focused on utilizing waste EPS in the production of EPS–gypsum composites with the compression method. It has been observed by Guopu Shi et al. that significant quantities of large voids appear in the samples if low gypsum and water content are used and this leads to difficulty in shaping and a sharp decrease in mechanical properties [15]. To solve this problem the compression method could be used. Such EPS–gypsum composites possess low density and thermal conductivity and there is no fire combustion during the direct flaming of the material.

Compression methods are associated with the compression ratio and pressure applied. A compression ratio between 1.4 and 1.8 has been previously studied. It was apparent that there were many voids in the samples with a compression ratio of 1.4. Moreover, stronger interface bonding between cementitious materials and EPS beads could be found in the samples with a compression ratio of 1.8 [15]. Further development of EPS–gypsum composites could be associated with the application of waste or secondary gypsum such as CDW gypsum or phosphogypsum, which could lead to a completely 100% recyclable insulation material [16].

This research investigates waste EPS as a lightweight aggregate in gypsum matrix composite prepared by traditional casting and semi-dry compression methods. The mechanical and thermal performances of composites were evaluated and the sound absorption coefficient was determined.

2. Results

2.1. Gypsum Composite—Physical and Mechanical Properties

The appearance of two different structure EPS–gypsum composites produced in this research is given in Figure 1. It can be seen that the composite made with CM has a dense structure and the gypsum is completely covering voids around the EPS granules (Figure 1a). With the SD production method, separate EPS granules are visible and voids between granules create open-structure material (Figure 1b).

(**a**) (**b**)

Figure 1. EPS–gypsum composites with (**a**) closed structure (CM production method) and (**b**) open structure (SD production method).

The physical properties of CM series samples are given in Table 1. An EPS–gypsum composite with an apparent density from 295 to 793 kg/m^3 was obtained. The compressive strength was affected by the gypsum and EPS content in the mixture composition; 2.5 MPa compressive strength was obtained for CM1 with the highest gypsum content. It gradually decreased to 1.0 for CM3 and 0.9 for CM4. A significant decrease in thermal conductivity was achieved by a change in mixture composition. A reduction from 0.246 to 0.128 W/(mK) was reached.

Table 1. Physical properties of EPS and gypsum samples for casting method.

Composition	Density, kg/m^3	Flexural Strength fm, MPa	Compressive Strength, fc, MPa	Thermal Conductivity, W/(mK)
CM1	793	1.9	2.5	0.246
CM2	631	2.0	1.2	0.181
CM3	561	1.4	1	0.160
CM4	416	1.1	0.9	0.128

Significantly lower bulk density was obtained for the SD series EPS–gypsum composite (Table 2). Gypsum content had a significant role in apparent density and it was decreased from 290 to 48 kg/m^3. Gypsum content reduction by four times (2400 to 300) lead to a reduction in density almost six times and compressive strength decreased 4.4 times. Thermal conductivity reduced from 0.079 to 0.039 W/(mK) (by 100%).

Table 2. Properties of EPS and gypsum samples for curing under pressure method.

Composition	Apparent Density, kg/m^3	Thermal Conductivity, W/(mK)	Compressive Strength, kPa
SD3-40	48	0.039	21.0
SD6-4	66	0.044	17.8
SD6-20	74	0.046	29.1
SD6-40	73	0.044	27.5
SD12-4	150	0.058	46.1
SD12-20	154	0.057	49.8
SD12-40	159	0.057	52.7
SD24-4	290	0.079	122
SD24-20	319	0.092	160
SD24-40	338	0.097	192

The role of pressure on the properties of EPS–gypsum composite is given in Figure 2. The most important factors affecting EPS–gypsum properties were gypsum content in the composition and applied pressure. The apparent density increased the most for the mixture with the highest gypsum content—from 290 to 338 kg/m^3. Higher density increase is associated with gypsum content, which during higher pressure, gives more gypsum particles in a specific unit volume. Gypsum content had a significant role in compressive strength. Low gypsum content provided weak bonding between EPS particles and strength was from 18 to 29 kPa (series SD3 and SD6). For series SD12, strength was from 46 to 53 kPa and SD24—from 122 to 190 kPa. An increase in applied pressure during the production of the material increased compressive strength from 55 to 61%. The thermal conductivity was from 0.039 to 0.046 for SD3 and SD6 series, respectively. With the production pressure increase, the thermal conductivity coefficient increased by 18%. Thermal conductivity for the SD12 series changed slightly and was not affected by applied pressure during the production. For SD24, the thermal conductivity coefficient increased by 55%.

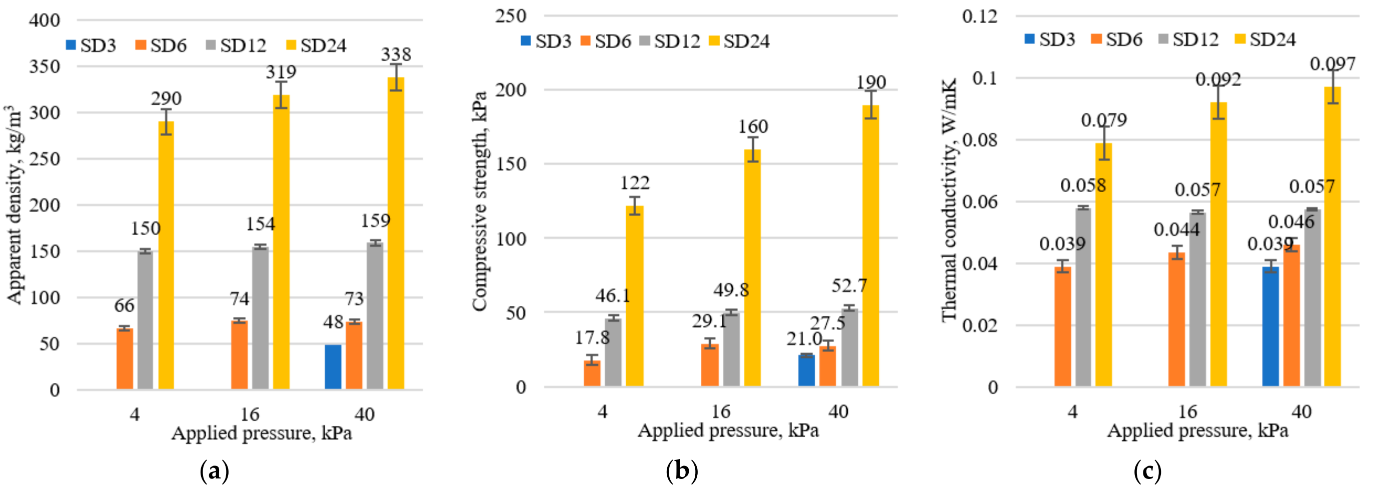

Figure 2. Properties of EPS gypsum composition with different gypsum content and compression pressure: (**a**) Apparent density; (**b**) Compressive strength; (**c**) Thermal conductivity.

The relationship between apparent density and thermal conductivity of gypsum–EPS composites produced with different casting methods is given in Figure 3. A good correlation between apparent density and thermal conductivity coefficient was achieved. The SD series with the highest gypsum content, and which was produced by the pressure method, is slightly beneath the mixture produced with the traditional casting method, which had a lower gypsum content and a structure that became more similar to the material produced with the compression method.

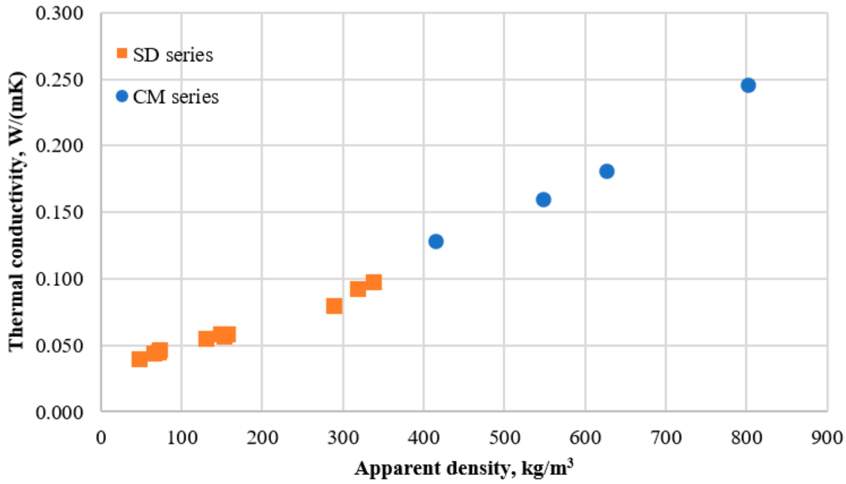

Figure 3. Relationship between apparent density and thermal conductivity of gypsum–EPS composites produced with different casting methods.

2.2. Sound Absorption Tests

Sound absorption coefficient α was measured for selected specimens using two described methods—the casting method and the semi-dry mixture cast with pressure application (Figure 4). The casting method specimen can be grouped into two groups from an acoustical point of view. The first group, which are specimens CM1, CM2, and CM3, had more EPS–gypsum in the mixture than water. These specimens are stiff, less prone to flaking off, and the testing surface is hard. Acoustical properties of tested materials are defined mostly by their porosity. The porosity of CM1, CM2, and CM3 depends only on the pores of the EPS granules implanted in the specimen. This group of specimens shows rather low absorption coefficient values, with the highest values of 0.3 at around 500 Hz for CM3.

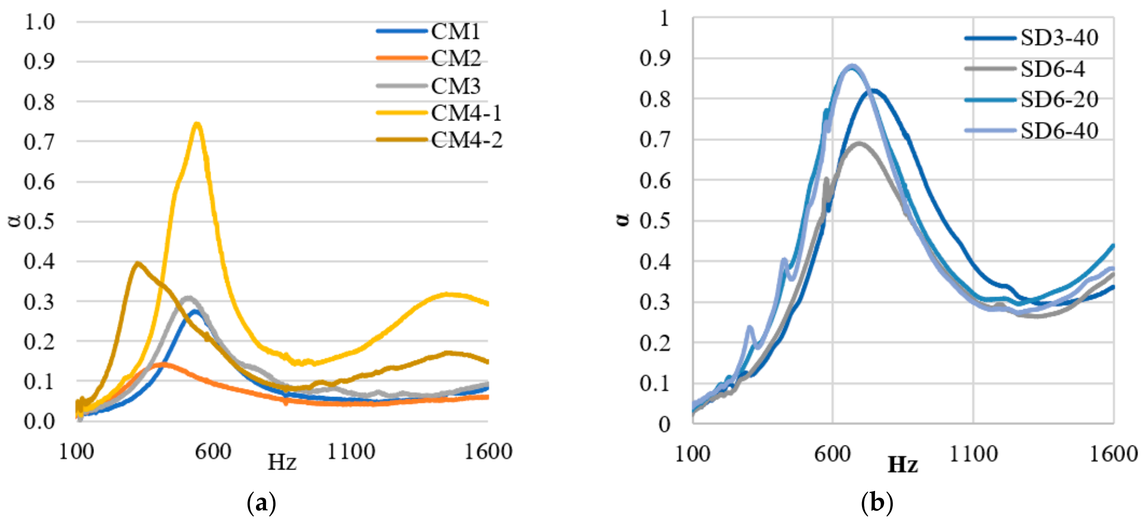

Figure 4. *Cont.*

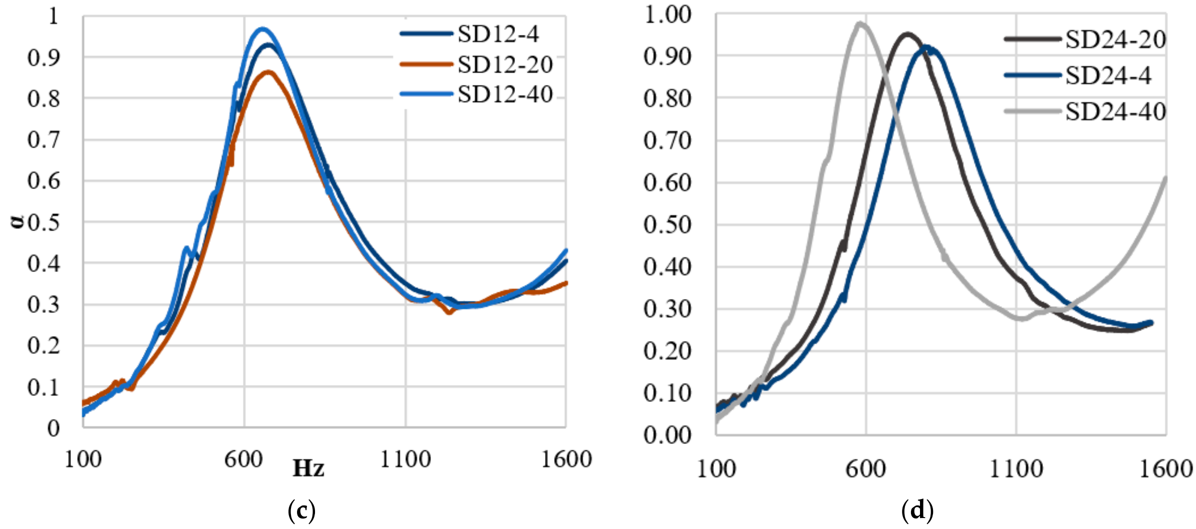

Figure 4. Sound absorption coefficient of gypsum EPS composites with different gypsum content: (**a**) CM series, (**b**) SD3 and SD6 series, (**c**) SD12 series, and (**d**) SD24 series.

The second group is the two CM4 specimens, which show relatively good absorption properties in narrow frequency bands of around 300–600 Hz.

The semi-dry mixture with pressure method shows good sound absorption, mainly in the region of 500–1000 Hz. The reason for this improved absorption compared to CM samples is the increased porosity of the samples, which is achieved by a lesser usage of gypsum. Different types of SD mixtures do not exhibit drastic changes in the absorption coefficient.

3. Discussion

The semi-dry compression method with increasing pressure after casting allows an increase in the compactness of prepared EPS–gypsum compositions. The apparent density increased from 6 to 16% and the highest increase was for compositions with the highest gypsum content. The compaction with a reduced gypsum content does not increase density, as light EPS granules, even in a slightly compacted state, do not significantly increase the weight of the material. The lowest gypsum content tested allowed a density of 48 kg/m^3 to be reached, which is only 5× higher than the EPS plate insulation material. The semi-dry compression method with high gypsum content reached a transition zone density between traditionally casted EPS–gypsum composites and it showed a good correlation between their properties. A further density increase was achieved by traditional casting and an increase in gypsum content in composition as well.

The strength properties for traditionally casted materials are higher as increased gypsum content ensures better strength properties than the EPS granule interaction zone. By reducing the amount of gypsum, the interaction zone between granules increases, and during testing, they are more subjected to deformations, meaning that gypsum cannot transfer the load without brittle displacement and cracking. This is summarized by the dramatic reduction in compressive strength of traditionally casted samples with strength from 0.9 to 2.5 MPa reduced even down to 21 kPa. This effect must be considered together with the thermal conductivity coefficient. Increased gypsum content allows heat to be transferred at a higher rate, meaning that the material is not as efficient as more traditional thermal insulation materials. High-value thermal conductivity results were achieved with EPS–gypsum composites with thermal insulation coefficients from 0.039 to 0.046 being effective values to create thermal insulation barriers for buildings.

EPS–gypsum composites produced by the casting method give a stiff and dense surface, which makes this material ineffective as a sound absorption material. The average sound absorption of CM1, CM2, and CM3 was relatively low—around 0.1, which defines these materials as reflective or non-absorptive materials. CM4 composition produced by casting methods showed improved sound absorption results. The reason for the improved absorption is the open structure of the mixture, which after drying, leaves greater porosity than with the first group of materials. Two separate CM4 samples were produced and tested, and while both of them were visually similar, however, they had different absorption coefficient frequency curves. The assumption made here is that CM4-1 and CM4-2 samples have different porosity due to manual production and a lack of quality control, as these are not industrially produced samples. The mixtures with low gypsum and water content are more subjected to segregation and uneven structure formation. Albeit there is good absorption in the mentioned frequency region, the average absorption coefficient is still rather low: 0.25 for CM4-1 and 0.15 for CM4-2. In terms of sound absorption qualities, the casting method produced materials that are only useful when the W/CG mixture is 0.60. EPS–gypsum compositions produced by the semi-dry-mixture casting method showed improved absorption coefficient. The reason for this improved absorption compared to CM samples is the increased porosity of the samples, which is achieved by the lesser usage of gypsum. Different types of SD mixtures do not exhibit drastic changes in the absorption coefficient.

4. Materials and Methods

4.1. Materials

Raw materials used in this study are commercially available gypsum (CG) and waste expanded polystyrene granules as aggregates. CG binder powder was used as a binding agent. It was characterized by d_{10} = 0.08 mm, d_{50} = 0.13 mm, and d_{90} = 0.22 mm. The set time of CG was tin 18:30 min and t_{fin} 22:50 min. Total amount of gypsum was 93%, SiO_2—3.73%, Al_2O_3—1.68%, Fe_2O_3—0.46%, CaO—35.64%, MgO—3.92%, SO_3—30.90%, Na_2O—0.31%, TiO_2—0.05%, and LOI—22.43%.

Recycled EPS granules were taken from the local distributor. The origin of recycled EPS granulate is in Poland, from where they are distributed all across Europe. EPS granules are packed in 200 l sacks with an average weight of 2 kg. Different EPS granule types are present in granule mixtures (e.g., white, gray, black, blue, pink, red, and green). In addition, most granules are completely separated into individual EPS beads; larger conglomerates that did not disintegrate during recycling can be identified. This is associated with the size of such conglomerates, which are reduced enough to pass the sieving of the material and the bending strength of individual granules. Such granule clusters are in different sizes and range from 4 to 10 mm. The appearance and macrostructure of EPS granules with different particle sizes are given in Figure 5. It is visible that the largest EPS granules have a rounded shape with angular planes indicating their previous compression border in EPS insulation of packaging plates. Raw EPS granules have a spherical shape after their production, which changes after heat treatment during the formation of insulation plates. Finally, small particles mostly have cut edges, which are produced during the grinding of recycled EPS plates (Figure 5a,b). These particles have a sheet and plate structure with a partially open pore structure. EPS granule microstructure is represented in Figure 5. In Figure 5i, an interlocking polymer border between the trapped air pores can be observed, representing the polystyrene polymer itself. The average pore size of the EPS granule was 0.14 mm.

Raw EPS granules were characterized by their physical properties (Figure 6) and appearance. The bulk and material density of EPS granules were determined, as well as particle size distribution and pore structure. The particle size distribution of recycled EPS granules is given in Figure 7. All of the granules are under 11.2 mm; 8–11.2 mm granules are 0.3% of all granules. Fractions 5.6–8 mm are 9.85% of all granules; fraction 4–5.6 mm has the largest particle size distribution with 48.56%. Particles of 2–4 mm are 36.42% of all granules; 0–1 mm and 1–2 mm fractions are 3.58% and 1.29%, respectively. The bulk density of granules was 10.56 kg/m^3 and thermal conductivity was 0.041 W/(m·K). Separate granule density was from 11.6 to 26.9 kg/m^3.

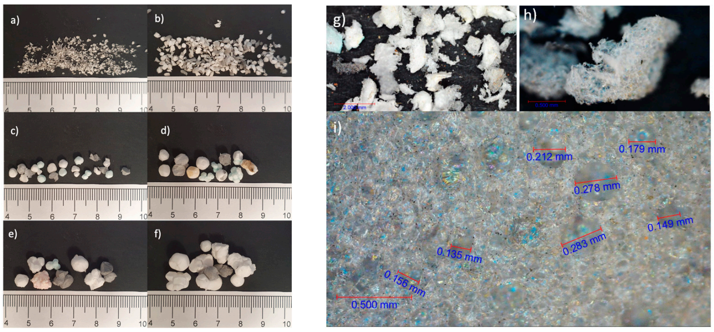

Figure 5. Appearance and macrostructure of different particle size EPS granules: (**a**) <1 mm; (**b**) 1–2 mm; (**c**) 2–4 mm; (**d**) 4–5.6 mm; (**e**) 5.6–8 mm; (**f**) 8–11.2 mm. Microstructure of EPS granules: (**g**) <1 mm, 35×; (**h**) <1 mm, 130×; (**i**) >8 mm, 130×.

Raw EPS	Value
Thermal conductivity, W/(m·K)	0.041
Bulk density, kg/m³	10.56
Granule density, kg/m³	
2–4 mm	21.4
4–5.6 mm	26.9
5.6–8 mm	11.6
8–11.2 mm	16.3

Figure 6. Physical properties of EPS granules and bulk EPS prepared for thermal conductivity test.

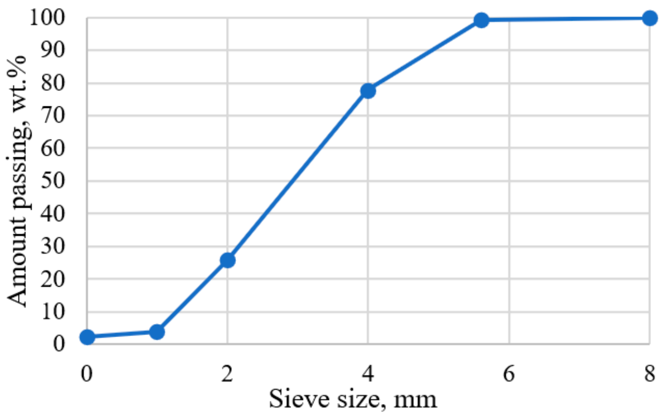

Figure 7. Particle size distribution of EPS granulate.

4.2. Samples Preparation

The experiment was divided into two series according to the production method used: (1) traditionally castable EPS–gypsum mortar (CM) and (2) semi-dry mixture cast with pressure application (SD). In such a way, wide-range density materials are proposed. The casting method is a technology for the construction of buildings where walls and slabs of the building are cast into molds, while curing under pressure differs from the casting method mainly with the added weight to sustain the different pressure rates. CM is traditionally associated with high density, while SD can reduce the density of the material. As given in Figure 8, the gap space between EPS beads could be reduced by using the compression method, resulting in a reduction in the use of gypsum needed to fill the space and ensure the bonding of EPS particles. This is the main reason for density reduction. Three pressure rates were applied for SD: 0.4 kPa just to obtain a flat surface of SD, 1.6 kPa, and 4.0 kPa for a high compression ratio. With lower pressure, the proportion of EPS beads increases correspondingly and leads to decreased density and improved thermal insulation performance. Additional reduction in gypsum can be achieved by improved bonding given by applied pressure. This is an advantage of using the compression method to prepare thermal insulation materials containing EPS beads compared to the casting method. Small deformation of EPS beads might occur in the compression process due to the flexibility (compressibility) of EPS beads, which was also an important reason why samples could be compressed.

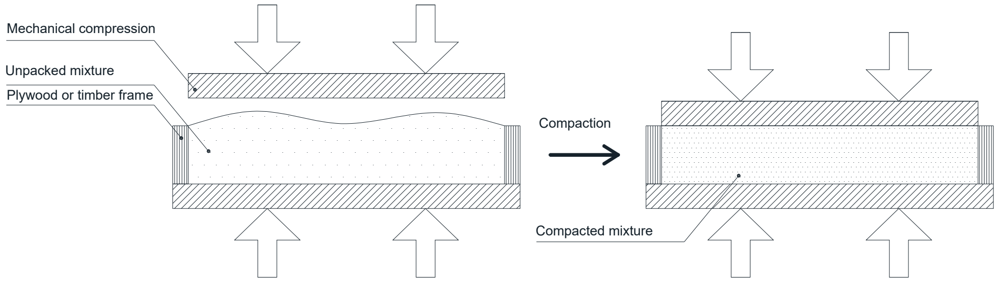

Figure 8. Discontinuous production method of semi-dry gypsum EPS composite with pressure application.

Mixture compositions of prepared EPS–gypsum composites are given in Tables 3 and 4. The first series (CM1-CM4) was designed as traditionally castable mortar. It is characterized by higher gypsum content, which allows it to be cast in mold due to material flowability. Gypsum and water content were changed to evaluate their effect on the composite. Similar castable compositions have been previously reported in the literature [13,14,17,18]. Mixture composition CM1 has high paste volume and good workability is achieved, while with CM4, reduced gypsum content ensures binding of EPS granules; the consistency is in-between CM and SD methods.

Table 3. Mixture compositions of EPS and gypsum samples made with the casting method.

Composition	EPS CDW, g	CG, g	H_2O, g	W/CG	Free Moisture, wt.%
CM1	80	9120	5200	0.57	32
CM2	90	4500	2700	0.60	32
CM3	90	5400	3240	0.60	31
CM4	90	2250	1800	0.60	32

Table 4. Compositions of EPS and gypsum samples for curing under pressure method.

Mixture Composition	Masa, EPS	BG	Water	Applied Pressure, kPa	W/B
SD3-40	120	300	300	4	1.00
SD6-4	120	600	450	0.4	0.75
SD6-20	120	600	450	2	0.75
SD6-40	120	600	450	4	0.75
SD12-4	120	1200	500	0.4	0.42
SD12-20	120	1200	500	2	0.42
SD12-40	120	1200	500	4	0.42
SD24-4	120	2400	800	0.4	0.33
SD24-20	120	2400	800	2	0.33
SD24-40	120	2400	800	4	0.33

Mixture compositions prepared with SD have two variables—pressure subjected to molded composite (i) and gypsum content in mixture composition (ii). These series are characterized by different pressure rates, which results in different compaction and, thus, other composite properties; 0.4 kPa, 2 kPa, and 4 kPa compression force were applied. The gypsum amount from 300 to 1200 was changed. The W/B ratio reduced from 1.00 to 0.33. Reduced W/B has an advantage as less free water remains in the structure and less energy is needed to dry samples after production.

4.3. Mixing Procedure

The mixing procedure for CM was performed with one shaft construction mixer Rubi. First, gypsum slurry was obtained by mixing CG with water for 1 min. Then, EPS granulate was poured into the slurry and mixed throughout until a homogenous mixture was obtained. Then, the material was cast in 35 × 35 × 100 mm molds. Total mixing time was up to 8 min. In the SD method, all water was homogenized with EPS beads in a way that EPS is covered with water and no excess water is present on a bottom of a mixing bowl. Then, CG powder was gradually poured into the mixture during mixing until a homogenous EPS-CG mixture was obtained. Then, the mixture was placed in plywood formwork with dimensions 35 cm × 35 cm × 10 cm and covered with a plywood sheet, and the proposed pressure was applied with weights.

4.4. Testing Methods

The compressive strength was tested by using a Zwick Z100 universal testing system (ZwickRoell, Kennesaw, GA, USA) for cubic specimens with a testing speed of 0.5 mm/min. The cubic specimens were also measured and weighted before the crushing to determine the material density and volume. Density was calculated by dividing the sample's mass by the respective volume. Compressive strength was calculated from the force applied to the sample's specific area. Samples were characterized with digital microscopy to assess their pore structure and appearance.

Thermal conductivity was performed with heat flow meter instrument LaserComp FOX 660 for dry lightweight samples with dimensions of 350 × 350 × 100 mm. The upper and lower plate temperatures were 0 °C and 20 °C with average temperature of 10 °C.

To identify how effective material can be at absorbing or blocking sound, a sound absorption coefficient α and transmission loss TL values are used. The absorption coefficient between a scale of 0.0 and 1.0 was measured. This measurement shows the average control of noise between the frequencies 50 and 1600 Hz. Ability to absorb is influenced by the density, thickness, and porosity of the material. The sound absorption coefficient is determined from the impedance tube method according to the ISO 10534-2 standard (Figure 9). Cylindrical samples of 100 mm in diameter were prepared and tested. Smaller samples of 29 mm in diameter were not tested as these samples are not stable enough for performing tests.

Figure 9. Testing apparatus of sound absorption coefficient.

5. Conclusions

The semi-dry mixture cast with pressure application method (SD) allows EPS–gypsum composite to be obtained with a lower binder content and low W/B ratio; however, it is easier to produce traditionally casted EPS–gypsum mortar. Apparent densities ranging from 295 to 795 kg/m^3 were achieved by using the traditional casting method, while with the SD method, this value was reduced to 48 kg/m^3. Pressure changes during the curing of composite did not play a significant role in EPS–gypsum composite properties at a low gypsum content. Thermal conductivity for tested EPS–gypsum composites was from 0.246 to 0.039 W/(mK). A strong correlation with apparent density was obtained for thermal conductivity and strength. A strength reduction from 2.5 MPa to 18 kPa was measured, as the gypsum content in the mixture composition decreased.

The sound absorption coefficient measured from 250 to 1600 Hz and showed a slight shift from lower to higher frequencies with the decrease in composite density. Sound absorption efficiency reduced from 0.97 to 0.69 in the interval from 600 to 700 Hz, which is the most effective range of sound absorption for this material.

Curing under pressure allows a compacted open-structure composite with low gypsum content to be obtained. This method is more suitable for on-site production, and slabs, wall panels, or blocks can be manufactured.

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