Mechanical and physical properties of pumice aggregated lightweight concrete with recycled polypropylene addition

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Abstract

Polypropylene polymer products are generally known for their use as fiber product derivatives in the production of building materials. However, there is not enough experience on the use of polypropylene polymer granular products, which are frequently used in the plastics industry, as cementing and lightweight aggregate products. In this study, especially the effects of recycled polypropylene copolymer granules on the physical and mechanical properties of hardened mixture in pumice lightweight aggregate (PLA) component block mixture were investigated with experimental analyses.

All samples in the laboratory and factory were prepared by applying manual compression on the vibration table in 50x200x400 mm sized molds. After drying, standard tests for compressive strength, water absorption, unit volume weight, thermal conductivity, equivalent thermal behavior and sound transmission loss were experimentally carried out. Sieve analysis of pumice, chemical analysis of materials and porosity analysis with optical microscopy were performed to support the results.

Keywords: Insulation; pumice; polypropylene polymer; lightweight aggregate; masonry.

1. Introduction

Concrete has been used since Roman times for the development of infrastructure and housing, but its basic components have remained the same. Three ingredients make up the dry mix: coarse aggregate, consisting of larger pieces of material like stones or gravel; fine aggregate, made up of smaller particles such as sand; and cement, a very fine powdered material that binds the mix together when water is added [1]. The great acceleration has been seen in the construction sector in recent years, so this situation requires for the use and application of many new building materials.

The importance of lightweight aggregate in the concrete sector is even better understood with the consequences of the tragic earthquake events in Turkey and many concrete manufacturers have started research and development studies on the use of light and natural materials for different purposes in the concrete industry. In recent years, the different forms of lightweight construction elements made from pumice, which have begun to find a wide range of uses due to their technical and cost advantages, are being used as wall-filling materials in constructions [2].

Pumice is widely used in construction industry as insulation bricks [3]. Pumice has high strength-to-weight ratio, low sound transmission characteristics and low thermal conductivity. These properties make it desirable for use as an additive for lightweight bricks, blocks and aggregate for concrete [4].

Approximately 40% (more than 7.4 billion m^3) of the world pumice reserves, which according to official data are around 18 billion m^3, are located in Turkey. Today, the Central Anatolian Region is the leader in terms of pumice fields operated in the country, and there are significant production activities in Mediterranean and Eastern Anatolia regions [2]. In Nevşehir province, pumice is used as lightweight aggregates (PLA) in concrete intensively and pumice aggregated lightweight concrete (PALWC) blocks are produced.

Lightweight aggregate characteristics have significant effects on their properties. There are several studies in literature to improve the concrete block properties dealing with alternative additive material in lightweight concrete like as powder polymer [5], expanded polystyrene [6], rubber [7], and expanded polystyrene foam [3]. Changes in compressive strength by adding perlite at 20 wt. %, 40 wt. %, 60 wt. % instead of pumice in the concrete block [8], bond strength of pumice added samples, pumice addition for porosity formation, pumice as filler [9–11], properties of concrete with polymer-coated pumice [12], the effect pumice/cement ratio on concrete properties [13], polymer addition, concrete reinforcement with plastic bottle addition, distribution of fibers in concrete and polymer addition's effect on concrete's service life [14-17]were also investigated. In another noteworthy study, epoxy resin based polymer was used as the binder material of pumice lightweight aggregates. Steel fibers were added to these lightweight aggregates at varying amounts as additive material [18].

Nowadays, urbanization and population growth have increased the energy demand to great extent. Energy saving has become very significant issue all around the world due to environmental and economic concerns. In developed countries, 40% of energy is consumed by the buildings for heating. Out of which, 12% is consumed only by the walls of buildings [19, 20]. For this reason, heat insulation, low thermal conductivity and lightweight are the main characteristic properties of the materials used in building industry.

The aim of this study is to improve the production of natural porous pumice aggregate and volcanic tuff admixture building materials in Nevşehir region, to improve heat and sound insulation properties with the addition of new generation polypropylene copolymer granules and to provide a lighter block element production in accordance with the technical specifications stipulated in the standards. Plastic recycling is a process used to recover plastic scraps for reprocessing and using them to produce valuable products. Polypropylene recycling is one of the most common plastic recycling processes, which mainly includes sorting, collecting, cleaning, and reprocessing of polypropylene wastes[21]. Thus, to examine the industrial use of a copolymer material, also known as recycling product, which can be used in different industrial fields. It is to ensure that the insulation requirements foreseen today are obtained more easily in wall element products.

2. Materials and methods

2.1. Purpose of assessment

Experimental studies have been carried out to determine the suitability of polymer granule admixture in order to produce lightweight concrete [22] in which polypropylene copolymer granular admixtures can be used in the development of non-load bearing lightweight masonry block elements with pumice and volcanic tuff aggregate, and to produce advantageous mixture design that can be provided to the physical, mechanical and thermal properties of such concrete. No other type and origin polymer admixtures or additions apart from pumice, volcanic tuff aggregates, cement and water were used in the mixtures.

2.2. Materials used in the research

Normal Portland cement (PC) suitable to ASTM Type I (42.5 N/mm^2) was used throughout this research. Pumice and volcanic tuff aggregates used in this experimental research were supplied from two different local quarries in Nevşehir Region, Centre Anatolian of Turkey. Pumice aggregates obtained from the quarries were first crushed by a primer crusher. Then they were first screened into 0-12 mm as coarse pumice aggregate. However, the pumice aggregate with this size distribution was obtained by sieving a group of materials with a higher proportion of fine material. This material was used as the main aggregate component in the preparation of laboratory samples. Pumice sizes used in the laboratory and in the factory were determined by laboratory sieves (Table 1). While the pumice used in the factory has a wide grain size distribution, the pumice used in the laboratory has a narrow grain size distribution and 80.20% of the grains are between -8+4 mm.

The chemical composition and some technical properties of the cement used in this research were given in Table 2 and Table 3.

Volcanic tuff was only screened into 0-3 mm size fractions as fine aggregate material with the use of original matter without crushing. The chemical composition of the pumice and volcanic tuff aggregates were also given in Table 2. The pumice aggregate as a natural material is a crumbly pyroclastic rock characterized by its light coloring. It is rich in highly vesicles volcanic glass which gives it high porosity and low density. It is mostly siliceous and rich in dissolved volatile constituents, especially for water vapor. On the other hand, volcanic tuff is a type of rock made of volcanic ash ejected from a vent during a volcanic eruption. Following ejection and deposition, the ash is compacted into a solid rock in a process called consolidation. It is also mostly siliceous and rich in dissolved volatile constituents as pumice, too.

Dry bulk unit weight, water absorption value, compressive strength and elastic modulus of pumice aggregate, as received from the quarry, are determined as 910±40 kg/m^3, 21±5%, 26.4±1.6 MPa and 10.5±1.5GPa, respectively. For the volcanic tuff, these values are 980±60 kg/m^3, 26±4%, 26.3±1.5 MPa and 14.1±1.5 GPa, respectively.

Chemical analyses of the raw materials used in the experiments were given in Table 2. According to chemical analyses, the pumice and tuff aggregates are very close to each other and very rich in silica, presents a structure perfectly vitreous, as called no crystalline structure. Because of high silica amount, the pumice and volcanic tuff materials show the acidic character that is most suitable for the masonry block element making due to their high durability advantages. Alteration of primary minerals and formation of secondary minerals at the particle level in volcanic tuffs are depended on environmental conditions. Weathering of primary mineral and formation of secondary mineral is dominant rock forming process in materials which contain appreciable amounts of easily weatherable minerals [23]. Although the pumice and volcanic tuff materials are mainly formed by hard minerals such as silica, alumina and ferrous, the trace element analysis also showed in a notably various and rich composition for special elements like Cr, Co, Zn, As, Sb, Ni, Ba etc. (Table 4). It has been found that the pumice and the tuff, which are two raw materials of the specimen, have different textural and physical properties, chemically (originated) from the same origins. In practice, two separate materials with the same chemical properties were used in production.

Polypropylene is an economical material that offers a combination of outstanding physical, mechanical, thermal, and electrical properties not found in any other thermoplastic. Compared to low or high density polyethylene, it has a lower impact strength, but superior working temperature and tensile strength. Noted for its excellent chemical resistance in corrosive environments, polypropylene provides excellent resistance to organic solvents, degreasing agents and electrolytic attack. It is light in weight, resistant to staining, and has a low moisture absorption rate.

Polypropylene materials generally provide the molding industry with a financially and environmentally friendly alternative to virgin - without compromising performance. Today polypropylene is used in many ways; cold water storage tanks, automotive, land drainage, and agricultural products. Polypropylene is available in two basic types as either homopolymer or copolymer material. Although similar in many respects each type exhibits distinct differences in both appearance and performance. In this research work, copolymer material type was preferably used. Special copolymer granular materials were obtained from the local market in Turkey. All of the polypropylene copolymer was actually black copolymer with the diameter of 2 mm and height of 2 mm (Figure 1).

The polypropylene copolymer granules that were actually derived from waste plastics that sourced from a manufacturing company. After melting process, polypropylene copolymer granules extruded and cut with a blade in rice size. These grains were water cooled, a blower continued to cool and dry them. Dusts on the grains were removed by sieving with a vibrated sieve.

2.3. Mixture design, sample preparation and testing

In order to examine the effect of polypropylene copolymer granule additive on the technical properties of lightweight masonry block elements, two main series of analysis have been carried out. The first series of these analyses are on samples prepared under laboratory conditions and the second series of studies are programmed as product samples on one-to-one production line in a real factory environment. In the first lightweight concrete mixture, pumice and tuff aggregate control lightweight concrete samples were prepared without using any polypropylene copolymer granule additive. In the standard composition prepared under laboratory and factory conditions, 70% pumice+ aggregate, 30% cement+ water was added to the composition. The aggregate analysis used in the preparation of test samples was determined according to the scope of EN 13055-1 standard. The preparation of non-bearing wall element test samples and also the physical and mechanical tests of the samples were analyzed according to the principles stipulated in the EN 771-3 standard [22] and its related standards.

First of all, lightweight concrete samples with cement, pumice and volcanic tuff were prepared without using any polypropylene copolymer granules similar to the preparation of laboratory and factory samples. These samples were used for control mixture purposes. In order to evaluate the samples prepared under laboratory conditions as initial trial batches, 2 different lightweight concrete sample mixtures were prepared at this stage. In the subsequent sample mixtures, 2.5% and 5% polypropylene copolymer granules [24] were added instead of the tuff aggregate, and lightweight concrete samples were prepared at the same cement dosage and mixing ratio and conditions. In other words, the polypropylene copolymer granules were substituted for the tuff aggregate for laboratory conditions. Accordingly, 3 different mixing ratios were used in the lightweight concrete mixture of the samples prepared for the factory line. Subsequently, the amount of lightweight concrete mixture was reduced by 2.5%, 5% and 10% by weight in the mixture composition, respectively. This subtracted amount, the same amount of polypropylene copolymer granules was added, 3 separate series of mix were designed. All samples were prepared by applying manual compression on the vibration table in 50x200x400 mm sized wooden molds (Figure 2.a). For mechanical and physical testing of the samples 50x200x400 mm size was chosen. The block samples were immediately de-molded and transferred on the pallet to a storage area for curing. The curing temperature of all the samples was 20°C throughout the research in room temperature conditions.

According to the test results of the laboratory samples, it was first investigated whether similar mixing ratios can be used in the current masonry block production line in factory. Prepared block samples were shown at Figure 2.b and before testing of them, laboratory and factory block samples were the same appearance. Due to the process difference in sample production, it is predicted that the use of lower amounts of polypropylene copolymer granules will be more real in the samples to be prepared for factory production. Since the compression force of the vibration and pressure-compression unit applied in the production of block elements in the factory production line cannot be represented exactly in laboratory environment conditions, it has been determined that the equivalent mixing ratios cannot be applied when considering the polypropylene copolymer granule characterization in terms of laboratory and factory environment.

The density values of each dry mix lightweight concrete samples were measured in the form of fresh concrete mixture after the mixing process and before casting into the sample molds, and the unit volume weight of the compacted mortar obtained after placing this fresh concrete mortar into the cube mold by vibration + pressing was determined. The difference between the two fresh lightweight concrete unit weights was determined to what extent each mixture can be placed in the mold, in other words, how much it can compress. Generally, it is inevitable that the fresh lightweight concrete will be compacted slightly by the effect of vibration and pressing, but the high amount of compacting will increase the unit weight of the settled concrete to be obtained. For this reason, it is generally possible to adjust the magnitudes of the vibration and pressing pressure by such application. In the vibration + pressing unit of the prepared mixtures, 10 samples were poured for each mixture of 50x200x400 mm sized prismatic samples in the consistency of dry mixture. The samples were then cut from these samples, especially for compressive strength analysis. For each mixture, ten samples were at least prepared and cured for 7, 14 and 28 days until the time of testing.

3. Results and discussion

The physical and mechanical properties obtained in the work program are summarized in Table 5. There are differences between the test results of laboratory and factory block samples. Dry volume unit weight, compressive strength, equivalent thermal behavior sound transmission loss, and thermal conductivity analysis results of the factory standard were obtained at lower values than the results of the laboratory standard. One of the reasons for these differences might be the difference in pumice sizes since the pumice amount is ~ 50 of the composition.

Another reason for the difference was thought that polypropylene copolymer granules were added instead of the tuff aggregate while preparing the laboratory samples, and added instead of the lightweight concrete mixture while preparing the factory samples. When the polypropylene copolymer granules were added instead of the tuff aggregate, the strength increased by 46.83% compared to the standard in the sample with 5% polypropylene copolymer granules added. However, when the polypropylene copolymer granules were added instead of the lightweight concrete mixture, the strength of the 10% polypropylene copolymer granules added sample decreased by 46.68% compared to the standard production line samples.

3.1. Microscopic structural analysis

Microscopy analysis is essential to understanding the microstructure of materials or products. Data from microscopy analysis is important to progress the research and product development programs. Microscopic examination is an extremely useful approach for properties such as understanding of the structure of the matrix, definition of porosity phenomena and definition of physical giants in the matrix structure.

Microscopic analysis of all hydrated and hardened lightweight concrete samples was carried out and the general findings are given representatively in Figure 3 to Figure 6 for samples cast in laboratory conditions. The biggest question in these macroscopic investigations is the observational examination of whether the polymer granules coincide with the matrix structure, create sufficient adhesion form and also affect the phenomenon of porosity. The test samples used in this microscopic examination, the parts of the surface parts that may be rough, were first corrected with sandpaper. Afterwards, it was obtained by turning it into a shiny surface form. In the context of the magnification applied in these examinations, only the values in terms of physical size in the matrix structure have been tried to be examined. As can be seen from Figure 3, it is seen that the matrix structure without polypropylene copolymer granules in its composition is completely hardened and has a very low porosity phenomenon. Although porosity formations in the form of capillary lines due to grain size of pumice aggregates are observed in some places, it is seen that the matrix structure forms a very compact form with the effect of volcanic tuff material because of its puzzolanic activity. When some polymer granules are added to the matrix structure, it is seen that it provides good overlap with the matrix structure components and can form a strong bond structure. This effect can be clearly seen in Figure 4, which is a matrix structure image using 2.5% polymer granules by weight. It can also be seen that no decomposition occurs in and around the polymer granule walls.

The similar phenomenon with the addition of the polymer granules can be seen more clearly in the matrix structure, which is 5% by weight in use. This phenomenon can be clearly seen in Figures 5 and 6. The higher amount of the polymer granules, the higher the adhesion forms to matrix due to the compactness of the matrix structure. This would normally lead to higher strength in the samples provided by the matrix structure. Accordingly, it can be foreseen that the water absorption values of the samples may be lower considering the lower porosity of this matrix structure due to the water resistance effect of the polymer granules.

The images of the surface obtained by microscope which from the real production line in the block production plant are given in Figure 7 - Figure 10.

It is seen that the aggregate grains in the structural form of the samples prepared as standard control mixture are quite coarse and the matrix structure shows high porosity (Figure 7). This high porosity phenomenon may represent that the matrix structure is weaker in strength but with higher water absorption capacity. In the matrix structure with the addition of 2.5% polymer granules in the mixture (Figure 8), it is seen that the matrix structure gains a more flexible form and the porosity phenomenon changes towards a lower value. In the case of matrix structures (Figure 9 and Figure 10), in which the amount of polymer granules is added to the mixture composition, it can be seen that the more porous phenomenon of the matrix structure is further reduced and the water absorption capacity is reduced accordingly. It is also observed that in all mixtures where polymer granules are used, adhesion form to matrix is formed which can affect the strength at the polymer + matrix structure interfaces.

When the structural form of the laboratory samples is examined, it is seen that the mortar consistency in the matrix structure is more fluid and due to the presence of sufficient water in the mixture, the cement hydration product minerals are formed and gain strength. It has been observed that ettringite minerals, which provide early strength, are formed as a result of cement hydration and due to the resulting CSH (calcium silicate hydrate) mineralization, the copolymer granules in the matrix structure are helically attached to the structure and improve the strength value [25]. In addition, it can be seen that the void ratio in the matrix structure is at lower levels, but it can also be seen that the low porosity structure provides a strength-enhancing effect.

On the other hand, in the factory-produced samples, due to the insufficient amount of water in the mixture, it was observed that the minerals representing the strength were formed at a low level as a result of cement hydration in the matrix structure, and the presence of mostly ettringite minerals. This caused the strength value to be lower than the lab samples. In addition, it was observed that high levels of voids were formed in the matrix structure of the factory-produced samples and the bonding degrees of the cement hydration product minerals and copolymer granules remained at low levels. It has been experienced that this situation is also a factor reducing strength.

3.2. Unit volume weight and compressive strength

Unit volume weight value is an important factor for lightweight concrete masonry units. This value is basically used to analyze the physical and mechanical characteristics such as compressive strength, water vapor permeability, thermal conductivity effects etc. As the unit weight of the hardened concrete mortar decreases, it is predicted that the compressive strength decreases. However, it is an important technical detail that a higher strength can be achieved with a reduction in unit weight. Unit volume weight values of all samples were analyzed in accordance with EN 678 standard [26]. In this context, while the unit weight value of the control sample was 880 kg/m^3 in laboratory samples, it was observed that this density value decreased by 3.75% and 5.11% with the use of 2.5% and 5% polymer granules respectively. In other words, the amount of polymer additive reduced the hardened lightweight concrete density (Figure 11). A similar phenomenon has been observed for the samples obtained at the factory production line. While the unit weight value of the control sample was 861kg/m^3, it was observed that this density value decreased with 1%, 1.74% and 16.11%-unit weight values by using 2.5%, 5% and 10% polymer granule additions respectively. Particularly in factory production line samples, it is seen that polymer granule additive plays a more effective role in unit weight axis. However, as mentioned above, although the volcanic tuff aggregate size is the same in the preparation of the factory line samples, the presence of more pore formation in the matrix structure is noteworthy since the grain size and granulometric distribution of the pumice aggregate is larger than the laboratory samples. This leads to a reduction in the density of the work with the use of polymer.

28 days' compressive strength values of all the samples were analyzed in accordance with EN 679 standard [27]. The research findings for the compressive strengths are given in Table 5 and Figure 12 as the trend of linear change. When the compressive strength of the tested samples was examined, it was seen that a very different situation arose. It was determined that when the usage rate of polymer granule additive in laboratory samples increased, a significant increase in compressive strength of the samples was obtained as opposed to falling unit weight. While the average compressive strength of the laboratory control mixture sample was 2.84 N/mm^2, it was determined that the compressive strength of the samples with 2.5% and 5% polymer granule additive ratio increased by 20.77% and 46.83%, respectively. This shows that the polymer granule additive increases the strength of the mortar, depending on the general format of the matrix structure. In other words, the strength increase due to the high fine material content of the aggregate grains in the matrix structure is observed (Figure 12).

However, similar strength gains could not be seen in the samples obtained in the factory production line. In contrast to the change in strength value of laboratory samples, the increase in polymer granule additive ratio exhibited a strength reducing function in hardened lightweight concrete samples. While the average compressive strength of the production line control mixture sample was 2.30 N/mm^2, it was determined that the compressive strength of the samples with 2.5%, 5% and 10% polymer granule additive ratio decreased by 14.60%, 27.96% and 46.68%, respectively, compared to the control sample. This shows that the polymer granule additive reduces the strength of the lightweight concrete provided that it depends on the general format of the matrix structure and aggregate grain size and porosity structure. This decrease in strength is clearly seen in the macroscopic matrix structure studies. However, it is observed that the aggregate grains in the matrix structure have a high material content and a decrease in strength due to the increased porosity ratio. With a similar approach, strength reduction can be anticipated as a natural consequence of the reduced unit weight of the hardened mortar. If a sampling is to be made in the context of a general comparison of laboratory samples and factory production line samples; it was observed that there is a difference between the compressive strength of the sample with 5% polymer granule additive ratio of laboratory mixture (4.17 ± 0.12 N/mm^2) and the compressive strength of the sample of the factory production line with the equivalent mixing ratio (1.66 ± 0.05 N/mm^2). It was observed that the reason for this difference was the difference between the unit weight values of the samples and also the possible difference between the granulometry of the sample prepared in the lab environment and the granulometry of the mixture applied in the factory production line. However, given the reasons for the increase in strength in laboratory samples, it can be considered that the polymer granule additive will have a strength-enhancing effect if similar aggregate granulometry is used in mixtures in the factory production line.

3.3. Water absorption

Water absorption capacity in hardened lightweight concrete is an extremely important technical parameter especially in terms of strength and thermal insulation properties. In general, an increase of water absorption capacity in concrete results in a decrease in strength and at the same time a weakening of thermal comfort. In this context, concrete combinations with low water absorption capacity are structural formats that are perceived to be more idealized. It is considered that the porosity ratio of the lightweight concrete material matrix structure is low. However, it is a known fact that the use of porous aggregates has a high effect on the reduction of the unit weight of the mortar. In lightweight concrete mixtures using these derivative aggregate components, additional material components may be required which may have a reducing effect on water absorption capacity. In this context, due to the structural characteristics of the polypropylene copolymer granules, their water absorption capacity is very low, and in lightweight concrete it may also have properties that may provide this desired technical approach. In the examination of all test samples, it was observed that the increasing amount of copolymer granules had an effective role in the water absorption capacity of the mortar (Table 5). This was even more pronounced in the laboratory samples, with a reduction in water absorption of approximately 21% in the mixture with the highest polymer granule admixture compared to the control mixture sample. A similar situation was observed in the production line example and it was determined that there was a decrease in water absorption capacity of approximately 10% in the mixture with the highest polymer granule additive ratio compared to the value of the control mixture.

3.4. Sound transmission loss

Sound transmission loss can be defined as a ratio of the sound energy transmitted through a treatment versus the amount of sound energy on the incident side of the material. In order to investigate the sound transmission loss properties of hardened lightweight concrete samples, the sound transmission loss value at 500 Hz sound level was taken as the reference value in the performance measurements made according to 1/3 octave band scale and the comparison of all test samples in this research study was made according to this value. The sound transmission loss value was obtained in dB unit in these measurements and the high value is perceived as a performance criterion in order to provide good sound insulation. In this context, it is generally accepted that the combinations of mixtures having a high value of transmission loss value at 500 Hz may have better performance. The sound transmission loss values of all the lightweight concrete mixture samples are given in Table 5. Due to the number of additional test samples used in the process of performing other physico-mechanical tests, sound transmission loss analysis could not be performed for the sample with 5% polymer granule additive ratio of laboratory mixture. As can be seen when the values of sound transmission loss of the laboratory samples are examined, the sound transmission loss value of the control mixture is at an average level of 21 dB at 500 Hz, while this value tends to decrease by 32.5% in the mixtures using copolymer additives. In other words, the polymer granule had a negative effect on the loss of sound transmission of the concrete matrix structure. A similar phenomenon was observed for the production line samples, while the sound transmission loss value of the control mixture sample was found to be an average of 17 dB at 500 Hz. According to the experimental results, high advantages of copolymer granular material in terms of sound loss performance were not observed in lightweight concrete samples.

3.5. Thermal conductivity

The thermal conductivity value (λ) of materials generally changes as a function of unit weight. It is generally expected that the thermal conductivity value tends to increase as the unit volume weight increases. This can also mean that the thermal comfort feature of the material is weakened. For this reason, materials with a low thermal conductivity value are perceived as more energy efficient material structures.

It is known that copolymer granules are used for improving the thermal conductivity of materials due to the material characterization in different fields of application. In this respect, the use of these polymer granules in lightweight concrete mixtures is not a matter of much consideration to the extent to which they can affect the thermal performance. In this context, it is expected that the use of proportionally copolymer granule admixture will decrease the thermal conductivity values of the concrete mortar samples and thus it will have higher thermal performance. For this purpose, the thermal conductivity values of all test samples were experimentally tested, and the equivalent thermal behavior properties were also defined according to EN 1745 standard [28] as parametric in $\lambda_{23,80}$. Thermal conductivity of all hardened lightweight concrete samples was experimentally analyzed after 28 days of curing time. The research findings are given in Table 5, too. Due to the number of additional test samples used in the process of performing other physico-mechanical tests, thermal conductivity analysis could not be performed for the sample with 2.5% polymer granule additive ratio of laboratory mixture. According to the test results, for samples prepared as laboratory lightweight concrete samples, λ values were determined in the range of 0.175-0.232 W/mK, while λ values for mixtures of production line were determined in the range of 0.162-0.220 W/mK based on the copolymer granular material usage rates. In the context of these findings, it was seen that increasing the amount of copolymer granules compared to the thermal conductivity values of the control mixture samples of both laboratory samples and production line samples significantly decreased the thermal conductivity value of the lightweight concrete. It was found that the copolymer granules could carry the thermal property and thermal performance of the existing concrete mortar to a more effective value.

4. Conclusions

In this paper, technical performances of recycled polypropylene copolymer granules as an additive material on the technical properties of pumice and tuff aggregated lightweight concrete were evaluated for the use of non-load bearing masonry units. In this experimental research, pumice and volcanic tuff materials were analyzed as porous aggregates in the mixture designs. Specifically, in two different ambient conditions - laboratory and block production line - the similar mechanical and physical properties of the samples were examined comparatively. Physical, mechanical, structural and insulation properties were discussed in detail.

In the general applications in the construction sector, the physical and mechanical properties of the unit weight value and compressive strength value are considered in the creation of non-load bearing wall units. In these applications, it is a general experience that the unit weight value for masonry block elements varies between 600 kg/m^3 - 900 kg/m^3 and the compressive strength value varies between 1.0 N/mm^2 and 3.5 N/mm^2. In this context, it has been observed that the unit weight and compressive strength values of the polypropylene copolymer granules added pumice aggregated lightweight concrete masonry block elements obtained within the scope of this study are suitable for these numerical values. The test results showed an improvement in the properties of lightweight concrete made with copolymer granules, in terms of inspected properties, compared with conventional concrete. The highest strength value (4.17 N/mm^2) was obtained at the highest level of polymer addition for the laboratory samples.

The research findings generally showed that; due to the structural characteristics of the polypropylene copolymer granules, their water absorption capacity is very low. This was even more pronounced in the laboratory samples, with a reduction in water absorption of approximately 21% in the mixture with the highest polymer granule admixture compared to the control mixture sample. According to the test results, the thermal conductivity of laboratory lightweight concrete samples was determined in the range of 0.175-0.232 W/mK, while thermal conductivity values for mixtures of production line were determined in the range of 0.162-0.220 W/mK based on the copolymer granular material usage amounts. It has been observed that increasing the amount of copolymer granules in all laboratory and production line samples compared to the control mixture samples significantly reduces the thermal conductivity value of lightweight concrete and can have higher thermal performance. The sound transmission of the samples measured at 500 Hz frequency. Compared to the control mixture, the sound transmission loss value of the laboratory samples decreased by an average of 32.5% depending on the copolymer additive ratio at 500 Hz. However, it has been observed that the polymer additive does not provide a significant added value in improving the sound transmission loss properties of the test samples. In contrast, the polymer additive was found to be an important factor in improving the thermal conductivity of the test samples. Water absorption capability and unit volume weight values of the tested samples were decreased with the addition of polymer for both laboratory and operation samples.

As a result, it has been observed that the copolymer granule admixture can be used to improve most technical properties of porous lightweight concrete especially for the non-load bearing concrete masonry units and can have feasible results in a sectoral context.

Acknowledgements

The financial support from the Nevşehir Hacı Bektaş Veli University Scientific Research Project (project NEÜBAP16F39), the support of Blok Bims Factory (Nevsehir, Turkey), Alfa Polymer Innovation Company (Kocaeli/Turkey), Izmir Kâtip Çelebi University, Faculty of Engineering and Architecture, Department of Civil Engineering, Building Materials Innovation Research and Development Laboratories (İzmir-Turkey) and Aksaray University Scientific and Technological Application and Research Centre (Aksaray-Turkey) are all gratefully acknowledged.

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Table Captions

Table 1. Pumice amounts in weight percent (%)

Table 2. Chemical composition of cement

Table 3. Mechanical and physical properties of cement

Table 4. Chemical trace element composition of cement, pumice and volcanic tuff

Table 5. Physical and mechanical properties of the tested samples

Figure Captions

Fig. 1. Polypropylene copolymer granules used for the experiments

Fig. 2. (a) Molds, (b) Blocks in the laboratory and factory

Fig. 3. Matrix view of a Lab. Std. sample

Fig. 4. Matrix view of a Lab. 2.5% sample

Fig. 5. Matrix view of a Lab. 5% sample

Fig. 6. Matrix view of a Lab. 5% sample

Fig. 7. Matrix view of Operation Std. sample

Fig. 8. Matrix view of Operation 2.5% sample

Fig. 9. Matrix view of Operation 5% sample

Fig. 10. Matrix view of Operation 10% sample

Fig. 11. Copolymer granule amount versus unit volume weight of the tested samples

Fig. 12. Copolymer granule amount versus compressive strength at 28 days for the tested samples