



EVALUATION OF COATING MATERIALS USED TO ENHANCE THE PROPERTIES OF LIGHTWEIGHT AGGREGATE

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<https://doi.org/10.30572/2018/KJE/170229>

ABSTRACT

Two major issues associated with the production of lightweight concrete are high-water absorption and low unit-weight. To minimize the absorption of lightweight aggregate LWA (pumice) with maintaining low unit-weight, pumice particles were treated using different coating materials. The research evaluates the effect of coating materials and technique on enhancing the properties of pumice based on absorbency and unit-weight. The research included 36 samples were prepared and coated in different materials, quantity, layers, and initial moisture content. The samples were coated with either cement paste (CP), CP containing silica fume (SF), or CP containing polymer, and applied in either one or two layers; the samples were either oven-dried or surface-saturated state. The results showed that the treatment of LWA significantly reduces the absorption of pumice. The pumice coated with CP containing SF exhibited the highest reduction in absorption by up to 65% when applied in two layers and by 57% when applied in a single layer under OD conditions. The results also presented that the smaller quantity of coating materials, the greatest effect on the pumice properties. Consequently, pumice coated with 500 gm showed the greatest reduction (9%) in absorption compared to pumice coated with 750 and 1000 gm, especially at OD conditions.

KEYWORDS

Aggregate impregnation, Cement paste, Lightweight aggregate, Pumice, Unit weight, Water absorption.



1. INTRODUCTION

The lightening of concrete structures is among the important topics in the construction industry and civil engineering, being of great interest to engineers and researchers. Reducing building weight by using lightweight materials as lightweight aggregate (LWA); which is known as granular and porous materials used in architecture, engineering, landscaping, and geotechnics. LWA has a low density ranging from 800 kg/m^3 to 2000 kg/m^3 or bulk densities less than 1200 kg/m^3 (EN13055-1, 2002) (González-Corrochano et al., 2011), excellent thermal insulation properties and fire protection. LWA could be used as prefabricated structural units and structural lightweight concretes, particularly in high-rise structures, as well as track ballasts and road coatings (Franus et al., 2015). Unfortunately, the inner structure of lightweight aggregate can have many porous, which causes the porosity problem. Besides, it also has a high absorption, therefore the LWA makes it difficult to keep track of how light aggregate-concrete is mixed during construction (Pasupathy et al., 2020). On account of the disadvantages, infrastructure maintenance and repair have become a major issue, and the protection of structures and elements has become a top priority. With the aim to overcome the current issues faced by LWA, therefore, the coating is the option to maintain and enhance the properties of LWA (Jiang et al., 2020). In recent years, several coating materials and techniques for surface coating of LWA have been investigated including cementitious pastes or pozzolanic materials carbonate deposition on aggregate surfaces and polymers (Hanif et al., 2023; Ul Rehman et al., 2020; Hasan and Ahmed, 2025). The use of such solutions helps in the impregnation of surface pores, reducing the water absorption of the aggregates and improving their mechanical and durability-related performance.

Many researchers have studied different types techniques of LWA coating. Vahabi et al. (2022) found that full immersion of Leca and scoria aggregates in latex hydrophobic polymers-polyvinyl acetate (PVA) and styrene-butadiene rubber (SBR) reduced water absorption by up to 82%. Bideci et al. (2013) used polymer coating, specifically Sonomeric1 (SNMC), KB Pur 214 (KBP), and Polipol3455 (PLP), for lightweight concrete, and revealed that KBP-coated aggregate enhances compressive strength, while PLP-coated aggregates exhibit higher porosity. Dixit and Pang (2022) highlighted that using of cement with silica fume and fly ash to coat expanded clay aggregates led to a 60% reduction in water absorption, up to a 150% increase in strength. Li et al. (2009) demonstrated that recycled aggregate coated with pozzolanic powder and a special mixing technique increased compressive and flexural strengths. Domagała and Podolska (2022) showed that impregnation of sintered fly ash Lytag and expanded clay with cement paste increased concrete density by 19%, reduced water absorption by 71%. Yew et al.

(2023) found that soaking plant-based aggregate in cement paste with various water-to-cement ratios (w/c) increased compressive and splitting tensile strengths and modulus of elasticity by 22%, 26%, and 34%, respectively. Mahanna et al. (2024) studied expanded perlite treated with water treatment sludge and cement using a cold bond method and reported the produced LWA had 24-hr water absorption (12.4–22%), 28-day water absorption (22–27%) for samples, respectively. Bideci et al. (2023) noted an increase in compressive strength in pumice coated with polyester using a spray gun method in accordance with dosages. Lastly, Shahedan et al. (2022) found that geopolymer coating on LWA enhanced properties and decreased water absorption.

This study aims to investigate the impact of coating materials and teachings for LWA (Pumice) particles based on absorption and unit weight. The evaluation included three coating materials: cement paste, cement paste with silica fume, and cement paste with polymer. Another considered factors were the volumes of coating materials, the number of coating layers, and the moisture content of pumice before coating. The research seeks to optimize the material and technique of coating to produce the optimum properties and performance of LWA that can use in concrete.

2. EXPERIMENTAL WORK

2.1. Materials

Cement: Type I Ordinary Portland Cement (OPC) was used, provided by Sinjar Factory (Mosul). The physical, chemical composition and components of cement is given in Table 1, Table 2 and Table 3, respectively.

Silica fume: Micro silica fume, provided by Sika Company, was used in coating material at a replacement ratio of 8% of cement weight based on (Siddiqi et al., 2023). The chemical composition of silica fume is given in Table 2. The activity index of silica fume was 110%, following ASTM C1240 (C1240-20, 2020).

Coarse Aggregate LWA: The volcanic pumice, which is widely available in the north of Iraq, has been utilized as a type of LWA, as shown in Fig. 1. The aggregate was tested for absorbability and unit weight, based on ASTM C127 (C127-24, 2024) and ASTM C29 (C29/C29M-23, 2023), respectively. The Physical properties and the gradation of pumice are shown in Table 4 and Table 5, respectively.

Water: Potable water from the network system was used for both mixing and curing the samples.

Polymer: the polymer (sika lite), provided by Sika Company, was used.



Fig. 1. Natural volcanic pumice

Table 1. Physical properties of Portland cement

Physical properties	Test results	Limits of IQS No.5/1984
Consistency (w/c)	0.292	----
Initial setting time (min.)	165 min.	≥ 45 min
Final setting time (hrs.)	5.25 hrs.	≤ 10 hrs.
Fineness (sieve NO.170)	2.4%	≤10%
Compressive strength at:		
3 days (MPa)	22.72 @ 3 days	≥ 15
7 days (MPa)	32 @ 7 days	≥ 23

* These tests were conducted in the Materials Test Laboratory in the Civil Engineering Department, College of Engineering, University of Mosul.

Table 2. Chemical composition of Portland cement and silica fume

Chemical composition	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	Free Lime	Loss of ignition	Insoluble residue
Cement *	19.80	5.00	3.63	61.57	2.27	2.54	0.79	5.12	0.27
Silica Fume**	96	1.36	0.019	0.018	0.012	0.31	-	1.02	-

* The chemical tests for cement were conducted in the Environmental Engineering Laboratory, University of Mosul.

** According to the manufacturing.

Table3. Chemical components of Portland cement

Chemical components	C ₃ S	C ₂ S	C ₃ A	C ₄ AF	L.S. F	Solid Solution
Cement *	50.85	18.40	7.11	11.06	93.70	16.7

* The chemical tests for cement were conducted in the Environmental Engineering Laboratory, University of Mosul.

Table 4. Physical Properties of pumice

Physical Properties	Test Result
Specific Gravity (SSD)	1.26
Unit Weight (SSD) kg/m ³	1260
Absorption (SSD)	37%
Fineness Modulus	6.04
Max. aggregate size	¾ inch

Table 5. Gradation of pumice

Sieve Size	passing %	IQS Limits No. 5/ 2019
¾ "	92.73	90-100
½ "	29.86	-
⅜ "	32.4	30-60
⅜ "	2.26	0-10
Pan	0.16	-

2.2. Approach

Four different parameters were evaluated in this study including, coating materials, volume of coating materials, number of coating layers, and moisture condition of Pumice.

2.2.1. Coating Materials

To evaluate the effect of coating materials on the particle's properties, three different compositions of cement pastes were prepared for the impregnation of pumice. The first was traditional cement paste. The second was cement paste contained 8% of silica fume (by weight of cement). The third was cement paste contained 2% of polymer (by weight of cement). This amount of polymer can significantly affect the product properties (alsaadi et al., 2024). According to the manufacturer's instructions, it is recommended to use 2% for best results. This is consistent with the results of (Baloch et al., 2019), where 1%, 2%, and 3% were used. All these materials were evaluated based on the absorption and unit weight of the coated Pumice particles. Fig. 2 shows the preparation of material, coating mixture, and pumice particles after coating.



Fig. 2. Pumice preparation, coating mixture, and pumice particles after coating

2.2.2. Volume of Coating Materials

To determine the volume of coating materials needed for Lightweight Aggregates (LWA), we need to consider the aggregate's size, shape, porosity, and the desired coating thickness, as well as the specific properties of the coating material itself (Tarekegn et al., 2025). Accurately determining this volume is crucial for achieving the desired properties of the coated LWA, such as improved workability, durability, and reduced water absorption. Based on the aggregate's volume and the desired coating thickness, the approximate volume of coating material can be calculated (Fernández-Fanjul et al., 2018). To evaluate the effect of the volume of coating materials, three different coating volumes were used. To coat 250 grams of pumice, several

coating mixes were prepared at double, triple, and quadruple volumes, containing 500, 750, and 1000 grams of cement with a w/c ratio of 0.55. From previous studies, it was concluded that a w/c ratio of 0.55 was the optimal ratio to obtain the optimal results (Domagała and Podolska, 2022). This variation in volume was performed to ensure comprehensive and accurate results. It was observed that when less than double the volume was applied, the mixture was too light and ineffective for forming a film around the aggregate. Conversely, when coating with mixes containing more than quadruple, workability was reduced significantly (Tuncer et al., 2025b). Determining the volume of coating material for LWA requires a combination of understanding aggregate and coating properties, using appropriate measurement techniques, and considering factors like water absorption and application methods. Experimental testing is often necessary to achieve the most accurate results (Aboul-Nour et al., 2020).

2.2.3. Number of coating layers

To determine the optimal number of coating layers for lightweight aggregate (pumice) in concrete, the desired properties of the final concrete and the characteristics of the coating material should be considered. Generally, increasing the number of coating layers can reduce aggregate water absorption and improve compressive strength (Drouna et al., 2025). However, there's a point where further layers offer diminishing returns and can even negatively impact workability (Ling et al., 2013). The desired coating thickness and the properties of the coating material determine the number of aggregate coating layers. It's often calculated based on the desired dry film thickness per coat and the spreading rate of the coating material. The specific gravity and absorption of the aggregate also play a major role in determining the spread rate and thus the number of layers (Yuan et al., 2024). These properties can also influence how the coating adheres to the aggregate and how much coating material is needed. To validate the effect of the number of coating layers, pumice particles were covered either with one layer or two layers of coating materials. It has been observed that if more than two coats are applied with a high cement content, the unit weight will increase significantly (Ling et al., 2013), which is an undesirable characteristic for lightweight aggregates.

2.2.4. Moisture condition of LWA

To evaluate the effect of moisture conditions, the particles were used in oven-dry (OD) conditions and saturated surface-dry (SSD) conditions to obtain the comprehensive results.

2.3. Coating procedure

This procedure was used to fully coating of Pumice particles, and it was equally applied to all coating materials.

2.3.1. Oven Dry (OD) Condition of Pumice

A sample of 250-gm weight of pumice was prepared for each test. All pumice particles were passed through a sieve of $\frac{3}{4}$ " and remaining on the sieve of $\frac{1}{2}$ ". The pumice samples were dried in the oven for 24 hours to obtain an OD condition. The particles were then immersed in the mix of cement paste, prepared previously, the immersion process took 45 minutes (which represents the least time of initial hardening or cement reaction time (Yuan et al., 2021), stirring the particles every 10 minutes. The coated pumice was then extracted from the coating materials by food tong and placed separately on a plastic sheet to prevent the coated particles from sticking to each other, as shown in Fig. 3, and covered with plastic sheets to avoid evaporating. After 24 hours, the pumice particles were dipped in water for 28 days for curing. The sample was then tested for absorption and unit weight.

2.3.2. Two layers coating

After 24 hours the coated particles were immersed in the coating materials and repeated the same procedure mentioned above. The sample was cured in water for 28 days before being applied to the tests.



Fig. 1. Coated Pumice particles placed on plastic sheet

2.3.3. Saturated Surface Dry (SSD) Condition of Pumice

For the SSD condition, the OD particles were dipped in water for 24 hours before the coating process. The LWA particles were extracted from water and dried the surfaces by towel to obtain the SSD condition. Then, the sample was applied to the same procedure in Section 3.1.

3. RESULTS AND DISCUSSION

The results of the experimental work of the study included two groups; the first represented the LWA (pumice) in OD condition, and the second represented the pumice in SSD condition. The pumice of each group was coated utilizing three different materials with three different volumes of coating materials, using a constant w/c ratio of 0.55. The coating was applied in one or two layers for two groups. All results were evaluated based on the absorption and unit weight tests.

3.1. Coating with Cement paste (CP)

Cement paste (CP) was applied to the pumice in two moisture conditions OD and SSD using different volumes of coating material with one or two layers to determine the effect of CP on enhancing the properties of the pumice.

3.1.1. Coating with one layer

The absorption results for OD and SSD conditions of pumice coated with a single layer of varying volumes of coating material are depicted in Fig. 4. The findings demonstrate a reduction in absorption for all coated pumice samples compared to the uncoated particles. This reduction becomes more pronounced as the volume of coating material decreases, with a constant w/c ratio. Pumice coated with a 500 g cement (C500) achieved the highest reduction in absorption (54%) in OD condition and 35% in SSD condition. In comparison, the specimens coated with a 1000 g cement (C1000) exhibited a reduction of approximately 38% and 32% in OD and SSD conditions, respectively.

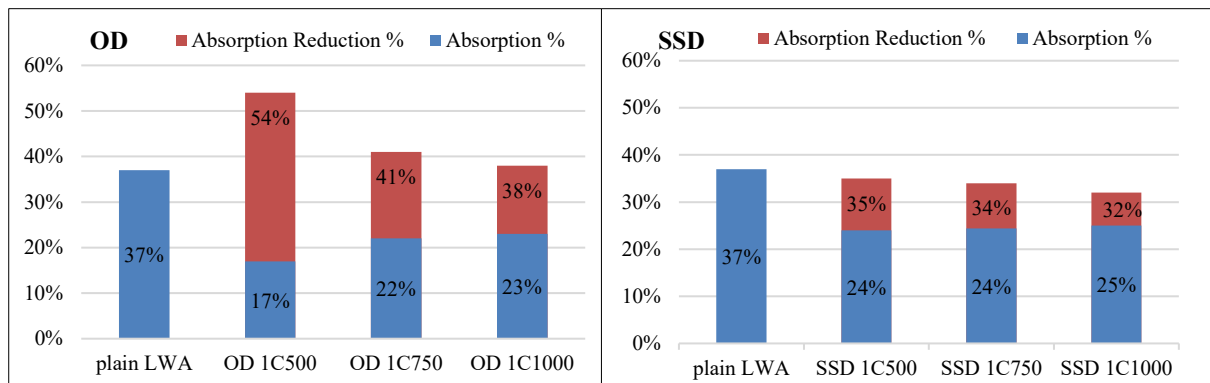


Fig. 4. Absorption of coated pumice in different volumes of CP with one layer in OD & SSD conditions

The unit weight test results for OD and SSD conditions of coated pumice with a single layer of varying volumes of coating material are illustrated in Fig. 5. The findings show an increase in unit weight for all coated pumice samples compared to the uncoated particles. For OD condition, the increase in unit weight was more observed, between 5% to 4%, across all coating material volumes, while for SSD condition, the increase was constant, 1%, across all volumes.

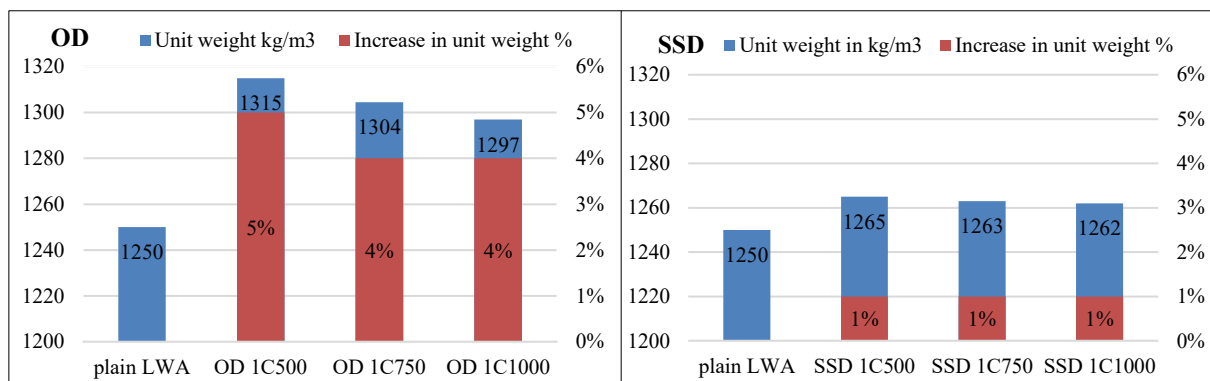


Fig. 5. Unit weight of coated pumice in different volumes of CP with one layer in OD & SSD conditions

The observed results could be attributed to the (OD) pumice particles absorb a consistent volume of water from all coating materials. Since a w/c ratio used was consistent, increasing the amount of cement leading to increase the amount of water, which increases the workability

of the coating material (Tuncer et al., 2025a). Consequently, a thinner coating layer was formed, resulting in higher absorption and lower unit weights compared to coatings with lower cement volume (Tuncer et al., 2025b). Furthermore, during the coating process, noticeable holes appeared on the surfaces of pumice particles when using a high cement volume, as illustrated in Fig. 6. These holes further contributed to greater water absorption by OD pumice particles. The appearance of holes on pumice particles during the coating process is likely due to the inherent vesicular texture of pumice and the coating process itself. Pumice is a lightweight volcanic rock with a porous structure due to the presence of numerous small, interconnected or isolated holes called vesicles. When coated, these holes can either remain exposed or become filled with the coating material, potentially creating visible defects (Tuncer et al., 2025a).



Fig. 6. The holes appeared during the coating process with the ratios (750) and (1000)

The findings also demonstrate that the absorption reduction in SSD condition for coated particles with one layer of varying coating volumes was less significant than that in OD condition for all coating volumes. This disparity can be explained by the thinner coating layers formed on SSD pumice due to their saturated condition, which reduces absorbing water from the coating material. In contrast, OD pumice readily absorbs water from the coating, resulting in thicker layers and more reduction in absorption, (Domagała and Bryła, 2021). Moreover, the unit weight of SSD pumice particles remained nearly constant across different coating volumes. This stability supports the aforementioned reasoning, as the saturated state of SSD pumice limits additional water absorption, regardless of the coating material volume.

3.1.2. Coating with two layers

The absorption results of coated pumice with two layers at varying coating material volumes in both OD and SSD conditions, are presented in Fig. 7. The data indicate a reduction in absorption for all coated pumice compared to the uncoated. This reduction becomes more pronounced as the volume of coating material decreases. In the OD condition, coated particles with 500 g cement (2C500) exhibited the greatest absorption reduction, reaching 62% compared to uncoated pumice, while those coated with 1000 g cement (2C1000) showed a less reduction of 54%, these results correspond with the findings of (Domagała and Bryła, 2021), which proved that the initial moistening of LWA limited its absorption of water of cement paste. Similarly,

in the SSD condition, coated particles with 500 g cement (2C500) demonstrated a maximum absorption reduction of 59%, whereas those coated with 1000 g cement (2C1000) experienced a reduction of 51%. In the meantime, there is a lot of evidence (Domagała, 2020; Bogas and Real, 2019; Tang and Brouwers, 2018; Lotfy et al., 2016) showing deterioration of LWAC performance when it is prepared with saturated aggregate.

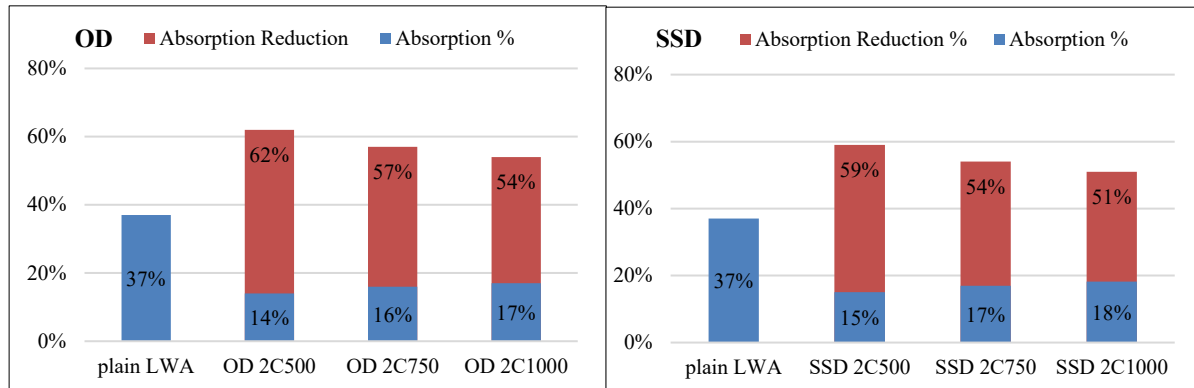


Fig. 7. Absorption of coated pumice using different volumes of CP with two layers in OD & SSD conditions

The results for unit weight for coated pumice with two layers and varying volumes of coating material in both OD and SSD conditions are presented in Fig. 8. The findings show an increase in unit weight for all coated particles compared to the uncoated ones; and this increase was slightly reduced when large volume of coating materials was used in both OD and SSD conditions. For OD condition, the increase in unit weight was between 14% to 11%; while for SSD condition, the increase was between 11% to 8% across all volumes. When coating with two layers, weak and almost negligible results were shown, coinciding with the result of (Domagała and Bryła, 2021), which proved the unimportance of the density criterion and its change because it is low compared to the initial density of plain aggregate.

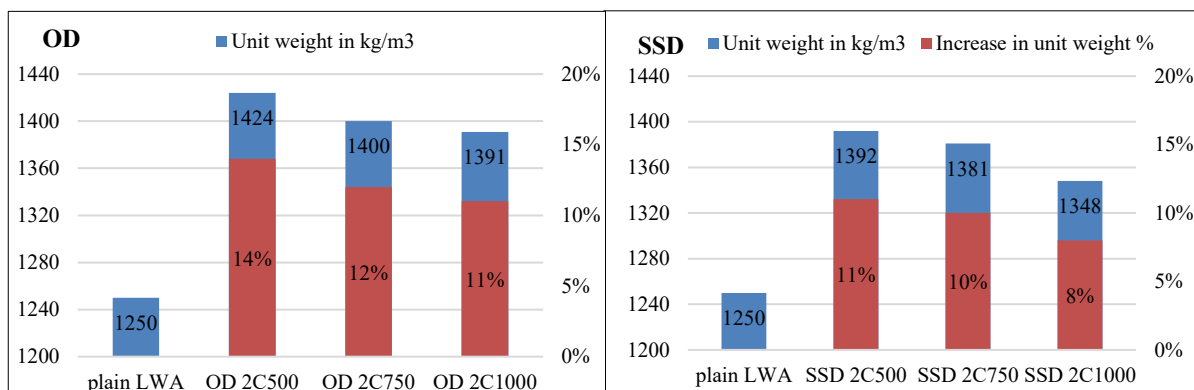


Fig. 8. Unit weight of coated pumice using different volumes of CP with two layers in OD & SSD conditions

The greater reduction in absorption observed for pumice coated with two layers, compared to a single layer, was consistent in both OD and SSD conditions. Under OD conditions, the reduction can be attributed to the increased resistance provided by the additional coating layer,

which reduces the pores and enhances the barrier against water absorption. Similarly, under SSD conditions, the additional layer contributes to a thicker coating. This increase in coating thickness may be due to the drying process of coated pumice with a single layer; after hardening, it became nearly dry, exhibiting similar behavior to pumice with two layers under OD conditions. In both cases, the second layer not only improved resistance to absorption but also increased the unit weight of the pumice.

3.2. Coating with cement paste containing silica fume (S)

Cement paste containing 8% silica fume (S) was applied to coat pumice in two moisture conditions using different volumes of coating materials with one or two layers to determine its effect on enhancing the properties of pumice based on absorption and unit weight.

3.2.1. Coating with one layer

The absorption results of coated pumice with a single layer of varying volumes of coating material in OD and SSD conditions are depicted in Fig. 9. The findings demonstrate a reduction in absorption for all coated pumice particles compared to the uncoated pumice. This reduction becomes more pronounced as the volume of coating material decreases. The coated particles with a 500 g cement (S500) achieved the highest absorption reduction by 57% and 43% in OD and SSD conditions, respectively. In comparison, the coated particles with a 1000 g cement (S1000) achieved the lowest absorption reduction by 49% and 42% in OD and SSD conditions, respectively.

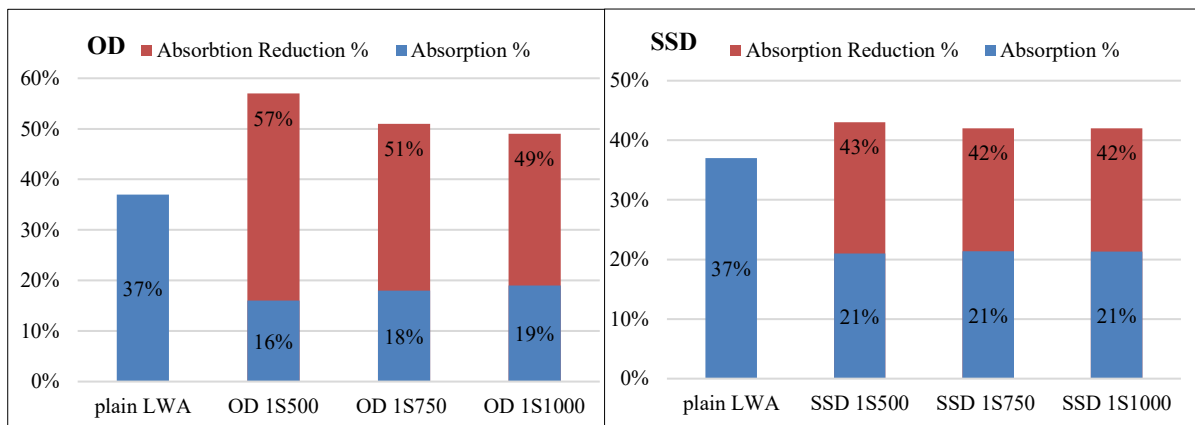


Fig.9. Absorption of coated pumice using different volumes of S with one layer in OD & SSD conditions

The unit weight results for coated pumice with one layer across varying coating material volumes in OD and SSD conditions are presented in Fig. 10. The findings indicate an increase in unit weight for all coated pumice compared to the uncoated particles. For OD condition, the increase in unit weight was more pronounced, between 12% to 10% across all coating material volumes; while for SSD condition, the increase was between 3% to 2% across all volumes.

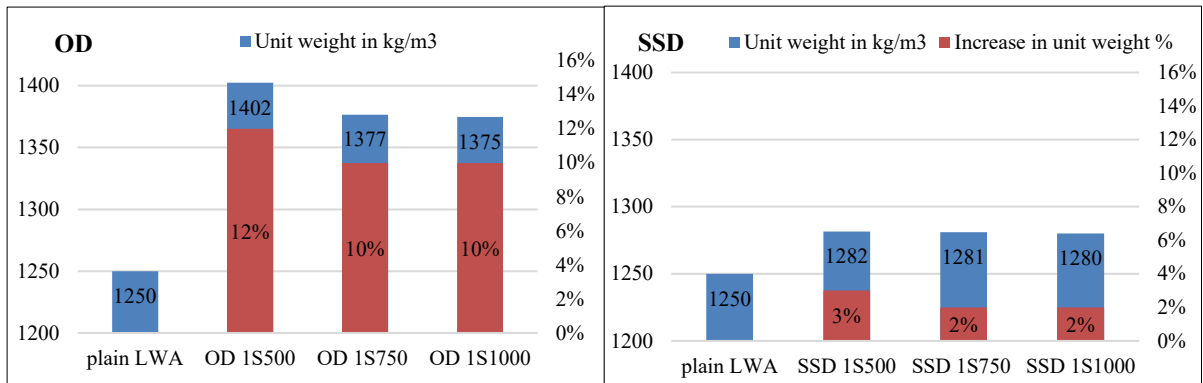


Fig. 10. Unit weight coated pumice in different volumes of S with one layer in OD & SSD conditions

The observed reduction in absorption for coated pumice with a single layer of cement paste with silica fume appears to stem from similar mechanisms previously discussed. However, an additional decrease in absorption is likely due to the influence of silica fume on the workability reduction of the coating material (Alazhari et al., 2018; Wang et al., 2020), which results in a thicker coating layer around the pumice particles. Moreover, silica fume enhances the structure of the cement paste itself (Kareem et al., 2019; Ismail and Ramli, 2014; Sasanipour and Aslani, 2020), leading to a greater reduction in absorption across all coating material volumes in OD pumice condition. When examining SSD pumice under identical coating conditions, a significantly lower reduction in absorption was observed compared to OD pumice. This discrepancy is likely attributed to differences in coating layer thickness due to SSD particles did not absorb much water from the coating material, unlike OD particles, where water absorption affects the interaction between the coating material and the aggregate. These results are supported by unit weight results shown in Fig. 10. In SSD samples where the three coating volumes produced nearly identical increase in unit weight. In contrast, in OD condition illustrates noticeable variations in unit weight increase among the three volumes, with increasing in unit weight reaching 12%.

Furthermore, SSD pumice coated with a single layer of cement paste contained silica fume exhibited a more pronounced reduction in absorption compared to SSD pumice coated with a single layer of cement paste. This behavior is likely due to the effect of silica fume in decreasing the workability of the cement paste, which increases the thickness of the coating layer. Additionally, silica fume enhances bonding strength within the material, further reinforcing the reduction in absorption.

3.2.2. Coating with two layers

The absorption results for coated pumice with two layers at varying coating material volumes in both OD and SSD conditions are presented in Fig. 11, respectively. The data indicate a

reduction in absorption for all coated pumice compared to the uncoated. This reduction becomes more pronounced as the volume of coating material decreases. The coated particles with a 500 g cement (S500) achieved the highest absorption reduction by 65% and 57% in OD and SSD conditions, respectively. In comparison, the coated particles with a 1000 g cement (S1000) achieved the lowest absorption reduction by 56% and 50% in OD and SSD conditions, respectively.

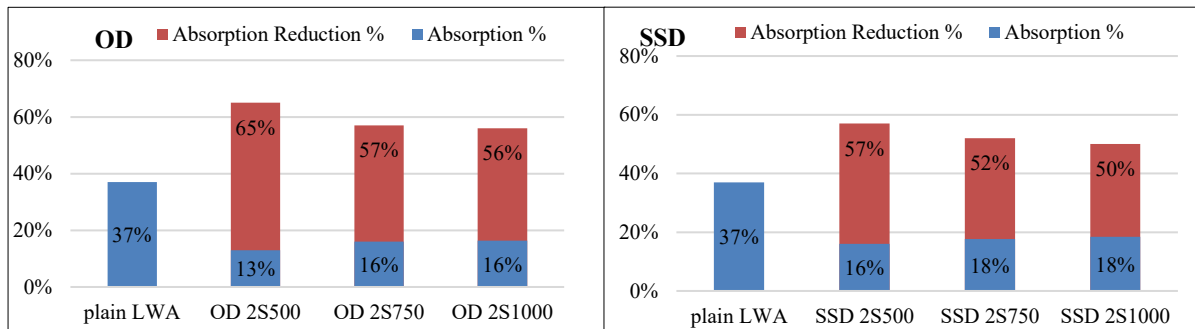


Fig. 11. Absorption of coated pumice in different volumes of S with two layers in OD & SSD conditions

The results of unit weight for coated pumice with two layers across varying coating material volumes in OD and SSD conditions are presented in Fig. 12. The findings show an increase in unit weight for all coated pumice compared to the uncoated pumice. For OD condition, the increase in unit weight was more pronounced, between 22% to 17% across all coating material volumes; while for SSD condition, the increase was between 13% to 12% across all volumes.

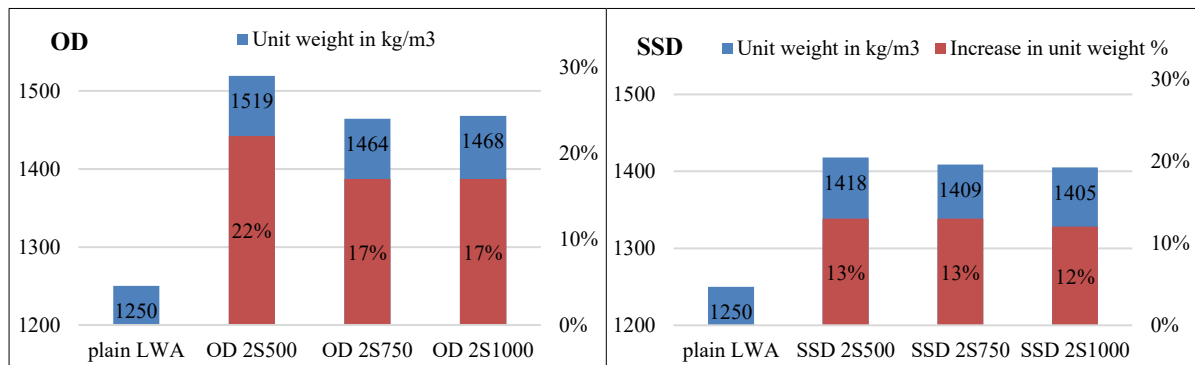


Fig. 12. Unit weight of coated pumice in different volumes of S with two layers OD & SSD conditions

The previous results might be due to the same reason mentioned in the earlier section about coating with two layers of cement paste. However, in this type of coating, there was a greater reduction in absorption compared to its counterpart coated with only cement paste. This increased reduction was attributed to the effectiveness of silica fume in decreasing the workability of the coating material, which, in turn, increases the thickness of the coating layer and results in less absorption for the pumice particles. However, this additional layer also increases the unit weight of the pumice.

3.3. Coating with cement paste containing polymer (P)

Cement paste containing 2% sika polymer (P) was applied to coat pumice in two moisture conditions using different volumes of coating material with one or two layers to determine its effect on enhancing the properties of pumice based on absorption and unit weight.

3.3.1. Coating with one layer

The absorption results of coated pumice with a single layer of varying volumes of coating material (P) in OD and SSD conditions are depicted in Fig. 13. The findings demonstrate a reduction in absorption for all coated pumice samples compared to uncoated pumice. This reduction becomes more pronounced as the volume of coating material decreases, with a constant w/c ratio. In OD condition, the effect of coating material volume was more significant on the absorption than SSD condition. The reduction in absorption dramatically dropped from 49% with a 500 g cement (P 500) to 35% with a 1000 g cement (P 1000); however, the reduction in absorption slightly dropped from 18% with a 500 g cement (P 500) to 16% with a 1000 g cement (P 1000).

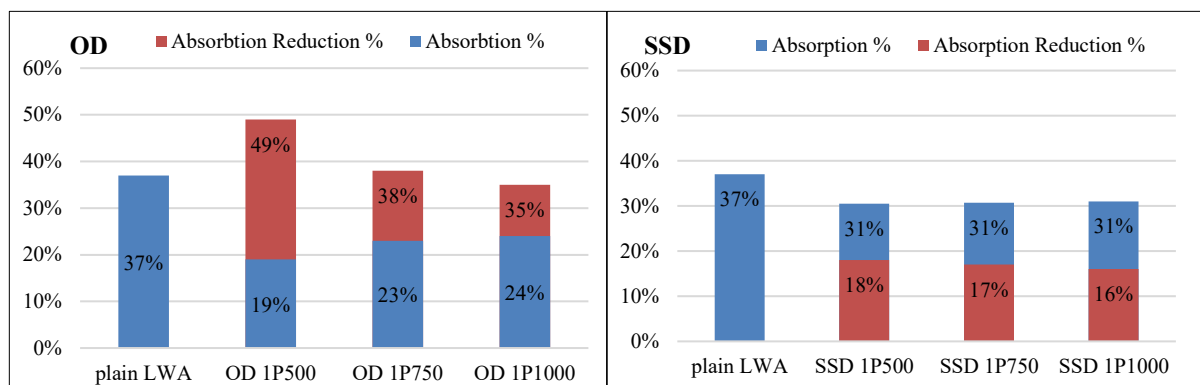


Fig. 13. Absorption coated pumice in different volumes of CPP with one layer in of OD & SSD conditions

The unit weight results for coated pumice with one layer across varying coating material volumes in OD and SSD conditions are presented in Fig. 14. The findings indicate slightly increase in unit weight for all coated pumice compared to the uncoated specimens. In OD conditions, the increase in unit weight was between 3% to 2% across all material volumes; While in SSD condition, the increase in unit weight was in between 1% to 0.5%.

The coating of P was expected to result in a greater reduction in absorption compared to the two previous materials (CP and S). However, as indicated by the aforementioned results, this coating produces less reduction in absorption. This could be attributed to the recommended replacement ratio of 2% from the manufacturer, which may not be compatible with the w/c ratio of 0.55. This is in line with the previous studies (Felekoğlu, 2012) while the polymers enhanced and improved the performance within certain limits of w/c ratio. Consequently, the coating

layer thickness on the pumice particles was observed to be very thin, almost transparent, and enhanced workability (Salli Bideci et al., 2014). Regarding the variation in the increase of absorption reduction between the three sizes of the coating material, the reason could be the same as previously mentioned in the case of coating pumice with a single layer of cement paste. In the SSD condition, the observed results can be attributed to the previously mentioned explanation, which suggests that pumice particles in the SSD condition are saturated with water and do not absorb any additional water from the coating material. This condition increases the workability of the coating material at a fixed w/c ratio. Which may reduce the polymer's effectiveness in decreasing the water absorption of the pumice.

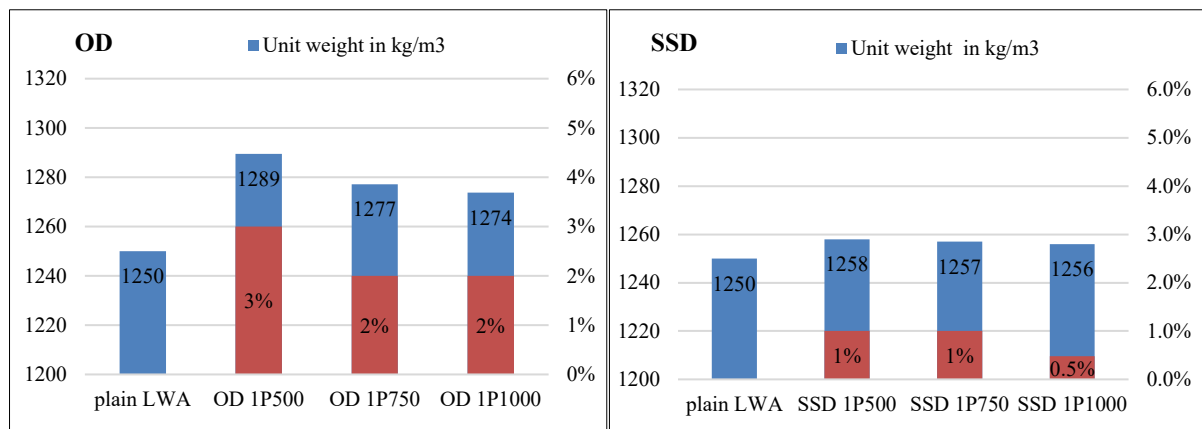


Fig. 14. Unit weight of coated pumice in different volumes of CPP with one layer in OD & SSD conditions

3.3.2. Coating with Two layers

The absorption results for coated pumice with two layers at varying coating material volumes in both OD and SSD conditions are presented in Fig. 15. The data indicate almost equally reduction in absorption for all coated material volumes in both OD and SSD conditions. The reduction in absorption was between 17% to 20% compared to the uncoated particles for both OD and SSD conditions.

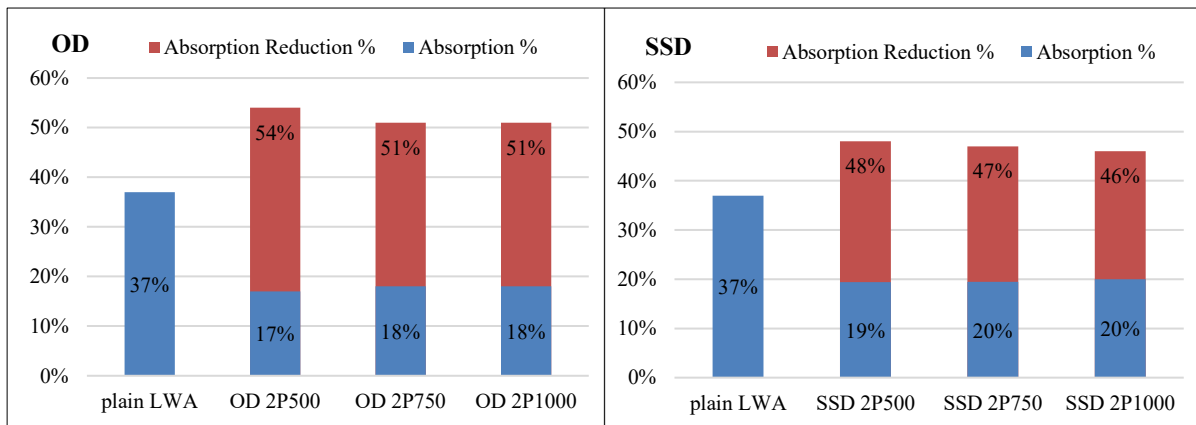


Fig. 15. Absorption of coated pumice in different volumes of CPP with two layers in OD and SSD conditions

The unit weight results for coated pumice with two layers across three coating material volumes in OD and SSD conditions are presented in Fig. 16. The findings indicate an increase in unit weight for all coated pumice compared to the uncoated particles. The increase in unit weight was mostly equal for OD and SSD conditions, between 8% to 6%, for particles coated with 500 g cement (P500) and 1000 g cement (P1000), respectively. The increase in unit weight was reduced with larger volume of coating materials.

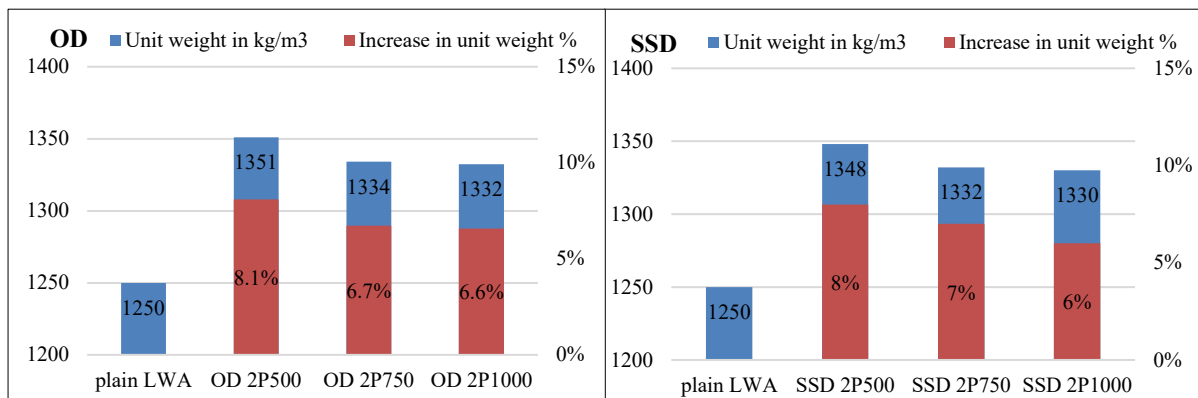


Fig. 16. Absorption of coated pumice in different volumes of CPP with two layers in OD and SSD conditions

The observed results can be attributed to the previously mentioned explanation, which suggests that the reduction in absorption is caused by the increased thickness of the coating layer around the pumice particles. When a second layer is applied, additional thickness is added, leading to an increase in the unit weight of the coated pumice. The previous results clarify what was mentioned in earlier paragraphs concerning the coating materials CP and S under the SSD condition, which were applied in two layers. Once the first layer of coating on the pumice particles dries, it transitions the material from the SSD condition to the dry condition. Consequently, the coating behavior aligns with that of the dry condition, resulting in a thicker coating layer. This enhanced thickness further reduces absorption and increases the unit weight of the coated pumice.

4. CONCLUSIONS

This study was conducted to investigate the feasibility of using coated LWA (pumice) instead of uncoated pumice to improve its properties, specifically absorption. The study investigates the effect of coating of pumice using three coating materials on the properties of LWAs based on absorption and unit weight. In addition, the volume of coating materials, number of coating layers, and the moisture content of pumice before coating were also assessed. The research seeks to optimize the material and technique of coating to produce the optimum properties and performance of pumice that can use in concrete. Based on the results, the study layout the following conclusions:

1. The type and volume of coating materials, moisture conditions, and the number of coating layers, have a high impact on the absorption of LWA. The coating of LWA with different materials decreases the absorption and slightly increases the unit weight.
2. Among the tested coating materials, cement paste modified with silica fume (CPS) demonstrated superior sealing efficiency. Notably, a two-layer application of CPS under OD conditions achieved a remarkable 65% reduction in water absorption, while a single-layer application achieved a 57% reduction—highlighting the role of both advanced cementitious chemistry and moisture pre-conditioning.
3. The OD condition proved to be substantially more effective than the SSD condition in enhancing coating penetration and bonding, particularly when pumice was treated with a single coating layer. The optimal performance was achieved with a 500g application of coating material, suggesting that minimal but targeted material usage under specific pre-treatment conditions can outperform bulkier applications.
4. A clear inverse relationship was observed between coating material volume and absorption efficiency. A 500g coating volume yielded the highest reduction in absorption compared to 750g and 1000g applications. This finding challenges the conventional approach of maximizing coating thickness and instead supports a precision-based application strategy, especially under OD conditions.
5. While increasing the number of coating layers from one to two enhanced water resistance across all materials, it also introduced trade-offs in terms of increased unit weight. The most significant weight gain was recorded in the two-layer CPS-coated pumice, with a 22% increase, raising considerations for structural applications where unit weight is critical.
6. Ultimately, the most efficient and balanced method for reducing water absorption while minimizing the impact on aggregate weight was the use of a single-layer, 500g coating of CPS under OD conditions. This method offers a practical and performance-optimized solution for producing enhanced LWA with improved durability and workability in concrete applications. Interestingly, as the volume of coating material decreases, its impact on the physical behavior of pumice becomes more pronounced. Notably, pumice coated with a lower dosage of 500 demonstrated a superior reduction in water absorption—especially under oven-dried (OD) conditions—outperforming those treated with higher volumes of 750 and 1000. This counterintuitive trend suggests that optimal coating efficiency may not necessarily align with greater material application, but rather with precise dosage control. Based on the results obtained in the study, it is possible to produce LWAC with coated LWA like pumice to enhance both the properties of LWA themselves and the properties of concrete made of these aggregates.

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