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Rheological and mechanical behavior of self-compacting mortars containing marble waste as a partial replacement of sand

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ABSTRACT

Materials recycling presents a compelling economic case for waste disposal sites and the conservation of natural resources. This study delves into the substitution of cement with varying percentages of marble waste (0%, 10%, 20%, 30%, 40% and 50%). The water-to-binder ratio is consistently set at 0.44 for all mixes. Chemical admixtures such as superplasticizers or viscosity agents are frequently added to the mortar to improve its flow and strength. We conducted mini-slump flow and rheometer tests to assess the fresh mixes' rheological properties, as well as tests to measure the compressive and tensile strength of the mixes. The findings indicate that including marble powder enhances the mechanical properties of self-compacting mortar. A substantial 29% enhancement was achieved for a mixture incorporating 30% marble waste. The most favorable rheological properties, including slump flow, yield stress, and superior mechanical performance in compressive and tensile strength, were observed in the mix containing 30% marble powder waste. Furthermore, the investigation showed that the self-compacting mortar with a yield stress of 0.98 MPa at a 50% MW replacement rate and a viscosity of 1.4 Pa.S can achieve a slump flow of 25–31 cm. These findings illustrate marble waste potential as a valuable addition to self-compacting mortar (SCM) manufacturing, delivering improved performance and structural integrity. However, specific application scenarios and long-term endurance restrictions require further investigation. Practical effects include the possibility of developing inventive, sustainable, and economic SCM compositions, which will help to advance construction practices and sustainability. The social ramifications include reducing environmental impact and increasing resource efficiency in the construction industry.

Keywords: Mortar; Workability; Compressive strength; Flexural strength; Marble waste.

1. INTRODUCTION

In recent years, in the concrete industry, self-compacting concrete (SCC) has made significant technological progress through the advantages affected by the latter, ease of implementation, prefabrication, and the needless vibration ensured by the concrete fluidity, also due to the workability characteristics of self-compacting concrete [1, 2]. Adding admixtures and utilizing adjuvants in SCC mixes affect its characteristics [3, 4]. Various studies by DHIYANESHWARAN *et al*. [5] and Messaoudi et al. [6] have devised individual mix proportion techniques.

Incorporating different types of waste in self-compacting concrete blends affects their properties in fresh and hardened states [6, 7]. Multiple research investigations have concentrated on formulating a method to forecast the rheological characteristics of these concrete mixes [8–10].

Using marble powder is a practical and cost-effective way to enhance the qualities of various types of concrete [11]. Numerous studies have outlined the benefits of marble powder. TOPÇU *et al.* [12] and SARDINH *et al.* [13] have examined its impact on the properties of concrete, both in its fresh state and once hardened. These studies concluded that substituting marble powder improved the workability and mechanical strength of the mortar.

The literature suggests that mortar containing marble waste can be produced with properties similar to standard mortar as long as the marble powder content does not exceed 30% [2]. Some studies have also investigated the impact of this experimental material on the shear threshold and viscosity of mixtures using a

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Herschel-Bulkley model [2, 14]. Furthermore, the influence of mineral additives on concretes' rheological and mechanical properties is discussed in [15]. Results from rheological and mechanical tests indicate that, depending on the type and amount of mineral additions, it is feasible to adjust rheological parameters to align with the used rheology assessments. The research discovered that replacing sand with limestone waste enhances the rheological properties of concrete. The study noted a rise in mechanical strength for fine aggregates with 25%, 50%, and 75% substitution ratios, exceeding the strength attained with natural aggregates [16]—However, a complete 100% replacement led to decreased strength values [17].

GADO [18] reported improvements in the properties of polymer-modified cementitious adhesive mixture formulations with the optimal addition of sludge. SIDDIQUE and MEHTA [19] demonstrated that using waste marble with a 5–20% replacement ratio in self-compacting concrete can increase its durability—additionally, reusing marble in concrete offers economic interest. AYDIN and AREL [20] noted that the concrete slump decreased with increasing amounts of marble waste. Similarly, KARAKURT and DUMANGÖZ [21] showed that slump test results extended between 55–72 cm with a 10–30% substitution of marble dust. Sharma et al. [22] found that the highest slump flow value was achieved with a 20% replacement of marble dust with cement, resulting in a slump value of 12 cm. According to JARUGUMALLI and MADUPU [23], the slump flow increases up to a 40% replacement with marble waste powder, after which it begins to decrease.

In this study, the influence of replacing natural sand with marble waste up to 50%, based on the literature review on the fresh and hardened properties of mortar, including porosity and water absorption, is considered. The main objective is to evaluate the rheological parameters such as yield stress and plastic viscosity, slump flow, compressive and flexural strength, bulk density, and microstructural properties.

2. MATERIALS AND METHODS

The experimental program used CEM I/A-L 42.5 cement sourced from Blida. The mineralogical and chemical composition of the cement are given in Tables 1 and 2. The particle size distribution of cement was determined by laser granulometry and is shown in Figure 1. Marble powder waste, primarily composed of calcium carbonate (98.8%), was obtained from recycled marble waste in the Blida region. Semi-crushed sand (0/4) was employed as the fine aggregate. The physical properties of the sand and marble waste are summarized in Table 3. The particle size distribution of the sand and marble waste particles is shown in Figure 2.

Table 1: The mineralogical constitution of cement.

COMPONENTS	VALUE (%)
C_3S	52.04
C_2S	28.95
C3A	7.02
C4AF	11.99

Table 2: Chemical composition of the cement used.

COMPONENTS	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	cl
CONTENT (%)	22.87	5.03	3.65	62.83	1.55	1.33	0.81	0.29	0.024

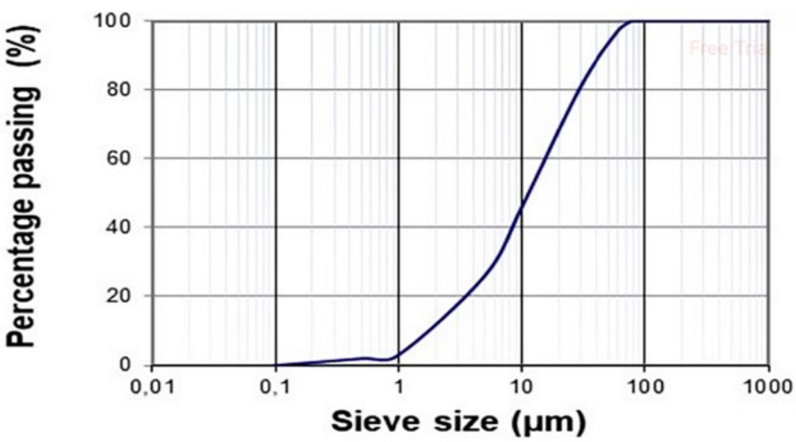

Figure 1: Particle size distribution of cement.

Table 3: Physical characteristics of sand and marble waste.

PHYSICAL CHARACTERISTICS	SAND	MARBLE WASTE
Water absorption (%)	1.29	1.66
Specific gravity (kg/m^3)	2500	2702
Fineness Modulus	2.51	2.72
Maximum size (mm)	5.00	2.94
Compactness (%)	59.8	62.2
Fineness modulus	2.37	–
Fine particles percentage (%)	–	33.3

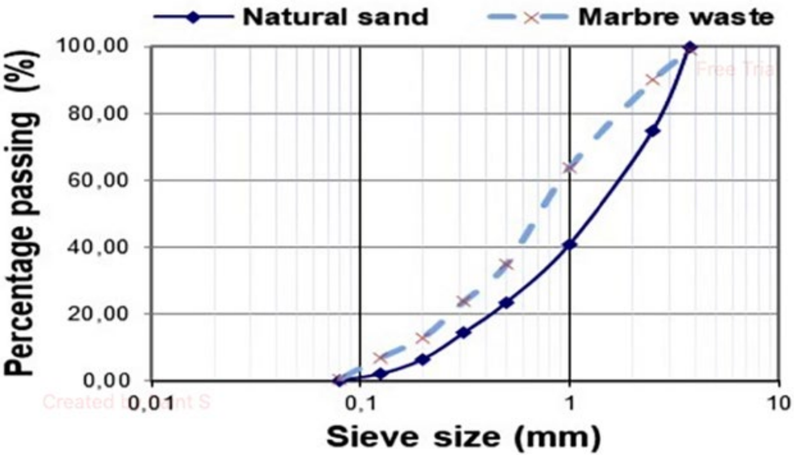

Figure 2: Particle size distribution of sand and marble waste.

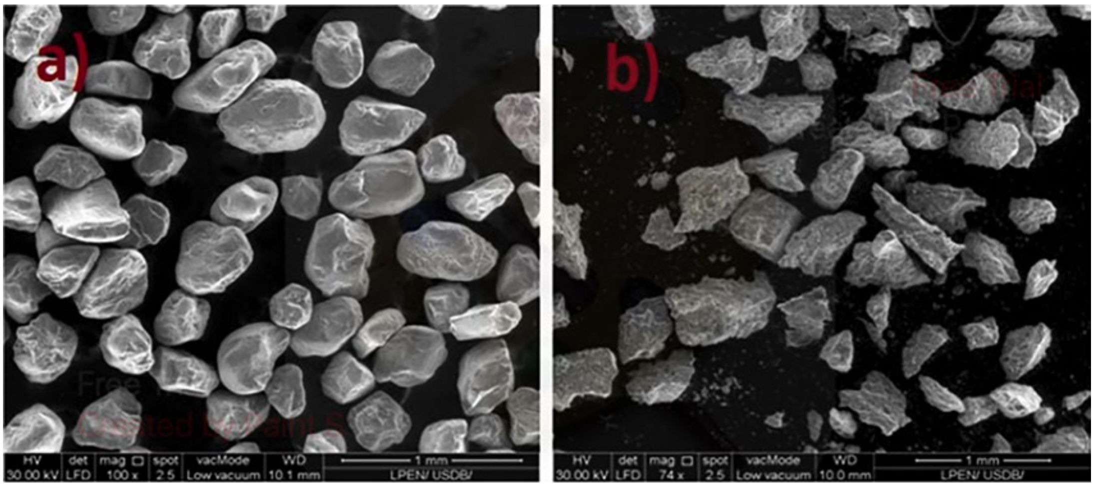

Figure 3: SEM (Scanning Electron Microscopy) images of (a) sand and (b) marble waste.

Figure 3 presents the SEM images of natural sand and marble waste. The shape of sand grains is spherical with a regular surface. Meanwhile, the marble waste grains are angular and have relatively rough surfaces.

The mineral composition of the marble powder was assessed through X-ray diffraction (XRD) analysis. Figure 4 shows the XRD diffractogram, revealing predominant components, including Calcite (Ca), Dolomite (D), and Quartz (Q).

The superplasticizer this research utilizes is a high-range water reducer, specifically a polycarboxylate. It had a density of 1.07 and has a pH of approximately 6.0. Notably, this superplasticizer's chloride ion (CI−) and sodium oxide (Na2O) contents are maintained below 0.1% and 1%, respectively. Figure 5 illustrates the various materials used in the mix design. Some papers may include a bibliographic review between the introduction, materials, and methods.

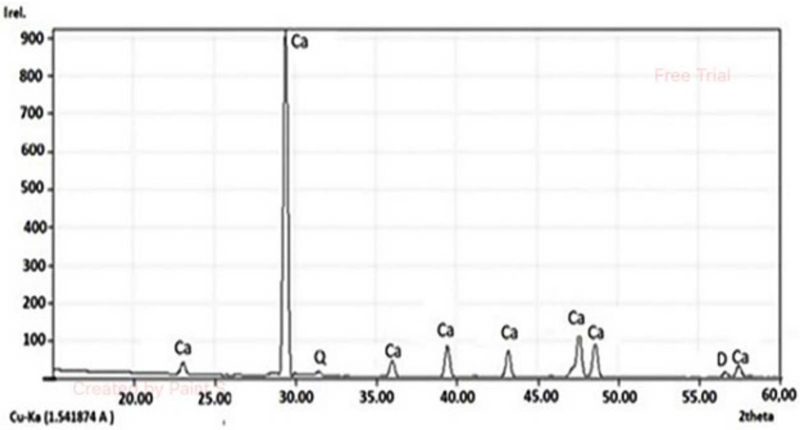

Figure 4: XRD (X-ray diffraction diffractogram) of marble.

Figure 5: Materials used in mix design.

Table 4: Composition of different mixtures.

MIXTURES	COMPOSITION	NS (%)	MW (%)	C (%)	W/C	SP (%)
SCM- 0MW	100% NS + 0% MW	100	0	100	0.44	0.9
SCM- 10MW	90% NS + 10% MW	90	10	100	0.44	0.9
SCM- 20MW	80% NS + 20% MW	80	20	100	0.44	0.9
SCM- 30MW	70% NS + 30% MW	70	30	100	0.44	0.9
SCM- 40MW	60% NS + 40% MW	60	40	100	0.44	0.9
SCM- 50MW	50% NS + 50% MW	50	50	100	0.44	0.9

Notations: NS: Natural sand; MW: Marble waste; C: Cement; W: Water; SP: Superplasticizer.

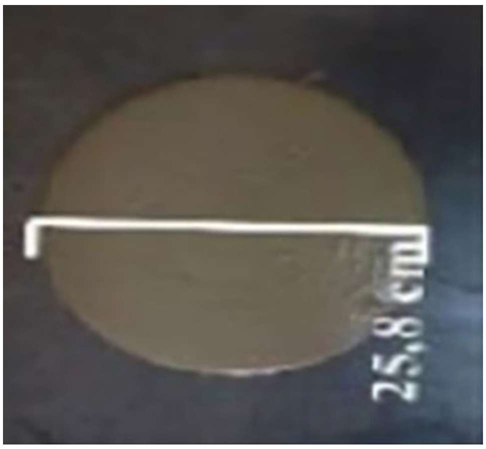

Figure 6: Slump flow test.

Figure 7: Rheometer AR 2000 test.

Figure 8: Electromechanical universal press.

To conduct this investigation and assess the rheological and mechanical properties of mortar incorporating marble waste, five distinct mixtures were formulated with varying proportions of marble waste (0, 10, 20, 30, and 40%) using the methodology proposed by FARIH *et al.* [24]. The compositional details of these mixtures are presented in Table 4.

The rheological properties of the mixtures were evaluated using two methods: the slump flow test (Figure 6), conducted by EN 12350-8 standard and described by AFNOR [25], and the rheometer test (Figure 7). The latter was employed to quantify specific rheological parameters. These complementary tests comprehensively assess the mixtures' flow behavior and rheological characteristics.

The mechanical performance of the mixtures was characterized through compressive and flexural strength tests. These mechanical evaluations were conducted using a TE 300 kN press (Figure 8) in compliance with the NF EN 196-1 standard [26]. The values are obtained by crushing the average of four specimens of the size of $4 \times 4 \times 16$ cm^3 at different curing times: 7, 28, and 90 days. The flexural strength was measured using a three-point bending test. The distance between supporting pins is 10 cm. This testing protocol ensures a standardized assessment of the mortar's mechanical properties, allowing for reliable comparisons between different mixture compositions.

3. RESULTS

3.1. Slump flow test

Figure 9 illustrates the relationship between the five mixtures' slump flow and the marble powder replacement ratio. A consistent decrease in slump flow was observed with increasing proportions of marble waste in the

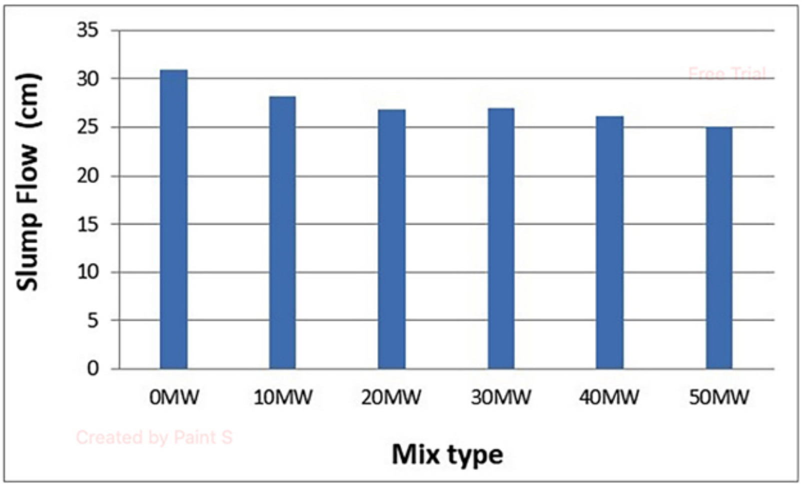

Figure 9: Slump flow of mixes according to MW substitution ratio.

mortar. The control self-compacting mortar (0MW, without marble powder) exhibited a slump flow of 33.5 cm. Mixtures containing 10%, 20%, 30%, 40%, and 50% marble demonstrated reductions in slump flow of 2.8%, 6.4%, 9.4%, 14.2 and 33.1%, respectively. A notable decrease in spread diameter was observed when the marble powder content reached 40%, corroborating the negative impact of marble powder on workability, as reported in previous studies by MESSAOUDI *et al.* [2].

3.2. Rheological parameters

Figure 10 illustrates the impact of marble waste incorporation on the yield stress of mortar mixtures. The results demonstrate that mortars containing marble powder exhibited higher yield stress values than the control mixture (0MW). A progressive increase in yield stress was observed with increasing marble powder content. Relative to MMP0, the yield stress increased by 30.1%, 49,4%, 53.5%, 59.1 and 70% for 10MW, 20MW, 30MW, 40MW and 50MW, respectively.

Figure 11 depicts the relationship between viscosity and marble powder content, with other parameters constant (W/C = 0.44, SP dosage = 1.30). The viscosity of the mixtures increased gradually with increasing marble powder content. Compared to 0MW, the viscosity increased by 9.99%, 19.9%, 27.3%, 69.7%, and 78.2 for 10MW, 20MW, 30MW, 40MW and 50MW, respectively.

These findings are consistent with previous research. GÜNEYISI *et al.* [27] reported that the addition of marble powder increased the plastic viscosity of mortars, while ÇINAR *et al.* [28] observed that increasing the marble powder waste content in cement-based Grout (CBG) mixtures led to higher plastic viscosity values.

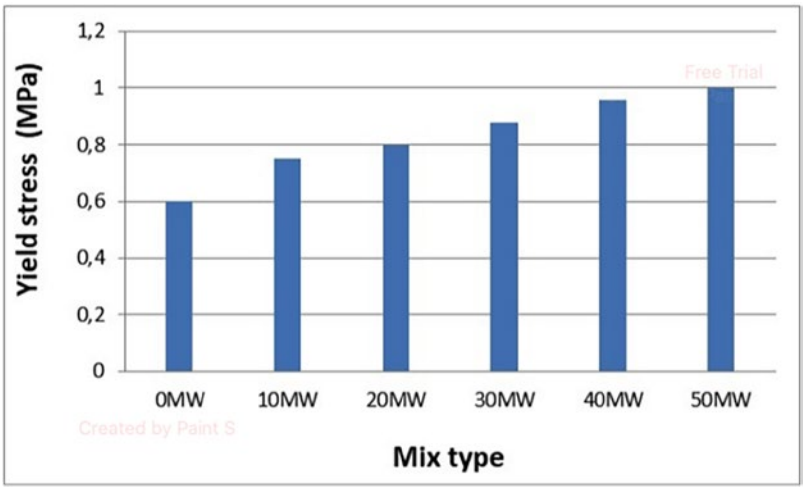

Figure 10: Influence of MW substitution ratio on yield stress.

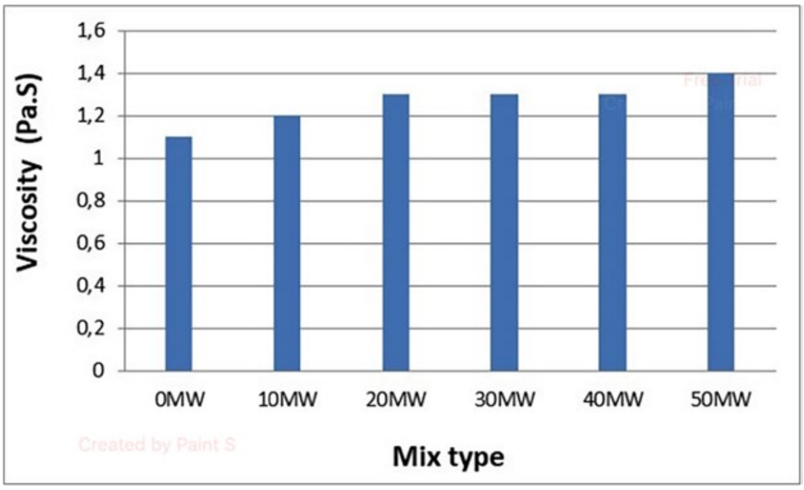

Figure 11: Influence of MW substitution ratio on viscosity.

3.3. Mechanical properties

Figure 12 illustrates the relationship between mechanical properties, marble powder content, and curing age. The compressive strength exhibited an initial increase up to a threshold value (30% marble powder), beyond which it decreased with further additions of marble powder waste. Compared to the control mixture (0MW), the compressive strength increased by 2.8%, 4.5%, 9.4%, 1.1 and 0.2% for mixtures 10MW, 20MW, 30MW, 40MW and 50MW, respectively. This enhancement in mechanical performance may be attributed to the chemical effects of marble powder, a finding that aligns with previous research by OMAR *et al.* [16].

Figure 13 depicts the progression of flexural strength in hardened mixtures based on varying amounts of marble powder waste. All mixtures containing marble powder exhibited significantly higher flexural strength compared to the reference mixture without marble powder (MMP0). Specifically, at 28 days, the flexural strength increased by 11.1%, 15.9%, 28.4%, and 28.4% for mixtures 10MW, 20MW, 30MW, 40MW, and 50MW, respectively, in comparison to 0MW. This observation validates the effectiveness of utilizing marble powder waste in self-compacting mortar [29, 30]. Furthermore, over time, the enhanced flexural strength is primarily attributed to the continuous cement hydration and the interaction between limestone fillers in cement type CEMII and the aluminates from the marble powder, leading to monocarboaluminates. PATEL *et al.* [31] showed that including ground granulated blast slag (GGBS) in mixes increased compressive strength. In related research, AIDJOULI *et al.* [32] demonstrated that including waste marble powder in mixed concrete requires a significant quantity

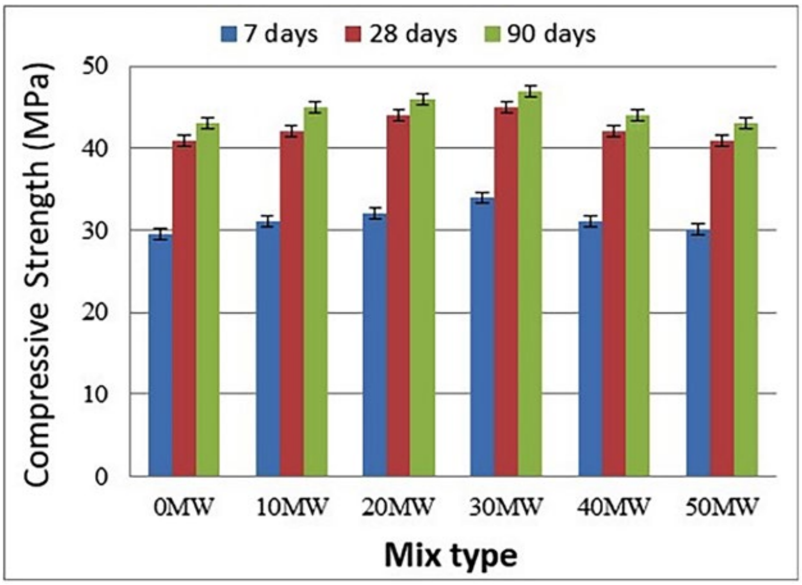

Figure 12: Influence of MW on compressive strength at 7, 28, and 90 days.

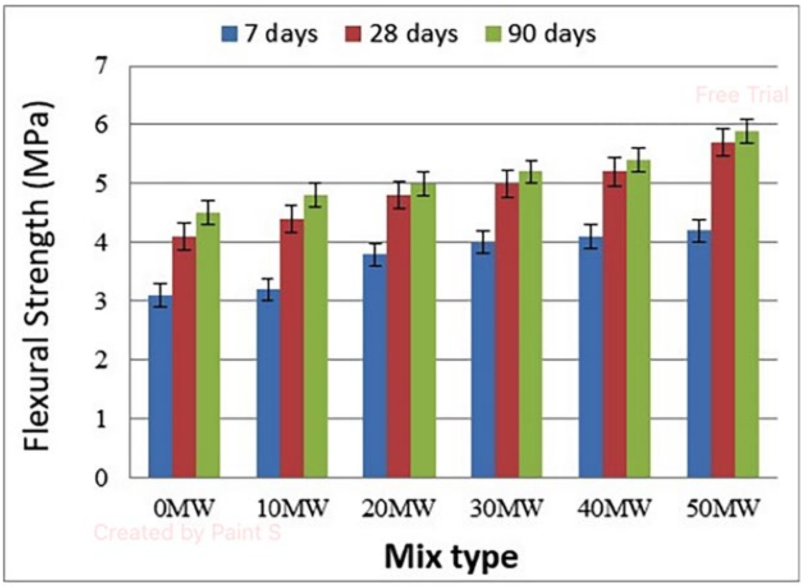

Figure 13: Influence of MW on flexural strength at 7, 28, and 90 days.

of superplasticizer to improve the workability, increasing the compressive strength of this concrete. Another analysis has suggested that an optimal cement substitution of 10% marble powder maintains the best mechanical and environmental characteristics in friendly concrete [33]. Furthermore, BOURZIK *et al.* [34] studied the influence of waste marble powder on the properties of concrete. Based on workability, density, and compressive strength, their results show that the inclusion of waste marble powder at 15% does not negatively influence the mixes' properties. On the other hand, AHMED *et al.* [35] concluded that using an adequate quantity (20%) of Waste Marble increases self-compacting concrete's compressive strength, tensile strength, and durability. In related research, FILALI and NASSER [36] examined the influence of marble powder and fly ash as a function of workability and compressive strength of concrete. They show that the incorporation of marble powder at 20% and 30% of fly ash as a partial substitution for sand increases the compressive strength of this concrete. Several researchers have observed similar findings [37–39]. KORE and VYAS [40] focused their study on the compressive strength of all the mixtures containing marble raised by 40% and 18% at 7 and 28 days, respectively, and comparable results have been mentioned by DEMIR *et al.* [41].

3.4. The bulk density of SCM

The bulk density in mixed materials is influenced by multiple parameters, including grain morphological characteristics, mixture porosity, mineralogical and chemical admixture types, cement composition, curing temperature, and water-to-cement ratio (W/C). The bulk density of hardened mortar was studied according to the European standards NF EN 1015-18 [42]. The effects of the marble waste on the bulk density of SCM are presented in Figure 14. The bulk density results show that the enhancement of mortar with marble waste results in a continuous rise in the bulk density. The SCM formulated with MW exhibited bulk density between 1.8 and 2.5 g/cm^3%. The minimum bulk density value (1.8 g/cm^3) was observed at 0% and 10% MW. The mortar's highest value was given by incorporating 50% MW (SCM–50MW); the substitution of MW can lead to an essential increase in bulk density of 39% compared to the mixture without marble waste (MW). This indicates that the inclusion of MW in the mixes reduces the porosity. This is consistent with findings from [43], who reported that the density increased with up to 50% substitution of marble.

3.5. Microstructure

Figure 15 shows SEM microstructure images in SCM mixes at 90 days. SEM images of the control mortar (SCM-0MW) and SCM-50MW are presented in Figure 15(a) and (b), respectively. These scanning pictures illustrate an apparent propagation of (C-S-H) gel. Figure 14(a) presents the SCM-0MW. It is observed that the mortar is comprised of micro-voids. This can be explained by the reference mortar's modest compressive and flexural strength compared to mixes containing 10% MW, 20% MW, 30% MW, 40% MW, and 50% MW, respectively. It is recorded that the micro-voids were decreased to improve the hydration action. Mixes containing 50% MW present extended spreading compared to the control mortar (SCM0-MW), which presents a compact structure compared to the reference mortar [24]. These observations align with the experimental values for

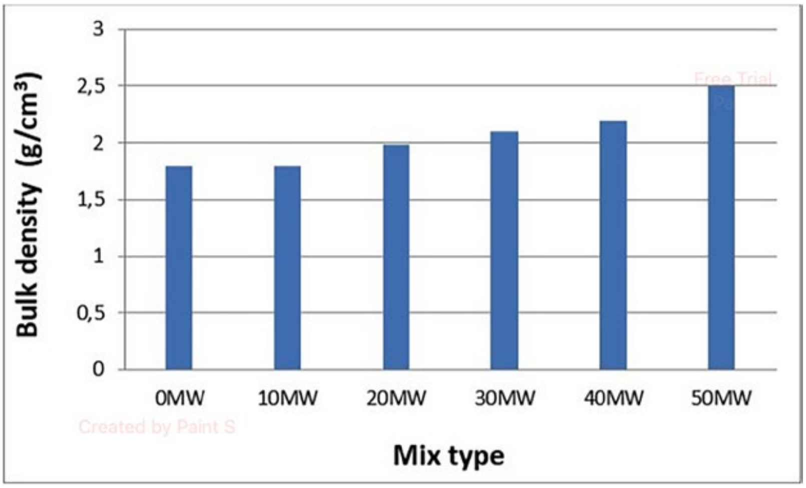

Figure 14: Influence of the incorporation of MW on bulk density.

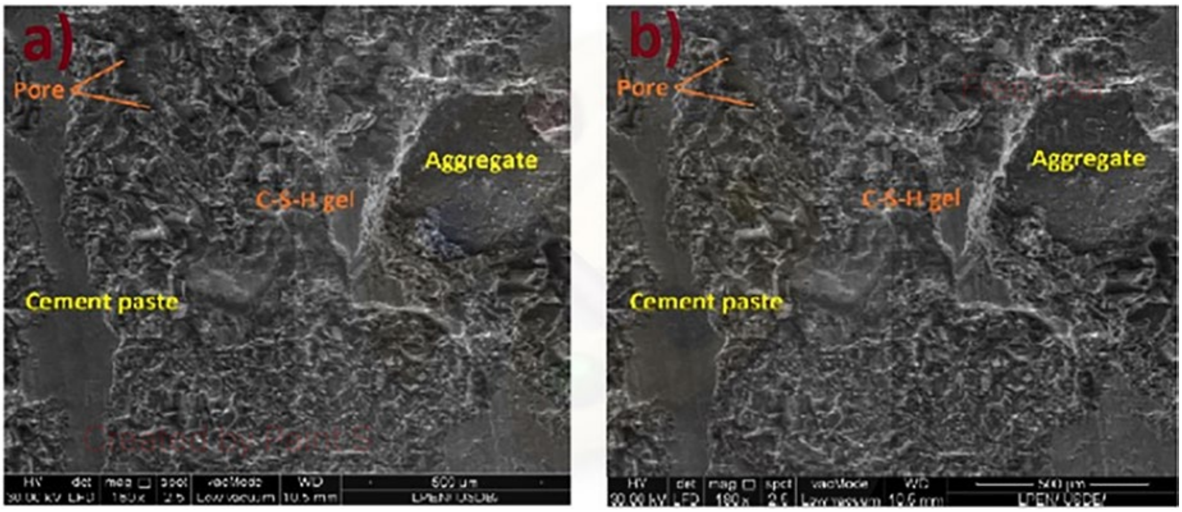

Figure 15: SEM images of the SCM.

compressive strength illustrated in Figure 12. Similar results have been documented by ADITTO *et al.* [44] and SINGH *et al.* [45] studied the influence of partial substitution of cement by waste marble. Their findings indicate that the marble mixes were denser than the reference mixes. Further, observing the specimens via SEM by ALAKARA *et al.* [46] showed that calcined marble powder increases hydration and microstructure densification and demonstrated improved mechanical properties.

4. CONCLUSIONS

Based on the experimental study of the impact of marble waste on the rheological and mechanical properties of SCM, the results presented and discussed the following conclusions have been reached:

- The quantity of marble waste significantly influences the properties of mixtures in the fresh and hardened state.
- The incorporation of marble waste (MW) decreased the slump flow of all mixes.
- The dosage of SP significantly impacted the plastic viscosity values, yield stress, and slump flow. Reduced flowability and rheological metrics resulted from an increase in SP dosage.
- Substitution of 40% of natural sand with marble powder improved compressive strength by around 13% by densifying the microstructure.
- The replacement of sand with 40% marble powder improves the flexural strength of SCM, mainly at 28 days, by 21%.

Finally, based on the main findings from this experimental study, the incorporation of marble waste as sand substitution in the mortar composition can provide an alternative material for producing any concrete class for different construction with low environmental impacts.

5. ACKNOWLEDGMENTS

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6. BIBLIOGRAPHY

[1] SONEBI, M., BARTOS, P.J.M., "Hardened SCC and its bond with reinforcement," In: *Proceedings of the First International RILEM Symposium on Self-Compacting Concrete*, Stockholm, pp. 275–289, 1999.

[2] MESSAOUDI, F., MAROUF, H., SONEBI, M., *et al*., "The rheological properties of modified self-compacting cementitious paste", *Journal of Materials and Engineering Structures*, v. 7, n. 2, pp. 215–225, 2020.

[3] BUSARI, A.A., AKINMUSURU, J.O., DAHUNSI, B.I., "Review of sustainability in self-compacting concrete: the use of waste and mineral additives as supplementary cementitious materials and aggregates", *Portugaliae Electrochimica Acta*, v. 36, n. 3, pp. 147–162, 2018. doi: http://doi.org/10.4152/pea.201803147.

[4] Concrete, S. C., "The European guidelines for self-compacting concrete", BIBM, V. 22 , p. 563, 2005.

[5] DHIYANESHWARAN, S., RAMANATHAN, P., BASKAR, I., *et al*., "Study on durability characteristics of self-compacting concrete with fly ash", *Jordan Journal of Civil Engineering*, v. 7, n. 3, pp. 342–353, 2013.

[6] FARIH, M., OMAR, C., ABUDAQQA, W.S., *et al*., "Rheological, mechanical and durability properties of mortar containing brick waste as a partial replacement of sand", *Case Studies in Construction Materials*, v. 21, pp. e04043, 2024. doi: http://doi.org/10.1016/j.cscm.2024.e04043.

[7] SAFI, B., SAIDI, M., DAOUI, A., *et al*., "The use of eashells as a fine aggregate (by sand substitution) in self-compacting mortar (SCM)", *Construction & Building Materials*, v. 78, pp. 430–438, 2015. doi: http://doi.org/10.1016/j.conbuildmat.2015.01.009.

[8] FERRARIS, C.F., OBLA, K.H., HILL, R., "The influence of mineral admixtures on the rheology of cement paste and concrete", *Cement and Concrete Research*, v. 31, n. 2, pp. 245–255, 2001. doi: http://doi.org/10.1016/S0008-8846(00)00454-3.

[9] ROUSSEL, N., "A theorical frame to study stability of fresh concrete", *Materials and Structures*, v. 39, n. 1, pp. 75–83, 2006. doi: http://doi.org/10.1617/s11527-005-9036-1.

[10] SONEBI, M., LACHEMI, M., HOSSAIN, K.M.A., "Optimisation of rheological parameters and mechanical properties of superplasticised cement grouts containing metakaolin and viscosity modifying admixture", *Construction & Building Materials*, v. 38, n. 1, pp. 126–138, 2013. doi: http://doi.org/10.1016/j.conbuildmat.2012.07.102.

[11] ALYOUSEF, R., BENJEDDOU, O., SOUSSI, C., *et al*., "Effects of Incorporation of marble powder obtained by recycling waste sludge and limestone powder on rheology, compressive strength, and durability of self-compacting concrete", *Advances in Materials Science and Engineering*, v. 2019, n. 1, pp. 4609353, 2019. doi: http://doi.org/10.1155/2019/4609353.

[12] TOPÇU, İ.B., BILIR, T., UYGUNOĞLU, T., "Effect of waste marble dust content as filler on properties of self-compacting concrete", *Construction & Building Materials*, v. 23, n. 5, pp. 1947–1953, 2009. doi: http://doi.org/10.1016/j.conbuildmat.2008.09.007.

[13] SARDINH, M., DE BRITO, J., RODRIGUES, R., "Durability properties of structural concrete containing very fine aggregates of marble sludge", *Construction & Building Materials*, v. 119, n. 30, pp. 45–52, 2016. doi: http://doi.org/10.1016/j.conbuildmat.2016.05.071.

[14] BOURAS, R., KACI, A., CHAOUCHE, M., *et al*., "Relationship between the rheological and the adhesive properties of cementitious pastes", *AIP Conference Proceedings*, v. 1027, n. 1, pp. 809–811, 2008. doi: http://doi.org/10.1063/1.2964855.

[15] BENAICHA, M., BELCAID, A., ALAOUI, A.H., *et al*., "Effects of limestone filler and silica fume on rheology and strength of self-compacting concrete", *Structural Concrete*, v. 20, n. 5, pp. 1702–1709, 2019. doi: http://doi.org/10.1002/suco.201900150.

[16] OMAR, O.M., ABD ELHAMEED, G.D., SHERIF, M.A., *et al*., "Influence of limestone waste as partial replacement material for sand and marble powder in concrete properties", *HBRC Journal*, v. 8, n. 3, pp. 193–203, 2012. doi: http://doi.org/10.1016/j.hbrcj.2012.10.005.

[17] HEBHOUB, H., AOUN, H., BELACHIA, M., *et al*., "Use of waste marble aggregates in concrete". France", *Construction & Building Materials*, v. 25, n. 3, pp. 1167–1171, 2010. doi: http://doi.org/10.1016/j.conbuildmat.2010.09.037.

[18] GADO, R.A., "The feasibility of recycling marble & granite sludge in the polymer-modified cementitious mortars. Part A: In polymer-modified cementitious adhesive mortar", *Process Safety and Environmental Protection*, v. 159, pp. 978–991, 2022. doi: http://doi.org/10.1016/j.psep.2022.01.059.

[19] SIDDIQUE, R., MEHTA, A. "Utilization of industrial by-products and natural ashes in mortar and concrete development of sustainable construction materials", In: Harries, K.A., Sharma, B., eds. *Nonconventional and Vernacular Construction Materials*, Duxford, Woodhead Publishing, pp. 247–303, 2020.

[20] AYDIN, E., AREL, H.Ş., "High-volume marble substitution in cement-paste: towards a better sustainabilit", *Journal of Cleaner Production*, v. 237, pp. 117801, 2019. doi: http://doi.org/10.1016/j.jclepro.2019.117801.

[21] KARAKURT, C., DUMANGÖZ, M., "Rheological and durability properties of self-compacting concrete produced using marble dust and blast furnace slag", *Materials (Basel)*, v. 15, n. 5, pp. 1795, 2022. doi: http://doi.org/10.3390/ma15051795. PubMed PMID: 35269026.

[22] SHARMA, U., GUPTA, N., SAXENA, K.K., "Comparative study on the effect of industrial by-products as a replacement of cement in concrete", *Materials Today: Proceedings*, v. 44, pp. 45–51, 2021. doi: http://doi.org/10.1016/j.matpr.2020.06.211.

[23] JARUGUMALLI, V., MADUPU, L.S., "The flow properties of SCC with marble waste powder as a partial substitute for cement", *Materials Today: Proceedings*, v. 52, pp. 617–621, 2022. doi: http://doi.org/10.1016/j.matpr.2021.10.047.

[24] FARIH, M., OMAR, C., ABUDAQQA, W.S.K., *et al*., "An experimental study on the rheological properties of self-consolidating mortars, affected by superplasticizer, waste marble powder, and a viscosity-modifying agent", *Civil Engineering and Architecture*, v. 12, n. 6, pp. 4045–4055, 2024. doi: http://doi.org/10.13189/cea.2024.120620.

[25] AFNOR STANDARDS ORGANISATION, *Bétons - Mesure du temps d'écoulement des bétons et des mortiers aux maniabilimètres NF 18–452*, France, AFNOR, 1988.

[26] AFNOR STANDARDS ORGANISATION, *Méthodes d'essais des ciments - Partie 1 : détermination des résistances mécaniques NF EN 196–1*, France, AFNOR, 2006.

[27] GÜNEYISI, E., GESOĞLU, M., ÖZBAY, E., "Effects of marble powder and slag on the properties of self compacting mortars", *Materials and Structures*, v. 42, n. 6, pp. 813–826, 2009. doi: http://doi.org/10.1617/s11527-008-9426-2.

[28] ÇINAR, M., KARPUZCU, M., ÇANAKCI, H., "Effect of waste marble powder and fly ash on the rheological characteristics of cement based grout", *Civil Engineering Journal*, v. 5, n. 4, pp. 777–788, 2019. doi: http://doi.org/10.28991/cej-2019-03091287.

[29] MESSAOUDI, F., SONEBI, M., BOURAS, R., "Investigation of rheological behaviour of self-compacting marbled paste", In: *Proceedings of 6th North American Conference on the Design and Use of SCC Self-Consolidating Concrete (SCC) and 8th RILEM International Symposium on Self-Compacting Concrete (SCC)*, pp. 1–9, 2016.

[30] BENTLEMSAN, N., YAHIAOUI, W., KENAI, S., "Strength and durability of self-compacting mortar with waste marble as sand substitution", *Case Studies in Construction Materials*, v. 19, pp. e02331, 2023. doi: http://doi.org/10.1016/j.cscm.2023.e02331.

[31] PATEL, V.J., JUREMALANI, J., KUMAVAT, H.R., "Incorporation of high volume ground granulated slag from blast furnaces in pavement quality concrete", *Engineering Technology & Applied Science Research*, v. 14, n. 4, pp. 14888–14893, 2024. doi: http://doi.org/10.48084/etasr.7466.

[32] AIDJOULI, Y., BELEBCHOUCHE, C., HAMMOUDI, A., *et al*., "Modeling the properties of sustainable self-compacting concrete containing marble and glass powder wastes using response surface methodology", *Sustainability (Basel)*, v. 16, n. 5, pp. 1972, 2024. doi: http://doi.org/10.3390/su16051972.

[33] ÖZKILIÇ, Y.O., ZEYBEK, Ö., BAHRAMI, A., *et al*., "Optimum usage of waste marble powder to reduce use of cement toward eco-friendly concrete", *Journal of Materials Research and Technology*, v. 25, pp. 4799–4819, 2023. doi: http://doi.org/10.1016/j.jmrt.2023.06.126.

[34] BOURZIK, O., BABA, K., AKKOURI, N., *et al*., "Effect of waste marble powder on the properties of concrete", *Materials Today: Proceedings*, v. 72, pp. 3265–3269, 2023. doi: http://doi.org/10.1016/j.matpr.2022.07.184.

[35] AHMAD, J., ZHOU, Z., DEIFALLA, A.F., "Self-compacting concrete with partially substitution of waste marble: a", *International Journal of Concrete Structures and Materials*, v. 17, n. 1, pp. 25, 2023. doi: http://doi.org/10.1186/s40069-023-00585-5.

[36] FILALI, S., NASSER, A., "Evaluating the impact of marble waste and fly ash as sand replacements on concrete's compressive strength and workability", *Engineering, Technology & Applied Science Research*, v. 14, n. 5, pp. 16797–16801, 2024. doi: http://doi.org/10.48084/etasr.8234.

[37] SOUZA, N.S.L., ANJOS, M.A.S., SÁ, M.V.A., *et al*., "Desenvolvimento de agregados leves a partir de resíduo de corte de pedras ornamentais (granitos e mármores) e argila", *Matéria (Rio de Janeiro)*, v. 25, n. 1, pp. e–12559, 2020. doi: http://doi.org/10.1590/s1517-707620200001.0884.

[38] ALZABEN, N., MAASHI, M., NOURI, A.M., *et al*., "Artificial neural network to predict the compressive strength of high strength self-compacting concrete made of marble dust", *Matéria (Rio de Janeiro)*, v. 29, n. 3, pp. e20240329, 2024. doi: http://doi.org/10.1590/1517-7076-rmat-2024-0329.

[39] SANTOS, V.R.D., GENOVA, L.M., SOARES, S.M., *et al*., "Experimental study of the production of resin granite and marble using their solid waste", *Matéria (Rio de Janeiro)*, v. 29, n. 1, pp. e20230353, 2024. doi: http://doi.org/10.1590/1517-7076-rmat-2023-0353.

[40] KORE, S.D., VYAS, A.K., "Impact of marble waste as coarse aggregate on properties of lean cement concrete", *Case Studies in Construction Materials*, v. 4, pp. 85–92, 2016. doi: http://doi.org/10.1016/j.cscm.2016.01.002.

[41] DEMIR, I., ALAKARA, E.H., SEVIM, O., *et al*., "Effect of magnetized water on alkali-activated slag mortars incorporating raw and calcined marble powder", *Construction & Building Materials*, v. 424, pp. 135943, 2024. doi: http://doi.org/10.1016/j.conbuildmat.2024.135943.

[42] AFNOR STANDARDS ORGANISATION, *Méthodes d'essai des mortiers pour maçonnerie - Partie 18: détermination du coefficient d'absorption d'eau par capillarité du mortier durci*, France, AFNOR, 2003.

[43] AHMAD, J., ASLAM, F., MARTINEZ-GARCIA, R., *et al*., "Effects of waste glass and waste marble on mechanical and durability performance of concrete", *Scientific Reports*, v. 11, n. 1, pp. 1–17, 2021. PubMed PMID: 34728731.

[44] ADITTO, F.S., SOBUZ, M.H.R., SAHA, A., *et al*., "Fresh, mechanical and microstructural behaviour of high-strength self-compacting concrete using supplementary cementitious materials", *Case Studies in Construction Materials*, v. 19, pp. e02395, 2023. doi: http://doi.org/10.1016/j.cscm.2023.e02395.

[45] SINGH, M., SRIVASTAVA, A., BHUNIA, D., "An investigation on effect of partial replacement of cement by waste marble slurry", *Construction & Building Materials*, v. 134, pp. 471–488, 2017. doi: http://doi.org/10.1016/j.conbuildmat.2016.12.155.

[46] ALAKARA, E.H., SEVIM, O., GÜNEL, G., *et al*., "Effect of calcined marble powder and magnetized water on the performance of cement-based composites", *Applied Sciences (Basel, Switzerland)*, v. 14, n. 24, pp. 11923, 2024. doi: http://doi.org/10.3390/app142411923.