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Effects of scrap rubber waste on the mechanical performance of mortar made of crushed sand and sediment

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Abstract:

Introduction/purpose: The consumption of natural sand in Algeria is high due to its extensive use in mortar, while sediments and rubber waste pose significant environmental and societal challenges. This study investigates the effects of incorporating rubber waste content in mortars mixed with crushed sand and sediment. The primary goal is to valorize crushed sand particles through physical and mechanical tests, evaluating their potential as an alternative to natural sand in mortar mixtures.

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Methods: Experimental work was carried out to study the impact of partially and fully replacing sediments with crushed sand particles in mortar mixes. Mortar mixtures were prepared using different sediment-to-crushed sand ratios (10%, 25%, 35%, 50%, and 100%) to observe their influence on physical and mechanical properties. Additionally, the effects of adding 2%, 4%, and 6% granulated rubber to the optimal mortar were analyzed. Various tests, including those tsting compressive strength, flexural strength, and ultrasonic pulse velocity, were performed to evaluate the performance of the mixtures.

Results: The results indicated that replacing sediment with crushed sand improved the strength properties of mortar, particularly due to better particle packing. The mortar containing 65 wt% sediments and 35 wt% crushed sand showed properties similar to the reference mortar. The addition of rubber waste increased compressibility but enhanced mechanical properties when used in moderation. Ultrasonic pulse velocity decreased with higher crushed sand content, and the porosity of the mixtures was reduced.

Conclusions: Crushed sand and sediment particles are effective fillers for mortar, ensuring good performance and improved strength. The efficiency of these materials depends on their morphology and genesis. The study demonstrates that crushed sand can be a viable alternative to natural sand, and rubber waste can be used as a reinforcing material in mortar, though its proportions should be carefully controlled to avoid negative effects on mechanical properties.

*Key words**:** mortar, sediment, crushed sand, scrap rubber waste, compressive strength, tensile strength.*

Introduction

The surge in demand for sand in Algeria over the past decade, driven by substantial development programs in construction, has resulted in a shortage of this essential material. For this reason, the use of alternative materials is essential, such as tuff (Cherrak et al, 2013), crushed sand (Srivastava & Singh, 2020), dune sand, fine limestone, natural pozzolans, and various wastes (Chouhan et al, 2020; Bederina et al, 2013). Moreover, reusing all concrete and mortar waste can effectively protect the environment and contribute to sustainable development (Benyamina et al, 2019). In addition, the quantities of limestone fines and crushed sand are very abundant in many quarries, which poses the problem of disposal and reuse in the manufacture of concrete (Chouhanet al, 2020).

The problem of sedimentation also affects dams and energy production; for example, the Fargoug dam, located in the northwest of

Algeria, about 20 km south of the city of Mohammedia (region of Mascara), is one of the many dams that suffer from this problem. Thus, dredging these sediments and reusing them as alternative materials is a solution to recycle and valorize them, given their physical, chemical, and biological properties and stabilizing capacity (Fonti et al, 2013). Also, one can reuse them in base layer locations for roadways (Sellaf et al, 2023).

Researchers have recently conducted numerous studies to explore using crushed sand in mortar and concrete. The strength properties of concrete using crushed sand are almost identical to traditional concrete. Furthermore, bottle chips are combined with crushed sand to partially replace the conventional sand used in the proposed concrete (Cepuritisa et al, 2016). The use of crushed sand also ensures the position of natural sand as an aggregate for concrete's durability and mechanical performance (Lam, 2020; Bédérina et al, 2005). It should be noted that sediment and crushed sand particles are nearly identical, owing to their physical nature and high flour content (Ma et al, 2022). Therefore, it is very appropriate to use sediment as an alternative material, and it serves as a filler in the cement slurry that reinforces the dense microstructure (Singh et al, 2015).

On the other hand, more than 26,000 tonnes of waste rubber tires are dumped annually in Algeria (Nakhaei et al, 2012). Waste tires mainly comprise synthetic rubber, carbon black, silicone, and steel. There are many ways to dispose of rubber tires, including storage or landfills. Alternatively, there are various ways to recycle rubber waste, including using it for fencing and decorative elements (Khan et al, 2016; Trouzine et al, 2012; Khorrami et al, 2010) and in the field of filtration of landfill leachate.

This study is planned to develop the consistency limit properties, bulk density, compressive and tensile strength, and ultrasonic pulse velocity of mortar composed of crushed sand particles and sediments with different mixing ratios and to find out the effect of its different percentage addition on some important physical-mechanical properties of such mortar. Then, the optimal mortar sample was obtained with rubber scraps in different proportions to improve the mechanical strength. The importance of this research lies in examining the effectiveness of the combined use of sediments, crushed sand, and rubber scraps as partial substitutes for sand in mortar mixtures. Also, this study aims to eliminate rubber waste, sediments, and aggregate grinding waste and recycle them as substitutes for aggregates used in mortars, thus protecting the environment.

Experimental procedures

Materials and preparation methods

Sediment

Sediment specimens are dam sediment of the region of Fergoug in the south of Mascara in the northwest of Algeria, and they are generally cohesive brown and grey soils. The specific gravity of the sediment was 2.55.

The particle size distribution for the soils is shown in Table 1.

Table 1 – Properties of the investigated materials

Property	Sediment	Reference sand	Particles of crushed sand
Liquid limit (%)	38	22	15
Plastic limit (%)	23	14	0.00
Plasticity index (%)	15	8	0.00
Volume of blue VB (cm^3)	5.5	0.75	0.39
Specific gravity	2,55	2.63	2.70
Visual sand equivalent (%)	0.00	70	45
Apparent density (g cm-3)	1.26	1.45	1.53
Fineness modulus	1.2	1.80	3.10
Organic content (%)	3.2	1	0.00

Specific gravity is the ratio of a material's density with that of water at 4 °C (where it is most dense and is taken to have the value 999.974 kg m^{-3}). It is therefore a relative quantity with no units.

The soil chemical analysis was conducted following the AFNOR standard NF EN 1744 (AFNOR, 1998a), and the results are presented in Table 2. The main constituent of the sediment is silica with 76.01 % where the ratio SiO_2/Al_2O_3 equals 19.02.

Table 2 – Chemical compositions of materials

Property	Soil S	Soil RS	Soil CS
SiO_2 (%)	64.18	76.010	6.39
SO_3 (%)	0.021	0.034	0.106
Al_2O_3 (%)	0.03	3.996	2.33
Fe_2O_3 (%)	0.84	1.551	0.807
CaO (%)	17.30	5.918	47.41
K_2O (%)	17.30	1.261	0.44
MgO (%)	0.27	1.365	1.49
NaOH (%)	0.00	0.221	0.079
CL (%)	0.00	0.006	0.00
P.A.F (%)	0.5	8.150	41.330
$CaCO_3$ (%)	22.73	12	67.00

The particle size analyses were conducted using the sieving and hydrometer methods (Amar et al, 2018). The grain size distribution curve indicates that the sediment is predominantly silt-sized, with 55.3% clay. Furthermore, the percentage of particles with a diameter less than 80 µm is approximately 82.90%. The limit liquid is about 38% (AFNOR, 1992, 1996), and the plasticity index is about 15%. The material from the Fergoug sediment is classified as inorganic silts. The organic matter content is determined using the ignition test at 450°C, following the standard NF EN 1744 (AFNOR, 1998a), which is about 3.2% for sediment samples. The specific gravity, determined through a pycnometer, is approximately 2.55. The maximal and minimal void ratios were theoretically calculated based on dry density and specific gravity. The void ratio values range from 1.53 to 1.95.

Particles of crushed sand

Two soils samples of different origins and physical properties were selected. The first sample, crushed sand, was obtained from the Tizi quarry site in Mascara, northwest Algeria. These two soil samples underwent various laboratory identification tests, following standard procedures established by AFNOR and ISO standards. The specific gravity of particles in crushed sand was 2.70, whereas that of the reference sand was 2.63. The particle size distribution for the materials is presented in Table 1. The results of the chemical analysis of the soils, shown in Table 2, are carried out according to the standard NF EN 1744 (AFNOR, 1998a).

The tests to determine the Atterberg limits and the density of solid particles were conducted following the standards NF P94-054 and NF P94-051 (AFNOR, 1991, 1993), and the specific surface area of the sand was determined using the Methylene Blue test (AFNOR, 1998b). The specific surface area is approximately 115.5 m^2 g^{-1}, and the volume of Methylene Blue used is approximately 7cm^3.

The materials used included (S), (CS), (RS), and (SCS), representing sediment, crushed sand, reference sand, and a soil mixture, respectively. The sediment (S) and crushed sand (CS) were utilized as fine aggregates, as depicted in Figure 1.

Figure 1 – Fine aggregates: sediment (S) and crushed sand (CS)

Figures 2a and 2b represent the main components of sediment (S) and crushed sand (CS) using X-ray diffraction.

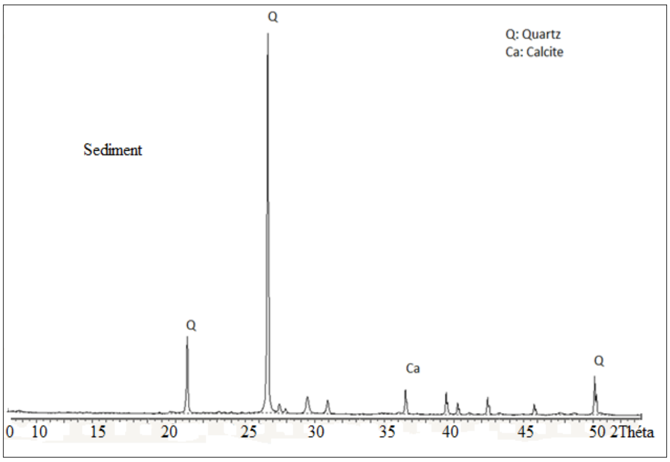


Figure 2a – X-ray diffraction of sediment

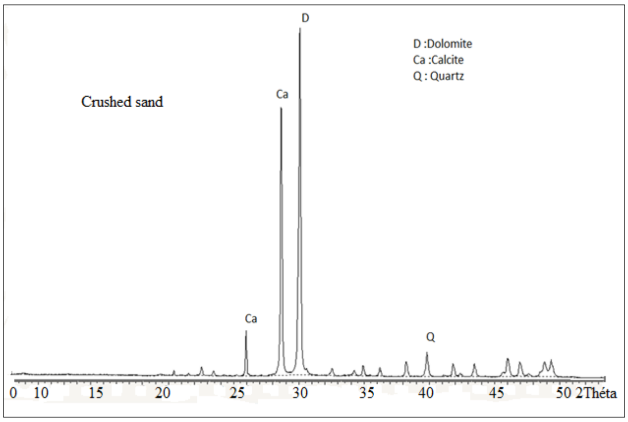
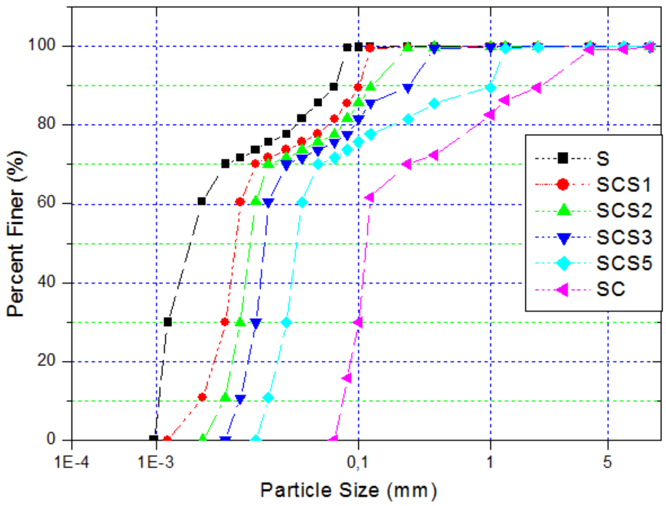


Figure 2b – X-ray diffraction of crushed sand.

Figure 3 shows the values of grain size distribution for the studied specimens. The grain size distribution decreases with the crushed sand content. For sediment (S), the fineness modulus was 1.2 for the sand samples. In contrast, the values for the composite samples with 10%, 25%, 35%, 50%, and 100% crushed sand content were 1.45, 1.65, 1.98, 2.55, and 2.55, respectively. When compared to the reference sand, the fineness modulus was observed to be equivalent to the SCS3 mixture.



S: 100% sediment, RS: Reference sand, SCS1: 90% sediment and 10% crushed sand; SCS2: 75% sediment and 25% crushed sand; SCS3 65% sediment and 35% crushed sand, SCS5: 50% sediment and 50% crushed sand; SC: 100% crushed sand

Figure 3 – comparative grain size distribution in the investigated samples

Mortar-mix design

Five mortars are mixed with a constant water/cement (W/C) ratio and a variable sediment/crushed sand (S/CS) ratio. The main objective of using a variable S/CS ratio is to emphasize the sole effect of this addition on the physical and mechanical characteristics of the mortar, serving as a substitute for sand. Mortar compositions were prepared by integrating sediment with crushed sand in the following ratios: 100% sediment, 90% sediment with 10% crushed sand, 75% sediment with 25% crushed sand, 65% sediment with 35% crushed sand, 50% sediment with 50% crushed sand, and 100% crushed sand. A reference specimen was also produced, consisting of mortar with sediment, for comparison.

To facilitate the readings, the mixtures with the acronym MSCS refer to the mortar made from sediment to crushed sand, while the reference mortar is called MRS. For further investigation, a similar mortar containing a superplasticizer has been formulated. The polycarboxylate superplasticizer has been used in constant amounts, comprising 1.2 by weight of cement.

Table 3 – Cement chemical and mineralogical features and the water chemical analysis.

Chemical and mineralogical composition of cement (%)		Chemical analysis of water(mg/l)	
SiO_2	20.19	Cl	113,60
Al_2O_3	5.23	SO_4	65,46
Fe_2O_3	2.34	NO_3^-	12,22
CaO	56.90	NO_2	0,00
MgO	2.01	Na^+	0,00
NaOH	0.15	K^+	0,00
CL	0.01	Mg^{2+}	51,36
$P.F_2$	5.84	Ca^{2+}	32,86
Ins	4.26	CO_3^{2-}	0,00
Free CaO	1.01	HCO_3	368,44
C_3S	60	Fe	0,03
C_2S	16	Cl^-	113,60
C_3A	5	SO_4^-	65,46

The cement utilized in this investigation is ordinary Portland cement (CPJ), comprised of 76% clinker, 18% calcareous material, and 6% gypsum. The chemical analysis of the cement and mineral admixtures is presented in Table 3.

Scrap tires rubber

Scrap tire rubber fibers can be derived from tires using two primary processes: (i) ambient processing, where scrap tire rubber is ground or treated at or above regular room temperature, and (ii) cryogenic processing, which involves freezing waste rubber with liquid nitrogen and subsequently grinding frozen rubber into small particles using a mill (Caltrans, 2006). The tire rubber fiber constitutes an intricate blend of elastomers, encompassing polyisoprene, polybutadiene, and styrene-butadiene. The key components of rubber include stearic acid (1.2%), zinc oxide (1.9%), extender oil (1.9%), and carbon black (31.0%) (Akbulut et al, 2007). Table 4 presents some properties of scrap tire rubber.

Table 4 – Some properties of the scrap tire rubber fibre

Properties	Tire rubber
Density (mg m^{-3})	1.153-1.198
Tensile strength (MPa)	16-20
Elongation (%)	400-500

Sample preparation

The mortars were mixed, and prisms of 40 x 40 x 160 mm were prepared according to the standard NF EN 196-1 (AFNOR, 1990). The mortar samples were cured for 24 hours in the laboratory at 20 ± 2°C with a relative humidity of approximately 50%. The mixed design of mortars is detailed in Table 5. At the onset of the experiment, the mortar specimens were immersed in potable water, and the penetration time was measured at intervals of 4, 7, 14, 28, 56, and 90 days.

Table 5 – Compositions of mortar (kg m^{-3}).

Mixture code	MS	MCS	MRS	MSCS1	MSCS2	MSCS3	MSCS5
Cement	450	450	450	450	450	450	450
Water	225	225	225	225	225	225	225
Sediment	1350	-	-	1215	1012	878	675
Crushed sand	-	1350	-	135	338	472	675
Reference sand	-	9	1350	-	-	-	-
Superplasticizer	9		9	9	9	9	9

Results and discussion

Consistency limits

Atterberg limit tests were conducted to ascertain the consistency limit values of the sands and their mixtures following the reference standard NF P94-057 (AFNOR, 1992).

As shown in Figure 4, the consistency limits of the mixture of sediment and crushed sand decrease progressively with increasing the crushed sand particle content. The consistency limit of the mixture of 75% sediment with 25% crushed sand is close to the consistency limit of the reference sand.

As shown in Figure 4, for sediment, the plastic limit gradually decreases with an increased amount of crushed sand particles. The results of the Atterberg limit test indicate that sediment has a higher plasticity index value than crushed sand. The results of the plastic limit test indicate that crushed sand has a null value (sediment 23%, RS 14.00%, SCS1 14.02%, SCS2 12.50%, SCS3 12.03%, and SCS5 10.00%, SC: 0.00%).

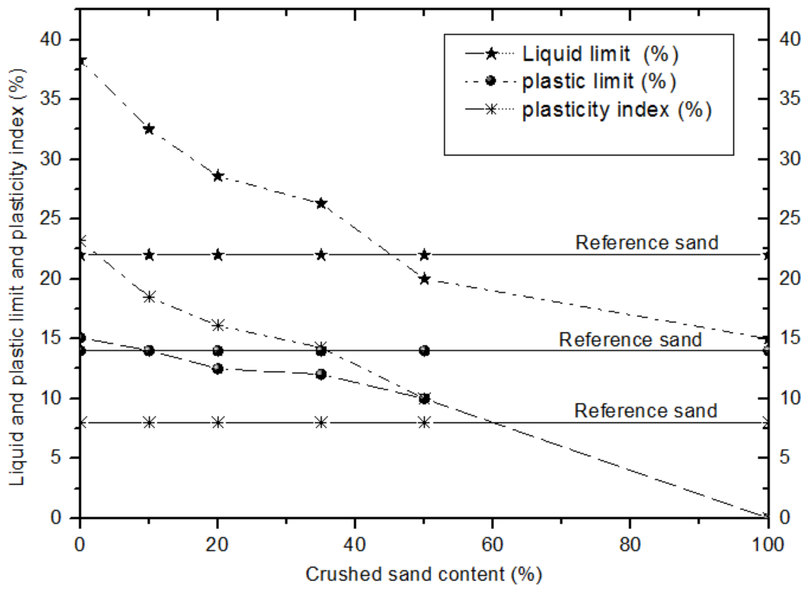


Figure 4 – Effect of the particles of the crushed sand content on the consistency limits of sediment

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Changes in the consistency limits of the mixtures may result from factors such as the type of mixture, the exchange capacity of the clay (Cetin et al, 2006; Bell, 1993), and the proportion of clay minerals in the mixtures (Okagbue & Onyeobi, 1999). Notably, plastic limits were investigated for the mixtures of tire-cohesive clayey soil in the reference (Sivapullaiah et al, 2000). They initially remain stable, exhibit a subsequent decrease, and stabilize again. These findings are parallel to those observed in fine-grained cohesive soils with medium plasticity.

Bulk density

As shown in Figure 5, the bulk density shows a significant proportional increase with the percentage of incorporated fines. This phenomenon appears primarily attributable to the top density of crushed sand waste fines compared to regular sand, as measured during the experimental campaign. This result aligns with the findings in the reference material (Schmitz et al, 2004).

This test was conducted following the European Standard EN 1015-10 (NBN, 1999). Dry bulk density suddenly decreases in the mortar with crushed sand replacement and linearly decreases with increasing the proportion of crushed sand.

Unlike fresh mortar, hardened mortar MSCS 4 exhibited a higher dry bulk density than the reference mortar MRS. This seems to be due to the addition of crushed sand in the mixture induced by the reduction of air voids in the mortars (Arnould & Virlogeux, 1986). Thus, voids in the mortar that are not filled with sand due to the absence of sediment incorporation are instead filled with the latter.

On the other hand, mortar MSCS3, which incorporates twice as much sediment and includes crushed sand, exhibits the same dry bulk density as MRS, similar to that of the reference mortar.

As outlined in numerous studies, the primary concern with porous aggregates is their water absorption capability. This factor impacts the workability during casting and the material properties (Aoual-Benslafa et al, 2015). One portion of water facilitates the hydration of cement, while another portion is absorbed by the aggregates, contributing to the plasticity of the mixture. Pavia & Toomey (2008) substantiates this phenomenon in his research on mortars.

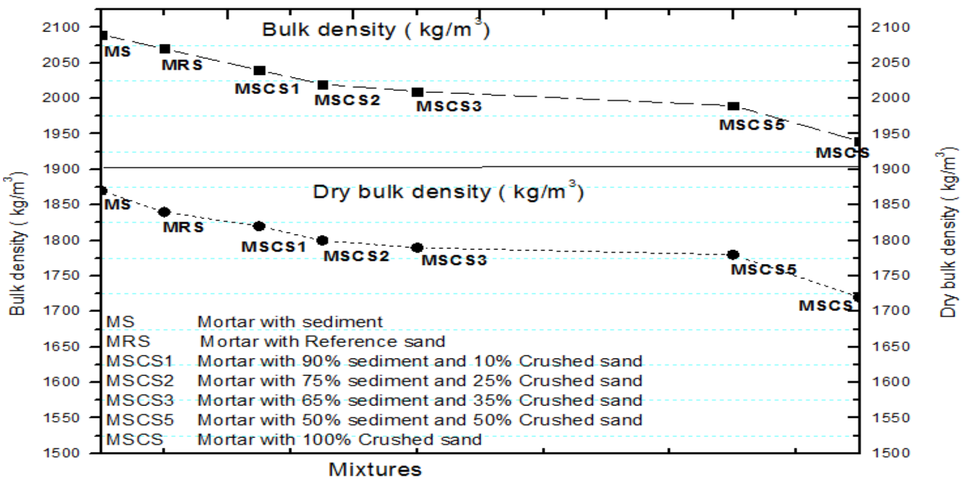

Figure 5 – Effect of crushed sand and sediment content on the bulk density of mortars

Tensile strength

To calculate the tensile strength of the specimen, beam specimens of size 40 · 40 · 160 mm are cast according to specifications. The flexural strength is determined by applying three-point loads (i.e., to achieve pure bending) on these specimens. For each type of mortar, a set of three specimens, previously subjected to curing periods of 4, 7, 14, 28, 56, and 90 days, was used, and the results are presented in Figures 6.

The compressive strength of all the mortars falls within the range of 2.16–6.25 MPa, 5.32–15.41 MPa, 10.11–25.23 MPa, 15.66–28.42 MPa, and 18.52–30.23 MPa at curing periods of 4, 7, 14, 28, 56, and 90 days. The compressive strength of all mortar mixtures increases with changing the curing period. The mortar with crushed sand exhibits lower compressive strength than the reference mortar at all test ages. Moreover, an increase in the replacement level of crushed sand results in an overall improvement in the compressive strength of the mortar.

Crushed sand, when used to replace river sand, improves the aggregate particle packing. Moreover, it can be observed from Figure 6 that at the replacement levels of 35% and 50%, the compressive strength of the mortar with crushed sand is higher by 10% and 25% during the curing periods of 4, 7, 14, and 28 days. Additionally, the compressive strength at 56 and 90 days for the mortar with crushed sand is only slightly higher by 1.66%, 1.57%, 1.20%, and 1.30% compared to the mortar with MRS.

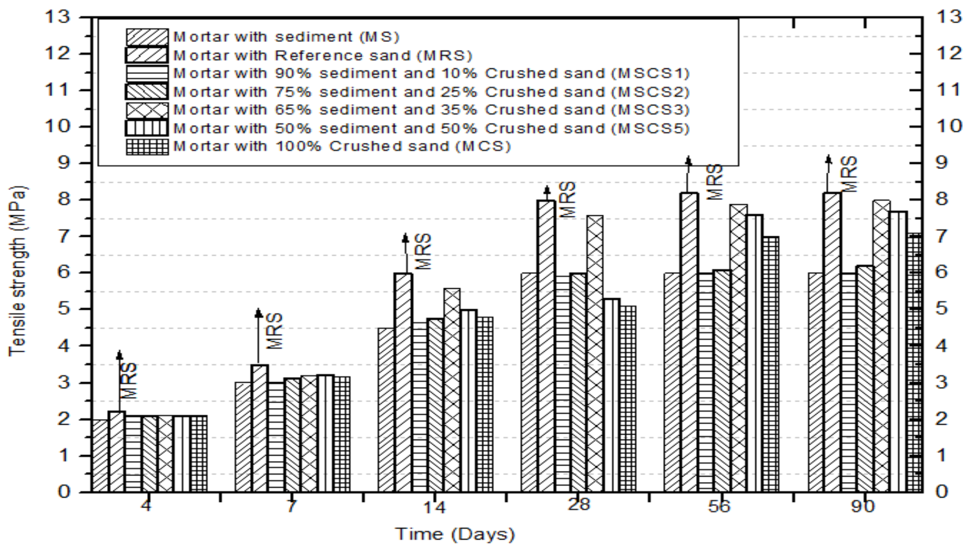

Figure 6 – Effect of crushed sand and sediment content on the tensile strength of mortars

Compressive strength

Compressive strength follows the same trend as the tensile strength obtained in the test, as shown in Figure 7. It is found that the maximum strength is observed at MRS (8.21 MPa), MSCS3 (8.02 MPa), MSCS5 (7.7 MPa), MSCS2 (6.24 MPa), and MSCS1 (6.08 MPa). Regarding mortar, the obtained values for MS (6.00 MPa) are lower than those for the reference mortar (MRS). Generally, the properties of hardened mortar are influenced by the characteristics of the granular constituents, which depend on the relative water absorption of aggregates. Consequently, the increase in resistance is subordinate to the rise in the water absorption capacity (Torres & García-Ruiz, 2009; Wang et al, 2013).

The increase in the replacement level of crushed sand results in an enhancement of the flexural strength of the mortar. The 28-day flexural strength of the mortar with crushed sand at 25%, 35%, and 50%, is measured at 6.00 MPa, 7.61 MPa, and 5.32 MPa, respectively. This represents an increase of 1.33%, 1.05%, and 1.51% compared to the corresponding reference mortar. A similar trend of increasing flexural strength with higher levels of crushed sand replacement is also observed in the mortar during the curing periods of 56 and 90 days.

These results align with the previous findings by Tommaso and Revecca, who utilized crushed sand and sediment as substitutes for reference sand aggregate in a reinforced mortar (D'Antino et al, 2019; Li & Liu, 2021). Corinaldesi (2012) attributed the observed detrimental effect of crushed sand to a high porosity of its particles, resulting in a decrease in severity. Lu et al. (2022) discovered an intriguing relationship between compressive strength and particle size, noting that this relationship is consistent across all specimens.

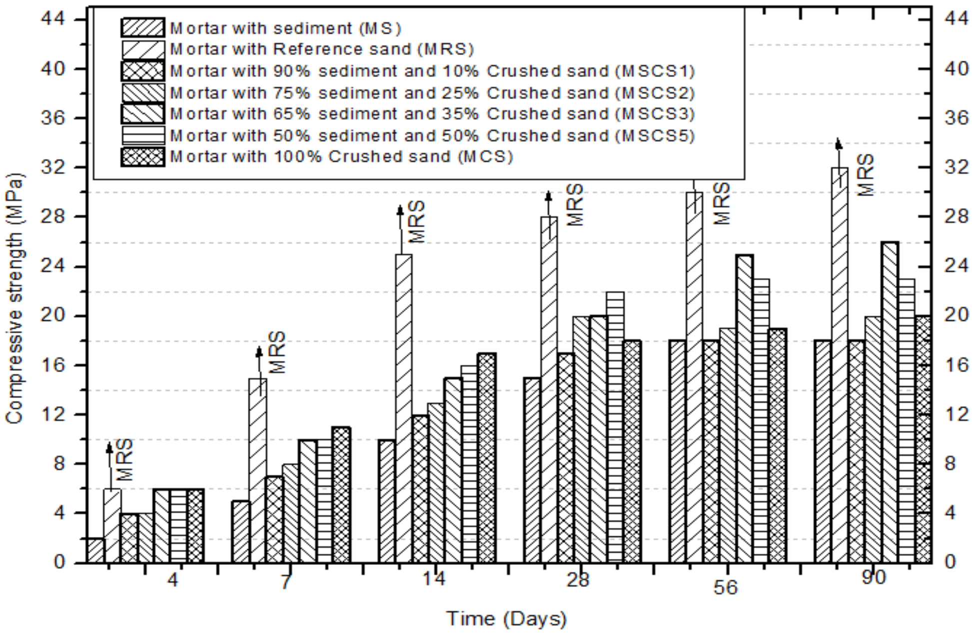

Figure 7 – Influence of crushed sand and sediment content on the compressive strength of mortars

Ultrasonic pulse velocity

The values obtained show that all the mortars made with crushed sand material obtained slightly lower results, around 6.6%- 14.8% concerning the reference sand.

Generally, the pulse velocity of mortars made with crushed sand was greater than that of mortars made with reference sand. As depicted in Figure 8, the 28-day ultrasonic pulse velocities for the mortar types MRS, MSCS3, MSCS5, MSCS2, MSCS1, MS, and MSC were 4120 m/s, 3850 m/s, 3760 m/s, 3740 m/s, 3680 m/s, 3620 m/s, and 3510 m/s, respectively. These values were lower than the 4120 m s^{-1} recorded for the control group.

Moreover, as depicted in Figure 8, it is evident that, at the 35% replacement level, ultrasonic pulse velocities of the mortar containing crushed sand are higher by 10%, 25%, and 50% at the curing periods of 28 days. The increased incorporation of crushed sand enhanced the velocity of mortar MSCS3, and all the produced mortars exhibited lower velocities than MRS. These results align with the findings reported by Corinaldesi in 2012 (Jiang et al, 2022).

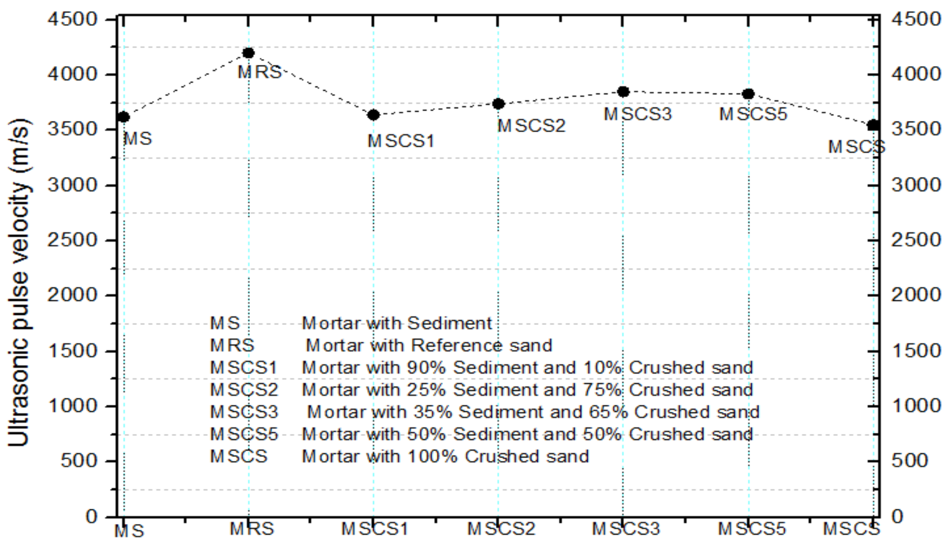

Figure 8 – Effect of crushed sand and sediment content on the ultrasonic pulse velocities of mortars

Reinforcement of mortar MSC35 with scrap tire rubber

The optimal mortar, MSC35opt, was treated with scrap tire rubber, as indicated in the studies by Jiang et al. (2022) and Su et al. (2022). The goal was to determine the best content of rubber powder. Jeon prepared a slurry with crumb rubber powder contents ranging from 0% to 15%, with 5% intervals, based on the volume of sand. Su et al. (2022) replaced the natural aggregates with four different volume percentages: 2%, 5%, 7.5%, and 10%, according to the differential contents of 2%, 4%, and 6%. Five specimens were prepared for each blend of mortars. The mixed mortar designs are detailed in Table 5. Samples of each composition were individually immersed in water. Before conducting the mechanical tests, the specimens were dried for three hours in the laboratory. Compressive strengths were determined at 14, 28, 56, and 84 days. The mixture code includes a letter indicating the type of sand used. Further details about the mixtures can be found in Table 5.

Table 5 – Compositions of MSCS mortar containing scrap rubber (kg m^{-3}).

Mixture	MSCS	MSR2	MSR4	MSR6
Cement	450	450	450	450
Water	225	225	225	225
Sediment	877	864	838	824
Crushed sand	473	463	453	443
Scrap rubber	Nul	10	20	30
Superplasticizer	9	9	9	9

Compressive strength and tensile strength

When scrap rubber was added to partially substitute coarse aggregates, compressive strength decreased as rubber quantity increased. To calculate the flexural strength of the specimens, beam specimens with dimensions of 40 x 40 x 160 mm were prepared. Their flexural strengths were determined by applying three-point loads (to induce pure bending) on these specimens, as illustrated in Figure 9, following the standard NF EN 196-1 (AFNOR, 1995).

Figure 9 – Compression and tensile strength machines to test prisms 40 · 40 · 160 mm^3

The variation in flexural strength concerning the percentage increase in scrap rubber is notable. It is observed that the flexural strength of the specimens with rubber particles exhibits a decreasing trend as the quantity of rubber increases, as depicted in Figure 10.

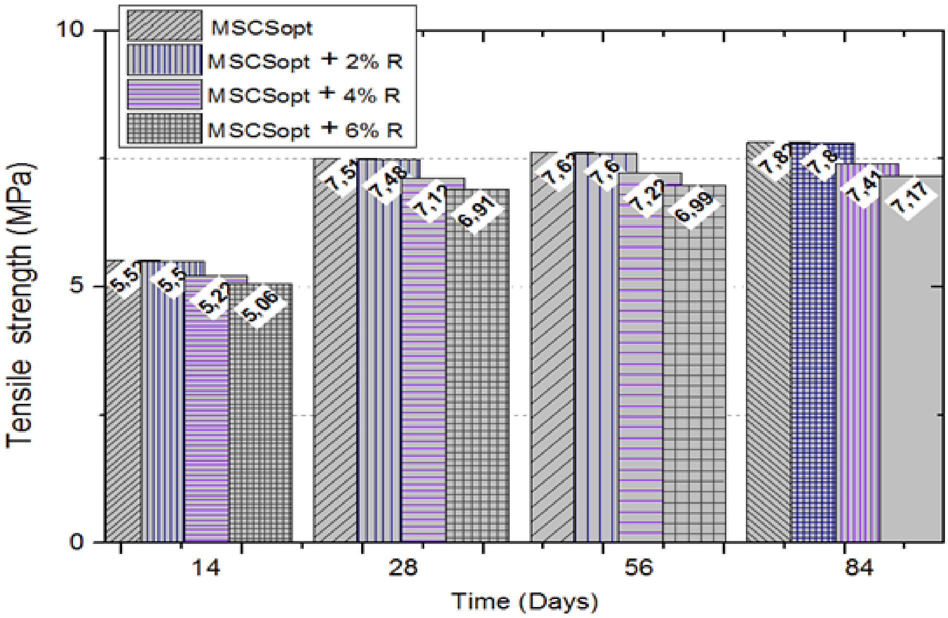

Figure 10 – Influence of scrap rubber addition rate on tensile strength.

Figure 11 illustrates that substituting rubber aggregate significantly diminishes the compressive strength of the composite at 14, 28, 56, and 84 days. This is the primary reason why the rubber aggregate substitution volume fraction was restricted to 6% (84-day compressive strength: MSCSopt = 26 MPa; compressive strength with 6% rubber granulate = 23.19 MPa). Specifically, it is evident that a 2% rubber aggregate substitution results in an almost imperceptible 0.8% drop in compressive strength and a 0.2% decrease in tensile strength. Meanwhile, the strength loss due to a 4% rubber aggregate substitution is approximately 8.5%. These findings are consistent with the previous studies. The study reveals that the observed impact of rubber aggregates on the high compressibility of the particles in the mixture induces local bonding stresses between the rubber and the cementitious matrix (Gupta et al, 2019).

Bin Kabit et al. (2021) concluded that a modified rubber mortar mixture has the potential to effectively reduce shrinkage in cement mortars. Wei et al. (2021) found that tire rubber decreased the mortar's consistency, compressive strength, and flexural strength.

The decrease in Si-O-Si hybrid compounds, inhibited by the hydroxyl group during the hydrolyzation process, may be the cause of the poor bending strength observed in the mortar containing 6% rubber powder (Rattanaveeranon et al, 2019).

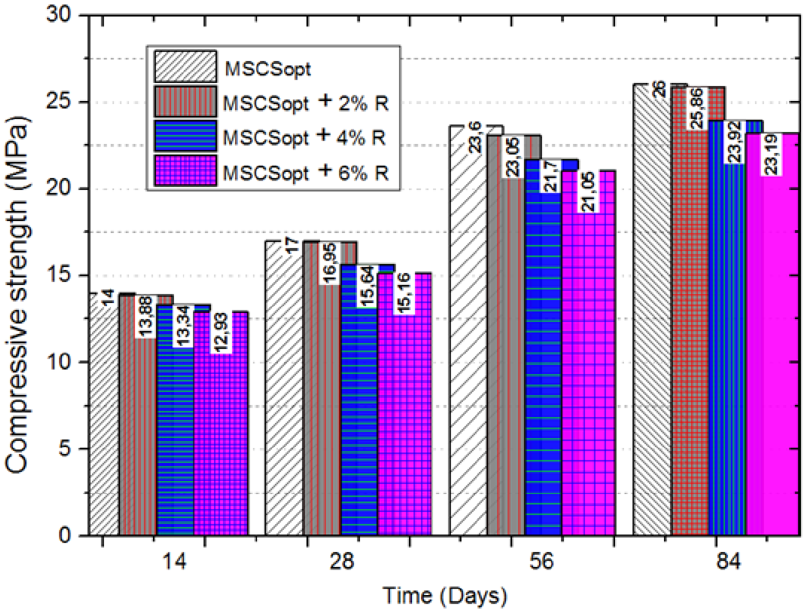

Figure 11 – Influence of scrap rubber addition rate on compressive strength

Conclusions

- Crushed sand and sediment particles are used as very effective fillers to mortar to ensure good performance, sufficient workability, and improved strength. The efficiency of particles depends on their morphology and genesis.
- The compressive strength and tensile strength of the resulting mortar depended on the fineness modulus of the aggregate and the plasticity index. In general, compressive strength was reduced with reduced fineness modulus of the aggregate and th eincreased sand plasticity index.
- Incorporating crushed sand particles in mortar enhances mechanical properties, successfully minimizing porosity through improved pore size distribution.

- Mortar modified with 65 wt% sediments and 35 wt% crushed sand particles demonstrated a significantly approximate resistance compared to the reference sand mortar.
- The bulk density of fresh mortar and the dry bulk density of hardened mortar for different mixes showed a significantly approximate match.
- Ultrasonic pulse velocity decreases with the increased quantity of crushed sand particles.
- Due to the high compressibility of used scrap rubber waste, the compression and recompression indices increase dramatically with the rubber content of used tire.
- Scrap rubber waste can be used as a reinforcing material in mortar mixes, but proportions should not be exceeded.

References

-AFNOR Association française de normalisation. 1991. *NF P94-054: Sols : reconnaissances et essais - Détermination de la masse volumique des particules solides des sols - Méthode du pycnomètre à eau* [online]. Available at: https://www.boutique.afnor.org/fr-fr/norme/nf-p94054/sols-reconnaissance-et-essais-determination-de-la-masse-volumique-des-parti/fa020767/11077 [Accessed: 29 March 2024].

-AFNOR Association française de normalisation. 1992. *NF P94-057: Sols : reconnaissance et essais - Analyse granulométrique des sols - Méthode par sédimentation* [online]. Available at: https://www.boutique.afnor.org/fr-fr/norme/nf-p94057/sols-reconnaissance-et-essais-analyse-granulometrique-des-sols-methode-par-/fa020768/11074 [Accessed: 29 March 2024].

-AFNOR Association française de normalisation. 1993. *NF P94-051: Sols : reconnaissance et essais - Détermination des limites d'Atterberg - Limite de liquidité à la coupelle - Limite de plasticité au rouleau* [online]. Available at: https://www.boutique.afnor.org/fr-fr/norme/nf-p94051/sols-reconnaissance-et-essais-determination-des-limites-datterberg-limite-d/fa020765/11080 [Accessed: 29 March 2024].

-AFNOR Association française de normalisation. 1990. *NF EN 196-1: Méthodes d'essais des ciments. Détermination des résistances mécaniques* [online]. Available at: https://www.boutique.afnor.org/fr-fr/norme/nf-en-1961/methodes-dessais-des-ciments-determination-des-resistances-mecaniques/fa020279/77168 [Accessed: 29 March 2024].

-AFNOR Association française de normalisation. 1996. *NF P94-056: Sols : reconnaissance et essais - Analyse granulométrique - Méthode par tamisage à sec après lavage* [online]. Available at: https://www.boutique.afnor.org/fr-fr/norme/nf-p94056/sols-reconnaissance-et-essais-analyse-granulometrique-methode-par-tamisage-/fa026936/11075 [Accessed: 29 March 2024].

-AFNOR Association française de normalisation. 1998a. *NF EN 1744-1: Essais pour déterminer les propriétés chimiques des granulats - Partie 1 : analyse chimique* [online]. Available at: https://www.boutique.afnor.org/fr-fr/norme/nf-en-17441/essais-pour-determiner-les-proprietes-chimiques-des-granulats-partie-1-anal/fa039721/62422 [Accessed: 29 March 2024].

-AFNOR Association française de normalisation. 1998b. *NF P94-068: Sols : reconnaissance et essais - Mesure de la capacité d'adsorption de bleu de méthylène d'un sol ou d'un matériau rocheux - Détermination de la valeur de bleu de méthylène d'un sol ou d'un matériau rocheux par l'essai à la tache* [online]. Available at: https://www.boutique.afnor.org/fr-fr/norme/nf-p94068/sols-reconnaissance-et-essais-mesure-de-la-capacite-dadsorption-de-bleu-de-/fa043689/394 [Accessed: 29 March 2024].

Akbulut, S., Arasan, S. & Kalkan E. 2007. Modification of clayey soils using scrap tire rubber and synthetic fibres. *Applied Clay Science*, 38(1-2), pp.23-32. Available at: https://doi.org/10.1016/j.clay.2007.02.001.

Amar, M., Benzerzour, M., Safhi, A.E.M. & Abriak, N.-E. 2018. Durability of a cementitious matrix based on treated sediments. *Case Studies in Construction Materials*, 8, pp.258-276. Available at: https://doi.org/10.1016/j.cscm.2018.01.007.

Aoual-Benslafa, F.K., Kerdal, D., Ameur, M., Mekerta, B. & Semcha, A. 2015. Durability of Mortars Made with Dredged Sediments. *Procedia Engineering*, 118, pp.240-250. Available at: https://doi.org/10.1016/j.proeng.2015.08.423.

Arnould, M. & Virlogeux, M. & 1986. *Granulats et bétons légers.* Champs-sur-Marne, France: Presses de l'école nationale des Ponts et Chaussées. ISBN: 978-2-85978-086-9.

Bédérina, M., Khenfer, M.M., Dheilly, R.M. & Quéneudec, M. 2005. Reuse of local sand: effect of limestone filler proportion on the rheological and mechanical properties of different sand concretes. *Cement and Concrete Research*, 35(6), pp.1172-1179. Available at: https://doi.org/10.1016/j.cemconres.2004.07.006.

Bederina, M., Makhloufi, Z., Bounoua, A., Bouziani, T. & Quéneudec, M. 2013. Effect of partial and total replacement of siliceous river sand with limestone crushed sand on the durability of mortars exposed to chemical solutions. *Construction and Building Materials*, 47, pp.146-158, Available at: https://doi.org/10.1016/j.conbuildmat.2013.05.037.

Bell, F.G. 1993. *Engineering Treatment of Soils*, *1st Edition*. London: CRC Press. Abailable at: https://doi.org/10.1201/9781482288971.

Benyamina, S., Menadi, B., Bernard, S. & Kenai S. 2019. Performance of self-compacting concrete with manufactured crushed sand. *Advances in concrete construction*, 7(2), pp.87-96, Available at: https://doi.org/10.12989/acc.2019.7.2.087.

Bin Kabit, M.R., Sarkawi, S.S.R., Mannan, M.D.A. & Adebayo, J.O. 2021. Effect of Silica Fume and Synthetic Fibre towards the Compressive Strength of Modified Crumb Rubber Cement Mortar. *Defect and Diffusion Forum*, 411, pp.135-142. Available at: https://doi.org/10.4028/www.scientific.net/DDF.411.135.

Cepuritisa, R., Jacobsena, S., Pedersenc, B. & Mørtsell, E. 2016. Crushed sand in concrete – Effect of particle shape in different fractions and filler properties on rheology. *Cement and Concrete Composites,* 74, pp.26-41. Available at: https://doi.org/10.1016/j.cemconcomp.2016.04.004.

Cetin, H., Fener, M. & Gunaydin, O. 2006. Geotechnical properties of tire-cohesive clayey soil mixtures as fill material. *Engineering Geology*, 88(1-2), pp.110-120. Available at: https://doi.org/10.1016/j.enggeo.2006.09.002.

Cherrak, M., Bali, A. & Silhadi, K. 2013. Concrete mix design containing calcareous tuffs as a partial sand substitution. *Construction and Building Materials*, 47, pp.318-323. Available at: https://doi.org/10.1016/j.conbuildmat.2013.05.051.

Chouhan, H.S., Kalla, P., Nagar, R., Gautam, P.K. & Arora, A.N. 2020. Investigating use of dimensional limestone slurry waste as fine aggregate in mortar. *Environment, Development and Sustainability,* 22, pp.2223-2245. Available at: https://doi.org/10.1007/s10668-018-0286-9.

Corinaldesi, V. 2012. Recycled-Aggregate Bedding Mortars for Repair of Historical Buildings. *Applied Mechanics and Materials*, 174-177, pp.1481-1488. Available at: https://doi.org/10.4028/www.scientific.net/AMM.174-177.1481.

D'Antino, T., Carozzi, F.G. & Poggi, C. 2019. Diagonal Compression of Masonry Walls Strengthened with Composite Reinforced Mortar. *Key Engineering Materials*, 817, pp.528-535. Available at: https://doi.org/10.4028/www.scientific.net/KEM.817.528.

Fonti, V., Dell'Anno, A. & Beolchini, F. 2013. Influence of biogeochemical interactions on metal bioleaching performance in contaminated marine sediment. *Water Research*, 47(14), pp.5139-5152, Available at: https://doi.org/10.1016/j.watres.2013.05.052.

Gupta, T., Siddique, S., Sharma, R.K. & Chaudhary, S. 2019. Behaviour of waste rubber powder and hybrid rubber concrete in aggressive environment. *Construction and Building Materials*, 217, pp.283-291. Available at: https://doi.org/10.1016/j.conbuildmat.2019.05.080.

Jiang, W., Zhu, H., Haruna, S.I., Shao, J., Yu, Y. & Wu, K. 2022. Mechanical properties and freeze–thaw resistance of polyurethane-based polymer mortar with crumb rubber powder. *Construction and Building Materials,* 352, art.number:129040. Available at: https://doi.org/10.1016/j.conbuildmat.2022.129040.

Khan, I.M., Kabir, S., Alhussain, M.A. & Almansoor, F.F. 2016. Asphalt Design Using Recycled Plastic and Crumb-rubber Waste for Sustainable Pavement Construction. *Procedia Engineering*,145, pp.1557-1564. Available at: https://doi.org/10.1016/j.proeng.2016.04.196.

Khorrami, M., Vafai, A., Khalilitabas, A.A., Desai, C.S. & Ardakani, M.H.M. 2010. Experimental Investigation on Mechanical Characteristics and Environmental Effects on Rubber Concrete. *International Journal of Concrete Structures and Materials*, 4(1), pp.17-23. Available at: https://doi.org/10.4334/IJCSM.2010.4.1.017.

Lam, N.N. 2020. A Study on Using Crushed Sand to Replace Natural Sand in High-Strength Self-compacting Concrete Towards Sustainable Development in Construction. In: *IOP Conference Series: Earth and Environmental Science; 6th International Conference on Environment and Renewable Energy*, Hanoi, Vietnam, 505, art.number:012003, February 24-26. Available at: https://doi.org/10.1088/1755-1315/505/1/012003.

Li, X. & Liu, J. 2021. One-dimensional compression feature and particle crushability behavior of dry calcareous sand considering fine-grained soil content and relative compaction. *Bulletin of Engineering Geology and the Environment*, 80, pp.4049-4065. Available at: https://doi.org/10.1007/s10064-021-02160-2.

Lu, L.L., Zhang, R. & Zhang, Y.B. 2022. Experimental Study of Cement Mortar on Compressive Strength and Wave Velocity Characteristics for Different Sand/Cement Ratio and Particle Sizes. *Key Engineering Materials,* 931, pp.199-204. Available at: https://doi.org/10.4028/p-dlhef1.

Ma, Z., Shen, J., Wang, C. & Wu, H. 2022. Characterization of sustainable mortar containing high-quality recycled manufactured sand crushed from recycled coarse aggregate. *Cement and Concrete Composites*, 132, art.number:104629. Available at: https://doi.org/10.1016/j.cemconcomp.2022.104629.

Nakhaei, A., Marandi, S.M., Sani Kermani, S. & Bagheripour, M.H. 2012. Dynamic properties of granular soils mixed with granulated rubber. *Soil Dynamics and Earthquake Engineering,* 43, pp.124-132. Available at: https://doi.org/10.1016/j.soildyn.2012.07.026.

-NBN Bureau of Normalization. 1999. *NBN EN 1015-10:1999: Méthodes d'essai des mortiers pour la maçonnerie - Partie 10: Détermination de la masse volumique apparente séche du mortier durci* [online]. Available at: https://app.nbn.be/data/r/platform/frontend/detail?p40_id=273242&p40_language_code=fr&p40_detail_id=101336&lang=fr [Accessed: 29 March 2024].

Okagbue, C.O. & Onyeobi, T.U.S. 1999. Potential of marble dust to stabilize red tropical soils for road construction. *Engineering Geology*, 53(3-4), pp.371-380. Available at: https://doi.org/10.1016/S0013-7952(99)00036-8.

Pavia, S. & Toomey, A.B. 2008. Influence of the aggregate quality on the physical properties of natural feebly-hydraulic lime mortars. *Materials and Structures*, 41, pp.559-569. Available at: https://doi.org/10.1617/s11527-007-9267-4.

Rattanaveeranon, S., Dumrongsil, S. & Jiamwattanapong, K. 2019. Effect of Latex Rubber and Rubber Powder as an Admixture on Bending Strength of Cement Mortar. *Applied Mechanics and Materials*, 891, pp.180-186. Available at: https://doi.org/10.4028/www.scientific.net/AMM.891.180.

Schmitz, R.M., Schreoder, C. & Charlier, R. 2004. Chemo-mechanical interactions in clay a correlation between clay mineralogy and Atterberg limits. *Applied Clay Science*, 26(1-4), pp.351-358. Available at: https://doi.org/10.1016/j.clay.2003.12.015.

Sellaf, H., Balegh, B. & Bkhiti, M. 2023. The Assessment and Treatment of Dredged Sediments and Limestone Tuff Using Waste Ceramic with Low-Cement.

Advanced Engineering Forum, 48, pp.45-58. Available at: https://doi.org/10.4028/p-2j4d93.

Singh, L.P., Goel, A., Bhattachharyya, S.K., Ahalawat, S., Sharma, U. & Mishra, G. 2015. Effect of Morphology and Dispersibility of Silica Nanoparticles on the Mechanical Behaviour of Cement Mortar. *International Journal of Concrete Structures and Materials,* 9(2), pp.207-217. Available at: https://doi.org/10.1007/s40069-015-0099-2.

Sivapullaiah, P.V., Sridharan, A. & Bhaskar Raju, K.V. 2000. Role of amount and type of clay in the lime stabilization of soils. *Proceedings of the Institution of Civil Engineers - Ground Improvement,* 4(1), pp.37-45. Available at: https://doi.org/10.1680/grim.2000.4.1.37.

Srivastava, A. & Singh, S.K. 2020. Utilization of alternative sand for preparation of sustainable mortar: A review. *Journal of Cleaner Production*, 253, art.number:119706, Available at: https://doi.org/10.1016/j.jclepro.2019.119706.

Su, P., Dai, Q., Li, M., Ma, Y. & Wang, J. 2022. Investigation of the mechanical and Shrinkage properties of plastic-rubber compound modified cement mortar with recycled tire steel fiber. *Construction and Building Materials,* 334, art.number:127391. Available at: https://doi.org/10.1016/j.conbuildmat.2022.127391.

Torres, M.L. & García-Ruiz, P.A. 2009. Lightweight pozzolanic materials used in mortars: Evaluation of their influence on density, mechanical strength and water absorption. *Cement and Concrete Composites*, 31(2), pp.114-119. Available at: https://doi.org/10.1016/j.cemconcomp.2008.11.003.

Trouzine, H., Bekhiti, M. & Asroun, A. 2012. No AccessEffects of scrap tyre rubber fibre on swelling behaviour of two clayey soils in Algeria. *Geosynthetics International*, 19(2), pp.124-132, Available at: https://doi.org/10.1680/gein.2012.19.2.124.

Wang, J.-J., Zhang, H.-P., Deng, D.-P. & Liu, M.-W. 2013. Effects of mudstone particle content on compaction behavior and particle crushing of a crushed sandstone–mudstone particle mixture. *Engineering Geology*, 167, pp.1-5. Available at: https://doi.org/10.1016/j.enggeo.2013.10.004.

Wei, C.B., Othman, R., Sheng, T.W., Jaya, R.P. & Al Bakri Abdullah, M.M. 2021. Properties of Mortar with Waste Tyre Rubber as Partial Sand Replacement. *Key Engineering Materials,* 879, pp.49-61. Available at: https://doi.org/10.4028/www.scientific.net/KEM.879.49.

Efectos de los desechos de caucho sobre el comportamiento mecánico de morteros de arena triturada y sedimentos

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CAMPO: materiales, ingeniería civil
TIPO DE ARTÍCULO: artículo científico original

Resumen:

Introducción/objetivo: El consumo de arena natural en Argelia es elevado debido a su uso extensivo en morteros, mientras que los sedimentos y los residuos de caucho plantean importantes desafíos ambientales y sociales. Este estudio investiga los efectos de la incorporación de residuos de caucho en morteros mezclados con arena triturada y sedimentos. El objetivo principal es valorizar las partículas de arena triturada mediante pruebas físicas y mecánicas, evaluando su potencial como alternativa a la arena natural en mezclas de morteros.

Métodos: Se realizó un trabajo experimental para estudiar el impacto de reemplazar parcial o totalmente los sedimentos con partículas de arena triturada en mezclas de mortero. Se prepararon mezclas de mortero utilizando diferentes proporciones de sedimento a arena triturada (10%, 25%, 35%, 50% y 100%) para observar su influencia en las propiedades físicas y mecánicas. Además, se analizaron los efectos de agregar 2%, 4% y 6% de caucho granulado al mortero óptimo. Se realizaron varias pruebas, incluidas las de resistencia a la compresión, resistencia a la flexión y velocidad del pulso ultrasónico, para evaluar el desempeño de las mezclas.

Resultados: Los resultados indicaron que la sustitución de sedimentos por arena triturada mejoró las propiedades de resistencia del mortero, en particular debido a una mejor compactación de las partículas. El mortero que contenía 65 % en peso de sedimentos y 35 % en peso de arena triturada mostró propiedades similares al mortero de referencia. La adición de desechos de caucho aumentó la compresibilidad, pero mejoró las propiedades mecánicas cuando se utilizó con moderación. La velocidad del pulso ultrasónico disminuyó con un mayor contenido de arena triturada y se redujo la porosidad de las mezclas.

Conclusión: La arena triturada y las partículas de sedimento son materiales de relleno eficaces para el mortero, garantizando un buen rendimiento y *una mayor resistencia. La eficiencia de estos materiales depende de su morfología y génesis. El estudio demuestra que la arena triturada puede ser una alternativa viable a la arena natural, y los residuos de caucho pueden utilizarse como material de refuerzo en el mortero, aunque sus proporciones deben controlarse cuidadosamente para evitar efectos negativos en las propiedades mecánicas.*

Palabras claves: mortero, sedimento, arena triturada, desechos de caucho, resistencia a la compresión, resistencia a la tracción.

Влияние резиновой крошки на механические характеристики раствора, изготовленного из измельченного песка и отложений

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РУБРИКА ГРНТИ: 81.09.00 Материаловедение
ВИД СТАТЬИ: оригинальная научная статья

Резюме:

Введение/цель: Природный песок в Алжире широко используется в строительных растворах, в то время как отложения и резиновые отходы создают серьезные экологические и социальные проблемы. В данном исследовании изучается влияние содержания резиновых отходов в строительных растворах, смешанных с измельченным песком и отложениями. Основная цель исследования заключалась в валоризации измельченных частиц песка путем физико-механических испытаний и оценка их потенциала для замены природного песка в строительных смесях.

Методы: В ходе исследования было экспериментально изучено влияние частичной и полной замены отложений измельченными частицами песка в растворных смесях. Раствор готовился в различном соотношении отложений и измельченного песка (10%, 25%, 35%, 50% и 100%) с целью изучения их влияния на физические и механические свойства. Также были проанализированы влияние добавок 2%, 4% и 6% резиновой крошки на оптимальный раствор. Для оценки характеристик смесей были проведены различные испытания, включая испытания на прочность, прочность на изгиб и испытания на скорость ультразвукового импульса.

Результаты: Результаты показали, что замена отложений измельченным песком улучшила прочностные свойства раствора, в частности, за счет лучшей утрамбовки частиц. Раствор, содержащий 65 мас.% отложений и 35 мас.% измельченного песка, показал свойства, аналогичные контрольному раствору. Добавление резиновой крошки повышает сжимаемость, но улучшает механические свойства при умеренном использовании. При увеличении содержания измельченного песка скорость ультразвукового импульса снижается, а пористость смесей уменьшается.

Вывод: Измельченный песок и частицы отложений являются эффективными связывающими элементами в строительных растворах. Они обеспечивают превосходные эксплуатационные характеристики и повышенную прочность. Эффективность этих материалов зависит от их морфологии и происхождения. Исследование показывает, что измельченный песок может быть жизнеспособной альтернативой природному песку, а резиновую крошку можно использовать в качестве армирующего материала в строительных растворах. Однако их пропорции следует тщательно контролировать во избежание негативного влияния на механические свойства.

Ключевые слова: строительный раствор, отложения, измельченный песок, резиновая крошка, прочность на сжатие, растяжение.

Утицај отпадног гуменог гранулата на механичке перформансе малтера од дробљеног песка и седимента

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ОБЛАСТ: материјали, грађевинарство
КАТЕГОРИЈА (ТИП) ЧЛАНКА: оригинални научни рад

Сажетак:

Увод/циљ: Потрошња природног песка у Алжиру је велика због његове широке употребе у малтерима, док седименти и гумени отпад представљају значајан еколошки и друштвени проблем. Ова студија истражује утицај коришћења гуменог отпада у малтерима помешаног са дробљеним песком и седиментима. Основни циљ био је да се изврши валоризација честица дробљеног песка путем физичког и механичког испитивања, као и да се процени њихов потенцијал да замене природни песак у мешавинама малтера.

Методе: Експерименталним путем проучаван је утицај делимичне и потпуне замене седимената честицама дробљеног песка у мешавинама малтера. Оне су припремљене у различитим односима седимента и дробљеног песка (10%, 25%, 35%, 50% и 100%) како би се испитао њихов утицај на физичка и механичка својства. Такође, анализирани су ефекти додавања 2%, 4% и 6% гуменог гранулата оптималном малтеру. Извршена су различита испитивања, укључујући тестирања чврстоће, чврстоће на савијање и брзине ултразвучног импулса ради процене перформанси мешавина.

Резултати: Показано је да замена седимента дробљеним песком побољшава својства чврстоће малтера, нарочито због бољег паковања честица. Малтер са 65 теж% седимента и 35 теж% дробљеног песка испољио је својства слична референтном малтеру. Додавање гуменог отпада повећало је стишљивост, али и побољшало механичка својства када се користио умерено. Брзина ултразвучног импулса опала је са већим садржајем дробљеног песка, а порозност мешавина се смањила.

Закључак: Честице дробљеног песка и седимената су ефекасна везива за малтер која обезбеђују добре перформансе и побољшавају чврстоћу. Ефикасност ових материјала зависи од њихове

морфологије и порекла. Студија показује да дробљени песак може да буде одржива алтернатива природном песку, а да се гумени отпад може користити као материјал за ојачавање малтера, мада треба пажљиво контролисати његов удео како би се избегао негативан утицај на механичка својства.

Кључне речи: малтер, седимент, дробљени песак, гумени гранулат, чврстоћа на притисак, чврстоћа на истезање.

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