International Research Journal of Multidisciplinary Scope (IRJMS), 2025; 6(3):56-65

Original Article | ISSN (O): 2582-631X DOI: 10.47857/irjms.2025.v06i03.04042

Influence of Sea Sand and River Sand on the Formulation of Ordinary Concrete

Raja Moussaoui[1, 2]*, Driss El Hachmi[2], Mohammed Cherraj[2], Sara El Haddouni[3]

[1]Laboratory of Applied Geosciences, Faculty of Sciences, Mohammed I University, Oujda, Morocco, [2]MSME, Faculty of Sciences, Mohammed V University, Rabat, Morocco, [3]S2G Laboratory, Mohammedia, Morocco. *Corresponding Author's Email: r.moussaoui@ump.ac.ma

Abstract

Sand is one of the main constituents of concrete. Its granular skeleton enables the aggregates to be combined with cement, giving concrete greater compactness. This research evaluated the influence of sand type on the formulation parameters of ordinary concrete, specifically the dosage of each constituent, the cement/water ratio and the compressive strength. Two types of sand were chosen for this study: sea sand and river sand from Rabat (Morocco). These sands underwent characterization tests to ensure their feasibility of use in concrete. Using the Dreux Gorisse method, two formulations were studied. The first consisted of cement, water, crushed sand, sea sand and GI and GII gravel. The second uses the same constituents, but with replacement of sea sand by river sand. The characterization results confirmed that river sand is marked by its high fineness, elevated cleanliness and low water absorption capacity, illustrated respectively by a fineness modulus of 2.49%, a sand equivalence coefficient of 75% and a water absorption coefficient of 0.79%. As for sea sand, it has a considerable cleanliness and high-water absorption (1.50%). Furthermore, river sand exceeds sea sand in terms of concrete strength. This strength difference can be explained by the high cleanliness and rounded texture of river sand, which ensures excellent compactness and better cement adhesion. Also, the presence of chlorides in sea sand can reduce its strength. In summary, it appears that the sand type has an impact on the concrete formulation and on its properties in terms of density, compactness and strength.

Keywords: Dreux Gorisse Method, Formulation, Ordinary Concrete, River Sand, Sea Sand, Strength.

Introduction

The composition of ordinary concrete is based on the combination of various materials, such as cement, sand, gravel, water and eventually some adjuvants. The proportion of these constituents can be varied according to the characteristics of each material, the formulation methodology chosen and the specific requirements of the building project. To formulate concrete, it is essential to know the characteristics of the aggregates used (1). For this reason, a series of tests is performed. These tests include: particle size analysis, sand equivalence test and methylene blue test for cleanliness verification, Micro-Deval and Los Angeles test for aggregate strength control, flattening coefficient test for external grain shape determination, and other tests to identify aggregate density, water absorption coefficient and fines content. These aggregate characteristics have a considerable impact on the workability (2), strength and durability of concrete (3). An integral part of concrete's composition is sand. Its application guarantees the granular continuity between gravel and cement, which is essential for improved concrete cohesiveness. Sand has a significant impact on concrete's flow ability, weather resistance, strength, and dry shrinkage (4). Sand reduces volume changes caused by the setting and hardening processes and provides a mixture that can withstand the action of applied loads and last longer than cement paste alone (4). All these advantages make sand the world's most widely consumed natural resource after water (5). In fact, a recent study claimed that demand for sand in the building sector was increasing at a tremendous rate and estimated that its resources would be depleted by 2050 (5). Due to the evolution of construction methods, urbanization and population growth, demand for sand has tripled. Sand consumption stands at around 50 billion tons a year, or an average of 18 kilograms per person per day (6). This high rate of sand consumption represents one of the main reasons

(Received 07th February 2025; Accepted 19th June 2025; Published 20th July 2025)

for its depletion, particularly for sand extracted from natural sources. According to its origin, sand can be divided into six types: river sand, sea sand, quarry sand, dune sand, artificial sand and recycled sand. In the present study, we are particularly interested in the use of river sand and sea sand in concrete. The choice of these two types of sand more precisely is due to their frequency of use in concrete formulation. The aim of this research is to compare the effect of river sand and sea sand on the formulation of ordinary concrete. Rivers are one of the main sources to supply sand for buildings projects (7). The texture of river sand is generally rounder and smoother than other types of sand found in environments. This is due to the action of water, which shapes and polishes the grains over time. River sand is ruling construction industry due to its tremendous properties and excellent composition (8). It is commonly used in concrete as a fine aggregate (9). However, excessive river sand mining is responsible for riverbed degradation, which causes a wide range of problems, including the loss of water-holding soil strata and the slippage of riverbanks (10). Furthermore, sand extraction represents a major threat to river biodiversity, due to changes in the direction of water flow (10) and depletion of natural river sand accumulation resulting from the high rate of extraction compared with the natural regeneration rate (6). As for sea sand, it has a number of advantages, including good grain size and excellent workability, making it an ideal building material (11). However, this type of sand requires treatment to eliminate the salt content (12). In addition, sea sand contains high concentrations of chloride ions, which are a source of corrosion in reinforced concrete steel (13) and a major cause of reduced concrete durability (14). The limit value for the chloride content of sea sand ensuring its feasibility of use in concrete is about 0.075% of the weight of sand (15, 16). Above this limit, the chloride ions can threaten the properties of concrete if they are not treated before use (17–19). For this reason, preliminary treatment is recommended by successive washing with distilled water (20). Chloride ions can penetrate by diffusion or migrate by capillary action inside the concrete, crossing the coating zone, reaching the reinforcement and subsequently causing corrosion. To ascertain the extent of the chloride ion penetration and the envisaged degree of reinforcement corrosion, it is necessary to perform accelerated durability tests on the concrete. More precisely, the Rapid Chloride Migration (RCM) test and the accelerated corrosion test by wetting/drying cycles in the presence of chlorides. According to the results of these tests applied to some research, it has been proven that sea sand concrete is a source of corrosion of steel reinforcing bars, leading to structural deterioration (21). Furthermore, due to the presence of soluble chlorides and sulfates in sea sand, accelerated carbonation and sulfate attack tests are essential to ensure concrete durability. These tests proved that the presence of these ions in sea sand is responsible for an increase in the depth of carbonation and the appearance of cracks in concrete. Despite these disadvantages, some studies have affirmed that the addition of sea sand increases the durability of concrete, thanks to its smoother surface texture and finer particle size distribution (22). In summary, these two types of sand have interesting geometric and physical characteristics that encourage a detailed study of their influence on the formulation of ordinary concrete.

Methodology

Materials

The aggregates used in this study come from quarries located in the region of Rabat. They include two types of gravel (GI and GII), crushed sand (CS), and sea sand (SS) and river sand (RS). These aggregates were transported to the laboratory in waterproof bags in order to preserve their properties. Subsequently, in the laboratory, test samples were obtained using adjustable sample dividers that homogenized and subdivided the material into more representative parts (23). Then, each of the constituents has been the subject of a series of identification and characterization tests within the laboratory (24).

Characterization of Aggregates

The aggregates were identified and characterized in accordance with the Moroccan and European standards. They underwent a series of tests to ensure their granular distribution (25), cleanliness and strength (26). These tests were performed to ensure the feasibility of using these aggregates in the formulation of ordinary concrete. For GI and GII gravels (Figure 1), we conducted the particle size analysis test according to NM EN 933-1 (27), the flattening coefficient test in accordance with NM EN 933-3 (28), the Los Angeless test according to NM EN 1097-2 (29) and other tests to determine true and bulk densities, the water absorption coefficient and superficial cleanliness.

Figure 1: Gravel Samples GI and GII

For river sand, sea sand and crushed sand (Figure 2), particular tests are taken into account. It combines particle size analysis in accordance with NM EN 933-1 (27), the sand equivalence test according to NM EN 933-8 (30) and other tests to determine true and bulk density, fineness modulus, fines content and water absorption coefficient.

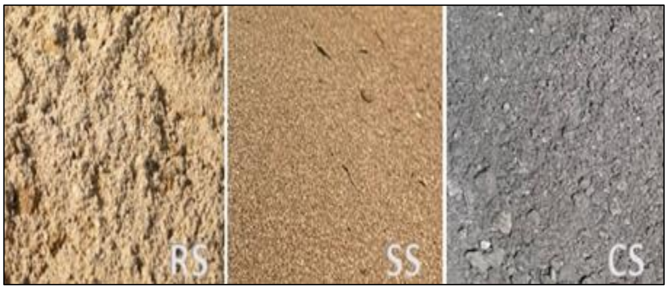

Figure 2: River Sand (RS), Sea Sand (SS) and Crushed Sand (CS) Samples

Formulation of Ordinary Concrete

Concrete formulation enables us to select the concrete constituents and choose their proportions in order to attain a characteristic 28-day compressive strength. The formulation study has a very important effect on the characteristics of the concrete, due to the variation in the dosage of each component. For this reason, it is important to choose the most suitable concrete formulation method. Various methods are available for formulating concrete, among them the Bolomey method, the Abrams method, the Faury method and the Dreux Gorisse method. This latter method is the simplest and most widely used method for formulating ordinary concrete in Moroccan laboratories. It is appreciated for its simplicity and effectiveness in determining the proportions of concrete components needed to achieve the desired characteristics, such as plasticity and strength. For this reason, we have chosen the Dreux Gorisse method for the formulation of our ordinary concrete containing different types of sand. The Dreux Gorisse method is a technique that uses granulometric analysis to determine the proportions of each constituent (1, 31). This method is founded on the following successive steps:

- Specification of slump and 28-day compressive strength desired to be achieved;
- Calculation of the C/W (Cement/Water) ratio using the Bolomey formula;
- Calculation of cement and water dosages;
- Determination of the optimum mix with minimum voids using the Dreux reference line;
- Determination of the theoretic concrete formulation.

Our research focused on two ordinary concrete formulation studies using the Dreux Gorisse method. The first contains GI and GII gravel, crushed sand, sea sand, cement and water. The second consists of a mixture of GI and GII gravel, crushed sand, river sand, cement and water. Both formulations are completely free of adjuvants. The only difference between them is the replacement of sea sand with river sand. These concrete formulation studies are valid only for reinforced concrete structural elements manufactured in a non-aggressive environment.

Results and Discussion

Gravel Characteristics

The GI and GII gravels underwent a series of geometric, physical and mechanical characterization tests to ensure their feasibility of use in the formulation of concrete mixtures. The results of these tests are summarized in Table 1. A comparison of the values obtained with the recommended limit values shows that all the results obtain respect the specifications of the NM 10.1.271 standard (32). From these results, it appears that GI gravel slightly exceeds GII gravel in terms of granularity, density and strength.

Sand characteristics

As for river sand, sea sand and crushed sand have also been subjected to a series of tests in order to determine their characteristics and to verify their suitability for use in concrete formulation. Table 2 summarizes the characterization results for these three types of sand applied. All of the results obtained are satisfactory and comply with the limit values of standard NM 10.1.271 (32). From these results, it appears that the river sand evaluated has a fine granularity, with a maximum diameter of 2.5 mm, and a high degree of cleanliness, with a sand equivalence coefficient of 75%. As for sea sand, it is characterized by its considerable cleanliness and its high water absorption capacity reaching up to 1.50%. For its part, crushed sand has a remarkable density and a high fines content ranging up to 12.9%. By comparing the characterization values obtained with the limit values of other standards applied for the specification and conformity control of sands for hydraulic concretes, it appears that the results obtained also comply with NF EN 12620+A1 (33).

Table 1: Characteristics of GI and GII Gravel

Characteristics	GI Gravel	GII Gravel	Uncertainty	Limit Values
Granular class (mm)	6.3/16	12.5/25	-	-
Flattening coefficient (%)	18.00	9.00	± 0.177	≤ 25
Superficial cleanliness (%)	0.50	0.50	± 0.069	< 3
True density (t/m^3)	2.73	2.71	± 0.014	> 2.00 and < 2.80
Bulk density (Mg/m^3)	1.44	1.39	± 0.037	-
Water absorption coefficient (%)	0.50	0.50	± 0.009	≤ 2.50
Los Angeless coefficient (%)	26.00	23.00	± 0.890	≤ 30

Table 2: Characteristics of River Sand (RS), Sea Sand (SS) and Crushed Sand (CS)

Characteristics	RS Sand	SS Sand	CS Sand	Uncertainty	Limit Values
Granular class (mm)	0/2.5	0/6.3	0/5	-	-
Sand equivalent coefficient (%)	75.00	67.00	63.00	± 1.220	> 60
Fineness modulus (%)	2.49	1.04	2.96	-	-
True density (t/m^3)	2.68	2.67	2.69	± 0.014	>2.00 and < 2.80
Bulk density (Mg/m^3)	1.56	1.40	1.55	± 0.037	-
Water absorption coefficient (%)	0.79	1.50	1.00	± 0.009	≤ 2.50
Fines content (%)	3.40	4.30	12.90	-	-

Formulation of Sea Sand Ordinary Concrete

The formulation of the ordinary concrete mixtures of the present research is made according to the Dreux Gorisse method. This method is based on the results of the particle size analysis performed on each constituent incorporated in the concrete mixture. These results are shown in Figure 3 for the first formulation of ordinary concrete containing sea sand, crushed sand and gravel GI and GII.

In order to determine the dosage required for each constituent used in this formulation, it is necessary to calculate the cement/water ratio (C/W) using Bolomey's formula. A ratio (C/W) of 1.61 is obtained for an ordinary concrete with an average compressive strength of 25 MPa, made with CPJ 45 cement. Taking into account this ratio and an 8 cm slump, the cement and water dosages found are 350 kg/m^3 and 217 l/m^3 respectively. For aggregate dosage, we used the Dreux reference curve, whose coordinates are indicated in Table 3. This curve was projected onto the particle size curves obtained by combining the crushed sand and sea sand curves into a single sand mixing curve. The intersection of this reference curve with the other curves enabled us to estimate the granular distribution of the first ordinary concrete formulation. Figure 4 shows that this concrete will be made up of 40% sand, 15% GI gravel and 45% GII gravel. This 40% of sand is distributed as almost 10% sea sand and 30% crushed sand. By respecting these proportions, the dosage of each component in the present formulation is calculated. The results obtained are summarized in Table 4. The sum of these dosages is around the 2500 kg/m^3 required for ordinary concrete.

Table 3: Dreux Reference Curve Coordinates for Sea Sand Formulation

Coordinates	x	y
O	20	0
A	42	47
B	45	100

Table 4: Dosage of Constituents in the Formulation of Ordinary Concrete with Sea Sand

Materials	Cement	Water	SS Sand	CS Sand	GI Gravel	GII Gravel
Dosage	350 kg/m^3	217 l/m^3	184 kg/m^3	586 kg/m^3	294 kg/m^3	874 kg/m^3

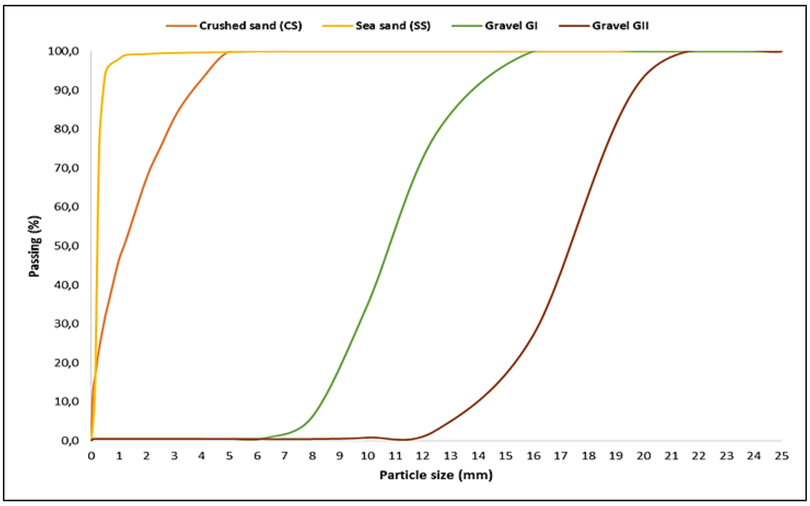

Figure 3: Granular Distribution of Crushed Sand (CS), Sea Sand (SS) and Gravel GI and GII Used for the First Formulation of Ordinary Concrete

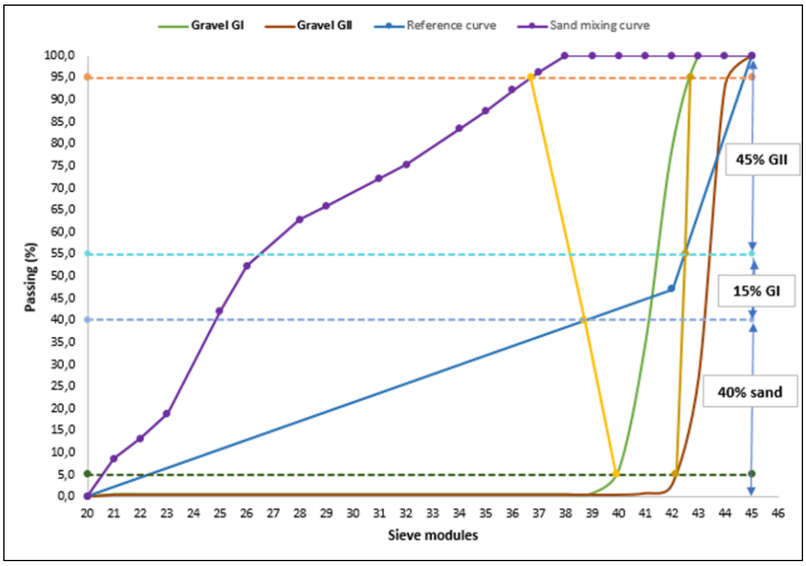

Figure 4: Proportions of Aggregates in the First Formulation of Ordinary Concrete with Sea Sand

Formulation of River Sand Ordinary Concrete

A second formulation of ordinary concrete was the subject of our study. In this second formulation, we used the same constituents as in the first, but replaced the sea sand with river sand. The results of the particle size analysis test carried out for the constituents of the second ordinary concrete formulation are illustrated in Figure 5. By comparing the granular distribution of river sand with that of sea sand, we can see that sea sand is made up of around 93% fine elements passing through a 0.5 mm sieve. It is therefore fine sand. However, river sand contains only 45% fine sand, the rest being medium sand.

Similar to the first formulation, we found for the second formulation containing river sand a ratio (C/W) of 1.61, a cement dosage of 350 kg/m^3 and a water dosage of 217 l/m^3. For the Dreux reference curve, these coordinates are identical to the coordinates of the first formulation, with the exception of the y_A value, which has been slightly modified due to the higher fineness modulus of river sand compared to sea sand (Table 5). The granular distribution of the second formulation of ordinary concrete is distributed as follows: 41% sand, 16% GI gravel and 43% GII gravel (Figure 6). This 41% of sand is distributed as almost 40% river sand and 1% crushed sand. The high percentage of river sand is due to its grain size, which is very similar to that of crushed sand. Respecting these proportions, the calculated dosage of each constituent for the second formulation is indicated in Table 6. The density of this concrete is approximately 2050 kg/m^3. In summary, we can conclude that river sand can partially or totally replace crushed sand due to its assimilable particle size distribution and fairly similar density. However, for ordinary concrete formulations containing sea sand, it is necessary to add high quantities of crushed sand.

Table 5: Dreux Reference Curve Coordinates for River Sand Formulation

Coordinates	x	y
O	20	0
A	42	48
B	45	100

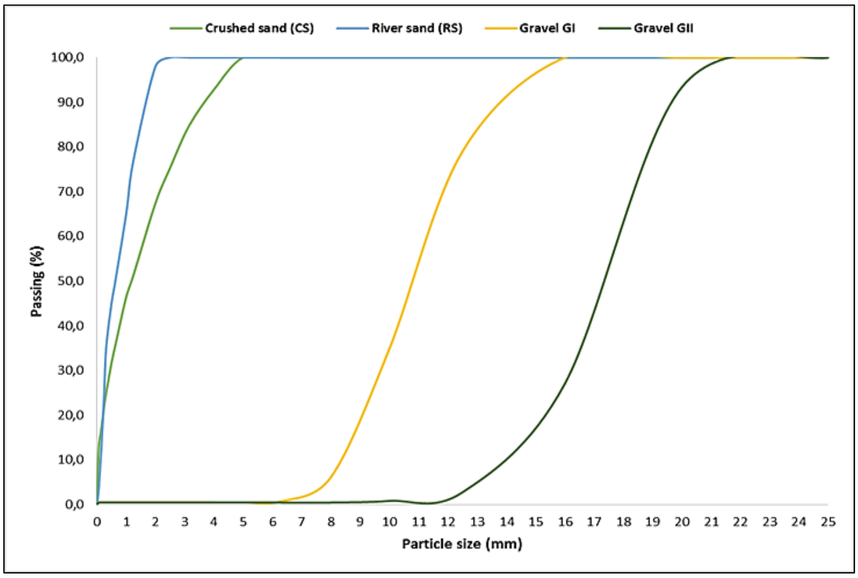

Figure 5: Granular Distribution of Crushed Sand (CS), River Sand (RS) and Gravel GI and GII Used for the Second Formulation of Ordinary Concrete

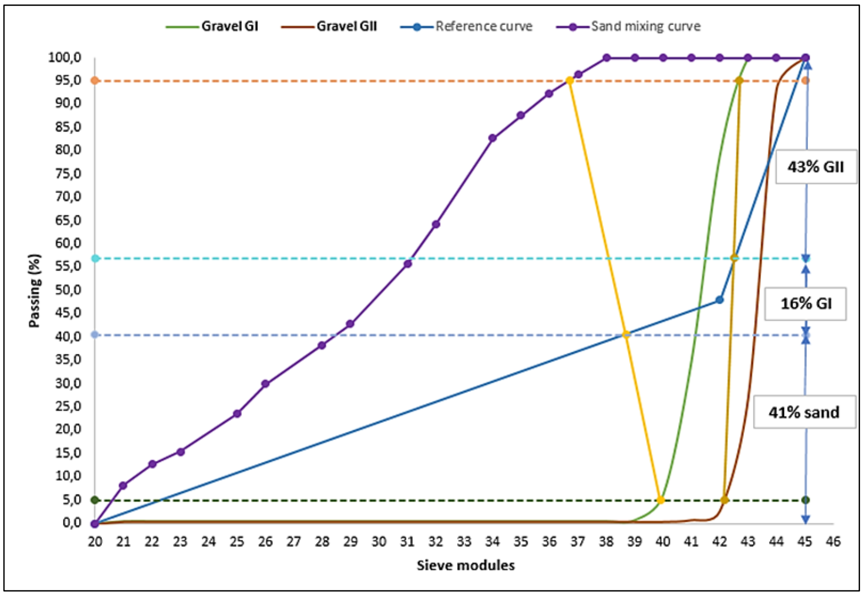

Figure 6: Proportions of Aggregates in the Second Formulation of Ordinary Concrete with River Sand

Table 6: Dosage of Constituents in the Formulation of Ordinary Concrete with River Sand

Materials	Cement	Water	RS sand	CS sand	GI gravel	GII gravel
Dosage	350 kg/m^3	217 l/m^3	315 kg/m^3	10 kg/m^3	313 kg/m^3	836 kg/m^3

Compressive Strength of Ordinary Concrete Formulations

In order to evaluate the compressive strength of ordinary concrete mixes prepared respecting the dosages of the two formulations, it was necessary to perform the specimen crushing test in accordance with the NM EN 12390-3 standard (34). Six cylindrical specimens of 16 cm diameter and 32 cm height were prepared for each formulation, in compliance with the recommendations of NM EN 12390-1 (35) and NM EN 12390-2 (36). Among the twelve prepared specimens, six were crushed on the 7th day and the remaining specimens were crushed on the 28th day to determine their characteristic compressive strengths. These concrete specimens were crushed using a hydraulic press with a loading capacity of up to 3000 kN. The compressive strengths of ordinary concrete obtained for each formulation at the 7th day and the 28th day have been summarized in Tables 7 and 8 respectively. These results demonstrated that ordinary concrete containing river sand has a higher compressive strength than that containing sea sand. This can be explained by the high cleanliness and rounded texture of river sand, which ensures excellent concrete compactness and better cement adhesion. Research has been approved that the surface texture and particle size distribution of sand can reduce the strength development of concrete. Furthermore, the presence of salt in sea sand, even at low percentages, can adversely affect cement setting and hydration, and consequently reduce the compressive strength of concrete. In fact, the chloride content of sea sand can reduce the strength of concrete and hence adversely affect the durability of structures (37). For this reason, many research studies have recommended the treatment of sea sand with various chemical products in order to eliminate the chloride content and equalize its properties, to achieve the same characteristics and strength as river sand (37). Moreover, these results show that the 28-day compressive strength of sea sand concrete is lower than the minimum characteristic strength of ordinary concrete, which is around of 25 MPa. This can be explained by the chloride content of our sea sand samples reaching 0.082% of the sand weight. This value exceeds the recommended chloride limit (0.075%), despite treatment by washing with distilled water. However, river sand concrete satisfies this strength condition with a concrete compressive strength of 27 MPa. By comparing the compressive strength results obtained with the results of other studies. It appears that some studies report that sea sand concrete could relatively achieve a compressive strength similar to that of ordinary concrete, while other studies have shown that sea sand concrete has a lower compressive strength than ordinary concrete (38). In summary, the strength of concrete is linked to the type and composition of sand used in the concrete mix (39) (Table 7 and 8).

Table 7: 7-Day Compressive Strengths for Ordinary Concrete Formulations with Sea Sand and River Sand

Formulation	Weight (kg)	Failure load (kN)	7-day compressive strength (MPa)	7-day average compressive strength (MPa)
Formulation 1	15.42	409.60	20.10	
Sea sand concrete	15.42	417.20	20.50	20.10
	15.41	395.80	19.70	
Formulation 2	15.41	429.60	21.50	
River sand concrete	15.40	437.20	21.70	21.40
	15.40	420.80	20.90	

Table 8: 28-Day Compressive Strengths for Ordinary Concrete Formulations with Sea Sand and River Sand

Formulation	Weight (kg)	Failure Load (kN)	28-day Compressive Strength (MPa)	28-day Average Compressive Strength (MPa)
Formulation 1	15.54	548.30	24.30	
Sea sand concrete	15.52	524.70	23.10	23.70
	15.52	536.50	23.70	
Formulation 2	15.51	569.30	27.30	
River sand concrete	15.50	553.70	26.50	27.00
	15.50	566.50	27.20	

Conclusion

The present research started by characterizing sea sand and river sand samples collected from the region of Rabat in Morocco for their use in the formulation of ordinary concrete. In light of the characterization results obtained, a formulation study of ordinary concrete was carried out using the Dreux Gorisse method. Two formulations of ordinary concrete were the subject of our study. The first consists of cement, water, crushed sand, sea sand and GI and GII gravel. The second formulation is almost identical to the first, but with replacement of the sea sand by river sand. After determining the proportions of each constituent in each formulation, the prepared specimens were tested to ensure the compressive strength of concrete. The characterization results confirmed that river sand is characterized by its great fineness, high cleanliness and low water absorption capacity, illustrated respectively by a fineness modulus of 2.49%, a sand equivalent coefficient of 75% and a water absorption coefficient of 0.79%. As for sea sand, it has a considerable degree of cleanliness and a high-water absorption coefficient on average of 1.50%. The grain size of river sand is similar to that of crushed sand, so the latter can be totally or partially replaced by river sand in a formulation study. Taking into account the dosages obtained using the Dreux Gorisse method; cylindrical specimens were prepared for the crushing test to check the concrete's strength at 7 and 28 days. The results of this test affirmed that river sand concrete has higher compressive strengths than sea sand. This can be explained by the high fineness of river sand, which improves its adhesion to cement, and by the chloride content of most sea sands, which adversely affects aggregate/cement adhesion and therefore compressive strength. In addition, river sand concrete remains economically more viable in the long term due to its stable technical properties and durability.

Abbreviations

CS: Crushed sand, C/W: Ciment/Water ratio, GI: Gravel GI, GII: Gravel GII, RS: River sand, SS: Sea sand.

Acknowledgement

The authors would like to thank everyone who contributed to the success of this research.

Author Contributions

RM: Study conception and design, data collection, analysis, interpretation of results, writing and reviewing article, DEH: Study conception and design, data collection, analysis, interpretation of results, reviewing article, MC: Analysis, interpretation of results, reviewing article, SEH: Data collection, analysis, reviewing article.

Conflict of Interest

The authors declare that there are no conflicts of interest related to this research.

Ethics Approval

Not applicable.

Funding

No financial support received for this study.

References

1. Hamza C, Bouchra S, Mostapha B, Mohamed B. Formulation of Ordinary Concrete using the Dreux-Gorisse Method. Procedia Struct Integr. 2020;28:430-9.
2. Aïssoun BM, Hwang SD, Khayat KH. Influence of aggregate characteristics on workability of superworkable concrete. Mater Struct. 2016;49(1-2):597-609.
3. Thomas MDA, Folliard KJ. Concrete aggregates and the durability of concrete. In: Page CL, Page MM, editors. Durability of concrete and cement composites. Elsevier; 2007:247-81. https://doi.org/10.1533/9781845693398.247
4. Ahmad J, Zhou Z, Martínez-García R, Vatin NI, de-Prado-Gil J, El-Shorbagy MA. Waste Foundry Sand in Concrete Production Instead of Natural River Sand: A Review. Materials. 2022;15(7):2365.
5. Rentier ES, Cammeraat LH. The environmental impacts of river sand mining. Sci Total Environ. sept 2022;838:155877.
6. Xiao J, Zhang H, Hu X, Ding T, Xiao X. Impact assessment of river sand resource shortage under different policy scenarios in China. Low-Carbon Mater Green Constr. 22 mai 2023;1(1):16.
7. Haghnazar H, Sangsefidi Y, Mehraein M, Tavakol-Davani H. Evaluation of infilling and replenishment of river sand mining pits. Environ Earth Sci. 2020;79(14):362.
8. Patil AY, Banapurmath NR, Shivangi US. Feasibility study of epoxy coated Poly Lactic Acid as a sustainable replacement for river sand. J Clean Prod. 2020;267:121750.
9. Santhosh KG, Subhani SM, Bahurudeen A. Cleaner production of concrete by using industrial by-products as fine aggregate: A sustainable solution to excessive river sand mining. J Build Eng. 2021;42:102415.
10. Dinh HL, Liu J, Ong DEL, Doh JH. A sustainable solution to excessive river sand mining by utilizing by-products in concrete manufacturing: A state-of-the-art review. Clean Mater. déc 2022;6:100140.
11. Ge L, Feng Z, Sayed U, Li H. Research on the performance of seawater sea-sand concrete: A review. Constr Build Mater. 2023;409:133921.
12. Pranavan S, Srinivasan G. Investigation on behaviour of M-sand and sea sand based concrete. Mater Today Proc. 2021;45:7079-85.
13. Ioannidou D, Sonnemann G, Suh S. Do we have enough natural sand for low-carbon infrastructure? J Ind Ecol. 2020;24(5):1004-15.
14. Kong JS, Ababneh AN, Frangopol DM, Xi Y. Reliability analysis of chloride penetration in saturated concrete. Probabilistic Eng Mech. 2002;17(3):305-15.
15. Dias WPS, Seneviratne GAPSN, Nanayakkara SMA. Offshore sand for reinforced concrete. Constr Build Mater. juill 2008;22(7):1377-84.
16. Karthikeyan M, Nagarajan V. Chloride Analysis of Sea Sand for Making Concrete. Natl Acad Sci Lett. févr 2017;40(1):29-31.
17. Li T, Sun X, Shi F, Zhu Z, Wang D, Tian H, et al. The Mechanism of Anticorrosion Performance and Mechanical Property Differences between Seawater Sea-Sand and Freshwater River-Sand Ultra-High-Performance Polymer Cement Mortar (UHPC). Polymers. 2022;14(15):3105.
18. Li Q, Geng H, Huang Y, Shui Z. Chloride resistance of concrete with metakaolin addition and seawater mixing: A comparative study. Constr Build Mater. 2015;101:184-92.
19. Zhu J, Shen D, Jin B, Wu S. Theoretical investigation on the formation mechanism of carbonate ion in microbial self-healing concrete: Combined QC calculation and MD simulation. Constr Build Mater. 2022;342:128000.
20. Bouatiaoui MR, Alaoui AH. L'influence du sable de mer sur la durabilité du béton. In: CFM 2011-20ème Congrès Français de Mécanique. AFM, Maison de la Mécanique, 39/41 rue Louis Blanc-92400 Courbevoie; 2011. https://hal.science/hal-03420932v1
21. Su M ni, Wei L liang, Zeng Z wen, Ueda T, Xing F, Zhu JH. A solution for sea-sand reinforced concrete beams. Constr Build Mater. avr 2019;204:586-96.
22. Dhondy T, Remennikov A, Shiekh MN. Benefits of using sea sand and seawater in concrete: a comprehensive review. Aust J Struct Eng. 2019;20(4):280-9.
23. Moussaoui R, El Moudni El Alami S, Aouraghe H. Characterization of the Zellidja Lead Smelter Slag (Eastern Morocco) in order to their Valorization in Civil Engineering. J Ecol Eng. 2019;20(8):71-81.
24. Moussaoui R, El Moudni El Alami S, Aouraghe H. Valorization of the Zellidja Lead Smelter Slag (Eastern Morocco) in Road Building. Int J Pavement Res Technol. 2024;17(6):1620-36.
25. Hachmi DE, Bensalah MO, Moussaoui R, Bergui SE, Zoubair AB, Chakchak H, et al. Original Mortar Characterization of the Ramparts of Salé Medina in Morocco. Civ Eng Archit. 2024;12(4):2557-66.
26. Hachmi DE, Moussaoui R, Bergui SE, Aqil M, Bouayadi RE, Saad A, et al. Energy valorization of the authentic rammed earth of the Sale medina ramparts in Morocco. Sustain Mediterr Constr. 2024;19:85-62.
27. IMANOR. Essais pour déterminer les caractéristiques géométriques des granulats - Partie 1: Détermination de la granularité - Analyse granulométrique par tamisage. NM EN 933-1. Institut Marocain de Normalisation, Maroc. 2018. https://www.imanor.gov.ma/Norme/nm-en-933-

1/
28. IMANOR. Essais pour déterminer les caractéristiques géométriques des granulats - Partie 3: Détermination de la forme des granulats - Coefficient d'aplatissement. NM EN 933-3. Institut Marocain de Normalisation, Maroc. 2017. https://www.imanor.gov.ma/Norme/nm-en-933-3/
29. IMANOR. Essais pour déterminer les caractéristiques mécaniques et physiques des granulats - Partie 2: Méthodes pour la détermination de la résistance à la fragmentation. NM EN 1097-2. Institut Marocain de Normalisation, Maroc. 2022. https://www.imanor.gov.ma/Norme/nm-en-1097-2/
30. IMANOR. Essais pour déterminer les caractéristiques géométriques des granulats - Partie 8: Evaluation des fines - Équivalent de sable. NM EN 933-8. Institut Marocain de Normalisation, Maroc. 2022. https://www.imanor.gov.ma/Norme/nm-en-933-8/
31. Elat E, Pliya P, Pierre A, Mbessa M, Noumowé A. Microstructure and Mechanical Behavior of Concrete Based on Crushed Sand Combined with Alluvial Sand. CivilEng. 2020;1(3):181-97.
32. SNIMA. Granulats pour bétons hydrauliques - Définitions, spécifications, conformité. NM 10.1.271. Service de Normalisation Industrielle Marocaine, Maroc. 2008. https://www.imanor.gov.ma/wp-content/uploads/2016/08/RCNM027-Règles-NM-Granulats-v01.pdf
33. AFNOR. Granulats pour béton. NF EN 12620+A1. Association Française de Normalisation, France. 2008. https://www.boutique.afnor.org/fr-fr/norme/nf-en-12620-a1/granulats-pour-beton/fa157250/31276
34. IMANOR. Essais pour béton durci - Partie 3: Résistance à la compression des éprouvettes. NM EN 12390-3. Institut Marocain de Normalisation, Maroc. 2021. https://www.imanor.gov.ma/Norme/nm-en-12390-3/
35. IMANOR. Essais pour béton durci - Partie 1: Forme, dimensions et autres exigences aux éprouvettes et aux moules. NM EN 12390-1. Institut Marocain de Normalisation, Maroc. 2021. https://www.imanor.gov.ma/Norme/nm-en-12390-1/
36. IMANOR. Essais pour béton durci - Partie 2: Confection et conservation des éprouvettes pour essais de résistance. NM EN 12390-2. Institut Marocain de Normalisation, Maroc. 2021. https://www.imanor.gov.ma/Norme/nm-en-12390-2/
37. Thunga K, T VD. An experimental investigation on concrete with replacement of treated sea sand as fine aggregate. Mater Today Proc. 2020;27:1017-23.
38. Guo M, Hu B, Xing F, Zhou X, Sun M, Sui L, et al. Characterization of the mechanical properties of eco-friendly concrete made with untreated sea sand and seawater based on statistical analysis. Constr Build Mater. 2020;234:117339.
39. Hasdemir S, Tuğrul A, Yılmaz M. The effect of natural sand composition on concrete strength. Constr Build Mater. 2016;112:940-8.