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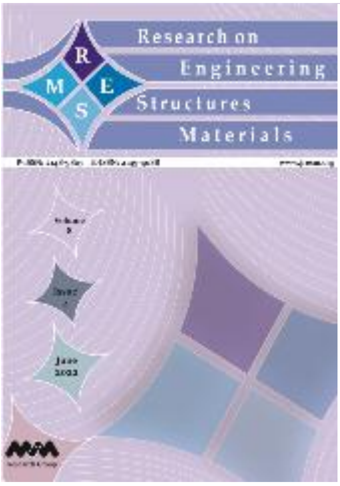

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Research Article

Effect of sea sand in the behaviour of fresh concrete partially replaced with M-sand

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Abstract

The research paper aims to address the environmental challenges caused by uncontrolled river sand mining in various regions of the country. Indiscriminate mining has led to multiple issues, necessitating restrictions on river sand extraction, but these restrictions have also affected the building industry's stability. As a solution, exploring cost-effective alternative materials for cement production becomes essential to promote resource utilization and efficiency in the construction sector. The study focuses on using excavated marine sand as a fine aggregate to develop enduring and resilient concrete. Partial replacement of river sand and manufactured sand (MS) with dredged sea sand (DSS) is conducted to understand the benefits of the proposed concrete in terms of strength and durability compared to traditional concrete made of river sand (RS). This investigation is significant in the current scenario to assess the potential of DSS as a building material. The methodology employed includes grading analysis, assessment of flexural and compressive strength, evaluation of water absorption, alkalinity testing, rapid chloride penetration test, bond strength examination, and sorptivity assessment. The research aims to determine the behavior of fresh concrete with sea sand as a partial replacement for traditional sands, ultimately contributing to more eco-friendly and resource-efficient construction practices. The gradation has been done in three different proportions say 10, 20, and 30%. The results indicate that for all the mixes the compressive strength of the cylinder shows an average value of 0.83 times the strength of the cubes, while the flexural strength value ($K\sqrt{fck}$) shows an average of 0.69 times the strength of the cubes for all the mixes. RCPT and Water Absorption results show an average value of 1775 and 3.96 respectively which is within the limit specified. The addition of MS improves the alkalinity of concrete and the result was in accordance with ASTM D 4262. The bond strength increases with an increase in the replacement of sea sand and sorptivity decreases with an increase in the replacement of sea sand. This is indeed a study of the strength of concrete and toughness using MS as a partial replacement for dredged sand. The analysis shows that a 30% replacement of dredged sea sand with MS does not impact the overall strength of concrete, ensuring satisfactory strength and durability.

1. Introduction

Uncontrolled river sand mining in India for construction causes severe environmental challenges, including river bank erosion, biodiversity loss, lowered water tables, groundwater contamination, flooding, sedimentation, siltation, altered landscapes, social

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conflicts, and illegal activities. Sustainable alternatives and stringent regulations are vital to address these impacts and promote responsible mining practices. It is seen nowadays that there is a scarcity of river sand (RS) due to an increase in the construction industry and other major environmental issues. Because of its readiness, ease of mining, ample source, and price benefits, marine sand is considered an effective alternative to other sands [1 & 2]. The corrosion impact caused by chloride ions and the stability of reinforced concrete members has been a major concern while making sea-sand concrete. [3–6].

On the other hand, how would dredge sea sand (DSS) affect the output of the concrete? Various research has indicated different findings [7-10]. Liu et al. discovered that the workability of concrete, compressive strength, elastic modulus, and flexural strength with marine sand possessing fewer sodium and shells were unaffected [11]. If Cl-induced rust is not a concern, both cleaned and unclean marine sand should be used in place of river sand in concrete. According to Chandrakeerthy et al [12], Marine sand concrete has a compressive strength lower than that of conventional concrete. Limeira et al [13–15] demonstrated that marine sand could be effectively used as a fine aggregate for construction purposes because of the similar mechanical and physical properties of marine sand concrete compared to standard concrete. Various researchers [16-18], on the other hand, discovered that the compressive strength of marine sand concrete was lower than that of normal concrete after 28 days. Jau et al. [21] concluded that after investigating 35 weeks of accelerated corrosion tests under wet-dry cycles on marine sand concrete, the cylinder compressive strength was found to show enhancement in strength during the initial phase and reached a maximum value at the age of 21 weeks. However, the strength was found to decrease by about 5%–8% at the age of 35 weeks.

According to Shuai Wu's research [22], on the crust of beach sand, there may be microfilm that includes chemical substances and organic compounds which are constituents of marine water. The appearance of a film on such sand will affect the mechanical properties of marine sand concrete. Other studies [23–29] have discovered that the particle size of sea sand influences the interlocking characteristics of cement thereby the strength of concrete. Saeed Moradi et al [30] used dredged marine sediments (DMS) to replace sands obtained from quarries with different percentages and discovered that replacing DMS material enhanced the particle packing density of a cementitious system, which was due to the particles obstruction of capillary pores. Under pressure, the availability of pores, sorptivity, and water penetration depth was maintained or decreased when raw sand was replaced with DMS. According to Matthew Zhi Yeon Ting et al. [31], incorporating silicomanganese slag with sea sand reduced the compressive and tensile strengths of concrete by 9.2% and 17.5%, respectively. In terms of sorptivity and chloride penetration, however, sea sand enhanced concrete's durability by at least 42.3 percent and 11.5 percent, respectively. Norpadzlihatun Manap et al [32] investigates that, the strength of concrete made with sediments (sand) from Sungai Bebar replacing % of sand and aggregate components is 30.6 N/mm2 after 28 days of curing, while the strength of concrete made with silt from Kuala Perlis as an additive is 48.8 N/mm2 after 28 days of curing.

The most commonly used fine aggregate in concrete is river sand, but extensive processing of stream sand and gravel causes river degradation. The stream bottom is lowered by in-stream mixing, which can contribute to bank erosion. As a result, the government imposed some restrictions on river sand mining. Today Manufactured sand (MS) is used as fine aggregate in concrete. MS unlike natural sand is not smooth and round; hence more water and cement are required to sustain the workability of concrete. The use of dredged marine sand to make green and robust concrete may be a perfect remedy to the engineering industry's problems.

2. Need and Scope of the Study

The dredged sea sand has been collected from the Puthuvypeen beach area after getting special permission from Cochin Port Trust. The Port is now dumping around 21 million cubic meters per annum of dredging material in the permitted dumping zone in the sea, 20 kilometers from the beach [35]. Previously, attempts were attempted to utilize the waste in landfills or as bio-fertilizers. However, attempts have so far achieved no beneficial results due to the presence of heavy metals on one hand, and difficulties in removing the material from the Port's following suction hopper dredgers on the other. The Port has decided to focus its efforts in the Puthuvypeen area, where land is accessible. Every year, it is estimated that 4 million cubic meters of sand are dredged from an area of around 8 kilometers in the shipping channel for smooth ship movement and thrown in the open sea. The government has been looking into ways to cut the net cost of maintenance dredging. The use of dredge material was one of the recommendations made in this regard.

3. Materials Used and Properties

3.1. Cement

Cement is a substance used in construction that sets, hardens, and adheres to other materials in order to bind them together. Cement is seldom used on its own; rather, it is utilized to hold sand and aggregate together. The properties of Ordinary Portland Cement (OPC) 53-grade cement with a specific gravity of 3.14 were tested according to IS: 12269-2013 [38], and IS 4031- 4:1988 [39] regulations, as shown in Table 1.

3.2. Fine Aggregates

3.2.1. Dredged Sea Sand

The foreseeable need for river sand and M-sand as fine aggregate in the construction sector is almost fulfilled by sea sand. The sea sand samples were taken from the Puthuvypeen area, which lies close to the Arabian Sea coast. The sand samples were collected from the seabed which is approximately 7 – 8km away from the seashore by using the method of dredging. Also, the sea sand samples were subjected to rainfall for roughly a year and practically all the chlorine content was washed out because sand is an inert material. Dredged sea sand (DSS) used as a substitute for MS was in accordance with Zone IV. Specific gravity and water absorption of DSS were 2.28 and 5.9 percent respectively.

3.2.2. Manufactured Sand

In the construction industry, Manufactured sand (MS) is a substitute for river sand in concrete, and it is made from hard granite stones crushed in a quarry. Crushed sand from cubical rocks or stones with grounded edges is washed and processed for use as a construction material. The MS used for the concrete contains crushed powder and granite grains with a size of less than 4.75 mm. MS with a specific gravity of 2.59 and water absorption of 3.4% conforming to IS 383-2016 [36] was used as a partial replacement for sea sand. MS was partially replaced with 10%, 20%, and 30% of DSS.

3.3. Coarse Aggregates

In concrete, crushed granite stone coarse aggregate with a size of less than 20 mm is used as the major matrix component. According to IS 383–2016 [36], the aggregate size used in the concrete mix should be retained on a sieve having a 4.75 mm size. The coarse aggregate (CA) used in this investigation was found to have a specific gravity of 2.76 and water absorption of 1.2 percent. M sand used for the research work has been collected from S K Traders and M Sand Supplier, Coimbatore. MS features angular/cubical particles with consistent gradation, controlled moisture content (2-6%), minimal fines content (0-15%), and absence of organic impurities, it has a density of 1850 kg/m^3 and adheres to construction standards IS 383-2016 [36] for optimal workability, strength, and durability in concrete.

Table 1. Outlines the properties of all materials

Properties		Cement	Fine Aggregate		Coarse aggregates
			MS	DSS	
Normal consistency		28.60%	-	-	-
setting time (min)	Initial	161	-	-	-
	Final	259	-	-	-
Specific gravity		3.24	2.59	2.28	2.76
Impact factor		-	-	-	23.1%
Crushing value		-	-	-	19.4%
Water absorption		-	3.4%	5.9%	0.7%
Zone		-	II	IV	-

4. Methodology

4.1. Grading

The Sea sand was classified into the appropriate zone by means of sieving using a standard set of sieves as per IS 383-2016 [36]. The grading of sea sand indicates that they are very fine and hence need to go for gap grading with the replacement of MS which helps to maintain the particle size distribution curve lies within the boundary of zone III. Gap grading improves particle distribution, workability, and aggregate packing when mixing dredged sea sand with M sand, resulting in better concrete or mortar properties, including higher strength and durability, reduced risk of segregation, and optimized use of materials for a more sustainable construction process. M sand and Sea sand were taken and the samples were allowed to pass through standard sieves 4.75mm to 0.75micron size. After drawing the particle size distribution curve of Sea sand, a major portion of samples goes outside zone 4, according to IS 383 – 2016 [36] Table 9, Note 4: It is recommended that fine aggregate conforming to Grading Zone IV should not be used in reinforced concrete. Hence gap grading was done, i.e., samples passing through 4.75 to 600 microns of sea sand were taken in different proportions, 10, 20, and, 30% and the portion was filled with samples retained in 300 microns, 150 microns, and 75 microns sieve in different proportions say 10, 20 and 30% respectively.

4.2. Flexural Strength

Beams of size 100 x 100 x 500mm were cast, cured, and tested for 28 days in accordance with IS 516-2021 [37] in the Universal Testing Machine for flexure.

4.3. Compressive Strength

Cubes are the most common shape used for compressive strength testing because they are easy to manufacture and handle. Cylinders are also used for compressive strength testing which helps to ensure a comprehensive evaluation of concrete made with sea sand, considering material variability and different stress distributions during compressive strength testing. In accordance with IS 516-2021[37], Cubes of size 150 x 150 x 150mm and cylinders of size 150 x 300mm were cast, cured, and tested for 28 days in the Compression Testing Machine.

Fig. 1. Compressive strength test arrangement for Cylinder and cube

4.4. Water Absorption

According to ASTM C 140 [40], 100mmx100mmx100mm size cubes were cast and cured for 28 days. For testing, it was oven-dried at 100^{o}C for 24 hours and the dry weight of the specimen was taken. The specimen was then immersed in the water for 24 hours and then the wet weight was taken.

$$\%\ water\ absorption = \left(\frac{wet\ weight - dry\ weight}{dryweight} \right) \times 100 \qquad (1)$$

4.5. Alkalinity Test

The sample for the test was obtained by crushing the concrete cube from which a portion of the cement mortar was collected in accordance with ASTM D 4262 [41]. The cement mortar passing through a 50 microns sieve was collected as a sample for the test. 10g of the obtained material was taken in a glass beaker and mixed with 50 ml of distilled water and stirred in a Jar test apparatus till the particles settle down at the bottom. Then Alkalinity of surface water was determined using a pH meter.

4.6. Rapid Chloride Penetration Test

According to ASTM C 1202 [42], Concrete samples were cast using standard 100 mm x 50 mm x 50mm size moulds. The samples were stored for a period of time in vacuum desiccators until it is submerged in water and the sample is inundated. The samples were then secured within the two chambers of the diffuser cell. A solution of NaCl was used in the first chamber, a and NaOH solution was used in the second. 60V electrical current was connected to the diffuser cells. The readings were taken at 30-minute intervals for 6 hours.

4.7. Bond Strength

To determine the pullout strength of concrete made with partial replacement of MS with dredged sea sand, a steel rod is inserted into the concrete cube at the time of casting itself. After curing for 28 days, the specimens were tested for their pullout strength according to IS 2770 (Part 1): 1967 [43]

4.8. Sorptivity Test

The water sorptivity test is conducted to determine the rate of water movement under capillary suction through the concrete. It is highly sensitive with respect to the microstructural properties of the concrete near-surface region and thus represents the nature and efficacy of the curing process. The sorptivity can be determined by the measurement of the absorption rate due to capillary rise on reasonably homogeneous material. Sorptivity test based on ASTM C 642: 2021 [44] codes. In addition to the water sorptivity test, surface wettability can also be performed to estimate the durability of cementitious systems [33] [34]. Surface wettability refers to how readily the concrete's surface allows water to spread and penetrate. A surface with high wettability may indicate reduced durability and potential issues with water ingress and subsequent deterioration. Together, the water sorptivity test and surface wettability evaluation provide valuable insights into the concrete's quality, curing effectiveness, and potential long-term durability.

4.9. Mixture Design

It has been discovered that coastal sand comprises about 50% of particles that are smaller than 300 microns, which become unsuitable for concrete production. The particles were finer than 300 microns were separated from sea sand using sieves. Instead of discarded sea sand particles, MS passing through 300 microns was mixed in 10, 20, and 30 percentages to study the possible improvement of the properties of fine aggregate in concrete. M20, M25, and M30 grades of concrete mixes adopted in this investigation were designed as per IS 10262-2009 [45]. According to the results obtained from the mix design, the water-cement ratio was calculated as 0.55, 0.5, and 0.45 for M20, M25, and M30 grades respectively. The identification details of the specimens are given in Table 2.

Table 2 Details for Sample Identification

Sl No	Specimen ID	Label	Sl No	Specimen ID	Label
1	20(100% DSS)	SP1	15	25(30% MS + 70% DSS)	SP15
2	20(100% MS)	SP2	16	25(10% RS+ 90% DSS)	SP16
3	20(100% RS)	SP3	17	25(20% RS + 80% DSS)	SP17
4	20(10% MS+ 90% DSS)	SP4	18	25(30% RS + 70% DSS)	SP18
5	20(20% MS + 80% DSS)	SP5	19	30(100% DSS)	SP19
6	20(30% MS + 70% DSS)	SP6	20	30(100% MS)	SP20
7	20(10% RS+ 90% DSS)	SP7	21	30(100% RS)	SP21
8	20(20% RS + 80% DSS)	SP8	22	30(10% MS+ 90% DSS)	SP22
9	20(30% RS + 70% DSS)	SP9	23	30(20% MS + 80% DSS)	SP23
10	25(100% DSS)	SP10	24	30(30% MS + 70% DSS)	SP24
11	25(100% MS)	SP11	25	30(10% RS+ 90% DSS)	SP25
12	25(100% RS)	SP12	26	30(20% RS + 80% DSS)	SP26
13	25(10% MS+ 90% DSS)	SP13	27	30(30% RS + 70% DSS)	SP27
14	25(20% MS + 80% DSS)	SP14			

5. Results and Discussions

5.1. Sea Sand Grading

The sieve analysis was carried out for dredged sea sand and an attempt was made to compare the obtained grading with the grading zones specified by IS 383-2016 [36] for the Zones III and IV. Figures 2a and 2b show the comparison of the grading of dredged sea sand with Zone III and Zone IV separately. While observing the graphs, it was found that the grading of sea sand falls closer to the Zone IV classification of sand. However, the grading line obtained for sea sand while sieving through 300 microns sieve was found to fall outside the boundaries of Zone IV classification according to the IS Code.

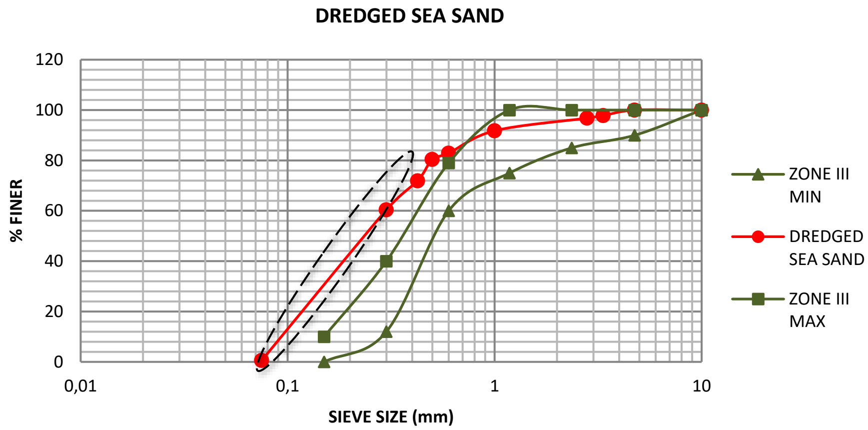

Fig. 2a Particle size distribution curve for sea sand in comparison with Zone III grading limits

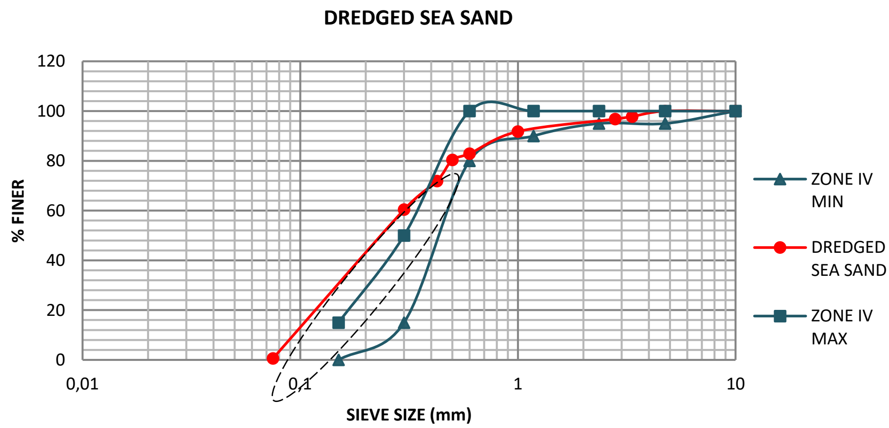

Fig. 2b Particle size distribution curve for sea sand in comparison with Zone IV grading limits

Sieve analysis was also carried out for MS that was used in this investigation and it was found that the grading curve of MS was well within the lower and upper limits of Zone III as per IS Code. This is depicted in Figure 3.

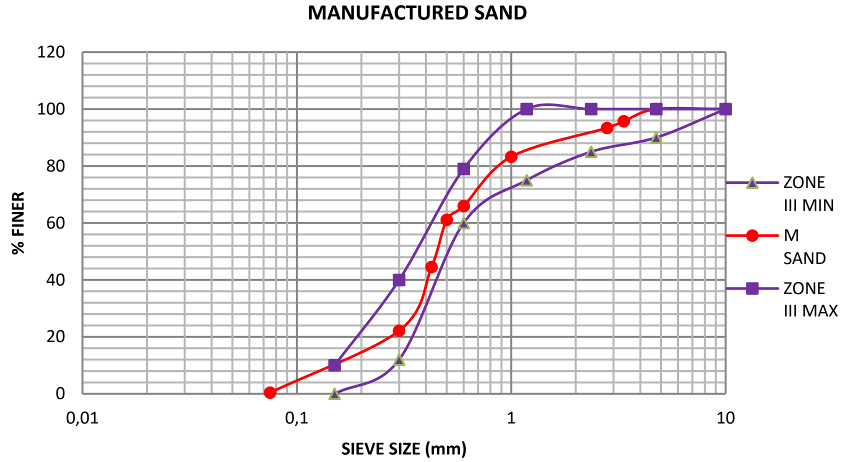

Fig. 3 Particle size distribution curve for MS in comparison with Zone III grading limits

5.2. Gap Grading of Sea Sand with MS

In this investigation, MS was taken as a partial replacement for sea sand. The too-fine portion of sea sand i.e., the sand particles passing through 300 microns sieve were replaced with MS passing through the same sieve. M sand and Sea sand were taken and the samples were allowed to pass through standard sieves 4.75mm to 0.75micron size. After drawing the particle size distribution curve of Sea sand, a major portion of samples goes outside zone 4, according to IS 383 – 2016 [36] Table 9, Note 4: It is recommended that fine aggregate conforming to Grading Zone IV should not be used in reinforced concrete.

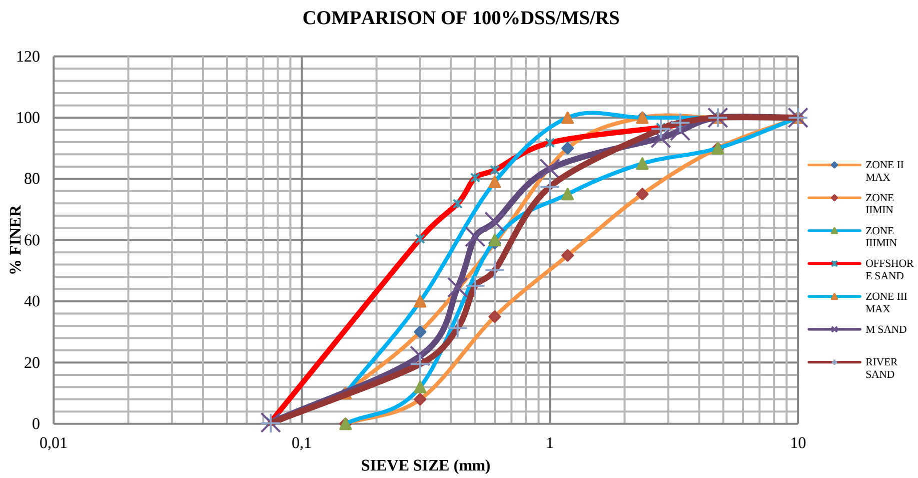

Fig. 4 Particle size distribution curve for 100% DSS/MS/RS in comparison with Zone II & III grading limits

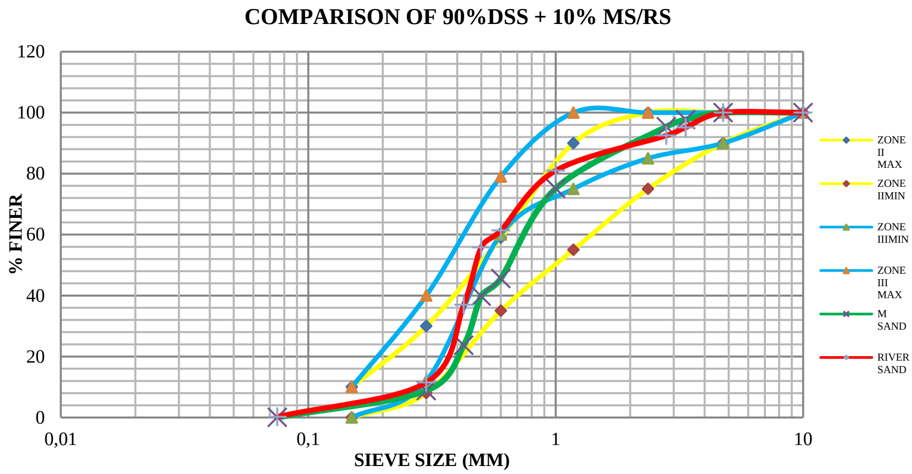

Fig. 5 Particle size distribution curve for 90% DSS + 10%MS/RS in comparison with Zone II & III grading limits

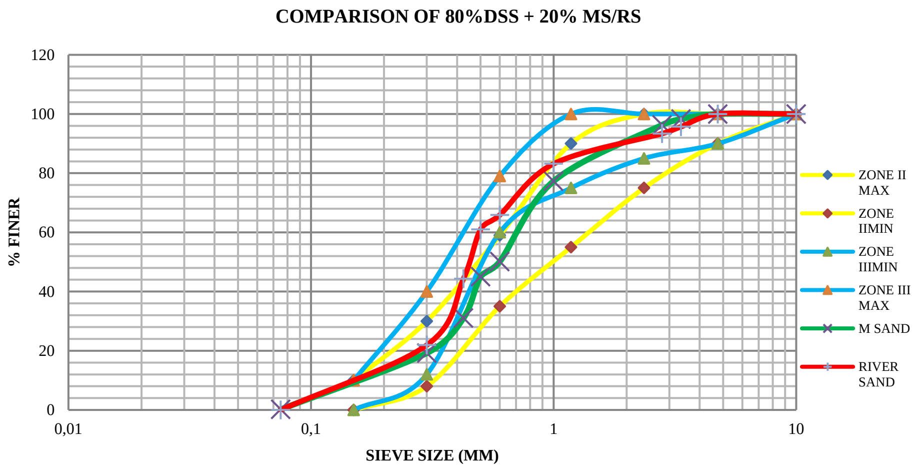

Fig. 6 Particle size distribution curve for 80% DSS + 20%MS/RS in comparison with Zone II & III grading limits

Hence gap grading was done, i.e., samples passing through 4.75 to 600 microns of sea sand were taken in different proportions, 10, 20, and 30% and the portion was filled with samples retained in 300 microns, 150 microns, and 75 microns sieve in different proportions say 10, 20 and 30% respectively.

To understand the comparison between 100% DSS, 100% MS, and 100% RS clearly, a particle size distribution curve has been drawn in comparison with Zone II & III grading limits which is depicted in Fig 4. Fig 5, 6, and 7 show the comparison of gap-graded DSS with MS as well as RS in different proportions say 10%, 20%, and 30% respectively.

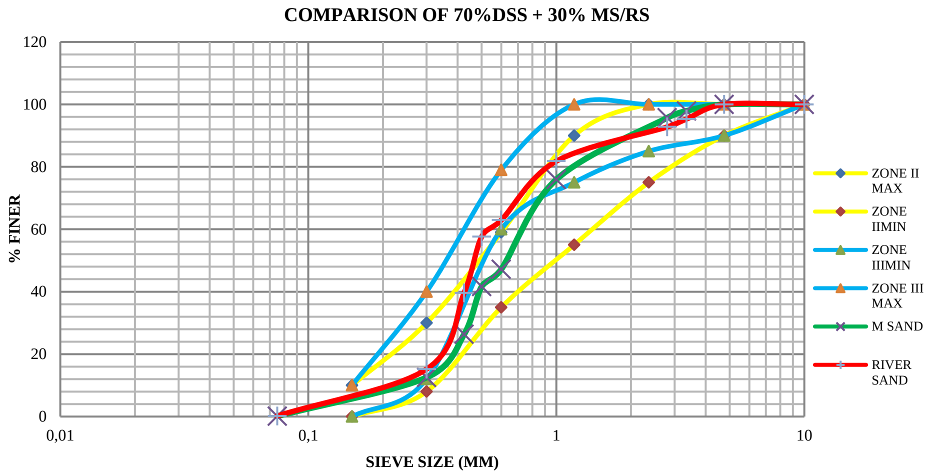

Fig. 7 Particle size distribution curve for 70% DSS + 30%MS/RS in comparison with Zone II & III grading limits

5.3. Compressive Strength

Cube and cylinder specimens were cast, cured, and evaluated for 28-day compressive strength to investigate the compressive strength of concrete specimens while DSS was replaced with MS. Figure 8 and 9 shows the comparison of various specimens' cube and cylinder compressive strengths.

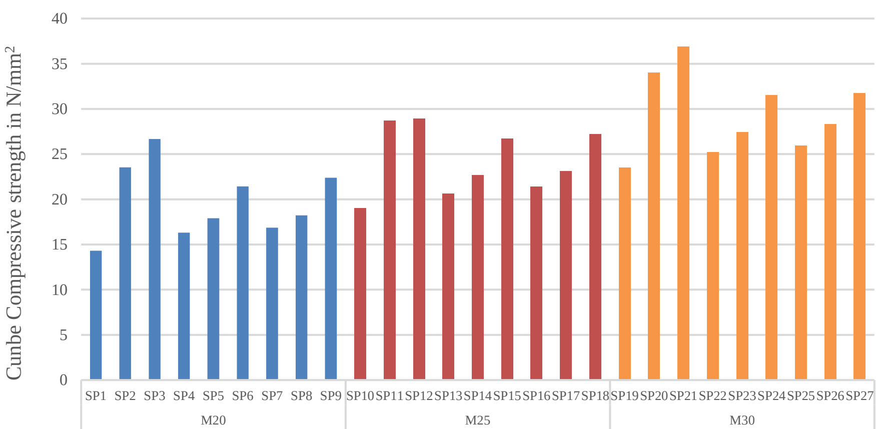

Fig. 8 28 days Cube Compressive Strength

From Figure 9, it was found that the concrete made of DSS with 10%, 20%, and 30% of MS as a partial replacement was closely equal to the design target strength of M20, M25, and M30 grade concrete. On the same line, Deepak et al. [17] discovered that there is almost a 44% reduction in the compressive strength of concrete mixed with 40% river sand and 60% river sand.

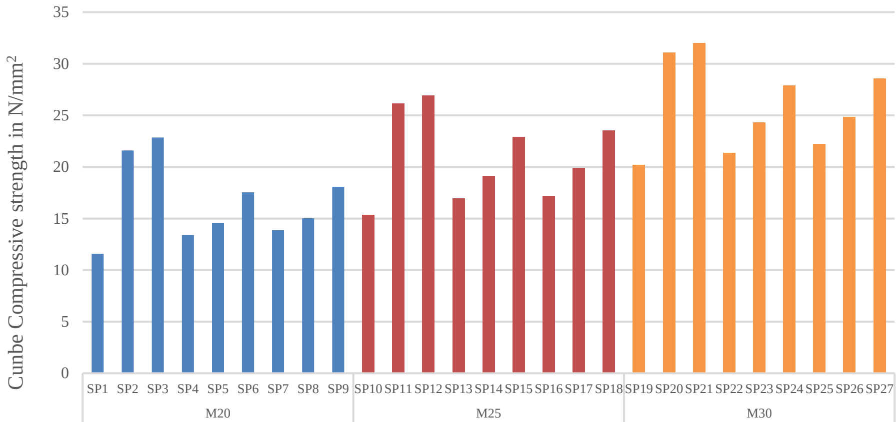

Fig. 9 28 days Cylinder Compressive Strength.

5.3.1. The Ratio Between Cube Compressive Strength and Cylinder Compressive Strength

The compressive strength of cylinder specimens with DSS partially replaced with or without MS was found to be around 0.85 times the compressive strength of cube specimens. This is in accordance with BS 1881: Part 120:1983 [46] i.e., the Strength of the cylinder is equal to 0.8 times the strength of cubes. Table 3 shows the details of the obtained ratios.

Table 3. Ratio between the strength test on cubic and cylindrical sample

Ratio Between the strength test on cubic and cylindrical sample			
Sample	Ratio	Sample	Ratio
SP1	0.81	SP15	0.86
SP2	0.92	SP16	0.81
SP3	0.86	SP17	0.86
SP4	0.82	SP18	0.87
SP5	0.81	SP19	0.86
SP6	0.82	SP20	0.91
SP7	0.82	SP21	0.87
SP8	0.82	SP22	0.85
SP9	0.81	SP23	0.89
SP10	0.81	SP24	0.89
SP11	0.91	SP25	0.86
SP12	0.93	SP26	0.88
SP13	0.82	SP27	0.90
SP14	0.84		

5.3.2. The Effect of The Grade of Concrete on The Strength Parameters

Overall, the concrete specimens with DSS demonstrated lower cube and cylinder compressive strength compared to the specified target strength. However, it was observed that as the grade of concrete increased, the extent of this reduction in compressive strength in relation to the design target strength gradually decreased. The specific data regarding this reduction for different grades of concrete and the DSS mix can be found in Table 4.

Table 4. Details of the reduction in Cube and Cylinder Strength

Specimens	SP1	SP10	SP19
Cube with 100% DSS	28.45%	24.00%	21.67%
Cylinder with 100% DSS	42.15%	38.64%	32.63%

5.4. Flexural Strength

By carrying out two-point loading, the flexural strength of different samples was calculated. The flexural resistance represents the strongest tension within the material and its moment of rupture.

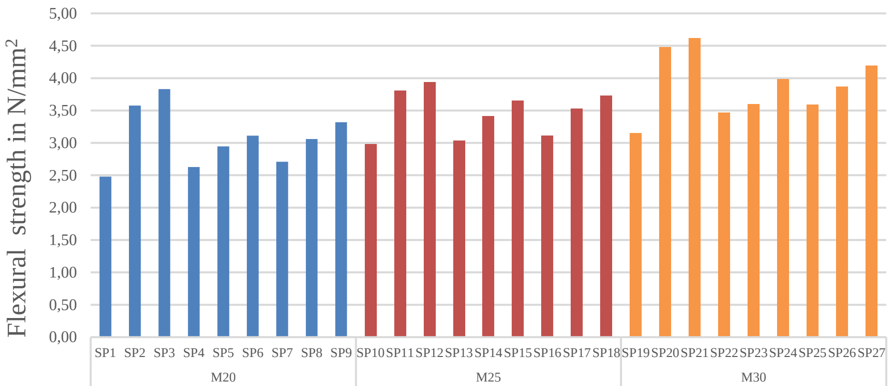

Fig. 10 Flexural Strength after 28 days

5.4.1. Flexural strength and compressive strength relation

Fig 10 shows the flexural strength of different concrete specimens. In accordance with IS 516-2021 [37], the flexural strength of concrete beam specimens with dredged sea sand partially replaced with or without MS was calculated as per IS 456-2000 [47]. S. Pranavan [18] observed that the percentage of flexural strength results increases on the addition of MS in concrete. Table 5 shows the details of the obtained values.

Table 5. K values for dredged sea sand with partial replacement of MS

Indirect tensile strength due to bending, ft in terms of fck ($f_t=K\sqrt{(f_{ck})}$)			
Sample	Ratio	Sample	Ratio
SP1	0.66	SP15	0.71
SP2	0.74	SP16	0.67
SP3	0.74	SP17	0.73
SP4	0.65	SP18	0.72
SP5	0.70	SP19	0.65
SP6	0.67	SP20	0.77
SP7	0.66	SP21	0.76
SP8	0.72	SP22	0.69
SP9	0.70	SP23	0.69
SP10	0.68	SP24	0.71
SP11	0.71	SP25	0.71
SP12	0.73	SP26	0.73
SP13	0.67	SP27	0.74
SP14	0.72		

5.5. Rapid Chloride Penetration Test

The average current passing various samples were calculated. The outcomes of various models are shown in Figure 11.

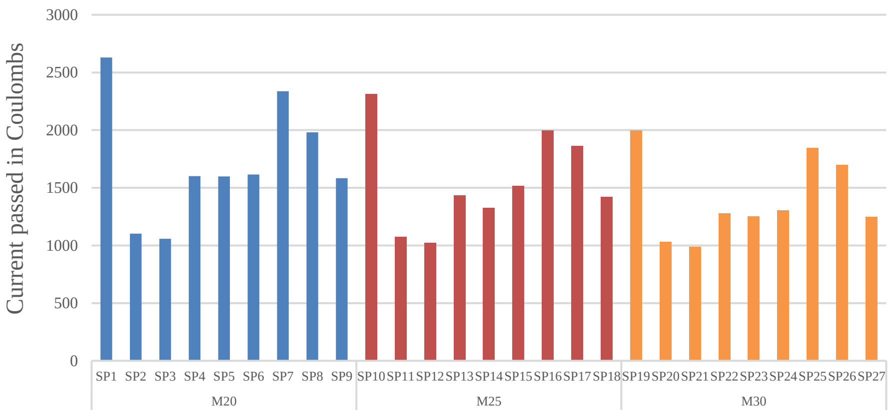

Fig. 11 Chloride penetration in Coulombs

According to ASTM C 1202 [42], the average current that flows through the Conventional concrete sample of concrete ranges between 1000 & 4000 coulombs. From the experimental investigation, it was found that the average chloride penetration through the specimens made with DSS partially replaced with or without MS is 1791 which is well within the limit specified by ASTM C 1202 [42]. The presence of MS as a partial replacement of DSS was found to improve the resistance to Chloride penetration. This is owing to the reason that the quality of DSS while partially replaced with MS improves the quality of the sand by filling the finer side of the fine aggregate. It is worth mentioning that B S Dhanya et al [28] found similar results that, as the Supplementary cementitious material dosage increases, the charge passed gets decreased, thereby improvement in the concrete quality.

5.6. Water Absorption

Figure 12 displays the results of calculating the proportions for water absorbed by various specimens.

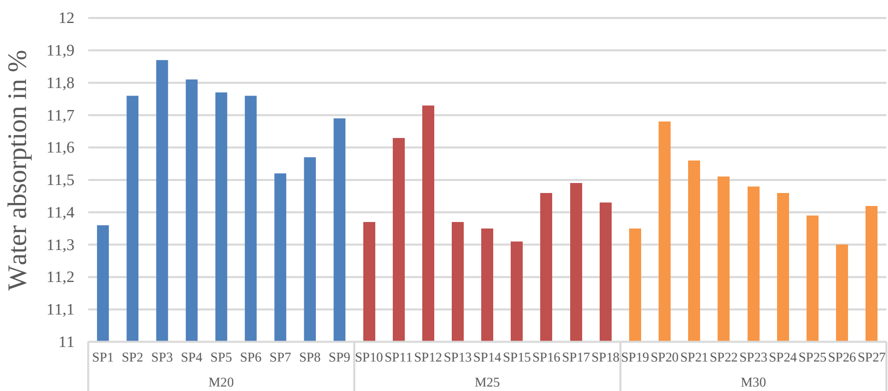

Fig. 12 Percentage of water absorption

5.7. Alkalinity Test

The alkalinities of different samples were calculated and are shown in Figure 9.

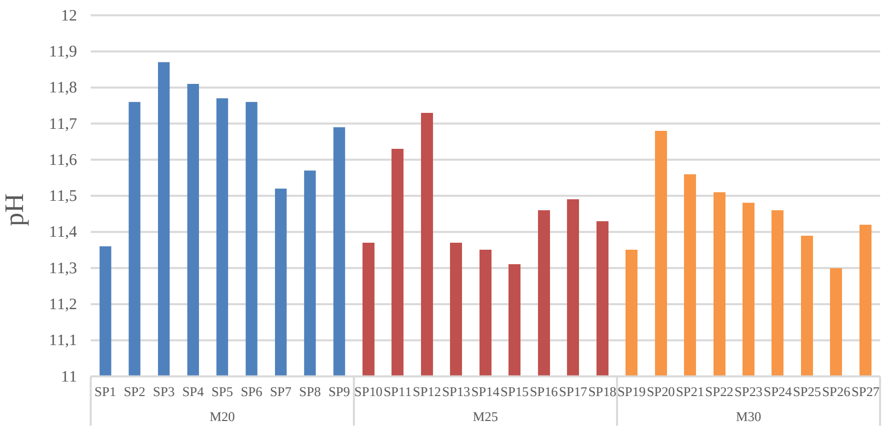

Fig. 13 Alkalinity test result after 28 days

The DSS has been collected from a dumping area near Puthuvypeen, also a major portion of the chloride content has been washed out because the sand samples were subjected to rainfall for roughly a year. According to ASTM D 4262 [41], healthy concrete has a high pH of 12 – pH 13.3 whereas in newly cured concrete it is expected to be between 11 and 13.5. The Alkalinity of concrete specimens made with DSS partially replaced with or without MS was found to be an average of 11.47. It was found that the addition of MS as a partial replacement for dredged sea sand improves the alkalinity of concrete.

5.8. Bond Strength

The bond strength of all mixtures was tested on specimens with reinforcement bars having 16 mm diameter. A pull-out test was done to find out bond strength. According to Adarsh M S [26] concrete specimens covered with mortar made with 15% dredged marine sand showed better results with higher bond strength when compared to concrete made with mortar composed of fine aggregate only. Table 6 displays the test results of the bond strength of specimens.

Table 6. Pull-out test results of specimens

Bond strength of Corroded specimen							
Mix	Specimen	Maximum load (kN)	Bond strength N/mm^2	Mix	Specimen	Maximum load (kN)	Bond strength N/mm^2
M20	SP1	13.98	0.27	M30	SP19	16.03	0.38
	SP2	22.79	0.51		SP20	32.60	0.64
	SP3	23.39	0.54		SP21	34.01	0.67
	SP4	15.21	0.31		SP22	17.45	0.44
	SP5	16.39	0.38		SP23	19.61	0.51
	SP6	19.98	0.42		SP24	23.42	0.58
	SP7	15.62	0.34		SP25	18.55	0.47
	SP8	17.03	0.39		SP26	20.39	0.56
	SP9	20.23	0.45		SP27	24.69	0.61

	SP10	14.70	0.32
	SP11	24.10	0.56
	SP12	25.81	0.60
	SP13	15.99	0.38
M25	SP14	16.78	0.43
	SP15	20.86	0.50
	SP16	16.30	0.40
	SP17	17.99	0.47
	SP18	22.20	0.53

5.9. Sorptivity Result

The Sorptivity expresses the tendency of a material to absorb and transmit water and other liquids by capillarity. The greater the absorption and flowability, the more corrosion of steel rods may happen fast which weakens the structural component. The sorptivity values of various mixes are shown in Table 7. The result shows a decrease in sorptivity with an increase in the sea sand proportion.

Table 7(a) Sorptivity results for M20 Grade Concrete

	Specimen of M20 grade (mm/m)								
Time (Min)	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9
0	197.56	144.41	142.12	185.72	181.38	175.90	184.32	179.78	174.10
5	197.56	144.41	142.12	185.76	181.45	175.86	184.36	179.85	174.06
10	197.56	144.42	142.13	185.82	181.39	175.80	184.42	179.79	174.00
20	197.56	144.42	142.14	185.82	181.45	175.83	184.42	179.85	174.03
30	197.57	144.39	142.16	185.81	181.43	175.81	184.41	179.83	174.01
60	197.57	144.40	142.16	185.84	181.43	175.79	184.44	179.83	173.99
120	197.58	144.40	142.18	185.87	181.45	175.78	184.47	179.85	173.98
180	197.59	144.42	142.18	185.95	181.42	175.74	184.55	179.82	173.94
240	197.61	144.44	142.18	185.97	181.44	175.79	184.57	179.84	173.99
300	197.61	144.45	142.20	185.97	181.44	175.90	184.57	179.84	174.10

Table 7(b) Sorptivity results for M25 Grade Concrete

	Specimen of M25 grade (mm/m)								
Time (Min)	SP10	SP11	SP12	SP13	SP14	SP15	SP16	SP17	SP18
0	189.03	142.37	139.45	174.23	158.05	152.57	172.73	156.25	150.47
5	189.03	142.37	139.46	174.24	158.13	152.54	172.74	156.33	150.44
10	189.03	142.38	139.48	174.24	158.07	152.48	172.74	156.27	150.38
20	189.19	142.38	140.88	174.26	158.15	152.53	172.76	156.35	150.43
30	189.19	142.38	142.03	174.26	158.12	152.50	172.76	156.32	150.40
60	189.27	142.41	144.74	174.27	158.13	152.49	172.77	156.33	150.39

120	189.27	142.41	147.66	174.29	158.16	152.49	172.79	156.36	150.39
180	189.27	142.42	147.98	174.32	158.15	152.47	172.82	156.35	150.37
240	189.39	142.42	148.01	174.32	158.15	152.50	172.82	156.35	150.40
300	189.40	142.43	149.23	174.32	158.15	152.61	172.82	156.35	150.51

Table 7(c): Sorptivity results for M30 Grade Concrete

	Specimen of M30 grade (mm/m)								
Time (Min)	SP19	SP20	SP21	SP22	SP23	SP24	SP25	SP26	SP27
0	173.82	120.67	118.87	161.98	145.80	140.32	160.28	144.20	138.52
5	173.82	120.67	118.87	162.02	145.91	140.32	160.32	144.31	138.52
10	173.82	120.68	118.88	162.08	145.91	140.32	160.38	144.31	138.52
20	173.82	120.68	118.88	162.08	145.97	140.35	160.38	144.37	138.55
30	173.87	120.69	118.89	162.11	145.97	140.35	160.41	144.37	138.55
60	173.87	120.70	118.90	162.14	146.00	140.36	160.44	144.40	138.56
120	173.88	120.70	118.90	162.17	146.04	140.37	160.47	144.44	138.57
180	173.88	120.71	118.91	162.24	146.07	140.39	160.54	144.47	138.59
240	173.88	120.71	118.91	162.24	146.07	140.42	160.54	144.47	138.62
300	173.88	120.72	118.92	162.24	146.07	140.53	160.54	144.47	138.73

From the tables 7(a), 7(b), and 7(c) it was found that the Sorptivity is of lower value in the case of concrete made with 100% MS. In the case of concrete with 100% dredged sea sand, the sorptivity value was higher by about 44%. By the addition of MS in Concrete as a partial replacement to dredged sea sand, the sorptivity value was found to be 24% lower than the specimens made with MS. From the observation by Davoud Vafae et al [19] replacing fresh water and normal sand with sea water and dredged sea sand results in a significant reduction in sorptivity parameters.

6. Conclusions

This paper investigates the behavior of dredged sea sand partially replaced with manufactured sand in concrete.

- According to the literature review, practically all prior studies were carried out by replacing fine aggregate directly into concrete in varied proportions. Hence, the method gap grading is adopted in the present experimental investigation which helps to maintain the particle size distribution curve lies within the boundaries of Zone III as per IS 383- 2016 [36].
- After partially substituting dredged sea sand with 10%, 20%, and 30% MS, the grade of dredged sea sand was found to be improved and the grading curve of the composition lies within the boundaries of Zone III. 28 days Cube Compressive Strength of 100% dredged sea sand was 46% lesser than that of MS, however partial replacement of dredged sea sand with 10, 20, and 30% of MS has shown improvement in the strength of concrete. Additionally, the compressive strength of the cube and cylinder specimens was in accordance with BS 1881: Part 120:1983 [46] (i.e., the cylinder strength is roughly 0.83 times that of the cubes).

- The flexural strength of concrete made of dredged sea sand was significantly lower than that of MS. The flexural strength of each concrete beam specimen made with dredged sea sand partially replaced with or without MS was determined to be 0.69 times the compressive strength of cube specimens in accordance with IS 516-2021 [37].
- The results of the Rapid Chloride Penetration Test were well within the limit specified by ASTM C 1202 [42]. By filling the finer side of the fine aggregate with MS, the grade of dredging sea sand improves, and hence the degree of the risk of corrosion is therefore lower.
- The water absorption rate for concrete made from sea sand was higher. After partially replacing dredged sea sand with 10, 20, and 30% shows better results in accordance with ASTM C 140 [40].
- The alkalinity of concrete specimens created with dredged sea sand partially replaced with or without MS was determined to be within the ASTM D 4262 [41] standard as the collected dredged sea sand samples were exposed to rainwater for nearly a year. Also, the addition of MS improves the alkalinity of concrete compared to the 100% replacement of MS with dredged sea sand.
- The bond strength increases with an increase in the replacement of sea sand, however, the 30% replacement of sea sand with MS gives a closer result than the 100% replacement with MS.
- The sorptivity which is greater for concrete with dredged sea sand was found to decrease as the portion of dredged sea sand was partially replaced with MS.

On the basis of the above results, it can be concluded that dredged sea sand can be used as a partial replacement for fine aggregate in concrete. As a future research direction, further investigations can be carried out to explore the incorporation of fiber-reinforced concrete with dredged sea sand. Fiber reinforcement has gained prominence in recent times for enhancing the mechanical properties and durability of concrete structures. Incorporating fibers in concrete mixtures with dredged sea sand can offer significant advantages, particularly in terms of eliminating the corrosion risks caused by steel reinforcements. Recommendations for future studies include evaluating the mechanical properties, crack resistance, and long-term performance of fiber-reinforced concrete containing dredged sea sand. Moreover, examining the effects of different types and dosages of fibers on the concrete's behavior can provide valuable insights for optimizing the mix design. By exploring the potential of fiber-reinforced concrete with dredged sea sand, researchers and practitioners can contribute to the development of sustainable and corrosion-resistant construction materials, thus fostering a more resilient and eco-friendly infrastructure for the future.

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