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Performance Evaluation of M25 Grade Concrete Using Manufactured Sand as A Sustainable Alternative to River Sand

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Abstract— The construction industry has grown rapidly in its development, and this has created a greater demand for natural river sand, hence causing a deficiency and environmental hazards. The project is focused on exploring the possibility of using Manufactured Sand (M-sand) to replace river sand completely and partially for producing M25 grade concrete. Manufactured sand is produced by crushing hard stones such as granite, and this makes it a more environmentally friendly alternative to natural sand. The study created M25 grade concrete mixtures using different ratios of manufactured sand to replace natural sand. The study team molded concrete samples to test their workability and compressive strength and total performance. The study team conducted standard tests based on Indian Standards, including slump test and compressive strength test. The study team compared results from M-sand concrete mixtures to those from conventional concrete mixtures using river sand. The results showed that the compressive strength of M-sand concrete mixtures is greater than that of conventional concrete mixtures. The angular shape and texture of M sand have assisted in improving the bond between cement paste and aggregate. This has resulted in an increase in strength. It has been observed that there is a reduction in workability. This can be controlled through mix design and use of admixtures. M sand can be used as an alternative to river sand used in M25 grade concrete.

Index Terms— Manufactured Sand (M-Sand), M25 Grade Concrete, River Sand Replacement, Compressive Strength, Workability, Sustainable Construction, Concrete Mix Design

I. INTRODUCTION

The reason for choosing concrete as the major material for the construction industry is its good properties and long-lasting results, as well as its suitability to meet different needs. The M25 grade of concrete is used as the major material for the design of buildings and the development of infrastructure in the construction industry. River sand is found to be in short supply due to over-extraction, which leads to environmental problems. This calls for the search for another alternative material to replace the river sand. The method of manufacturing manufactured sand involves the crushing of hard rocks, which makes it of high quality compared to river sand. The project seeks to locate manufactured sand as an alternative to river sand for the M25 grade of concrete. The research seeks to assess the impact of various factors on the performance of concrete.

II. LITERATURE REVIEW

Anitha J. (2025), different grading systems were considered and used in the evaluation of manufactured sand, which acts as an ingredient in self-compacting concrete. The study proved that the best particle size distribution in manufactured sand improves workability and increases the compressive strength and durability of concrete. The study proved that manufactured sand can be used as an alternative to river sand in the mixture of concrete, as the mechanical and durability properties are maintained in the concrete.

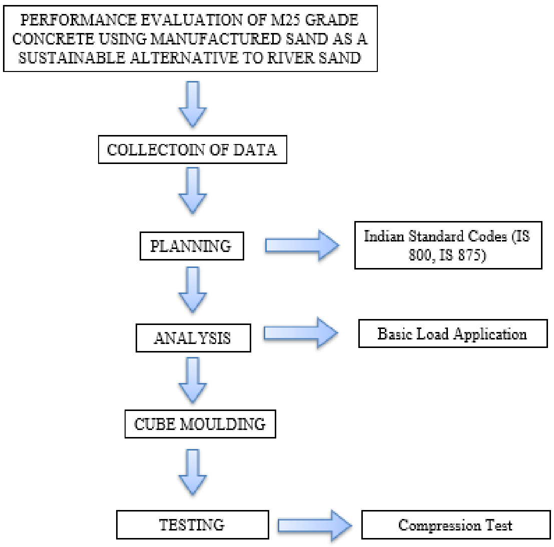
Bardhan A. (2024), the hybrid models of artificial neural networks and metaheuristic optimization techniques were developed to predict the compressive strength of manufactured sand concrete. In the study, the accuracy of the models in predicting the compressive strength of manufactured sand concrete was found to be very high.

Cui Z. (2025) focused on predicting compressive strength using hybrid machine learning models and optimization techniques. The study showed that computer prediction techniques can be used to effectively predict concrete strength. This technique is important to engineers to optimize mix design and reduce experimental costs.

Di S. (2025), advanced machine learning techniques were used in the evaluation of experimental data on manufactured sand concrete mixes. The study showed that it is possible for machine learning algorithms to be used in the prediction of compressive strength. The study showed that it is possible for engineers to use algorithm-based models in an effective manner.

Huang P. (2025) applied hybrid machine learning models along with optimization techniques to investigate the compressive strength of manufactured sand concretes. The results showed that it is possible to apply machine learning models to predict the compressive strength. The results showed that it is possible to apply machine learning models to assist engineers in creating stronger mixes.

III. METHODOLOGY



- Study of M25 concrete using M-sand as a replacement for river sand.
- Collection of material data and relevant standards.
- Mix design planning as per IS codes.
- Analysis of materials and basic load application.
- Casting of concrete cubes with M-sand replacement.
- Testing of specimens for compressive strength.

IV. MATERIAL PROPERTIES AND MIX DESIGN

A) CEMENT

Ordinary Portland Cement (OPC-43 grade) will serve as a binding agent for the M20 concrete mixes, which will comply with the IS: 8112-2013 specifications. The Ordinary Portland Cement has a specific gravity of 3.15, a fineness of more than 320 m²/kg, an initial setting time of 180 minutes, and a 28-day compressive strength of 43 MPa.

Table:3 Material Properties of PET Bottle Fiber

S.No.	Property	Fine Aggregate
1	Specific gravity	2.67
2	Water absorption	1.27%
3	Moisture content	0.8%
4	Sieve analysis (Material status) IS:383/1970	Passes the requirements for zone II

S. No	Property	Cement (OPC)
1	Type	Ordinary Portland Cement (OPC 53 Grade)
2	Specific Gravity	3.15
3	Standard Consistency	30 – 35 %
4	Initial Setting Time	30 minutes (minimum)
5	Final Setting Time	600 minutes (maximum)
6	Fineness	225 – 300 m²/kg

B) COARSE AGGREGATE

The coarse aggregate of concrete is usually rounded shape, well graded, and smaller in size than that of conventional concrete and geopolymer concrete. The size of coarse aggregate used for concrete is between 10mm to 20mm. Rounded and smaller coarse aggregate helps to achieve better flowability and deformability of concrete. It also helps to avoid segregation of concrete. Graded aggregate is also important to cast concrete in highly congested reinforcement or formwork of smaller dimensions.

Table:2 Materials and Properties for Coarse Aggregate

s.no.	Property	Normal Coarse Aggregate
1	Specific gravity	2.17
2	Bulk Density Loose compacted	1857.33 kg/m^3
3	Flakiness index	3%
5	Bulk Density after compaction	2047 kg/m^3

C) M.Sand

M.sand, which can be granular material or crushed stones, is a primary constituent of concrete. The quality of fine aggregate and density of fine aggregate have a significant influence on the properties of hardened concrete.

Table:4 Materials and Properties for M.Sand

D) River Sand

River sand is a naturally occurring fine aggregate collected from riverbeds, widely used in concrete and construction. It provides good workability and strength due to its smooth texture and proper grading. However, excessive extraction leads to environmental issues such as erosion, habitat destruction, and depletion of natural resources.

FIGURE:1 Materials

MIX DESIGN

DATA:

Grade of concrete = M25
Type of fine aggregate = Manufactured Sand (M-Sand)
Grade of cement = OPC 43/53
Maximum size of coarse aggregate = 20 mm
Grade of steel (for RC members) = Fe 415
Exposure condition = Moderate

Method of design = IS 10262:2019
Code reference = IS 456:2000

STEP 1: TARGET MEAN STRENGTH
(IS 10262)
Formula:
$f_{ck(target)}$ $=f_{ck}+1.65\times S$
Where,
Standard deviation, S = 4 N/mm² (IS 456)
Substitution:
$f_{ck(target)}$ $=25+1.65\times 4$
Substitution:
$f_{ck(target)}$ = 316 N/mm2

STEP 2: SELECTION OF WATER–CEMENT RATIO
(IS 456 – Durability requirement)
From IS 456 (Moderate exposure):
Maximum w/c ratio = 0.50
Assumed for better strength:
Adopted w/c ratio=0.45

STEP 3: SELECTION OF WATER CONTENT
(IS 10262 – Table for 20 mm aggregate)
Water content for 20 mm aggregate
= 186 litres/m³
Answer:
Water content =186 litres/m^3

STEP 4: CALCULATION OF CEMENT CONTENT
Formula:
Cement content =Water content /(w/c ratio)
Substitution:
=186/0.45
Answer:
Cement content =413 kg/m^3
Check (IS 456):
Minimum cement content (Moderate exposure)
= 300 kg/m³
413>300⇒SAFE

STEP 5: VOLUME OF CEMENT
Formula:
V_c =Mass of cement / (Specific gravity×1000)
Specific gravity of cement = 3.15
Substitution:
V_c =413/(3.15×1000)
Answer:
V_c =0.131 m^3

STEP 6: VOLUME OF WATER
Formula:
V_w =186/1000
Answer:
V_w =0.186 m^3

STEP 7: VOLUME OF AGGREGATES
Formula:
V_a $=1-(V_c+V_w)$
Substitution:
V_a =1-(0.131+0.186)
Answer:
V_a =0.683 m^3

STEP 8: PROPORTION OF FINE & COARSE AGGREGATE
(IS 10262 – Zone II, 20 mm aggregate)
Coarse aggregate = 0.62
Fine aggregate (M-Sand) = 0.38

STEP 9: VOLUME OF FINE AGGREGATE
Formula:
V_{FA} =0.38×0.683
Answer:
V_{FA} =0.259 m^3

STEP 10: VOLUME OF COARSE AGGREGATE
Formula:
V_{CA} =0.62×0.683
Answer:
V_{CA} =0.424 m^3

STEP 11: MASS OF AGGREGATES
Fine Aggregate (Manufactured Sand)
Specific gravity = 2.65
Mass =0.259×2.65×1000
Answer:
M-Sand =686 kg/m^3
Coarse Aggregate
Specific gravity = 2.70
Mass =0.424×2.70×1000
Answer:
Coarse aggregate=1145 kg/m^3

V. DESIGN DATA

A) OUTCOME OF THE USE OF M.SAND IN M25 GRADE

Manufactured Sand (M-Sand) is suitable for M25 grade concrete, showing satisfactory strength, durability, and workability as per IS codes. It achieves target strength, ensures proper bonding, reduces voids, and improves compressive strength. Hence, M-Sand can be effectively and safely used as a replacement for natural river sand in concrete.

B) DESIGN OF REINFORCED CONCRETE COLUMN USING M25 GRADE

The column is designed using reinforced concrete to transfer loads from beams and slabs to the foundation. It follows IS 456:2000 specifications. Design involves selecting size, calculating loads, and ensuring strength and serviceability. M25 grade concrete made with manufactured sand is used, providing adequate performance and structural stability.

Parameter	Symbol	Assumed Value	Unit
Grade of concrete	f_{ck}	25	N/mm^2
Type of fine aggregate	—	Manufactured Sand	—
Grade of steel	f_y	415	N/mm^2
Column type	—	Short RC Column	—
Shape of column	—	Rectangular	—
Column size	b × D	300 × 450	mm
Effective length	Le	3.0	m
Unsupported length	L	3.0	m
End condition	—	Both ends restrained	—
Slenderness ratio	Le/D	< 12	—
Factored axial load	Pu	900	kN
Minimum eccentricity	e_{min}	20	mm
Clear cover	—	40	mm
Longitudinal bars	—	8 bars of 16 mm dia	—
Area of steel provided	Ast	1608	mm^2
Percentage of steel	p	1.19	%
Lateral ties diameter	—	8 mm	—
Spacing of ties	—	150	mm
Design load capacity	Pu, cap	> 900	kN
Overall design status	—	SAFE	—

C) DESIGN OF REINFORCED CONCRETE BEAM USING M25

The beam is designed using reinforced concrete with M25 grade concrete and Manufactured Sand as fine aggregate. It supports slabs and transfers loads to columns. Design follows IS 456:2000, including beam sizing, bending moment and shear calculation, reinforcement design, and deflection checks, with M-sand improving strength and bonding properties.

Parameter	**Sym bol**	**Assumed Value**	**Unit**
Grade of concrete	fck	25	N/mm^2
Type of fine aggregate	—	Manufactured Sand	—
Grade of steel	fy	415	N/mm^2
Type of beam	—	Simply supported	—
Beam size	b × D	230 × 450	mm
Effective depth	d	410	mm
Span of beam	L	4.0	m
Clear cover	—	25	mm
Factored load	wu	25	kN/m
Maximum bending	Mu	50	kN/m
Maximum shear force	Vu	50	kN
Main reinforcement	—	3 bars of 16 mm dia	—
Area of steel provided	Ast	603	mm^2
Shear reinforcement	—	8 mm stirrups	—

Parameter	Symbol	Assumed Value	Unit
Grade of concrete	fck	25	N/mm^2
Type of fine aggregate	—	Manufactured Sand	—
Grade of steel	fy	415	N/mm^2
Type of slab	—	One-way slab	—
Span of slab	L	3.5	m
Slab thickness	D	125	mm
Effective depth	d	100	mm
Clear cover	—	20	mm
Dead load	DL	3.5	kN/m^2
Live load	LL	3.0	kN/m^2
Factored load	wu	9.75	kN/m^2
Maximum bending moment	Mu	15	kN.m
Main reinforcement	—	10 mm bars @ 150 mm c/c	—
Distribution reinforcement	—	8 mm bars @ 200 mm c/c	—
Area of steel provided	Ast	As required	mm^2
Minimum steel check	—	Satisfied	—
Shear stress	τv	Within limit	—
Deflection check	—	Within limit	—
Development length	Ld	Provided	mm
Overall design status	—	SAFE	—
Spacing of stirrups	—	150	mm c/c
Percentage of eel	p	0.64	%
Deflection check	—	Within limit	—
Development length	Ld	As required	mm
Shear capacity	Vc	> Vu	—
Overall design status	—	SAFE	—

D) DESIGN OF REINFORCED CONCRETE SLAB USING M25

The reinforced concrete slab uses M25 grade concrete with Manufactured Sand as fine aggregate. It supports floor loads and transfers them to beams. Designed as per IS 456:2000, steps include thickness selection, load calculation, bending design, reinforcement detailing, and deflection checks. M-sand improves surface finish, strength, and overall concrete quality.

VI. CONCLUSION

The project titled "Use of Manufactured Sand in M25 Grade Concrete" evaluates concrete properties by replacing river sand with M-sand. Mix design follows IS 456:2000 and IS 10262 standards to ensure strength, durability, and workability. Tests show M-sand concrete provides better uniformity, bonding, and higher compressive strength.

Though workability is slightly reduced, it can be improved using admixtures or water adjustment. Water absorption remains within limits, indicating good durability. Overall, M-sand proves to be a reliable and eco-friendly alternative, reducing dependence on natural river sand and supporting sustainable construction practices effectively.

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