RESEARCH ARTICLE OPEN ACCESS

An experimental study on strength of concrete using recycled aggregates and manufactured sand

Raghav ravi naik[1], Prof. Ajith b.t [2], Prof. Arun Kumar[3]
1(M.Tech Student,Department of civil, KVG college, and Sulia Email: raghavnaik0@gmail.com)
2 (Assistant Professor, Department of civil, KVG college, and Sulia Email: ajithbt85@gmail,com)
3 (Assistant Professor, Department of civil, KVG college, and Sulia Email: arunkumarh446@gmail,com)

Abstract:

Use of manufactured sand (M-sand) and recycled coarse aggregates (RCA) in concrete manufacturing is investigated in the research. Natural coarse aggregates and river sand are in high demand as building materials, but this need is causing environmental problems. This is being addressed by making good use of recycled aggregates and synthetic sand. Research showed that compared to a control mix, concrete with 50% recycled coarse aggregates and manufactured sand had better toughened characteristics. Nevertheless, when recycled coarse aggregates were substituted at 75% and 100%, a decrease in strength was seen. Construction waste and landfill loads can be decreased, costs can be kept down, and environmental sustainability can be achieved with the use of RCA and synthetic sand.

***Keywords* — recycled coarse aggregates, manufactured sand, concrete, replacement, optimum strength, compression strength**

I. INTRODUCTION

Numerous constructions are being erected all over the globe, making the construction industry a quickly expanding sector. Yet, due to dwindling land resources, older buildings are being torn down to make way for newer ones. Due to unregulated disposals and a lack of landfill space, the concrete debris produced by this procedure is a threat to the environment. Every year, the building industry generates billions of tonnes of trash and utilises more energy and raw materials than any other industry in the economy. In response to these concerns, recycled concrete aggregate (RCA) and other alternative aggregates have gained popularity. RCA is made from a variety of materials, including demolition debris, leftover concrete from building projects, and concrete that has been tested in labs or in the field. Instead of using natural coarse aggregates, this project is using recycled concrete aggregates. Instead of using natural river sand, concrete is reinforced with synthetic sand. The building industry's negative effects on the environment are the target of this strategy.

A. *Recycled Coarse Aggregates*

The global construction sector's rapid expansion has led to an overuse of natural resources, particularly natural coarse aggregates (NCAs), a crucial component of concrete and other construction materials. This dependency has created environmental challenges like resource depletion, habitat degradation, and increased carbon emissions. To address these issues, recycled coarse aggregates (RCAs) are gaining popularity as an alternative to natural coarse aggregates, offering numerous advantages such as reduced waste, improved environmental sustainability, and reduced carbon emissions.

Recycled coarse aggregates offer several benefits for environmental sustainability, cost efficiency, and energy savings. They eliminate the need for new quarries, maintain natural landscapes, and reduce the environmental impact of construction activities. They also divert materials from landfills, lowering the overall environmental footprint. Recycled aggregates are often less expensive than natural aggregates, especially sourced from nearby demolition sites. They also reduce construction waste and landfill burden, reducing the burden on existing landfills. Additionally, recycled coarse aggregates require less energy to process and transport, especially if sourced locally from demolition waste.

However, there are some disadvantages to using recycled coarse aggregates in construction. They may lack required strength, absorb more water than natural aggregates, and have varying quality issues. These include the lack of specifications or guidelines for using recycled concrete aggregates, higher water absorption, and inconsistencies in the grade of recycled aggregates. Despite these drawbacks, recycled coarse aggregates can help maintain a balance between development and environmental preservation.

B. Manufactured sand

Manufactured sand (M-Sand) is an artificially produced sand obtained from crushing hard stones into small, angular particles. It is used as a construction aggregate in the construction industry, with natural river sand being the primary choice due to its availability and favorable qualities. However, the extraction of natural river sand has raised environmental and economic challenges. M-sand offers several advantages, including environmental sustainability, quality and consistency, reduced transportation costs and cost efficiency, conservation of natural resources, compliance with environmental regulations, and promotion of innovation in construction.

1. M-sand is produced under controlled conditions, ensuring consistent particle size and shape, which is crucial for high-quality construction. This results in increased concrete strength and longevity.
2. M-sand can be produced locally, reducing long-distance transportation costs and carbon impact. This cost-effective option offers a more cost-effective option as natural river sand becomes scarcer and more expensive.
3. M-sand is extracted from abundant rock sources, ensuring a steady and sustainable supply, promoting ethical sourcing methods and compliance with environmental regulations.
4. M-sand promotes sophisticated manufacturing technology and innovative construction methods, encouraging research and development in sustainable building materials, contributing to the overall advancement of the construction sector.

Manufactured sand offers advantages over natural sand, but has limitations such as lower workability due to its rough texture, which may require more water and cement, and a higher proportion of microfine particles, which may affect the strength and workability of screed or concrete.

C. *Contributions*

- To study the characterization of materials used for concrete.
- With the goal of creating a concrete mix of M30 grade that incorporates recycled coarse aggregates (RCAs) ranging from 0% to 100% by weight, and manufactured sand (M-sand) in lieu of natural river sand (NRS).
- Workability, compressive strength, split tensile strength, flexural strength, and water absorption rate are some of the qualities that should be studied when the aforementioned mixture is both fresh and hardened.
- Finding the sweet spot for recycled aggregate and manufactured sand dosage in concrete that produces long-lasting, strong, and cost-effective results.

D. *Organization of the paper*

Sections II describes about the research carried out by the previous research scholars on the recycled aggregate manufactured sand. Section III provides the inner details about the material used and the methodology employed. Section IV discusses about the specimen preparation and testing of it. Section V gives results and discussion. Lastly conclusion and future scope is discussed.

II. LITERATURE SURVEY

Research carried out in various field in manufactured sands are discussed

A. *Effect of recycled coarse aggregate used in concrete.*

In their 2021 research, M. Surender et al. compared recycled aggregate concrete (RAC) with traditional normal aggregate concrete (NAC) in terms of mechanical properties and durability. Zero, ten, fifteen, twenty-five, fifty, and seventy-five percent recycled coarse aggregate (RCA) was used as a replacement in seven different concrete mixes. At the ages studied, RAC specimens were somewhat weaker than NAC specimens in terms of strength.

This research suggests that 10% recycled aggregates as the ideal amount to provide strength while reducing water absorption. Past research has looked at how much cement is needed to get the desired mean strength and what proportion of natural coarse aggregate may be substituted with recycled coarse aggregate in a concrete mix.

In a study conducted by Hardik Gandhi et.al (2011), the characteristics of both fresh and hardened concrete were compared. The results showed that conventional concrete had lower early strength compared to recycled coarse aggregate concrete with a higher proportion of RCA. Recycled concrete's compressive, tensile, and flexural strengths were studied by Muthu Lakshmi and Nivedhitha (2015) when natural fine aggregates (NFA) and natural coarse aggregates (NCA) were partially replaced with recycled coarse aggregates (RCA) and recycled fine aggregates (RFA).

The early compressive strength of concrete made using recycled coarse aggregate and concrete made using natural coarse aggregate is almost same, according to research by Ravi Patel et.al (2013). The most workable concrete was made by replacing 40% of the material with recycled aggregate, as this resulted in the highest compaction factor value.

Compressive strength of recycled aggregate concrete decreases when the proportion of recycled aggregates rises over 30%, according to research by Manik Goyal and Hinoni Goyal (2018). Using 50% recycled aggregates results in a 10% decrease in compressive strength after 28 days.

B. *Effect of Manufactured sand used in concrete*

The practicality of mixing recycled coarse aggregates (RCAs) with manufactured sand (M-sand) in concrete production is investigated in this study. In the experiment, natural coarse aggregates (NCAs) were added to 44 different concrete mixes in quantities ranging from 10% to 100%. When compared to the control mix, concrete with 50% M-sand exhibited superior toughened characteristics. Toughness was lower in concrete that included just recycled coarse aggregates (RCAs) compared to regular concrete. Substituting artificial sand for natural fine aggregate in concrete mixtures boosted their compressive capacity by as much as 50%. Increasing the percentage of manufactured sand in the concrete mixes had a noticeable effect on their compressive strength.

The effects of using M-Sand in lieu of or in addition to natural sand in concrete were investigated by Vijaya Bhoopathy and S. Senthil Selvan (2015). By use of acid, sulphate, and rapid chloride permeability tests (RCPT), they investigated the strength properties of both traditional and M-Sand concrete. The experimental results showed that the compressive strength of the concrete was 20% greater when M-sand was used in place of 60% of the sand.

Researchers P. Mahakavi and R. Chitra (2019) looked at the possibility of making self-compacting concrete using RCA and produced sand that came from a ready-mix concrete (RMC) plant. The findings showed that compared to the control mix, concrete with 50% M-sand exhibited much better hardened properties. Having said that, regular concrete has better hardened characteristics than SCC with 100% RCA.

Researchers U. Sridhar and B. Karthick (2015) looked at the properties of concrete that included different amounts of recycled aggregates (RCA) and 50% produced sand. The parameters used to establish the mix percentage for M20 grade concrete are in line with IS rules. Compressive strength was greater in concrete containing up to 50% recycled coarse aggregate (RCA) compared to conventional concrete.

In 2017, AMZ Zimar et.al. looked into the possibility of using manufacturing sand in M20 concrete buildings. The findings demonstrated that manufactured sand may fully substitute river sand; however, water-reducing admixtures should be applied as required. At the same weight-to-cement ratio, concrete mixed with manufactured sand had a higher compressive strength than concrete mixed with natural sand.

III. Materials and Methodology

Employed materials for carrying out the specimen preparation process is as follows,

A. *Ordinary Portland Cement*

Portland cement clinker, blended materials (ranging from 6–15 percent), and a certain proportion of gypsum (PO) are the main ingredients of Ordinary Portland Cement (OPC), a hydraulic binding substance. The maximum allowable mass of the active blended components in cement is 15%.

Kiln ash (up to 5% of the cement mass) and inactive mixed materials (up to 10% of the cement content) may be used as partial replacements for these components. The total mass of inert blended components, however, must not be more than 10%.

Table 1: Physical properties of OPC

S.NO.	CHARECTERISTICS	RESULTS	Requirements as per IS: 12269-1987
1	Specific gravity	3.14	-
2	Fineness modulus	3 %	<10 %
3	Normal consistency	32%	-
4	Initial setting time	35 mins	>30 mins
5	Final setting time	210 mins	<600 mins

Following the national standard GB175-1999 for Portland Cement, OPC is categorized into four strengths: 32.5, 32.5 R, 42.5, 42.5 R, and 52.5, 52.5 R. Each grade's strength reaches the numbers in Table 4.3 when a certain amount of time has passed. Regular cement requires a minimum of 45 minutes to set and no more than 10 hours to set completely. Cement must be boiling stable and leave no more than 10% residue on a 0.08 mm square-hole filter. In addition, the ignition loss of the cement must not exceed 5.0 percent.

Figure 1: OPC

B. *Sand*

Comparing the two types of sand such as natural river sand, M-sand

Natural river sand

Sand utilised for this project was locally sourced and graded zone II per IS 383-1970. Natural sand has 2.59 specific gravity. Water absorption is 0.5%, fineness modulus is 2.57, and free moisture is 0%.

Collected sand is dried to a desirable texture for complete mixing.

Physical properties and image of it as shown below,

Table 2: Physical properties of sand

Particulars	Result	IS range
Specific gravity	2.59	2.6 to 2.7
Fineness modulus	3.90	2-4
Bulk density (kg/m3)	1735	1200-1750 Kg/M3
Grading Zone	Zone II	Zone-I & II
Water Absorption	0.5%	0.5-2.5%

Figure 2: Natural sand

M-SAND

M-sand is formed by crushing large, hard stones like boulders or granite into little pieces and grading then cleaning them. Construction projects use this river sand substitute for mortar and concrete. This experiment used sand with a 1.18 mm Is sieve and 600 µm maintained size, per IS:383-1963.

Figure 3: M-sand

Table 3: Physical properties of M-sand

Characteristics	Result	As per IS range
Type	Artificial	Artificial
Size	600 µm	600 µm
Shape	angular	angular

Specific gravity	2.61	2.6 to 2.7
Bulk density(Kg/m3)	1.830 x 103	1200-1850 kg/m3
Grading zone by sieve analysis	Zone II	Zone-I & Zone-II preferrable
Fineness modulus	3.83	2-4
Water absorption (%)	2.0	0.5-2.5%

C. Coarse aggregates

Natural coarse and recycled coarse aggregates were employed in the analysis.

Natural coarse aggregates(NCA)

This experiment uses locally accessible coarse aggregates. This work uses coarse aggregate up to 20mm. The specific gravity of coarse aggregate is 2.68. Concrete's strongest and least permeable component is coarse aggregate. Water absorption is 1.25% and free moisture is 0%.

Figure 4: Natural coarse aggregates.

Recycled coarse aggregates

The study collected waste concrete from a demolished construction in Karwar, Karnataka, and separated coarse aggregate (C.A.) using hammering. The aggregates were sieved through a 20mm and 4.75mm sieve for passing and retention. Crushing strengths, specific gravity, water absorption, moisture content, and sieve analysis were among the preliminary tests performed on the recycled coarse aggregates. It was blended with both natural and recycled aggregates.

Figure 5: Recycled coarse aggregates.

Water

Water in cement is crucial for blending, compaction, and solidification, hydration of bonds, and binding ingredients. Quality depends on water amount and nature, with pH within 6-7 for mixing and curing water.

Super plasticizer

The study utilized Conplast SP430 DIS, a superplasticizer, as a 0.5% by weight of cement to enhance the workability of M30 grade concrete.

Figure 6: Superplasticizer

Methodology

Methodology for development of design mix standard cubes using manufactured sand and RAC aggregates

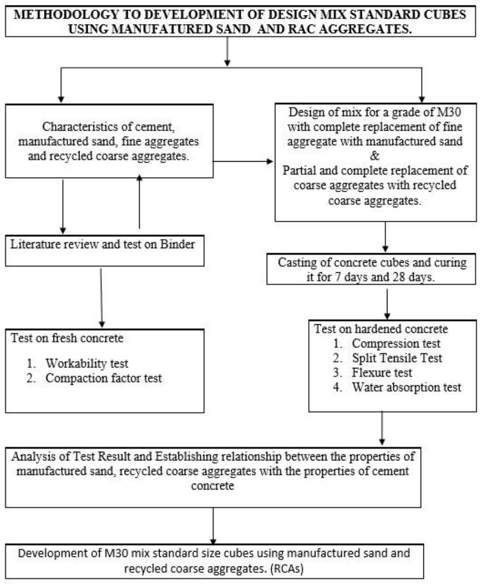


Figure 7: Methodology flow

IV. RESULT AND DISCUSSION

Results from experiments measuring both the beginning and final setting times indicated that, since recycled aggregates have weaker binding characteristics, a higher percentage of recycled aggregates lengthens both of these times.

Table 4: Initial and final setting time

Mix	IS (mins)	FS (mins)
OPC	110	265
R0N100	105	253
R25N75	168	326
R50N50	197	397
R75N25	239	498
R100N0	283	567

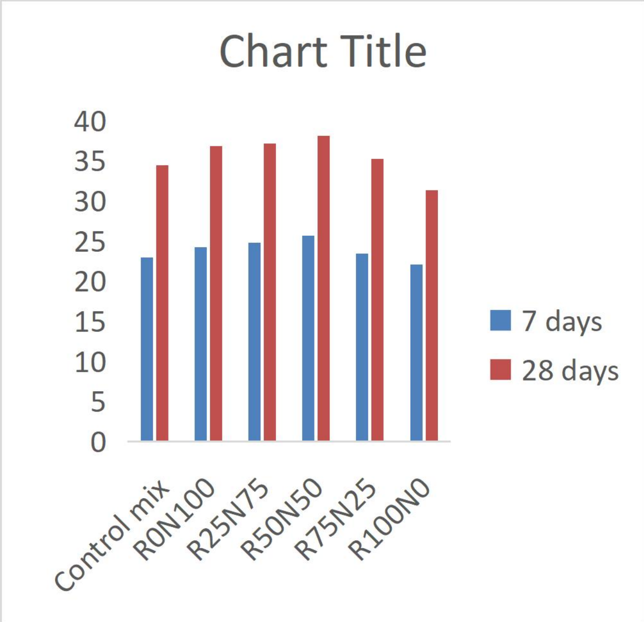
Slump test

The slump, the fundamental aspect of concrete behavior, should range from 70mm to 120mm for a nominal mix, as indicated in the table below.

Mix	Slump (mm)
Control mix	94
0%RCA and 100%NCA	90
25%RCA and 75%NCA	83
50%RCA and 50%NCA	76
75%RCA and 25%NCA	65
100%RCA and 0%NCA	53

A. Compressive strength of concrete mixes graph

When compared to natural sand, the compressive capacity of M-sand concrete mix is 7% higher, and when mixed with 50% recycled coarse aggregates, the strength is 11% higher.



Compressive test performed using the below machine

Figure 8: Machine conducted test.

Split Tensile Strength

Increased replacement of recycled coarse aggregates led to lower strength due to water absorption, weaker cement paste binding, and uneven particle size distribution, resulting in a 31.5% drop in tensile strength.

Table 5: Split tensile strength of concrete cube mixes.

Mix	Specimen	Average Split tensile strength at 7days (N/mm2)	Average Split tensile strength at 28days (N/mm2)
Control mix	M0	3.14	3.78
R0N100	M1	3.23	3.94
R25N75	M2	2.81	3.62
R50N50	M3	2.54	3.23
R75N25	M4	2.26	2.94
R100N0	M5	2.07	2.70

FLEXURAL STRENGTH

The study reveals that mixes made with recycled coarse aggregates and manufactured sand have significantly higher flexural strength than natural coarse aggregates, increasing until 50% proportion mix and decreasing at 75% and 100%.

Table 6: Flexural strength of concrete cube mixes.

Mix	Specimen	Average Flexural Strength at 7days (N/mm2)	Average Flexural strength at 28days (N/mm2)
Control mix	M0	4.14	4.98
R0N100	M1	4.26	5.24
R25N75	M2	4.38	5.40
R50N50	M3	4.54	5.62
R75N25	M4	4.36	5.36
R100N0	M5	4.19	5.17

WATER ABSORPTION OF CONCRETE MIXES

The concrete mix with 100% recycled coarse aggregate showed the highest water absorption, while RCA concrete mix absorbs more water due to bonded mortar materials, resulting in increased water absorption in RAC.

Table 7: Water absorption test

Mix	Specimen	Water absorption rate at 7days (%)	Water absorption rate at 28days (%)
Control mix	M0	1.67	1.35
R0N100	M1	1.95	1.56
R25N75	M2	2.86	2.47
R50N50	M3	3.40	3.04
R75N25	M4	5.58	5.13
R100N0	M5	6.83	6.32

V. CONCLUSION

Experimental investigations on nominal concrete mix, recycled coarse aggregates (RCA), and manufactured sand concrete found that RCA and M-sand concrete mix had higher compressive strength than nominal mix until 50% replacement levels. The highest optimum compressive strength was achieved at 50% RCA and M-sand replacement, with 38.16 N/mm2 at 28 days. RCA also showed higher water absorption than NCA, but lower split tensile strength. The study concludes that RCA can replace natural aggregates and river sand.

Future scope

The study investigates the strength parameters of concrete with recycled aggregates and manufactured sand, RCA and M-sand, and different grades of concrete, while maintaining constant slump for specified work.

REFERENCES

1. *S. M. Metev and V. P. Veiko, Laser Assisted Microtechnology, 2nd ed., R. M. Osgood, Jr., Ed. Berlin, Germany: Springer-Verlag, 1998.*
2. *Breckling, Ed., The Analysis of Directional Time Series: Applications to Wind Speed and Direction, ser. Lecture Notes in Statistics. Berlin, Germany: Springer, 1989, vol. 61.*
3. *S. Zhang, C. Zhu, J. K. O. Sin, and P. K. T. Mok, "A novel ultrathin elevated channel low-temperature poly-Si TFT," IEEE Electron Device Lett., vol. 20, pp. 569–571, Nov. 1999.*

4. *Wegmuller, J. P. von der Weid, P. Oberson, and N. Gisin, "High resolution fiber distributed measurements with coherent OFDR," in Proc. ECOC'00, 2000, paper 11.3.4, p. 109.*

5. *R. E. Sorace, V. S. Reinhardt, and S. A. Vaughn, "High-speed digital-to-RF converter," U.S. Patent 5 668 842, Sept. 16, 1997.*

6. *(2002) The IEEE website. [Online]. Available: http://www.ieee.org/*

7. *M. Shell. (2002) IEEEtran homepage on CTAN. [Online]. Available: http://www.ctan.org/tex-archive/macros/latex/contrib/supported/IEEEtran/*

8. *FLEXChip Signal Processor (MC68175/D), Motorola, 1996."PDCA12-70 data sheet," Opto Speed SA, Mezzovico, Switzerland.*

9. *Karnik, "Performance of TCP congestion control with rate feedback: TCP/ABR and rate adaptive TCP/IP," M. Eng. thesis, Indian Institute of Science, Bangalore, India, Jan. 1999.*

10. *Padhye, V. Firoiu, and D. Towsley, "A stochastic model of TCP Reno congestion avoidance and control," Univ. of Massachusetts, Amherst, MA, CMPSCI Tech. Rep. 99-02, 1999.*

11. *Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification, IEEE Std. 802.11, 1997.*