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Original Research Article

Experimental Investigation on Reinforced Concrete Beam with Prosopis Juliflora Ash and Basalt Fiber Bar as Reinforcement

Dr. S. Sundari, *Associate professor, Dept of Civil Engineering, Government College of Engineering, Salem*.

Kavya S, *PG Student, Dept of Civil Engineering, Government College of Engineering, Salem*.

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Abstract: The increasing environmental concerns caused by global warming and the rising costs of cement production due to quarrying have created a pressing need to explore alternative materials. To address this challenge, extensive research has been carried out to identify suitable replacements for cement. This research work is aimed to investigate the strength of concrete with partial replacement of cement with Prosopis juliflora ash (PJA) and compare it with conventional concrete. The grade of concrete is M30. Incorporating Prosopis juliflora ash can potentially reduce the overall consumption of cement in the country while promoting sustainable construction practices. The primary objective of this research is to evaluate the influence of Prosopis juliflora ash as a partial replacement for cement on the compressive, split tensile, and flexural strength of concrete. In this investigation, Prosopis juliflora ash (locally known as Seemaikaruvelam) was used to replace cement in varying proportions of 10%, 20% and 30%. Based on the experimental results, the mix containing 20% Prosopis juliflora ash exhibited optimal strength characteristics. Two beams (0% PJA and 20% PJA) were cast one with steel reinforcement and the other with partial replacement of steel with basalt fiber bars. Their flexural behavior and crack properties were studied in which PJA beam with basalt bars show high load bearing properties. The findings of this study highlight the potential of Prosopis juliflora ash as an eco-friendly and cost-effective alternative material for sustainable construction.

Keywords: Prosopis Juliflora Ash, Basalt Fiber Reinforced Polymer, Reinforced Concrete Beam, Partial Cement Replacement, Sustainable Concrete, Flexural Behaviour, Durability Performance, Pozzolanic Materials.

1. Introduction

Global warming has emerged as one of the most critical environmental challenges of the 21st century. Among the major contributors to anthropogenic greenhouse gas emissions is the cement industry, which is responsible for approximately 8% of global carbon dioxide (CO_2) emissions. In response to growing environmental concerns and the global push toward sustainable development, there is an increasing focus on identifying and incorporating alternative materials that can partially or wholly replace conventional cement in construction. Sustainable construction practices are guided by three primary pillars: environmental sustainability, economic feasibility, and social responsibility. Within this context, the present study investigates the partial replacement of cement with *Prosopis juliflora* ash, a biomass-derived waste material, and the incorporation of basalt fiber as a reinforcing agent in concrete. Prosopis juliflora, often considered an invasive species, offers potential for value-added utilization when processed into ash, thus contributing to waste management and sustainability goals.

1.1 Literature review

1. A.Durai Murugan, M.Muthuraja, Experimental Investigation on Prosopis juliflora ash as a partial replacement of cement in conventional concrete, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 6, Issue 5, May 2017. This study was on partial replacement of cement by Prosopis juliflora and its characteristic behavior in concrete. M30 concrete was prepared. The investigation include beam specimens of dimension 1600x150x100 mm. After curing for 28 days, these flexural strength specimens were tested under two point loading as per I.S. 516-1959, over an effective span of 400 mm. Load and corresponding deflections were noted up to failure. In each category three beams were tested and their average value is reported. Partial replacements were done at 10, 20, 30 and 40 percentages. Higher strength was obtained at 30% replacement of the ash.

2. Zhijie Huang et al, Experimental and numerical study on concrete beams reinforced with Basalt FRP bars under static and impact loads, Composite Structures, Volume 263, 1 May 2021. Six BFRP bars reinforced concrete beams were tested under quasi-static and impact loads. The test results showed the flexure-critical beams experienced the failure mode changing from flexure-governed under quasi-static loads to flexure-shear combined under impact loads. The shear-critical beams still failed in diagonal shear under impact loads, but experienced severer concrete spalling and more critical diagonal cracks on both sides of the beams. Numerical results showed increasing tension reinforcement ratio could change the failure mode from flexure-governed to flexure-shear combined along with the reduced maximum midspan deflection. The BFRP bars reinforced concrete beams had comparable impact resistant performance with the conventional steel reinforced concrete beams.
3. Lapko Wiejska St., et al, "Experimental and Theoretical Analysis of deflections of concrete beams reinforced with basalt rebar", Springer nature, 14 April 2014, Volume 15. This paper presents a comparative analysis of experimental and theoretical deflections of simply supported beams reinforced with BFRP rebar (Basalt Fiber 25 Reinforced Polymers). The tested BFRC model beams have been made of concrete class C30/37 and reinforced with flexural basalt bars of 8 mm in diameter with the characteristic identified in strength tests in tension. During the investigation of model beams there were registered beam deflection, concrete strains and width cracks, as well as critical forces. It has been shown that much lesser cross-sectional stiffness of basalt BFRP bars produces higher deflections and crack widths compared to the beams reinforced with steel bars of the same cross-section. The results clearly show that basalt rebar having full resistance against corrosion may be good alternative for the reinforcement of concrete structures, like RC bridge girders subjected to environmental attack.

1.2 Prosopis Juliflora Ash

Given its high silica and mineral content upon combustion, Prosopis juliflora ash (PJA) has shown promising potential as a supplementary cementitious material (SCM). When finely ground, the ash may exhibit pozzolanic properties, contributing to the strength and durability of concrete. It enhances mechanical properties when used in combination with reinforcements like basalt fiber.

1.3 BFRP Rebars

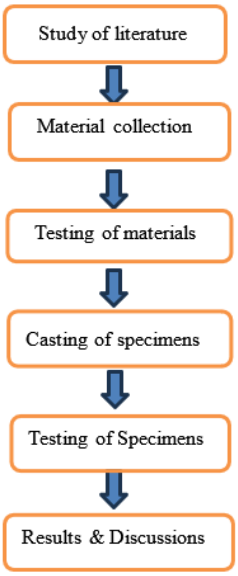
Basalt fiber is revered for its exceptional mechanical, thermal, and chemical properties, which make it a competitive alternative to traditional reinforcement materials like steel and fiberglass. This contributes to reduced structural weight.

i. **Density- 2700 kg/m3**
ii. **Modulus of elasticity- 89-110 Gpa**
iii. **Tensile strength- >2800 Mpa**
iv. **Average lifespan- >100 years**

1.4 Objective

- To minimize the disposal problem of the Prosopis plant.
- To study if Prosopis ash usage reduces the production cost of binding material (cement).
- To investigate the comparative strength properties of conventional concrete with concrete where the cement is replaced by the ash of Prosopis juliflora plant.
- To study the tensile strength of basalt fiber bar.

1.5 Methodology



2. Mix Design

The mix design as per IS 10262:2009. The code permits the use of supplementary materials such as chemical and mineral admixtures. All mixes were proportioned in order to achieve a design compressive strength of M30 concrete after 28 days. A control mix was produced with design mixes incorporating Prosopis juliflora ash as a partial replacement for cement in Proportions Of 10, 20 And 30%.

3. Material Preparation

3.1 Cement

In this work, Ordinary Portland Cement has been used. The cement thus procured was tested for physical properties in accordance with the IS: 4031-1988. Tests on Cement i) Specific Gravity

ii) Initial and Final Setting Time iii) Fineness of Cement iv) Consistency test v) Soundness.

3.2 Fine aggregate

The fine aggregate used was locally available sand without any organic impurities and conforming to IS: 383 – 2016. Tests on Fine aggregate i) Fineness modulus ii) Specific gravity. M-Sand of grading zone III was used.

3.3 Coarse aggregate

The aggregate which pass through 75 mm IS sieve and retain on 4.75 mm IS sieve are known as coarse aggregate. In this research, aggregate of 20 mm maximum size was used. Tests on Coarse aggregate i) Fineness modulus ii) Specific gravity iii) Impact value.

3.4 Prosopis Juliflora ash

The specific gravity of Prosopis ash was found to be less than that of cement. Specific gravity of Prosopis ash is 1.65. The suitable range of specific gravity of juliflora ash is 1.6 to 2.8.

4. Experimental Investigation

The most common of all checks on hardened concrete is the compressive strength test. This thesis work is based on IS: 10262 – 2019. Four different proportions of concrete mix (replacement of 10%, 20%, 30% by weight of cement) including the control mixture were prepared with water to binder ratio of 0.5. The tests are applied once seven & twenty eight days of casting of concrete.

4.1 Curing

Curing of cement concrete is defined as the process of maintaining the moisture and temperature conditions of concrete for hydration reaction to normally so that concrete develops hardened properties over time. The hydration process requires water to carry on and releases heat.

4.2 Strength study

All tests were done with reference to IS 516 (Part1/Section1):2021. The tests conducted on cubes, cylinders and prisms are 1) Compressive strength test 2) Split tensile strength test 3) Flexural strength test.

4.3 Microstructural analysis

Microstructural analysis, using Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray spectroscopy (EDX) is a standard technique for evaluating the physical morphology and chemical composition of materials at the micro- and nano-scale.

Durability test

S.NO	TESTS CONDUCTED ON CUBES	SPECIMEN SIZE
1.	Acid resistance test	100 x 100 x 100 mm cubes
2.	Sulphate resistance test	100 x 100 x 100 mm cubes
3.	Water absorption test	100 x 100 x 100 mm cubes
4.	Sorptivity test	100 mm diameter x 50 mm thickness discs

4.4 Testing of beams- RCC beam details

Material	0% PJA beam(Kg/m^3)	20% PJA beam(Kg/m^3)
Cement	394	314
PJA	0	80
Fine aggregate	617	617
Coarse aggregate	1200	1200
Water	200	200

5. Results And Discussion

Table and graph for Compressive strength test results

Mix ID	Compressive strength in N/mm2	
	7 DAYS	28 DAYS
PJA 0%	19.80	30.81
PJA 10%	21.37	31.39
PJA 20%	22.38	32.11
PJA 30%	19.71	27.47

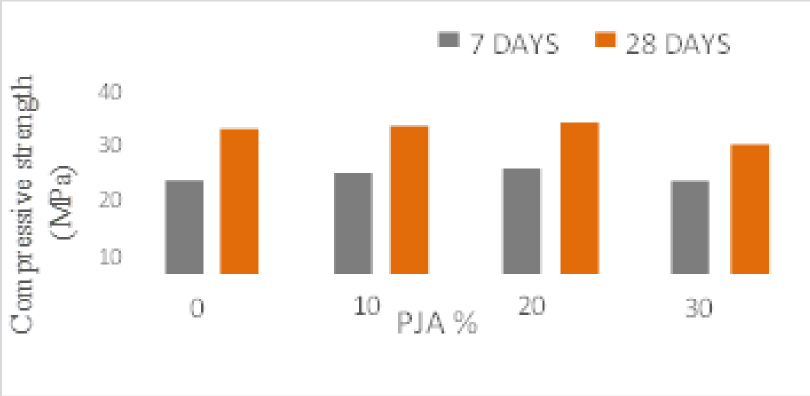


Table and graph for Split tensile strength test results

Mix ID	Split tensile strength in N/mm2	
	7 DAYS	28 DAYS
PJA 0%	1.71	3.09
PJA 10%	2.03	3.14
PJA 20%	2.22	3.23
PJA 30%	1.67	2.72

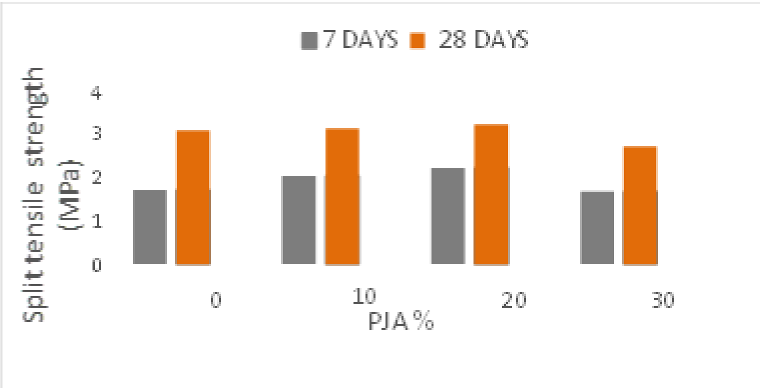
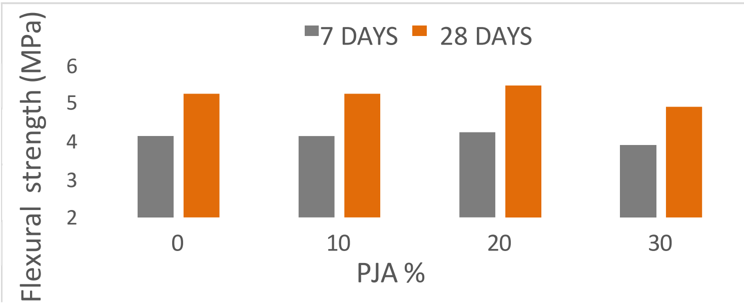


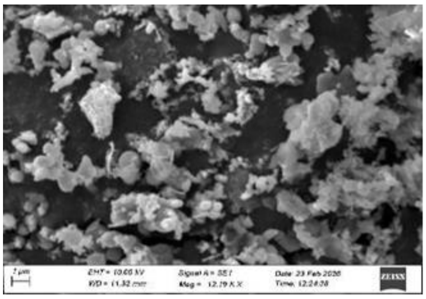
Table and graph for Flexural strength test results

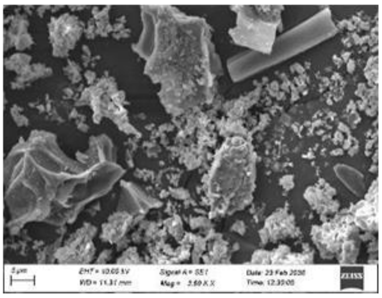
Mix ID	Flexural strength in N/mm²	
	7 DAYS	28 DAYS
PJA 0%	3.10	4.74
PJA 10%	3.11	4.74
PJA 20%	3.27	5.06
PJA 30%	2.78	4.25

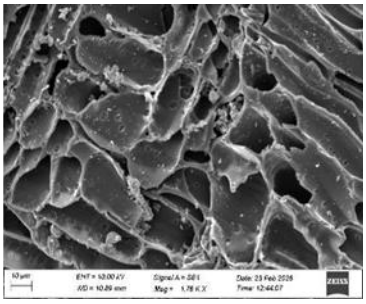


Microstructural Analysis Results

Sem Analysis



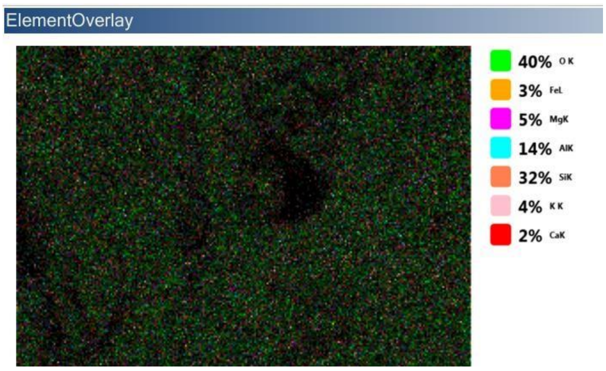




Interpretation From Sem Analysis

Fine agglomerated particles in smaller micron range and plate like fragments are found in micron ranges above that. Particle morphology shows that the ash contains irregular shaped particles. Porous texture due to organic burnout is seen. The larger structures show visible voids and cavities. Fine particles are clustered together due to high electrostatic attraction. Rough and uneven surface texture has been found. This confirms the ash is non uniform and heterogeneous, which indicates higher surface area and good mechanical interlocking if used in cement.

Edx Analysis



Element	Weight %	Atomic %
O K	43.10	58.81
FeL	3.42	1.34
MgK	3.68	3.30
AlK	11.01	8.91
SiK	27.57	21.43
K K	7.71	4.31
CaK	3.51	1.91

Interpretation From Edx Analysis

Oxygen (O): 43.10% - Indicates the sample is composed of oxides. Silicon (Si): 27.57% - Presence of silica phase indicates possible pozzolanic potential, a structural backbone of aluminosilicate framework. Aluminium (Al): 11.01% - Suggests an aluminosilicate framework. Si

+ Al = 38.5% Exhibits potential pozzolanic behavior. Ability to react with $Ca(OH)_2$ for the formation of secondary C–S–H gel. More C–S–H means denser matrix, hence better durability.

Durability Test Results

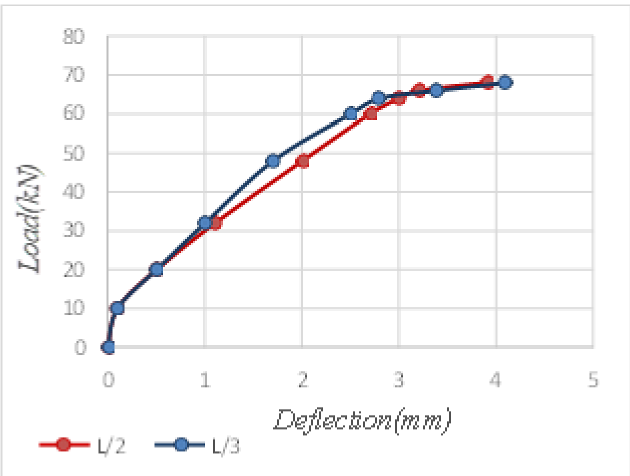
The durability performance of concrete incorporating 20% PJA was evaluated through acid resistance, sulphate resistance, water absorption, and sorptivity tests at curing ages of 15 and 30 days, in comparison with conventional concrete (0% PJA). In the acid resistance test, the 20% PJA mix exhibited lower weight loss and reduced compressive strength deterioration, with strength reductions of 7.81% and 14.29% at 15 and 30 days, respectively, compared to 8.96% and 19.55% for conventional concrete. Higher residual strength values were observed for the PJA mix, recorded as 92.19% and 85.71%, whereas conventional concrete showed lower values of 91.04% and 80.45%, indicating improved resistance to acidic environments. In sulphate resistance test, the 20% PJA mix demonstrated lower weight gain and reduced compressive strength loss, with strength reductions of 6.37% and 11.41% at 15 and 30 days, respectively, compared to 7.42% and 16.51% for conventional concrete. The residual strength values further supported this improvement, with the PJA mix achieving 93.62% and 88.58% at 15 and 30 days, respectively, compared to 92.58% and 83.48% for conventional concrete. The water absorption test revealed that the 20% PJA mix possessed lower absorption values of 1.964% and 3.828% at 15 and 30 days, respectively, compared to 2.882% and 4.584% for conventional concrete. In line with this, sorptivity values were also lower for the PJA mix, recorded as 0.0196 mm/√s and 0.0224 mm/√s at 15 and 30 days, respectively, compared to 0.0228 mm/√s and 0.0263 mm/√s for 0% PJA, suggesting decreased capillary water ingress.

Flexural Behaviour Test Results Of Reinforced Concrete Beams

Results of 0% Pja Beam With Steel Rebars

Table for Beam test results

LOAD (kN)	Deflection at L/2 (mm)	Deflection at L/3 (mm)	Remarks
0	0	0	
10	0.1	0.1	
20	0.5	0.5	
32	1.1	1	First crack
48	2	1.7	
60	2.7	2.5	
64	3	2.8	
66	3.2	3.4	
68	**3.9**	**4.1**	**Ultimate load**



Results of 20% Pja Beam With Basalt Rebars

Table and graph for Load-deflection of 20% PJA beam

LOAD (kN)	Deflection at L/2 (mm)	Deflection at L/3 (mm)	Remarks
0	0	0	
9	0.9	0.7	
13	1.3	1.7	
20	1.8	1.9	First crack
34	4	2.8	
48	5.8	3.6	
62	6.4	4.1	
72	8.2	5.1	
74	**8.8**	**5.8**	**Ultimate load**

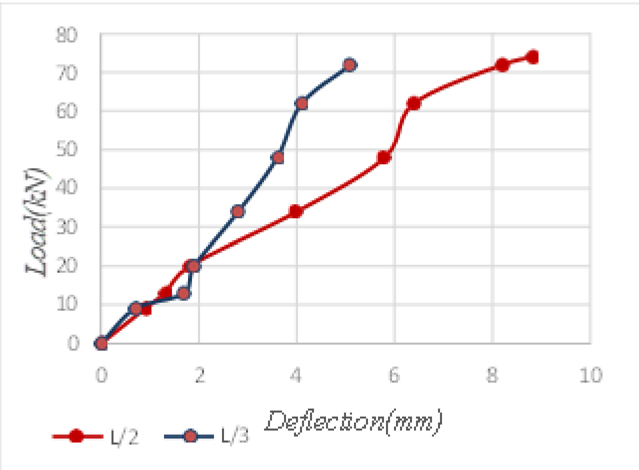


Table for Beam test results

PARAMETER	**0 % PJA**	**20% PJA**
First crack	32 kN	20 kN
Ultimate load	68 kN	74 kN
Max. deflection	3.9mm	8.8mm
Crack width	3mm, 4mm	3mm, 5mm
Flexural strength	16.11 N/mm^2	17.54 N/mm^2

Crack Pattern

Figure for Crack pattern for 0% & 20% PJA beam

- For both beams, the initial cracks developed in the tensile zone at mid-span and propagated vertically upward, typical of flexural crack pattern. In the 0% PJA beam, flexural cracks appeared suddenly after the first crack load and widened rapidly with increased loading, with an ultimate load of 68 kN.

- The 20% PJA beam with basalt fiber-reinforcement exhibited a more distributed crack pattern with flexural cracks and multiple fine cracks are formed gradually after the first crack load. The beam showed higher energy absorption with extensive cracking and deflection at the ultimate load of 74 kN.

6. Conclusion

The following conclusions are drawn from the experimental investigation of Prosopis concrete with partial replacement of cement by Prosopis juliflora ash by 10%, 20% and 30%

- PJA replacement levels of about 20% in this study demonstrated the best performance. A 20% replacement provides the ideal ratio of PJA to portlandite (the free calcium hydroxide by- product) to maximize the pozzolanic reaction. This process converts the weak and permeable calcium hydroxide into a strong, cementitious C-S-H gel.
- With 20% PJA, the fine particles fill a significant number of voids in the cement paste, creating a denser and less permeable microstructure.
- The mechanical properties deteriorated after this point, with strength reductions of up to about at 30% replacement. The delayed hydration may be the cause of the decreased performance at higher PJA dosages. Excessive replacement can weaken the bond between the cement paste and aggregates, decreasing the overall bonding strength and reducing the effectiveness of the pozzolanic activity.
- SEM confirms the ash is non uniform and heterogeneous, which indicates higher surface area and good mechanical interlocking if used in cement. EDX analysis suggests an alumino-silicate framework. Hence denser matrix and better durability could be achieved.
- Durability test confirmed that 20% PJA offers better performance than conventional concrete.
- Flexural testing of beams show that PJA beam exhibited high energy absorption, even though initial crack appeared at early load. Extensive cracking and higher deflection are observed for PJA beam. Flexural strength increased by 8.9% for PJA beam when compared to conventional beam.
- Overall, this study confirms that the combined use of Prosopis Juliflora ash and basalt fibers in concrete offers an eco-friendly, cost-effective, and structurally superior alternative for modern construction needs.
- Cost of construction reduces notably up to ~Rs. 600/m^3 of concrete with 20% PJA.

8.References

[1] Abushanab, A. R., et al. (2021). Experimental and FE studies on structural behaviour of BFRC continuous beams reinforced with BFRP bars. *Composite Structures, 281*(3), 114982. https://doi.org/10.1016/j.compstruct.2021.114982

[2] Balu, D. S., et al. (2024). Experimental study on partial replacement of cement by Prosopis juliflora in concrete. *International Journal of Innovative Research in Advanced Engineering, 11*(4). ISSN: 2349-2163.

[3] Dharmaraj, R. (2021). A feasibility study on cement with addition of Prosopis Juliflora ash in concrete. *Materials Today: Proceedings, 37*(Part 2), 1212. Elsevier Ltd.

[4] Govindasami, S., et al. (2020). An experimental study on flexural behaviour of Prosopis juliflora ash concrete. *International Journal of Civil Engineering and Technology (IJCIET), 11*(4).

[5] Karthikeyan, G., et al. (2023). Influence of utilizing Prosopis juliflora ash as cement on mechanical properties of cement mortar and concrete. *Global NEST Journal, 26*.

[6] Lapko, A., et al. (2014). Experimental and theoretical analysis of deflections of concrete beams reinforced with basalt rebar. *Springer Nature, 15*.

[7] Urbanski, M., et al. (2013). Investigation on concrete beams reinforced with basalt rebars as an effective alternative of conventional R/C structures. In *11th International Conference on Modern Building Materials, Structures and Techniques (MBMST 2013)*.

[8] Bureau of Indian Standards. (2019). *IS 10262:2019 – Concrete mix proportioning guidelines*.

[9] Bureau of Indian Standards. (2000). *IS 456:2000 – Plain and reinforced concrete code of practice*.

[10] Bureau of Indian Standards. (1970). *IS 383:1970 – Specification for coarse and fine aggregates for concrete*.

[11] Bureau of Indian Standards. (1996). *IS 4031 (Part 1):1996 – Methods of physical tests for hydraulic cement, Part 1: Determination of fineness by dry sieving*.

[12] Bureau of Indian Standards. (1988). *IS 4031 (Part 3):1988 – Methods of physical tests for hydraulic cement, Part 3: Determination of soundness*.

[13] Bureau of Indian Standards. (1988). *IS 4031 (Part 4):1988 – Methods of physical tests for hydraulic cement, Part 4: Determination of consistency of standard cement paste*.

[14] Bureau of Indian Standards. (1988). *IS 4031 (Part 5):1988 – Methods of physical tests for hydraulic cement, Part 5: Determination of initial and final setting times*.

[15] Bureau of Indian Standards. (1988). *IS 4031 (Part 11):1988 – Methods of physical tests for hydraulic cement, Part 11: Determination of density*.

[16] Bureau of Indian Standards. (2021). *IS 516 (Part 1/Section 1):2021 – Hardened concrete – Methods of test, Part 1: Testing of strength of hardened concrete, Section 1: Compressive, flexural and split tensile strength*.

[17] Shetty, M. S. (n.d.). *Concrete technology: Theory and practice*.