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Feasibility Study on Properties of Multi Layered Concrete Elements

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Abstract
A particular concrete grade is frequently used in traditional concrete building, with strength and its durability being the main priorities. In order to understand it's impact on structural performance as well as visual appeal, this project tests several grades of concrete within a structural element, challenging the traditional method. Higher grade mixtures, like M60, have merits in terms of enhanced strength and durability, while lower grade mixes could be appropriate for some applications. Considering the bottom concrete zone in high-strength reinforced concrete beams primarily struggles tension, supported by reinforcement, while the upper zone suffers compression, the concrete in the bottom zone is not obliged to be equally strong as that of the top zone. Three totally different concrete grades, Low strength concrete (LSC) M10, Normal strength concrete (NSC) M20 and High strength concrete (HSC) M60 have been analyzed in this study. The compressive, flexural, and split tensile strengths of NSC, LSC, and HSC concrete have been investigated distinctly for each concrete grade as well as their combinations such as 1/3 NSC at the bottom and 2/3 HSC at the top and vice versa, 1/3 HSC from the top, 1/3 NSC from the bottom of the soffit, and the remaining 1/3 LSC at the center using cubes, prisms, and cylinders, respectively. The research also focused on the characteristic features of concrete's durability, such as the depth of chlorine penetration and water absorption. The acquired results improve our understanding of the mechanical and durability characteristics of the concrete by recommending a phased casting approach that makes use of many grades of concrete.
Keywords: *HSC, NSC, LSC, Compressive Strength; Durability Assessment.*

1. Introduction

A trend toward a more complex and adaptable building perspective appears in the different set concrete grades. One of the interesting and challenging developments in concrete constructions over the past few decades is high strength concrete (HSC). This material started to be used in actual structures and was eventually expanded beyond the scope of academic study. Nowadays in the present construction era and the demand of economy as well as the performance of the structural elements the adaptation of new technique like layered concrete is evolved. Hence, in place of HSC for the whole structural element, the use of layered concrete technique offers a strategic advantage in structural engineering by optimizing material use, enhancing performance, and reducing costs and environmental impact [1]. Maier et.al.,[2] research looks at the effects of pouring of concrete in interval between layers and the interlayer fracture qualities of multi-mix concrete parts. From test findings it was observed that pour delay duration and mix compositions affect multi-mix fracture behavior. According to Sumit Choudhary et al., [3] Beams made of two layers of Functionally graded (FG) were cast between steel fiber reinforced rubberized concrete (SFRRUC), rubberized concrete (RuC), and ordinary concrete. The top layer of the FG beams was constructed using normal concrete,

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while the lower layer was constructed using RuC. The evaluation's conclusions showed that the FG beam with SFRRUC and plain concrete layers had flexural behavior that was 9.9%, 12.9%, and 24.4% greater than the displacement, toughness, ductile ratio, and bending strength of the plain concrete beam. Using ANSYS, Dinh Tho Vu et al., [4] studied and evaluated the performance of three-layered reinforced composite beams comprising Glass fiber reinforced polymer (GFRP) bars and steel bars. Test results showed that, in comparison to steel bars, the GFRP bars cracking resistance more than doubled. Hongduo Zhao.,[5] analyzed the B-PCP's mechanical reactions to temperature and moving wheel loads using the finite element technique. Sensitivity analysis was used to establish the ideal concrete beam geometry. slab curling, and faulting. In comparison with conventional precast concrete pavement, the ideal construction exhibited good fatigue resistance and around 40 percent reduced slab curling. Du Linpu et al., [6] discussed about Ultra-high-performance (UHPC) & lightweight aggregate concrete (LWAC) to create the functionally graded two-layer concrete slab. Fire experiments were conducted in order to have a better understanding of fire resistance behaviors. Studies showed that, with interfacial temperatures of 197°C and 325°C, respectively, LWAC greatly decreased temperature transfer to ultra-high-performance layers. Tingbin Liu et al.,[7] assessed the shear resistance of multilayer beams by considering variables such as precast layer quantity, ratio of shear span to depth, and concrete interface treatment. The assessments of the evaluation showed that the shear bearing capacity decreased by 14.17% with an increase in precast layer height and 34.12 percent with an increase in ratio of shear-span to depth. The layered beam with steel bars has an 8.43% better stress bearing strength. I.A. Sharaky's et al., [8] investigation suggests that utilizing the functionally graded material (FGM) technique, Recycled materials provided fewer of a negative effect regarding the way reinforced concrete beams responded. The ABAQUS application was used to test and simulate nine beams numerically. The findings revealed that introducing rubberized concrete (CR) to concrete might save natural sand by 13.3–16.6% and reduce load capabilities by up to 3.8%. Sangram K. Sahoo's et al,.[9] investigated on 3 types of double layered cube samples each containing OPC and GGBFS. The properties of concrete formed with two distinct layers—OPC and GGBFS blended—were investigated. In comparison to the control, the concrete's attributes improved in FGC, and the addition of value came from the development of a graded layer. The greatest outcomes were obtained when an impact was applied parallel to the graded layer. The benefits of different mix proportion concrete for the environment, energy, and cost were also looked at in the study. Aseel A.,[10] looked over the hybrid beams' flexural capabilities. made of self-compacting concrete (SCC), and reactive- powder concrete (RPC). Testing was done on five specimens, and the results included an investigation of the cracking pattern, strain-deflection response, maximum deflection, very first crack load, and final load In regards to the test findings, the hybrid beams performed much better than the SCC beam when RPC was used in the tension zone. The thickness of the tension zone and the RPC layer increased the improvement rate. Radhika Sridharet al.,[11] used sisal and steel fibers to Examine how fibers affect concrete beams with functional grading. she found the perfect fiber doses for reinforced concrete with single and hybrid fibers. The findings of the investigation showed that, in comparison to regular concrete, flexural strength peaks as fiber dosages increase. Functionally graded concrete beams' static behavior revealed a 90.8% strength gain over standard concrete. The study emphasizes the significance of fiber proportions in improving structural characteristics.

2. Materials

2.1.Cement

The material used is ordinary Portland cement (with a grade 43; also referred to as Zuari cement), which is easily found in the local market. The same batch of cement is used for each test. The cement was found to fulfil IS: 12269-1987 criteria after being evaluated for a number of characteristics that corresponded with IS 4031-1988. Table 1 provides an illustration of the physical attributes.

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Table 1 Physical Qualities of Cement

Sl No	Properties	Test Results
1	Normal Consistency	31%
2	Specific Gravity	3.01
3	Initial setting time	50min
4	Final setting time	178min
5	Soundness of cement	1.5 mm
6	Fineness of Cement	3.5%

2.2. Fine Aggregate

M-sand that complies with IS 383-1970 zone II and which is easily available locally was used. Table 2 lists the fine aggregate's characteristics. M sand has a size of less than 4.75 mm.

Table 2 Characteristics of Fine-Grained Aggregate

Sl No	Properties	Fine Aggregate
1	Specific gravity	2.53
2	Fineness modulus	2.31

2.3. Coarse Aggregate

The coarse aggregate is used at maximum fraction of 20 mm and 12.5 mm. According to IS 383-1970 & IS 2386-1983, experimental research was conducted to determine the characteristics of coarse aggregate, which are shown in Table 3.

Table 3 Characteristics of Coarse Aggregate

Sl No	Properties	Coarse Aggregate(20mm)
1	Specific gravity	2.61
2	Fineness modulus	7.71

2.4. GGBS

Ground granulated blast furnace slag (GGBS), a byproduct of the production of iron, is used in concrete i.e., more durable, workable, and strong. It is obtained from local market Bangalore and G is about 2.89.

2.5. Water

Fresh tap water that carried out with IS: 456-2000 standards was used for casting and curing (laboratory tap water). When mixing concrete, the required quantity of water was measured using a graduated jar and poured to the dry mixture.

3. Mix Design

The IS 10262-2019 and IS 456-2000 were consulted in order to create the M20 grade mixtures. Replace 5 per cent of the cement in M60 Grade concrete with GGBS. Certain performance criteria for different grades (e.g., M10, M20, and M60) are met by adapting mix designs in multi-layered concrete projects. In Table 4, 5 & 6 shows the Design mix ratio for M10, M20& M60 respectively.

Table 4 M10 Grade Design Mix Ratio

Sl No	Material	Quantity(kg/m^3)
Design Mix Ratio: 1:1.95:6.30 & W/c is 0.63		
1	Cement	241
2	Fine Aggregate	467
3	Coarse aggregate	1511

Table 5 M20 Grade Design Mix Ratio

Sl No	Material	Quantity(kg/m^3)
Design Mix Ratio: M20 & 1:2.30:3.75 & W/c is 0.5		
1	Cement	329
2	Fine Aggregate	1180
3	Coarse aggregate	731

Table 6 M60 Grade Design Mix Ratio

Sl No	Material	Quantity(kg/m^3)
Design Mix Ratio: 1:1.576:2.626 & W/c is 0.32		
1	Cement	450
2	Fine Aggregate	709
3	Coarse aggregate	1182

Notations given for different combinations of Layered beams which were casted are as follows, in Table 7.

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Table 7 Mix Details

Sl. no.	Mixes	Beam Designation
1.	M20 Grade of concrete	NSC
2.	M60 Grade of concrete	HSC
3.	M60 2/3rd from top and M20 1/3rd from soffit.	HSC - NSC
4	M20 2/3rd from top and M60 1/3rd from soffit.	NSC - HSC
5.	M20 1/3rd from top, Middle1/3rd M10 and last 1/3rd M60	NSC-LSC-HSC
6.	M60 1/3rd from top, Middle1/3rd M10 & last 1/3rd portion M20	HSC-LSC-NSC

4. Discussions of Test Results

4.1.Compressive Strength

Cube specimens of 0.15 x 0.15 x 0.15 m were made and assessed in a compression testing machine (CTM) after 7, 14, 28, and 56 days of curing for different concrete mix proportions. The three specimen averages for each percentage are shown in Table 8.

Table 8 Results of Compressive Strength Test

Concrete Mix	Compressive strength (MPa)			
	7 Days	14 Days	28 Days	56 Days
NSC	13.84	16.75	26.72	30.61
HSC	43.9	51.37	69.09	72.51
NSC-HSC	19.48	23.53	31.22	34.19
HSC-NSC	19.79	23.97	30.44	34.06
NSC-LSC-HSC	13.81	17.30	23.18	25.28
HSC-LSC-NSC	13.28	17.71	22.72	25.06

The results stated above illustrate the difference between the various concrete grades compressive strengths in all mix quantities. It has been found that adding GGBS in place of some of the cement in M60 grade results in a significant increase in strength. Multi-layered concrete projects with distinct grades like M10, M20, and M60 have varying compressive strength results. M10 has 10-15 MPa, M20 20-25 MPa, and M60 60-75 MPa or more, suitable for non-structural applications.

4.2.Split Tensile Strength

Multiple cylindrical specimens were tested for split tensile strength at days twenty-eight and fifty-six. (Diameter: 150 mm; Height: 300 mm). With a load applied along the vertical diameter of the cylinder till it fails, a compression testing apparatus with a 200-ton operational limit has a cylindrical specimen positioned horizontally between its loading surfaces and Figure 1 represents the test findings.

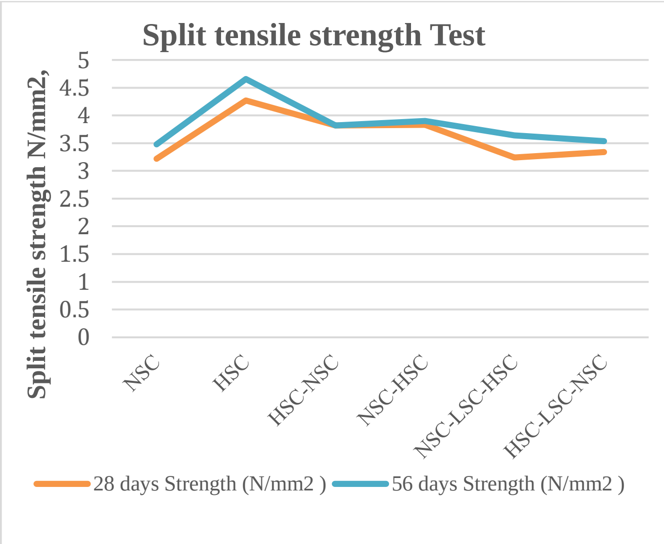

Figure 1 Split Tensile Strength Test Results

Split tensile strength in layered concrete varies: inherent characteristics give low strength concrete (LSC) a lower strength; normal strength concrete (NSC) shows a middle range balancing workability and strength; and Concrete made with high strength (HSC) has superior split tensile strength when measured against all other mixes.

4.3.Flexural Strength

At Fourteen and twenty-eight days of age, the flexural strength of concrete was measured using different prisms with dimensions of 10 x10 x 50 cm. For concrete prisms, two-point loading is used, and the failure load was taken into account while determining the flexural strength. test results obtained are shown in Figure 2.

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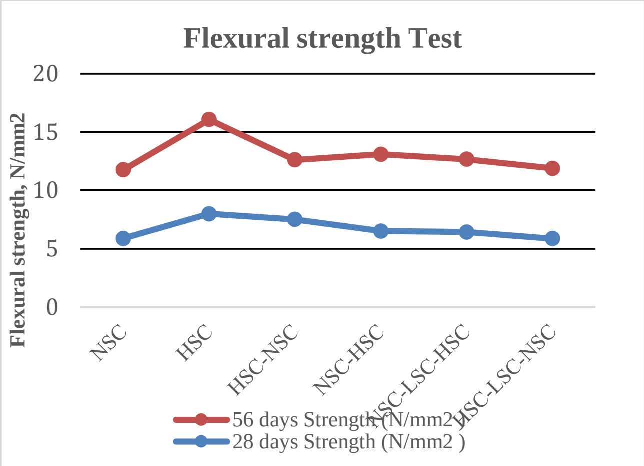

Figure 2 Flexural Strength Test Results

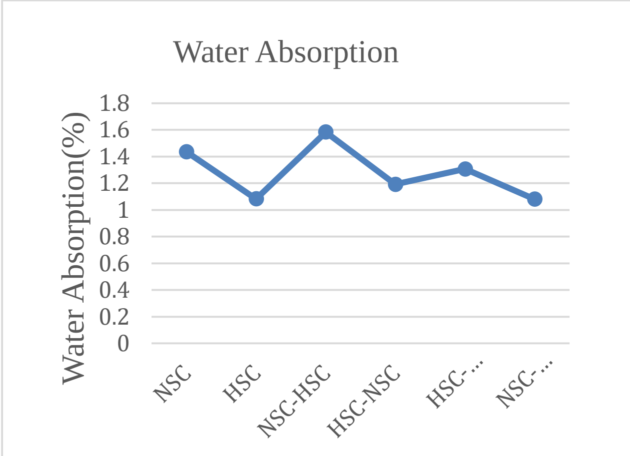

Figure 3 Water Absorption Test Results

Results of the flexural strength test for various combinations at 28, and 56 days are illustrated. According to test results, Flexural strength in layered concrete varies: high strength concrete (HSC) layers exhibit superior flexural strength, indicating modified structural performance; low strength concrete (LSC) layers show lower strength because of inherent properties; and normal strength concrete (NSC) layers strike a balance between strength and workability.

4.4.Water Absorption

Low permeability is a crucial characteristic of superior concrete, especially for freezing and thawing-resistant concrete. The water absorption test is conducted at 28 days of age in compliance with BE 1881: Part 122, 1983 standard practice. Before going through the absorption test, 150x150x150 mm cubes are dried in an oven at 100°C for at least A whole day. Before each sample is weighed, it must be taken out of the oven and allowed to cool in dry air until it reaches an internal temperature of 20 to 25 degrees Celsius. Until any two successive integers deviate by no more than 0.5% of the lowest value obtained, keep going. If the specimens dry out in less than 24 hours, they should be put to the oven. Within this current investigation, water absorption A test was carried out on three mixes such as conventional, HSC-LSC-NSC, NSC-LSC-HSC, NSC-HSC & HSC-NSC and the test results are shown in Figure 3.

Water Absorption Percentage = [(Wet Weight – Dry Weight)/Dry Weight] x 100

4.5.Chlorine Penetration Depth Test

The calorimetric chlorination technique is one way for determining the extent of chlorine penetration in a concrete sample. A minimum of two specimens with dimensions of 15 cm on all sides are considered for each mix. The specimens are taken out from the water after 28 days of treatment in water. allowed to dry at ambient temperature, and then immersed in water that has about 3.5% sodium chloride (NaCl) in it. After 28 days, the specimens are taken out of the NaCl solution. The specimens are allowed to dry at room temperature before being split into two equal halves. Silver nitrate (AgNO3) in a 0.1M solution is sprayed over the specimens immediately (broken portion). A white precipitate forms on the samples as a result of a chemical interaction between silver nitrate and sodium chloride. The depth of this precipitate is measured and recorded and showed below Table 9.

Table 9 Chlorine Penetration Depth

Different types of concrete cubes	Chlorine Penetration depth
NSC	0.39
HSC	0.42
NSC-HSC	0.55
HSC-NSC	0.66
HSC-LSC-NSC	0.707
NSC-LSC-HSC	0.398

Conclusions

In conclusion, this project exhibits a careful and thorough approach by utilizing a combination of concrete grades, such as M10, M20, and M60. In addition to maximizing strength distribution and cost effectiveness, it also permits modified performance, design flexibility, adaptability, sustainability, and safety standard compliance, all of which together add to the construction project's stability and performance. The project achieves economic efficiency by using M10 for non-critical areas, M20 for intermediate load-bearing sections, and M60 for high-stress zones, thereby reducing costs and meeting specific strength requirements. Combining different concrete classes reduces the unnecessary application of high-strength materials, which is a step toward sustainable construction. The project benefits from optimized construction processes, enhancing efficiency and reducing labor costs by using lower-grade concrete like M10 and judicious use of different grades. Grades M10, M20, and M60 ensure safety, while structural elements satisfy or exceed strength requirements, enhancing project quality and security. The mix of M10, M20, and M60 concrete grades optimizes resource utilization in project sections, ensuring each grade contributes to structural integrity.

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References

[1]. I. Iskhakov, Y. Ribakov," A design method for two-layer beams consisting of normal and fibered high strength concrete". Materials and Design 28 (2007) 1672–1677.

[2]. Marcus Maier, Janet Lees, "Interlayer fracture behaviour of functionally layered concrete" e 20 July 2022 0013-7944/Crown Copyright © 2022 Published by Elsevier Ltd.

[3]. Sumit Choudhary a, Sandeep Chaudhary b, Abhishek Jain a, Rajesh Gupta a," Valorization of waste rubber tyre fiber in functionally graded concret" 2214-7853/ 2020 Elsevier Ltd.

[4]. Dinh Tho Vu, Elena Koro, Yuliya Kustikova, Huy Hoang Nguyen "Finite element analysis of three-layer concrete beam with composite reinforcement" E3S Web of Conferences 97, 02023 (2019) https://doi.org/10.1051/e3sconf/20199702023 FORM-2019.

[5]. Hongduo Zhao, Haoyu Chen, Chenchen Li , Lukuan M," "Structural optimization and performance evaluation of precast concrete pavement with composite base layer". International Journal of Transportation Science and Technology,Volume 12, Issue 2, June 2023, Pages 525-533.

[6]. Linpu Du , Xuping Ji , Yuxuan Wang , Fangyu Han, Kaiwei Lu , Jingquan Wang "Experimental study on thermal behaviors of two-layered functionally graded concrete slabs subjected to fire" Engineering Structures Volume 297, 15 December 2023, 117047

[7]. Tingbin Liu, Zhihan Xu , Qiang Ma , Yanbao Huang , Shiyang Liu , Rubo Jia , Hong Bai , ShiPeng Cui , Qiang Li "Experimental research on shear resistance performance of fabricated reinforced concrete layered beams Structures". Volume 63, May 2024, 106450

[8]. I.A. Sharaky, M.H. Seleem, Ahmed S. Elamary, "Minimizing the crumb rubber effects on the flexural behaviour of the layered RC beams cast using rubberized concrete with or without recycled tire steel fibers". Construction and Building Materials Volume 400, 12 October 2023, 132503.

[9]. Sangram K. Sahoo, Benu G. Mohapatra, Sanjaya K. Patro, Prasanna K. Acharya, "Evaluation of graded layer in ground granulated blast furnace slag based layered concrete". Construction and Building Materials, Volume 276, 22 March 2021, 1222.

[10]. Aseel A. Abdulridha, Sura A. Abbas*, Lubna S. Danha & Zainab H. Shaker, "Flexural Behavior of the Layered Beams Containing Reactive Powder Concrete and Self-Compacting Concrete". J. Eng. Technol. Sci., Vol. 54, No. 3, 2022, 220302.

[11]. Radhika Sridhar, Mohamad Abbas, "Experimental study on hybrid fiber reinforced concrete with composite layers" Volume 65, Part 2, 2022, Pages 489-494.