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RESEARCH ARTICLE

STRENGTH OF REINFORCED CONCRETE BEAM USING DUAL GRADE CONCRETE

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ABSTRACT

The purpose of this work was to investigate the use two different grades of concrete in one single structural beam unit. A beam is specified with two zones as compression zone and tension zone. Compression zone arise at top part of neutral axis and tension zone arise at bottom part of neutral axis. Here in case of reinforced concrete beam, steel plays a vital role to support especially in tension zone. Here, to simply investigate, the process of using high grade concrete above Neutral axis and low-grade concrete below neutral axis by using nominal steel is done. For this experimental project, High grade concrete of M 60 is used and Low-grade concrete of M 20 is used.

For getting pre-execution remark, we have casted concrete cubes with dual grade concrete by keeping 30 mm interval along depth, and separate M 20 and M60 grade cubes. The result shows that dual grade concrete cubes achieve average strength of 100+30% as compare to M20 for 7 days and up to 55 to 60 % as compare to M60 for 7 days. And, average strength achieved is up to 70 % of M60 for 28 days. And average strength achieved is 100+55% of M20 for 28 days. Further, PC beams and Reinforced Concrete beams with double grade concrete has been casted.

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INTRODUCTION

Concrete is a composite material composed of coarse aggregate bonded together with fluid cement that hardens over time. As we've already seen, concrete is a composite material—a cement matrix with aggregates for reinforcement—that works well in compression, but not in tension. We can solve that problem by casting wet concrete around strong, steel reinforcing bars. When the concrete sets and hardens around the bars, we get a new composite material, reinforced concrete,that works well in either tension or compression: the concrete resists squeezing, while the steel resists bending and stretching. In effect, reinforced concrete is using one composite material inside another: concrete becomes the matrix while steel bars or wires provide the reinforcement. Concrete is good in resisting compression but is very weak in resisting tension. Hence reinforcement is provided in the concrete wherever tensile stress is expected. The best reinforcement is steel, since tensile strength of steel is quite high and the bond between steel and concrete is good. As the elastic modulus of steel is high, for the same extension the force resisted by steel is high compared concrete.

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However, in tensile zone, hair cracks in concrete are unavoidable. Reinforcements are usually in the form of mild steel or ribbed steel bars of 6 mm to 32 mm diameter. A cage of reinforcements is prepared as per the design requirements, kept in a form work and then green concrete is poured. After the concrete hardens, the form work is removed. The composite material of steel and concrete now called R.C.C. acts as a structural member and can resist tensile as well as compressive stresses very well. The behavior of composite beams, which are composed of cold-formed steel sheeting and normal strength concrete. The flexural strength and stiffness of the composite beams were highly increased in comparison with the equivalent reinforced concrete beam. Though there is not much difference between rib types, the rectangular rib is better for bond strength than the triangular rib (Song Jun 2000). As concrete is weak in tension steel is introduced in the tension zone to take the tension, but as strength of concrete is ignored in tension zone with respect to compression zone. But this concrete needs to be provided on tension side to act as strain transferring media to steel and may be called as sacrificial concrete. This led to the idea of concrete grade reduction in tension side for RCC beams to reduce construction cost (Kandekar, 2013).The failure composite beams include longitudinal cracking of the concrete slab and interlayer slip between the concrete slab and the steel beam (David, 2013). Flexural strengthening of concrete elements by adding new concrete layers is a common strengthening technique. A specific feature of concrete composite structures is the existence of an interface between the component parts which may be the weakest zone in view of the occurring discontinuity of the construction material. It is found that interface preparation and the type of strengthening considerably influence effectiveness (M. Arun, 2014). In the case of low-grade concrete beams, it is observed that the separation of aggregates in compression zone was more, but in the case of high grade of concrete beams number of cracks and crack width were reduced in tension zone (Khan, 2014). The composite column system has recently been developed by the author as a special form of dual grade-skin tabular columns, with the column manufactured using two different grades of concrete. In this system annular section of column is filled with normal –strength concrete (NSC) and the core section inside the tube is filled with higher grade concrete mix. The improved performance of new composite columns system is attributable to its ability to effectively utilize the two-confinement mechanisms to maximize benefits offered by normal strength concrete and high strength concrete (Ozbakkaloglu, 2015).

Concrete Material

The physical properties of aggregates are those that refer to the physical structure of the particles that make up the aggregate. Strength is a measure of the ability of an aggregate particle to stand up to pulling or crushing forces. High strength and elasticity are desirable in aggregate base and surface courses. These qualities minimize the rate of disintegration and maximize the stability of the compacted material.

Fine aggregate

River sand used as a fine aggregate resulting from the natural disintegration of rock and which has been deposited by streams or glacial agencies. The fine aggregate used for experiment work was belong to zone II and having specificationreferred with IS 383:1970. Table 1 showing physical properties of fine aggregate use for concreting work.

Table 1. Properties of fine aggregates (river sand)

Sr. No	Properties	Value
1	Silt content	3.42 %
2	Specific gravity	2.78
3	Fineness modulus	3.86
4lunm/.,	Bulking of Sand	25 %

Coarse Aggregates

Aggregate is a very crucial raw material for preparing concrete, especially coarseaggregate, which greatly affects the concrete performance. Concrete performances,such as frost resistance, permeability resistance, drying shrinkage, and durability,are closely related with aggregate. In our work coarse aggregate used was produced by trap crushed stone. Table 2 showing physical and mechanical properties of course aggregate use for concreting work.

Table 2. Properties of coarse aggregate

Sr.No	Properties	Value
1	Impact value	17.85 %
2	Crushing value	24.26 %
3	Specific gravity	2.88
4	Fineness modulus	3.11
5	Abrasion value	18.73%

Cement

The cement was used for experiment work Ordinary Portland Cement (OPC) of grade 53MPa.The cement was tested for following properties: consistency, setting time, soundness, workability and compressive strength, as per IS 546- 2003 (Table 3).

Table 3. Properties of cement according to IS: 12269

Sr. No.	Parameter	Birla Shakti OPC 53 Grade Cement	Test results
1	Compressive strength (MPa)	3 Days	31.0 MPa
		7 Days	42.2 MPa
		28 Days	67.6 MPa
2	Fineness (m^2/kg)	Minimum specific surface	230 m^2/ kg
3	Setting time (minutes)	Initial setting time	120 Minutes
		Final setting time	160 Minutes
4	Soundness	Autoclave	0.6 %
		Le- Chatelier	3 mm

Concrete Mix Design

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The trial mixes are designed

Grade of cement : OPC 53 Grade Cement confirming to IS12269-1987
Sand (fine aggregate) : River Sand
Size of coarse aggregate : 20 & 12mm Crushed Angular
Type of Exposure : Mild

Minimum Cement Content : 300 kg/m^3
Degree of quality control : Good
Maximum w/c ratio adopted : 0.45
Maximum Water Content/ Cum: 186 liters (as per SP 23-1982) Table 42, pg-113
Chemical admixture : ConplastSp 430

Table 4. Test result of trial mix (As per IS 9013:1978)

Trial	Proportion	W/C	Test Result for 28 Days (Mpa)			Average Strength (MPa)
M20	1 : 2.40 : 4.20	0.45	32.48	31.68	34.58	32.91
M60	1 : 1.52 : 2.90	0.32	71.43	73.81	69.87	71.70

Strength of Dual Concrete

In this chapter, results and discussions related to the project work are to be discusses. These will be in accordance with the procedure discussed

Compressive Strength

Figures 1and 2 below show the compressive strengths measured on 150 mm x 150mm cubes prepared as described in IS4031 Part 6. Average 7 days compressive strength for M20 grade concrete cube is found to be 21.40 MpaandM60 grade concrete cube is found to be 49.21 MPa**.**Thecompressive strength of concrete mix PCB is 32.01 MPa, that increase in the strength 50% as compared to M20 (PCA).The compressive strength of concrete mix PCC is 25.21 MPa that increase in the strength around 20% as compared to M20 (PCA).

Table 5. DaysAverage Compressive Strength

Sr. No	Mix	Layer of dual concrete	Cube 1 (MPa)	Cube 2 (MPa)	Cube 3 (MPa)	Average Compressive Strength(MPa)
1	PCA	Full M 20 Grade	22.34	21.48	20.4	21.40
2	PCB	120 mm M20 + 30 mm M60	28.92	34.67	32.46	32.01
3	PCC	90 mm M20 + 60 mm M60	23.34	27.46	24.84	25.21
4	PCD	60 mm M20 + 90 mm M60	25.95	27.63	28.67	27.41
5	PCE	30 mm M20 + 120 mm M60	25.34	24.75	26.59	25.56
6	PCF	Full M60 Grade	46.34	49.58	51.72	49.21

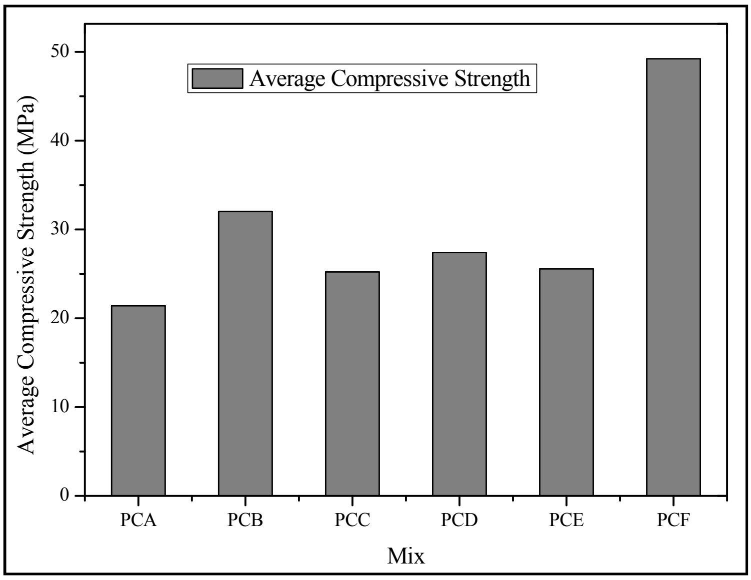

Figure 1. 7 DaysAverage Compressive Strength of Dual Concrete

Table 6. 28 DaysAverage Compressive Strength

Sr. No	Mix	Layer of dual concrete	Cube 1 (Mpa)	Cube 2 (Mpa)	Cube 3 (Mpa)	Average Compressive Strength (Mpa)
1	PCA	Full M 20 Grade	32.48	31.68	34.58	32.91
2	PCB	120 mm M20 + 30 mm M60	47.89	46.53	49.65	48.02
3	PCC	90 mm M20 + 60 mm M60	48.13	46.38	42.36	45.62
4	PCD	60 mm M20 + 90 mm M60	45.97	47.65	44.87	46.16
5	PCE	30 mm M20 + 120 mm M60	48.164	55.97	52.67	52.27
6	PCF	Full M60 Grade	71.43	73.81	69.87	71.70

The compressive strength of concrete mix PCD is 27.41MPa that increase in the strength 30% as compared to M20 (PCA).The compressive strength of concrete mix PCE is 25.56 MPa that increase in the strength around 20% as compared to M20 (PCA).But other proportion mixesdoes not showing any variations compare with M60 mix (PCF).

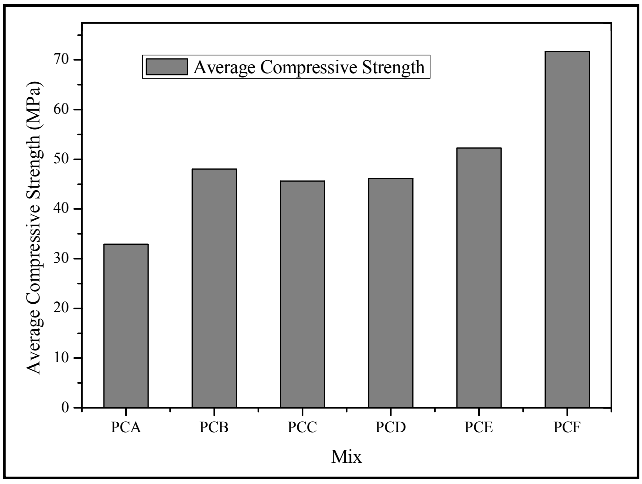

Figure 2. 28 DaysAverage Compressive Strength of Dual Concrete

The compressive strength of concrete mix PCC is 45.62 MPa that increase in the strength around 40% as compared to M20 (PCA) that show in early strength (7 days). The compressive strength of concrete mix PCD is 46.16 MPa that increase in the strength 45 to 50% as compared to M20 (PCA) that show in early strength (7 days). The compressive strength of concrete mix PCB is 48.02 MPa that increase in the strength 50 to 55% as compared to M20 (PCA) that show in early strength (7 days). In this test, plain concrete beam was subjected to flexure using symmetrical two-point loading until failure occurs. The theoretical maximum tensile stress reached in the bottom fiber of the test beam is called modulus of rupture.The comparative study of flexural strength shows in figures 5.3 and 5.4 measured on 150 mm x 300 mm beams prepared as described in IS516 1959.

Flexural Strength

It is seen that there is much difference in the flexural strength of control beams and that of beams with low grade concrete. Control beam PBK (M60) achieved 4.32 MPa early strength (7days), whereas low-grade concrete PBA (M20) achieved 2.69 MPa. With the increase in the grade of concrete bellow neutral axis, flexural strength of concrete also increases.

Table 7. 7 Days Flexural Strength of Dual Concrete

Sr.No	Mix	Layer of dual concrete	Specimen 1	Specimen 2	Average 7 Days Flexural Strength (MPa)
1	PBA	300 mm M20	2.54	2.84	2.69
2	PBB	270mm M20 + 30mm M60	2.81	2.89	2.85
3	PBC	240mm M20 + 60mm M60	3.05	3.19	3.12
4	PBD	210mm M20 + 90mm M60	3.17	3.00	3.09
5	PBE	180mm M20 + 120mm M60	3.08	3.57	3.33
6	PBF	150mm M20 + 150mm M60	3.50	3.71	3.61
7	PBG	120mm M20 + 180mm M60	3.49	4.01	3.75
8	PBH	90 mm M20 + 210mm M60	3.43	4.15	3.79
9	PBI	60 mm M20 + 240mm M60	3.87	3.01	3.44
10	PBJ	30 mmM20 + 270 mm M60	3.62	4.07	3.85
11	PBK	300 mm M60	4.21	4.43	4.32

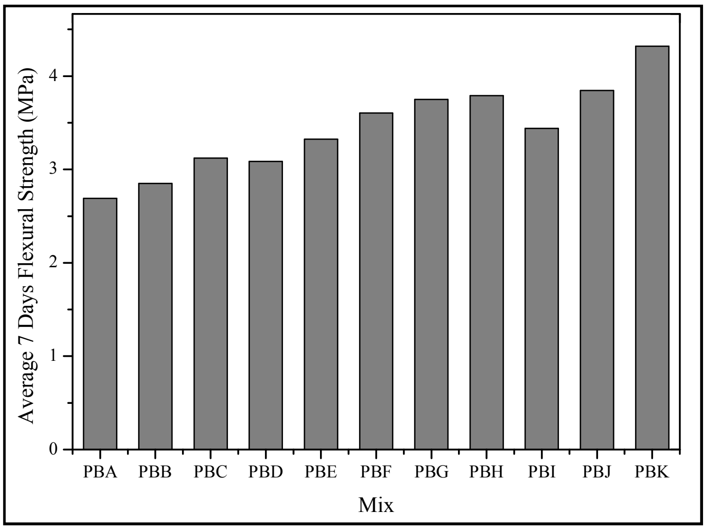

Figure 3. 7 Days Flexural Strength of Dual Concrete

Table 8. 28 Days Flexural Strength of Dual Concrete

Sr.No	Mix	Layer of dual concrete	Specimen 1	Specimen 2	Average 28 Days Flexural Strength (MPa)
1	PBA	300 mm M20	4.14	4.82	4.48
2	PBB	270mm M20 + 30mm M60	4.56	5.43	5.00
3	PBC	240mm M20 + 60mm M60	5.19	5.31	5.25
4	PBD	210mm M20 + 90mm M60	5.44	5.63	5.54
5	PBE	180mm M20 + 120mm M60	5.97	6.23	6.10
6	PBF	150mm M20 + 150mm M60	6.21	6.31	6.26
7	PBG	120mm M20 + 180mm M60	6.12	5.85	5.99
8	PBH	90mm M20 + 210mm M60	6.54	6.26	6.40
9	PBI	60mm M20 + 240mm M60	6.24	6.35	6.30
10	PBJ	30mm M20 + 270mm M60	6.32	6.58	6.45
11	PBK	300 mm M60	6.73	7.07	6.90

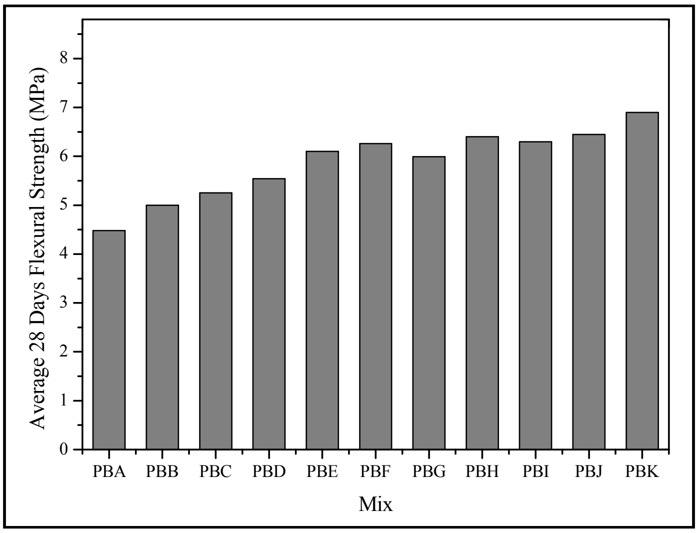

Figure 4. 28 Days Flexural Strength of Dual Concrete

It shows that the flexural strength of PBJ beam is more than that of PBB beam. It was also found that there was an increase of 34% flexural strength for PBF beam i.e. above NA; M20 grade concrete and bellow NA; M60 grade concrete, when compared with that of PBA beam as shown in figure 3. It was found that there was an increase of 12% flexural strength for PBK(300mm M60)beam when compared with that of PBJ (30mm M20 + 270mm M60)beam, where only 10% layer is replaced by rich concrete M60 due to bonding layer between these two mixes. From Fig. 4, it is seen that there is much difference in the flexural strength of control beams with that of beams with rich concrete at neutral axis. For M20 beam with M60 replaced below neutral axis, it was observed that the flexural strength increase by 40 % and with M60 replaced above neutral axis, the flexural strength increased by 44% when compared with that there is only 4% rise when rich concrete used above NA.Also, for PBF (150mm M20 + 150mm M60) beamM60 replaced below neutral axis, it was observed that the flexural strength 6.28 MPa where as compared to that of single-grade concrete beam PBK (M60) is only 13% increase in flexural strength.The beam filled with dual grade concrete achieves complete more 45% of flexural strength as compare to M20 mix and it achieves flexural strength up to -13% as compare to M60 mix. Beam PBK i.e., purely filled M60 mix has achieved average flexural strength of 6.90 Mpa.

Moment of Resistance of Reinforced Cement Concrete (RC) Beam

In this test, reinforced concrete beam was subjected to one-point loading until failure occurs. The theoretical maximum tensile stress reached in the bottom fiber of the test beam is called moment of resistance. The comparative study of moment of resistance shows in table 9 - 10 measured on 150 mm x 150 mm beams. As result shows in table 5.5, the single-grade concrete beam RC beam AS (M20) has achieved average moment of resistance of 5.46kNm which is nearly equal to theoretical value 4.46 kNm.Single-grade concrete beamBS (M60) has achieved average moment of resistance of 13.29kNm.Also, dual grade concrete beam CS i.e. M60 above the neutral axis and M20 below neutral axis shows nearby same moment of resistance that shows by BS i.e. 12.71 kNm. Beam of dual concrete around its neutral axis has achieved 133% more resistance as compare to single-grade concrete beam RC beam AS (M20). As result shows in table 10 and figure 5, the single-grade concrete beam RC beam AS (M20) has achieved average moment of resistance of 6.96kNm which is nearly equal to theoretical value 6.36kNm after 28 days curing. Single-grade concrete beamBS (M60) has achieved average moment of resistance of 22.92kNm. Whereas, dual grade concrete beam CS i.e. M60 above the neutral axis and M20 below neutral axis shows nearby same moment of

Table 9. Moment of Resistance for RC beam (Age: 7 Days)

Sr. No	Beam Description	Specimen 1	Specimen 2	Specimen3	Experimental Moment of Resistance (kN-m)	Theoretical Moment of Resistance (kN-m)
1	AS	5.75	5.25	5.38	5.46	4.46
2	BS	13.75	12.63	13.50	13.29	13.38
3	CS	12.63	12.25	13.25	12.71	13.38

Table 10. Moment of Resistance for RC beam (Age: 28 Days)

Sr. No	Beam Description	Specimen 1	Specimen 2	Specimen3	Experimental Moment of Resistance (kN-m)	Theoretical Moment of Resistance (kN-m)
1	AS	7.25	6.50	7.13	6.96	6.36
2	BS	21.75	23.63	23.38	22.92	19.12
3	CS	20.63	19.00	20.38	20.00	19.12

Table 11. Cost of concrete used in RC beam

Sr. No	Beam Description	Volume of M20 (m^3) beam	Volume of M60 (m^3) beam	Amount in Rs. / cum	% increase MR capacity as per M20 mix
1	AS	0.016875	--	4355.0	--
2	BS	--	0.016875	6750.0	229%
3	CS	0.0104625	0.0064125	5260.0	187%

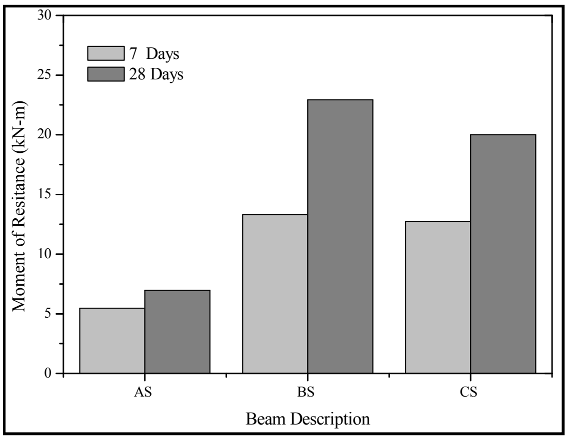

Figure 5. Moment of Resistance for RC beam

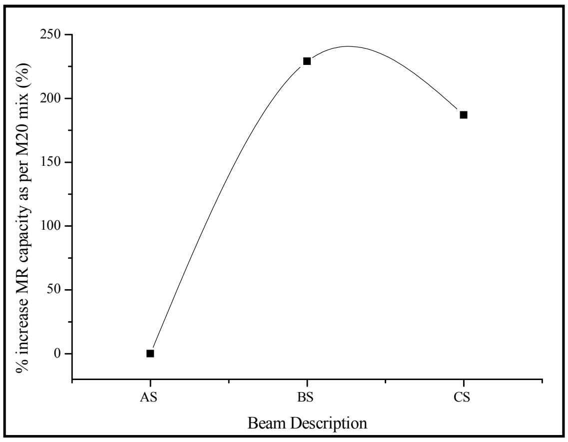

Figure 6.Moment Resisting Capacity w.r.t. M20 Grade Concrete

resistance that shows by BS i.e. 20.00kNm. As referring figure 5.6 dual grade concrete around its neutral axis has achieved 229% more resistance as compare to single-grade concrete RC beam AS (M20) and decreases strength 13% as compare to single-grade concrete RC beam BS (M60). It shows that there is no change in moment of resistance by using dual grade concrete by placing low grade bellow NA. As compared to strength dual grade concrete showing very good result in moment resting capacity of beam but also it is saving cost of concrete. As result shows in table 11, the cost of single-grade concrete beam RC beam AS (M20) Rs. 4355/- per cum for achieved strength 6.96 kNm. Single-grade concrete beamBS (M60) has cost Rs. 6750/- per cum and achieved average moment of resistance of 22.92kNm. Whereas, dual grade concrete beam CS i.e. M60 above the neutral axis and M20 below neutral axis shows nearby same moment of resistance that achieved by BS and saving around Rs. 1490/- per cum.

Summary and Conclusion

Construction of structural elements like beam is carried out using two different grades of concrete into one single structural element as beam. Following conclusions are drawn from the project work, which are listed below.

- It is observed that out of four mix of dual grade concrete for Plain beam, addition of rich concrete (M60) resulted in the increase of compressive strength. However, there is not much change in the compressive strength with change percentage of M60 grade concrete. The compressive strength of concrete mix PCB (120mm M20 + 30mm M60) is 48.02 MPa that increase in the strength 50% as compared to M20 grade concrete. Other mixes also show good strength as compared to single grade concrete (M20), i.e average increase in strength 45% as compared to PCA (150mm M20).
- The outcome of this work reveals that concrete made by replacement of M20 bellow neutral axis by rich concrete M60 gives more flexural strength for both 7-day and 28-day strength than the referred nominal concrete specimen made by M20 (PBA). It was observed that the flexural strength of concrete which replaced byM60 bellow neutral axis increased by 44% when compared with that there is only 4% rise when rich concrete (M60) used above NA.
- As the depth of higher grade concrete increases in compression zone, resistance to first crack development also increases. Dual grade concrete around its neutral axis has achieved 229% more resistance as compare to single- low grade concrete RC beam.
- Dual grade RC beam with low grade concrete below neutral axis shows nearby same moment of resistance that achieved by high grade concrete and make concrete more economical.

REFERENCES

Indian Standard Code IS 10262:2009 "Concrete mix proportioning guide lines" *Bureau of Indian Standards, New Delhi*

Indian Standard Code IS 1199: 1959 "Methods of sampling and analysis of concrete" *Bureau of Indian Standards, New Delhi*

Indian Standard Code IS 456-2000, "Code of Practice for Plain and Reinforced Concrete‖" *Bureau of Indian Standards, New Delhi*

Indian Standard Code IS 516:1959 "Method of test for strength of concrete" *Bureau of Indian Standards, New Delhi*

Indian Standard Code IS 5816 1999. "Method of Test Splitting Tensile Strength of Concrete" *Bureau of Indian Standards, New Delhi*

Indian Standard Code IS: 12269, "Specifications for 53 Grade Ordinary Portland Cement" *Bureau of Indian Standards, New Delhi*

Indian Standard Code IS: 2386, "Methods of test for Aggregates for Concrete", reprinted 1997, *Bureau of Indian Standards, New Delhi*

Indian Standard Code IS: 269, "Specifications for 33 Grade Ordinary Portland Cement" *Bureau of Indian Standards, New Delhi*

Indian Standard Code IS: 383 1970. "Specification for Coarse and Fine Aggregates from Natural Sources for Concrete" *Bureau of Indian Standards, New Delhi*

Indian Standard Code IS: 8112, "Specifications for 53 Grade Ordinary Portland Cement" *Bureau of Indian Standards, New Delhi*

Stephen Seguirant, J., Brice Richard, and KhaleghiBijan, 2005. "Flexural strength of reinforced and prestressed concrete T-beams," *PCI Journal*,January 2005.

Kandekar S.B., Dhake P.D, WakchaureM. R. 2013. "Concrete Grade Variation in Tension and Compression Zones OfRcc Beams," *International Journal of Innovative Research in Science, Engineering and Technology*, Vol. 2, Issue 8.

Khan I.K, 2014. "Performance of Reinforced Concrete Beam under Point Impact Loading," *American International Journal of Research in Science, Technology, Engineering.*

Kim Chul-Goo, Park Hong-Gun, Kang Su-Min, Hong Geon-Ho, 2014. "Shear Strength of Composite Beams with Dual Concrete Strengths," *International Conference on Geological andCivil Engineering*, Vol.62 IACSIT Press, Singapore 2014. V62. 8.

KwanK. H., Ho J. C. M., Pam H. J. 2002. "Flexural Strength and ductility of reinforced concrete beams," *Proceedings of the Institution of Civil Engineers Structures & Buildings*, 152 Issue 4 Pages 361–369.

Leaf David and LamanA Jeffrey, Aug 2013. "Testing and Analysis of Composite Steel-Concrete Beam Flexural Strength," *International Journal of Structural and civil engineering research*, Vol2 No3.

M Arun, H Aysha, R.K. Ramsundar, G Velrajkumar, 2014. "An Overview of Interface Behavior between Concrete to Concrete," *International Journal of Advanced Structures and Geotechnical Engineering*, Vol. 03, No. 02.

OzbakkalogluTogay, 2015. "A Novel FRP Dual Grade Concrete Steel composite column system," *Thin Walled Structures*.

Paul Mathews M. and KuriakoseAnuja Mary, 2015. "Behaviour Of Beams with Low Grade Concrete or Hollow Neutral Axis Zone*," International Journal of Civil Engineering and Technology (IJCIET),* Volume 6, Issue 10.

Tejaswi, S and J Eeshwar Ram, 2015. "Flexural Behavior of RCC Beams" *International Journals of Innovations in Engineering and Technology*, Volume 5 Issue.

Shiyekar M.R, and S Vidula v Sohoni, 2012. "Effect of Change in Grade of Concrete on the Composite Members of a Framed Structure," *International Journal of*

Engineering Research and Development, Volume 2, Issue 6 PP. 35-41.

Song Jun-Yeup and Kwon Young-Bong, 2000. "Flexural Behavior of Profiled Composite Beams," Fifteenth International Specialty Conference on Cold-Formed Steel Structures St. Louis, Missouri U.S.A., 19-20.

Thomas Nimmy, Dr. Joanna P.S., SakariaEapen, 2015. "Flexural Capacity of Composite Beams Using Truss Beams," *International Journal of Engineering Sciences & Research Technology*.

Uleiwi Jawad Kadhim, 2007. "Experimental Study of Flexural Strength of Laminate Composite Material,"*Engineering & Technology*, Vol.25, Suppl.of No.3.

****