How to Cite:
Reddy, G. M. K., Mounika, M., & Priya, P. V. (2022). Experimental and correlation study of destructive and non-destructive testing on blended concrete with metakaolin and bagasse ash. *International Journal of Health Sciences*, *6*(S2), 13580–13591.
https://doi.org/10.53730/ijhs.v6nS2.8568

Experimental and correlation study of destructive and non-destructive testing on blended concrete with metakaolin and bagasse ash

G. Madhava Krishna Reddy
Assistant Professor, Department of Civil Engineering, GMR Institute of Technology, Rajam, Andhra Pradesh, India
Corresponding author email: madhavakrishna.g@gmrit.edu.in

M. Mounika
Assistant Professor, Department of Civil Engineering, Gurunanak Institute of Technical Campus, Khanapur Village, Manchal, Ibrahimpatnam, Telangana, 501506

P. Vishnu Priya
Assistant Professor, Department of Civil Engineering, Annamacharya Institute of Technology and Science, Tirupati, Andhra Pradesh, India

***Abstract*---**The utilization of industrial wastes has been the hub of squander minimization research for environmental, economic and technical reasons. Bagasse is an off-shoot from sugar industries, which is ignited to develop the power needed for numerous activities in the factory. Its high pozzolanic property and the presence of alumina and silica content can enrich the properties of concrete. Metakaolin is a primitive output accomplished by calcinating kaolin clay inside a temperature sort of 650 to 800°C utilized to produce materials with lower porosity, greater strength, denser microstructure, greater resistance to ions improved durability. An experimental investigation has been done on blended concrete with a combined effect of Bagasse ash (B), and Metakaolin (M) with percentages 10%+2.5%, 20%+5%, 30%+7.5%, and 40%+10%, which are designated as B1M1, B2M2, B3M3, and B4M4 respectively were incorporated in Ordinary Portland Cement (OPC). The fresh (workability) and hardened properties (Splitting tensile and compressive strength) of concrete were compared to Control Concrete (CC) and also checked the contrast of non-destructive strength values over destructive testing. It is noted that destructive testing strength values are more and accurate compare to non-destructive because it

Manuscript submitted: 09 March 2022, Manuscript revised: 18 April 2022, Accepted for publication: 27 May 2022

exterminates interface transition zone failures, and it is observed that the B2M2 designated concrete was attained maximum compressive and tensile strength at 28 and 56-days curing phase contrasted to all other concrete.

***Keywords*---**bagasse ash, compressive strength, metakaolin, rebound hammer, splitting tensile strength.

Introduction

Disposal of industrial and agricultural squanders is a genuine natural issue as most final scraps go to landfills, which diminishes functional land regions as well as pollutes the environment. So, in the current study, Bagasse ash and Metakaolin have been successfully replaced with cementitious materials to about 25%. Metakaolin has been extensively considered for its extreme pozzolanic properties [Shelorkar Ajay *et al.,* 2013], suggesting that Metakaolin could be utilized as a Supplementary Cementitious Material (SCM). Not at all like other SCMs that are auxiliary items or outcomes, Metakaolin is a primitive item, attained by calcinating kaolin clay inside a temperature sort of 650 to 800°C [Ilić, B. R *et.al.,* 2010]. Metakaolin is progressively being utilized to produce materials with lower porosity, higher strength, denser microstructure, higher resistance to ions, and improved durability. The fine microcrystalline structure [Cordeiro G. C *et.al.,* 2019] and silica in Sugarcane Bagasse Ash (SCBA) reacts with cement components during hydration and imparts high strength and resistance against chloride penetration and corrosion.

Literature Review

1. Ilić, B. R *et.al.,* (2010). "Thermal treatment of kaolin clay to obtain metakaolin." The ideal conditions of the thermal treatment are calcination temperature of 650 °C and heating time of 90 min. Calcination brings about a dehydroxylation level of 0.97. The produced metakaolin has pozzolanic action 0.65 g $Ca(OH)_2$ / g of metakaolin.
2. Cordeiro, G. C *et.al.,* (2019). "Pozzolanic properties of ultrafine sugar cane bagasse ash produced by controlled burning." SCBA significantly further developed paste properties, with obvious evidence of a pozzolanic impact and pore structure refinement.
3. MJ, M. B and Varghese, M. S (2014)., "Ternary Blended Concrete with Bagasse Ash and Metakaolin." The workability of the altered concrete increments with an increase in bagasse ash content and the optimum percentage replacement can be about 20% with a steady metakaolin percentage of 5%.
4. Malagavelli V. *et.al.,* (2018)., "Mechanical properties of blended concrete with metakaolin." An apex of 10% can be replaced by cement with metakaolin. A fresh property like workability is increased as the percentage of metakaolin increments. A percentage increment in strength properties is 7.88% and 16.75% in Splitting tensile and compressive strengths respectively at 28 days.

5. Shelorkar Ajay *et.al.,* (2013)., "Experimental study on partial replacement of cement with metakaolin." The compressive strength of HGC increments by 10.13%, 14.24% and 22.90% because of adding up of Metakaolin content of 4 %, 6 %, and 8 % respectively in correlation with control concrete specimens of HGC because of its pozzolanic action, it was observed that the metakaolin percentage increases then the rapid chloride permeability of HGC decreases.

Materials Utilized

Cement

Portland cement of grade 53 confirming to IS 4031 is utilized in the current examination. The specific gravity, consistency, initial and final setting times were 3.15, 45 minutes, and 480 minutes respectively.

Metakaolin

The chemical constituent of metakaolin shown in table 3.3.1 and the specific gravity was 2.62.

Bagasse Ash

The chemical constituents of bagasse ash are shown in table 3.3.1 and the specific gravity is 2.14.

Table 3.3.1: Chemical Constituents of Bagasse Ash, Metakaolin and OPC

Composition	Bagasse Ash Mass (%)	Metakaolin Mass (%)	OPC Mass (%)
Silica (SiO_2)	76.53	55.62	21.51
Alumina (Al_2O_3)	10.21	37.33	5.32
Ferric oxide (Fe_2O_3)	4.12	4.31	6.09
Calcium oxide (CaO)	3.18	0.48	62.14
Potassium oxide (K_2O)	2.89	0.57	0.18
Sodium oxide (Na_2O)	0.19	0.11	0.39
Loss of Ignition	0.46	-	1.02

Fine Aggregate

Natural River Sand acquired from a close-by quarry was utilized as fine aggregate, affirming to IS 383, Zone-II. The specific gravity, water absorption, and fineness modulus were observed as 2.67, 1.1%, and 2.83 respectively when tested as per IS 2386.

Coarse Aggregate

The natural crushed gravel of size 10mm (40%) and 20mm (60%) coarse aggregate were utilized, confirming to IS 383. The specific gravity and water absorption of coarse aggregate were 2.72 and 0.6% respectively when tested as IS 2386.

Experimental Work

The M30 material loads, mix proportions, and slump values for numerous types of concrete were mentioned in table 4.1.1. The slump test during mixing has been shown in fig 4.1.1.

Table 4.1.1: Mix design for M30 Grade Concrete

Mix ID	CC	B1M1	B2M2	B3M3	B4M4
Metakaolin (%)	0	2.5	5.0	7.5	10
Bagasse ash (%)	0	10	20	30	40
Cement (Kg/m^3)	410.75	395.50	339.0	282.5	226.0
Metakaolin (Kg/m^3)	0	11.30	22.60	33.90	45.20
Bagasse ash (Kg/m^3)	0	45.18	90.40	135.6	180.8
Sand (F.A) (Kg/m^3)	660.6	640.95	639.22	638.02	634.36
C.A (Kg/m^3)	1133.51	1105.31	1100.54	1095.91	1088.42
Water (Kg/m^3)	197.16	197.16	197.16	197.16	197.16
Slump (mm)	102	96	85	79	68
Proportion	1:1.61:2.76	1:1.42:2.44	1:1.42:2.43	1:1.41:2.42	1:1.4:2.41

Figure 4.1.1: Slump Test

It is observed that by increasing in bagasse ash and metakaolin content the slump (workability) of concrete was decreasing and it is noted that ash absorbing more amount of water compared to OPC and Metakaolin.

Compressive Strength Test

Total 45 cubes were cast with a size of (150x150x150) mm to test the specimen for non-destructive and destructive testing for 7, 28, and 56-days curing periods. The experimental procedure was confirmed with IS 516.The cube specimen under UTM was shown in figure 5.2.1 and the corresponding loading unit was shown in figure 5.2.2

Figure 4.2.1: Compressive Strength test setup

Figure 4.2.2: Loading unit

Splitting Tensile strength test

According to code IS 516-1959, a total of 45 cylinders were cast with 150 mm diameter and 300mm height to test the samples for 7, 28, and 56-days curing periods. The cube specimen under UTM was shown in figure 5.3.1 and the corresponding loading unit was shown in figure 5.3.2

Figure 4.3.1: Splitting Tensile strength test setup

Figure 4.3.2: Loading unit

Rebound Hammer

The cubes cast for destructive testing were utilized to find rebound values first as per IS 13311 part 2 and the graph was drawn in between the rebound number and the compressive strength of specimens.

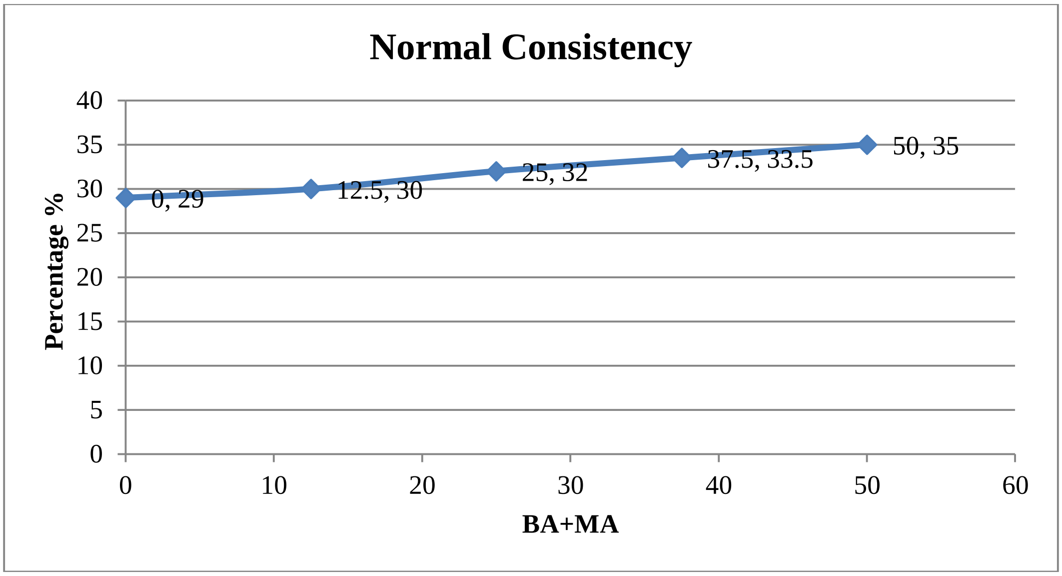
Results and Discussions

Normal Consistency

The normal consistency of cement when partially replaced with bagasse ash and metakaolin values are shown in table 5.1.1 and figure 5.1.1

Table 5.1.1: Normal Consistency

Cement (C) (%)	Bagasse ash (B) (%)	Metakaolin (M) (%)	(B+M) (%)	Normal Consistency
100	0	0	0	29%
87.5	10	2.5	12.5	30%
75	20	5.0	25.0	32%
62.5	30	7.5	37.5	33.5%
50	40	10	50.0	35%



Graph 5.1.1: Normal Consistency

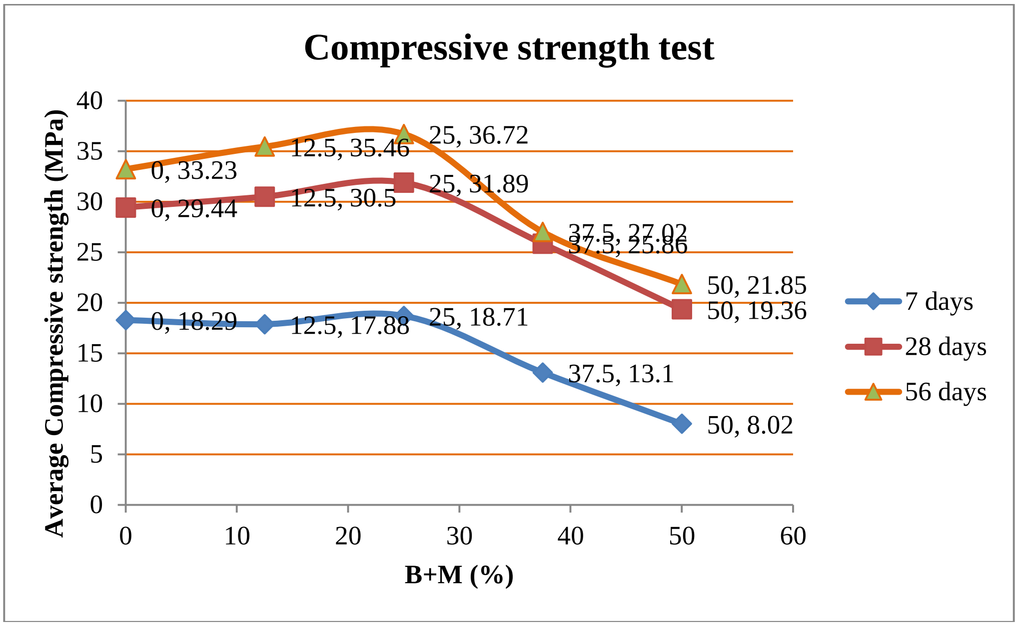
It is clear from the graph that normal consistency was increasing when increasing in percentage replacement of bagasse ash and metakaolin. It was observed that ash content absorbing more water than the OPC so the consistency might increase.

Compressive Strength

The test has been regulated as per IS 516:1959 and the results obtained were shown in table 5.4.1. Comparatively, B2M2 was shown utmost compressive strength for 7, 28 and 56 days curing period than other specified concrete.

Table 5.4.1

S.No.	Mix ID	Compressive Strength for 7 days curing (N/mm^2)	Compressive Strength for 28 days curing (N/mm^2)	Compressive Strength for 56 days curing (N/mm^2)
1.	CC	18.29	29.44	33.23
2.	B1M1	17.88	30.50	35.46
3.	B2M2	18.71	31.89	36.72
4.	B3M3	13.10	25.86	27.02
5.	B4M4	8.02	19.36	21.85



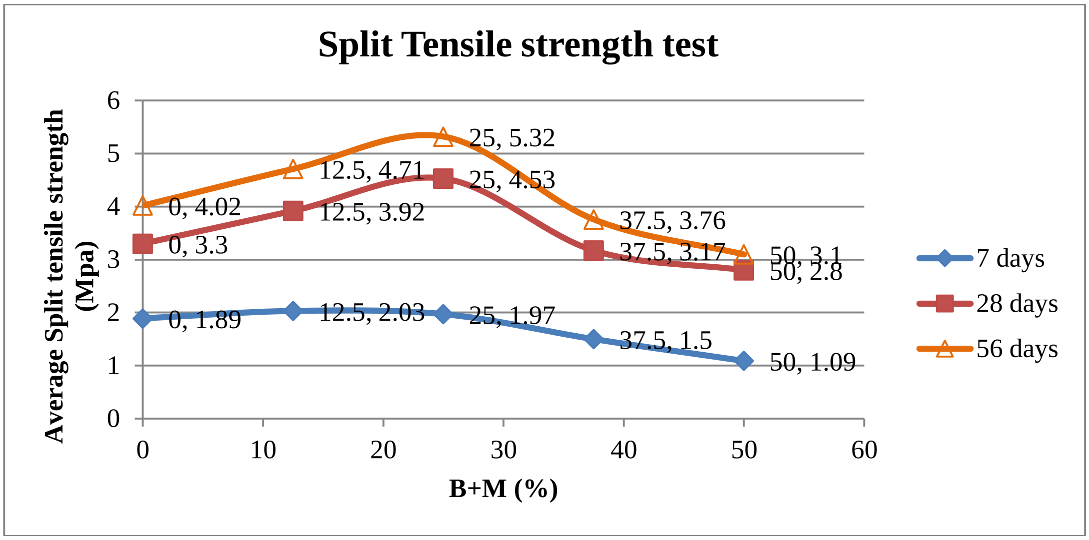
Graph 5.4.1: Compressive strength test

Splitting tensile strength

The test has been regulated as per IS 516:1959 and the outcomes obtained were shown in table 5.5.1. The concrete sample B1M1 was shown maximum tensile strength than any other for 7 days but for 28 and 56-days curing periods B2M2 was shown maximum results.

Table 5.5.2: Splitting Tensile Strength

S.No.	Mix ID	Splitting Tensile Strength for 7 days curing (N/mm²)	Splitting Tensile Strength for 28 days curing (N/mm²)	Splitting Tensile Strength for 56 days curing (N/mm²)
1.	CC	1.89	3.30	4.02
2.	B1M1	2.03	3.92	4.71
3.	B2M2	1.97	4.53	5.32
4.	B3M3	1.50	3.17	3.76
5.	B4M4	1.09	2.80	3.10



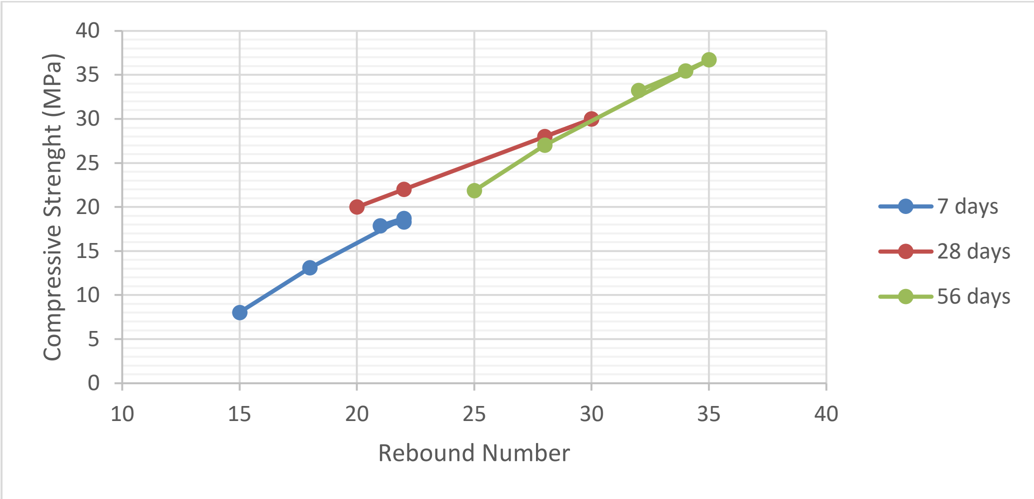
Graph 5.5.4: Splitting Tensile strength test

Rebound Number

The test has been regulated as per IS 13311 part 2 and the results obtained were shown in table 5.6.1. It is noted that while increasing the compressive strength of concrete rebound number also increasing but not at liner rate the graph 6.6.1 showed the correlation between compressive strength Vs rebound number.

Table 5.6.1: Rebound Number Vs Compressive Strength

S.No	Mix ID	Rebound Hammer (7 days)		Rebound Hammer (28 days)		Rebound Hammer (56 days)	
		Rebound Number	Compressive Strength (N/mm2)	Rebound Number	Compressive Strength (N/mm2)	Rebound Number	Compressive Strength (N/mm2)
1.	CC	22	18.29	28	29.44	32	33.23
2.	B1M1	21	17.88	30	30.50	34	35.46
3.	B2M2	22	18.71	30	31.89	35	36.72
4.	B3M3	18	13.10	22	25.86	28	27.02
5.	B4M4	15	8.02	20	19.36	25	21.85



Graph 5.6.1: Correlation between Rebound Number and Compressive Strength of Concrete

Conclusions

1. Increasing in bagasse ash and metakaolin content the slump (workability) of concrete was decreasing and it was noted that ash absorbing more amount of water compared to OPC and Metakaolin so it might increase the consistency of blended mortar.
2. Comparatively, B2M2 was shown maximum compressive strength for 7, 28, and 56-days curing period than other specified concrete so the utmost substitution of cement with a mix of bagasse and metakaolin can be possible up to 25%. The high level of silica content in bagasse and metakaolin than OPC may lead to the formation of more C3S and C2S which is responsible for higher strength might be the justification the augmentation in compressive strength.
3. The concrete sample B1M1 was shown maximum tensile strength than other concrete for 7 days but for 28 and 56-days curing periods, B2M2 was shown better results.
4. It is noted that while increasing the compressive strength of concrete samples rebound number also increasing but not at liner rate.
5. Increasing of bagasse and metakaolin to more that B2M2 specification it was seen that drastic decreasing in strength properties which is because of the high content of alumina and low contents of calcium oxide.
6. The correlation graph drawn between rebound number Vs compressive strength would be useful to the future study of compressive strength values concerning rebound number.

References

1. Ilić, B. R., Mitrović, A. A., & Miličić, L. R. (2010). "Thermal treatment of kaolin clay to obtain metakaolin." *Hemijskaindustrija*, *64*(4), 351-356.
2. Shelorkar Ajay, P. (2013). "Strength Appraisal of High Grade Concrete by using High Reactive Metakaolin." International Journal of Innovative

Research in Science, Engineering and Technology Vol. 2, Issue 3, March, 657-663.
3. Cordeiro, G. C., Andreão, P. V., & Tavares, L. M. (2019). "Pozzolanic properties of ultrafine sugar cane bagasse ash produced by controlled burning." *Heliyon*, *5*(10), e02566.
4. MJ, M. B., & Varghese, M. S. (2014). "Ternary Blended Concrete with Bagasse Ash and Metakaolin."
5. Malagavelli, V.,Angadi, S., Prasad, J. S. R., & Joshi, S. (2018). "Influence of metakaolin in concrete as partial replacement of cement." *Int J Civil Eng Technol*, *9*(7), 105-111.
6. Amin, N. U. (2011). "Use of bagasse ash in concrete and its impact on the strength and chloride resistivity." *Journal of materials in civil engineering*, *23*(5), 717-720.
7. Joshaghani, A., & Moeini, M. A. (2018). "Evaluating the effects of sugarcane-bagasse ash and rice-husk ash on the mechanical and durability properties of mortar." *Journal of Materials in Civil Engineering*, *30*(7), 04018144.
8. Chen, L., Zheng, K., Xia, T., & Long, G. (2019). "Mechanical property, sorptivity and microstructure of steam-cured concrete incorporated with the combination of metakaolin-limestone." *Case Studies in Construction Materials*, *11*, e00267.
9. Rakhimova, N. R., &Rakhimov, R. Z. (2019). "Reaction products, structure and properties of alkali-activated metakaolin cements incorporated with supplementary materials–a review." *Journal of Materials Research and Technology*, *8*(1), 1522-1531.
10. Nikhila, C. J., & Kumar, J. C. (2015). "Partial replacement of cement with metakaolin in high strength concrete." *Int. J. Engg. Res. & Sci. & Tech*, *4*(4), 336-349.
11. Yahya, M. A., Yusof, M. A., Hassan, Z. A., Daud, N., Misnon, N., Osmi, S. K. C., ... &Yusrin, M. (2013). "Usage of sugarcane bagasse as concrete retarder." *Int. J. Business Technopreneurship*, *3*(3), 495-503.
12. Duan, P., Shui, Z., Chen, W., & Shen, C. (2013). "Effects of metakaolin, silica fume and slag on pore structure, interfacial transition zone and compressive strength of concrete." *Construction and Building Materials*, *44*, 1-6.
13. Madandoust, R., & Mousavi, S. Y. (2012). "Fresh and hardened properties of self-compacting concrete containing metakaolin." *Construction and building materials*, *35*, 752-760.
14. Vejmelkova, E., Pavlikova, M., Keppert, M., Keršner, Z., Rovnaníková, P., Ondráček, M., ... &Černý, R. (2010). "High performance concrete with Czech metakaolin: Experimental analysis of strength, toughness and durability characteristics." *Construction and Building Materials*, *24*(8), 1404-1411.
15. Salimi, J., Ramezanianpour, A. M., & Moradi, M. J. (2020). "Studying the effect of low reactivity metakaolin on free and restrained shrinkage of high performance concrete." *Journal of Building Engineering*, *28*, 101053.
16. SR, S. K., Babu, D. V., &Udayashankar, B. C. (2018). "Experimental study on optimization of mid strength high performance concrete using particle packing technique." *International Journal of Engineering & Technology*, *7*(4), 5272-5280.
17. Shashikanth, D. V., Mallikarjuna Reddy, (2016)."Study on Fresh and Hardened Properties of High Strength Self Compacting Concrete With

Metakaolin And Micro silica As Mineral Admixture (M70 Grade)‖. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, *13*(5).
18. IS 10262: 2019 Concrete Mix Proportioning — Guidelines (Second Revision)
19. IS 13311-2 (1992): Method of non-destructive testing of concrete-methods of a test, Part 2: Rebound hammer.
20. IS 456:2000 "Plain and Reinforced Concrete- Code of Practice" Bureau of Indian Standards, New Delhi, India.
21. IS 383:2016 "Specification of Coarse and Fine Aggregate for Concrete" Bureau of Indian Standards, New Delhi, India.
22. IS 516:1959 "Method of Tests for Strength of Concrete" Bureau of Indian Standards, New Delhi, India.
23. IS 12269:2013 "Specification of Ordinary Portland Cement, 53 grades" Bureau of Indian Standards, New Delhi, India.
24. IS 4031:1988 Methods of physical tests for hydraulic cement.
25. IS 2386:1963: Methods of Test for Aggregates for Concrete.