International Journal of Technology and Emerging Sciences (IJTES)

www.mapscipub.com

Volume 04 || Issue 01 || January 2024 || pp. 17-23 E-ISSN: 2583-1925

Study On the Behavior of Self-Healing Concrete

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Abstract - *In this study, we have prepared a specimen of concrete with 53 grade cement, fine and coarse aggregates, bacillus subtilis was cultured and added to the water during mixing with different concentrations of different samples i.e more than 24 samples for different water contents variations and prepared a cube of size 150 mm x 150mm x 150mm. For mechanical properties, cylindrical specimen having 150mm diameter and height 300mm were casted. It is found that using light weight aggregates of size 2 to 4 mm along with the bacteria helps in increasing compressive strength and improves healing capacity of concrete. It is observed that bacterial concrete gives better tensile strength than a conventional concrete. It reduced water permeability which is also an important factor. Bacillus subtilis improved compressive strength of concrete by 14% as compared to conventional concrete. Bacillus sphaericus improved compressive strength by 32% in 28 days as compared to a conventional concrete. We have found that the compressive strength results of concrete for (Bacterial concrete) is maximum for sample S-2 in 7days, it was found 27.68 N/mm^2 and for 28 days the results was 41.15 N/mm^2 and for (Conventional concrete) of the sample no S-2 was found that, the maximum strength results in 7 days was 34.56 N/mm^2 and in 28 days was 41.82 N/mm^2 and for sample S-7 of Self-healing concrete and the optimum results of concrete for (Bacterial concrete) is maximum at 7 days curing was 22.55 N/mm^2 and at 28 days curing was 37.55 N/mm^2 the minimum value for (Conventional concrete) for sample S-7 of in 7 days was 31.65 N/mm^2 and for 28 days 37.55 N/mm^2. The Split tensile strength for the cylindrical specimens the results for (Bacterial concrete) is maximum for sample S-2 in 28days, it was found 5.71 N/mm^2 and minimum results for sample S1 was 4.82 and for (Conventional concrete) the maximum value of sample no S-3 was 5.81 N/mm^2 similarly the minimum strength results in 28 days was 4.22 N/mm^2. The flexural strength of Self-healing concrete (BC) for sample of S-6 was 5.45 N/mm^2 and maximum results for (cc for sample S-7 was 5.95N/mm^2) replacement for 28 days of curing.*

Key Words: CONCRETE, Cement, Aggregate, Recycle

1. INTRODUCTION

Strength recovery, improved durability, visual examination, and microstructural analysis are some of the methods used to assess SHC's performance. Stated differently, there are three methods to assess self-healing: recovery of strength qualities, increase in durability performance, and visible crack sealing monitoring together with the identification of the healing components causing it. Nonetheless, concrete's ability to regain strength throughout the self-healing process is often restricted.

As a result, physical fracture closure, durability improvement (i.e., permeability reduction metrics), and microstructural analyses are the most reliable ways to detect self-healing activity. As a result, there has been a rise in interest in self-healing materials, especially the ability of green and sustainable concrete materials to repair themselves, with an emphasis on various methods presented by several researchers throughout the globe in the previous two decades [1-10]

The fact that every research center uses a different set of test procedures to determine the effectiveness of healing makes it challenging to select the most efficient strategy. SHC has the ability to mend and reduces the need for external assistance in identifying and fixing internal damage (such as cracks). Engineers are often concerned about the formation of cracks because of the comparatively lower tensile strength of concrete, various loading scenarios, and environmental conditions that accelerate the decay of buildings.

2.LITRATURE REVIEW

Xiaohong et al [11]; in their study they performed a scient metric evaluation of the bibliometric data on self-healing concrete (SHC) in order to determine its major components. Manual review articles are inadequate in their capability to connect diverse areas of the literature in a systematic and ordered manner.

Gaikwad et al. [12]; Authors have reported that concrete is an irreplaceable ingredient in construction industry. We use different type of materials, procedures, methods to attain good, sustainable concrete. Even after proper precaution taken during mixing, casting and curing, we come across cracks. Eventually, crack formation in concrete has become inevitable phenomenon. There are various reasons which can cause cracks to our structure like temperature differences, application of heavy loads etc. Crack increases seepage which leads to corrosion of reinforcement, durability, life of the structure.

According to Navodaya T. [13], the production of cracks in concrete is a regular phenomena that is associated with durability. Cracks that seep through may result in leaks or the entry of harmful substances, which might corrode embedded steel reinforcement or weaken the concrete matrix. Preventing further water and material intrusion can improve durability. To increase the service life, a self-healing concrete based on bacteria has been created recently.

S. Luhar et al. [14] , Published a paper on self-healing concrete using various bacteria like bacillus sphaericus, bacillus subtilis, bacillus pasteurii. In this study, they have prepared a specimen of concrete with 53 grade cement, fly ash, fine and coarse aggregates, bacillus subtilis was cultured and added to the water during mixing with different concentrations like 105 cells/lit, 106 cells/lit etc. and prepared a cube of size 150mm x 150mm x 150mm. For mechanical properties, cylindrical specimen having 150mm diameter and height 300mm were casted. It is found that using light weight aggregates of size 2 to 4 mm along with the bacteria helps in increasing compressive strength and improves healing capacity of concrete. It is observed that bacterial concrete gives better tensile strength than a conventional concrete.

Bharanedharan G et al. [15] , Published a paper which has a comparison of bacillus subtilis with bacillus cohnii. M30 grade of concrete was prepared to study mechanical properties of microbial concrete. Results of this study has shown that bacillus subtilis were more effective than bacillus cohnii in crack healing. Compressive strength of bacterial concrete having bacillus subtilis has increased compressive strength by 11% whereas bacterial concrete with bacillus cohnii has increased compressive strength by 9%. It has shown that selected bacteria healed the cracks successfully by producing calcium carbonate as a filler material. Bacillus subtilis turned out to be efficient than bacillus cohnii.

E. Stephen [16], Published a paper having main objective to check and compare durability and properties of bio and conventional concrete. To make a concrete Pozzolana Portland Cement, fine and coarse aggregate, water, bacillus subtilis, chemical admixtures like super plasticizer, water reducing agents are used. Pozzolana Portland Cement produces less heat of hydration. Low sand content enhances every aspect of concrete. Concrete cubes of dimension 15cm x 15cm x 15cm were prepared and cured for 7,14,28 day. There was increase in compressive strength for every 10ml bacterial sample. After 28 days, compressive strength increased by 1.33% for 10ml bacterial sample compared to conventional concrete. Split tensile strength increased by 10% for 10ml bacterial sample. Flexural strength increased by 5.2% for 15ml bacterial concrete. In water absorption test, it showed lower rate of water absorption for bacterial concrete than conventional concrete due to layer of calcium deposited into pores.

3. Cement

A binder is a material that sets, hardens, and binds other materials together. Cement is used in building. The two most essential forms of cement are used in the creation of concrete, which is an aggregate and cement mixture that is used to create a sturdy construction material, and mortar in masonry [17-21]

As per IS: 12269-1987, ordinary Portland cement of grade 53 is utilized.

3.1. Experimental Work

In this present work, a comprehensive experimental schedule is being formulated to achieve the objective and scopes of the present investigation. At present the whole experimental work is done as follows:

1) Tests of materials
   (a) Tests of cement
   (b) Tests of coarse aggregate
   (c) Tests of fine aggregate
2) Selection of mix design

3.2. Cement

Throughout the whole experimental investigation, Portland Healing Cement that complied with IS: 455 was employed. In order to prevent extended periods of storage and strength degradation, cement was purchased based on the phase-by-phase need.

To reduce its exposure to humidity, the cement was kept in airtight storage bags. Table 3.2 provides a detailed list of cement's physical characteristics. Portland healing cement, produced by Lafarage Concerto, was the cement used in the experiment.

3.3. Aggregates:

Sand, gravel, crushed stone, healing, recycled concrete, and geo-synthetic aggregates are among the many coarse particle materials used in construction that are referred to as "aggregate" or simply "construction aggregate." The most mined substance in the world is aggregate. On cement, the experiments that follow were carried out.

3.4. Fineness test

The fineness of cement has an important bearing on the rate of hydration and hence on rate of gain of strength and also on the rate of evolution of heat. This test was conducted by using 90-micron sieve as per IS4301 (part1). Locally available fresh sand, free from organic matter is used. The result of sieve analysis confirms it to Zone-II (according to IS: 383-1970). The tests conducted and results plotted below.

	
Fine aggregates	**Fine aggregates**

Fig 1. Aggregates

Fig 2. Various sieve for sieve analysis

Fig 3. Bacterial Concrete

When concrete hardens, bacterial or self-healing concrete uses a bacterial response to fill up the gaps that have formed in the construction. We talk about the many kinds of bacteria, how they work, and how to make bacterial concrete. The employment of technology in the modern era has raised the bar for construction standards. In order to achieve an excellent, cost-effective, and sustainable concrete building, a variety of techniques, materials, and processes are employed. However, as a result of human error, careless handling, and unskilled work. Maintaining an efficient structure for its intended life is difficult. After construction, a number of issues including weathering, cracks, leaks, bending, etc., occur. Numerous corrective measures are implemented both before to and following construction in order to address these kinds of issues.

Crack is a prevalent issue in structures. Cracks can occur for a variety of causes. Listed below are a few of the causes;

- Concrete expands and shrinks due to temperature differences
- Settlement of structure
- Due to heavy load applied
- Due to loss of water from concrete surface shrinkage occurs
- Insufficient vibration at the time of laying the concrete
- Improper cover provided during concreting
- High water cement ratio to make the concrete workable
- Due to corrosion of reinforcement steel
- Many mixtures with rapid setting and strength gain performance have an increased shrinkage potential.

4. RESULTS AND DISCUSSIONS MATERIAL PROPERTIES

Table 1. Result for coarse aggregate

S. No.	Test	Coarse Aggregate
1	Unit weight	1.87 gm/cc
2	Moisture content	0 %
3	Water absorption	0.2 %
4	Specific gravity	3.0
5	Fineness modulus	7.92
6	Crushing value	23.43 %
7	Impact value	16.0 %
8	Abrasion value	17.50 %
9	Elongation index	5.50%
10	Flakiness index	4.0 %

4.1. FINE AGGREGATES

Table 2. Result for fine aggregate

S. No.	Test	Fine Aggregate
1	Zone	III
2	Moisture content	0.20%
3	Specific gravity	2.55
4	Unit weight	1.62gm/cc
5	Fineness Modulus	2.21
6	Water Absorption	1.37%

4.2. CONCRETE TESTS

FRESH CONCRETE TESTS, (SLUMP CONE TEST)

Table 3. slump test result of Fresh concrete

S.NO	Slump test for BC BC: Bacterial Concrete in (mm)	Slump test for CC CC: Conventional Concrete in (mm)
S-1	0	0
S-2	25	30
S-3	25	40
S-4	35	50
S-5	50	50
S-6	60	75
S-7	75	75

BC: Bacterial Concrete **CC: Conventional Concrete**

The water cement ratio is taken as 0.5 and the quantity of water is mixed as per w/C ratio. After that the quantity of water are replaced by bacteria solution with different percentage and mixing has been continued to get a uniformly mix with different samples S1, S2, S3, S4, S5, S6, and S7.

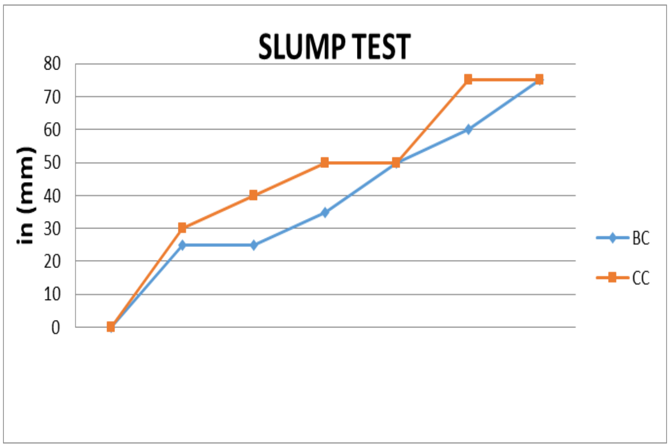

Fig. 4. Represent Slump test

4.3. COMPACTION FACTOR TEST

Table 4. Compaction Factor Test result

Sample no	Compaction factor test for BC in (mm)	Compaction factor test for CC in (mm)
S-1	0.98	0.94
S-2	0.95	0.92
S-3	0.89	0.87
S-4	0.88	0.84
S-5	0.86	0.86
S-6	0.82	0.82
S-7	0.84	0.76

BC: Bacterial Concrete **CC: Conventional Concrete**

The amount of water is combined in accordance with the w/C ratio, and the water cement ratio is set at 0.5. Following that, a variable amount of bacteria solution was added to the water, and mixing was maintained to achieve a homogeneous mix with the various samples S1, S2, S3, S4, S5, S6, and S7 [22].

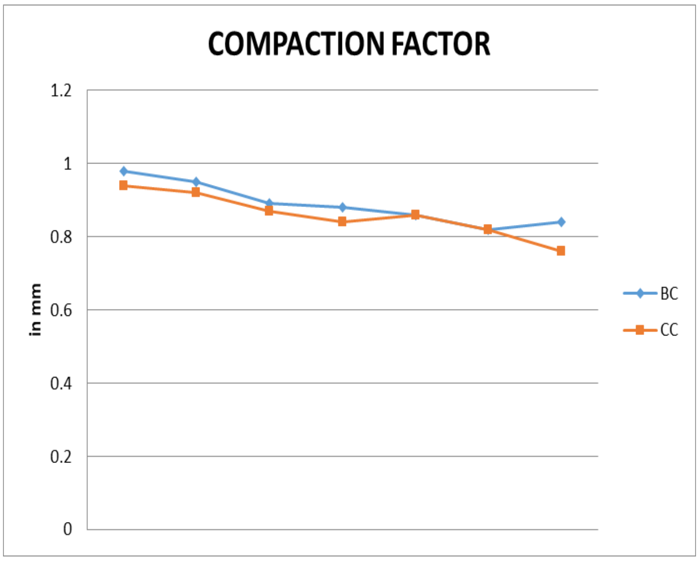

Fig. 5. Compaction factor

4.4. COMPRESSIVE STRENGTH OF CONCRETE

(BC: Bacterial Concrete &
CC: Conventional Concrete)

Table 5. Compressive Strength of Test Bacterial Concrete & Conventional Concrete

Sample no	Compressive strength of concrete M30 MIX			
	for BC		for CC grade	
	7days	28days	7days	28days
S-1	26.84	39.25	30.45	41.82
S-2	27.68	41.15	34.56	39.65
S-3	27.54	38.55	33.60	40.53
S-4	26.45	38.65	33.45	38.22
S-5	25.65	38.15	32.8	38.25
S-6	22.27	38.2	32.2	37.45
S-7	22.55	37.55	31.65	37.25

The amount of water is combined in accordance with the w/C ratio, and the water cement ratio is set at 0.5. Following that, a varying amount of bacteria solution was added to the water, and mixing was carried out to obtain a homogenous mixture with various samples of S1, S2, S3, S4, S5, S6, and S7.

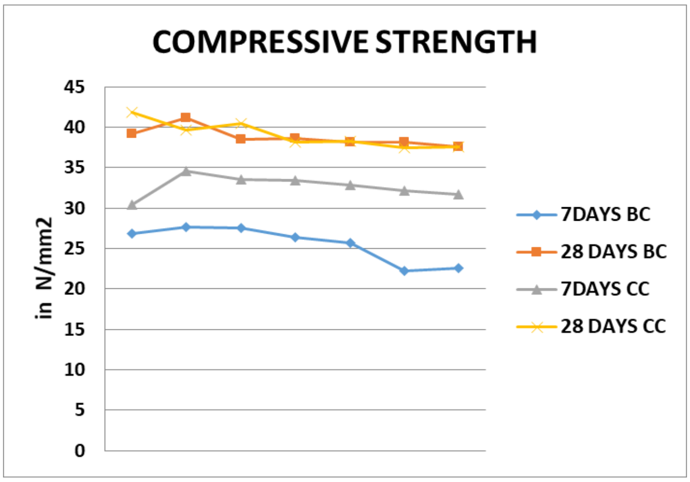

Fig. 6. Compressive Strength for (Bacterial Concrete & Conventional Concrete)

4.5. SPLIT TENSILE STRENGTH OF CONCRETE

Table 6. Split Tensile Strength of Test Bacterial Concrete & Conventional Concrete

Sample no	28 days split tensile test for BC	28 days split tensile test for CC
S-1	4.82	5.28
S-2	5.71	5.36
S-3	5.53	5.81
S-4	5.45	5.75
S-5	5.5	4.95
S-6	5.36	4.54
S-7	5.3	4.22

The amount of water is combined in accordance with the w/C ratio, and the water cement ratio is set at 0.5. Following that, a varying amount of bacteria solution was added to the water, and mixing was carried out to obtain a homogenous mixture with various samples of S1, S2, S3, S4, S5, S6, and S7.

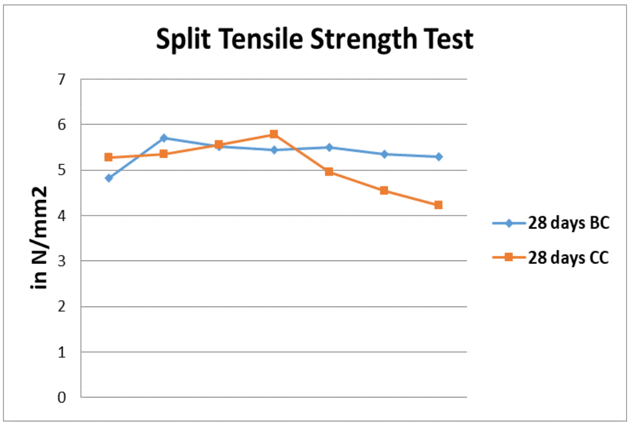

Fig 7. Split tensile strength for (BC: Bacterial Concrete & CC: Conventional Concrete)

4.6. FLEXURAL STRENGTH OF CONCRETE

(BC: Bacterial Concrete & CC: Conventional Concrete)

Table 7. Flexural Strength of Test Bacterial Concrete & Conventional Concrete

Sample no	28 days Flexural strength test for BC	28 days Flexural strength test for CC
S-1	4.25	4.65
S-2	4.3	4.7
S-3	4.6	5.2
S-4	4.55	5.4
S-5	5.25	5.65
S-6	5.45	5.8
S-7	5.40	5.95

The water-to-cement ratio is set at 0.5, and the water volume is blended in accordance with the w/C ratio. Then, a variable percentage of bacteria solution was added to the water, and mixing was maintained to achieve a consistent mix with various samples of S1, S2, S3, S4, S5, S6, and S7.

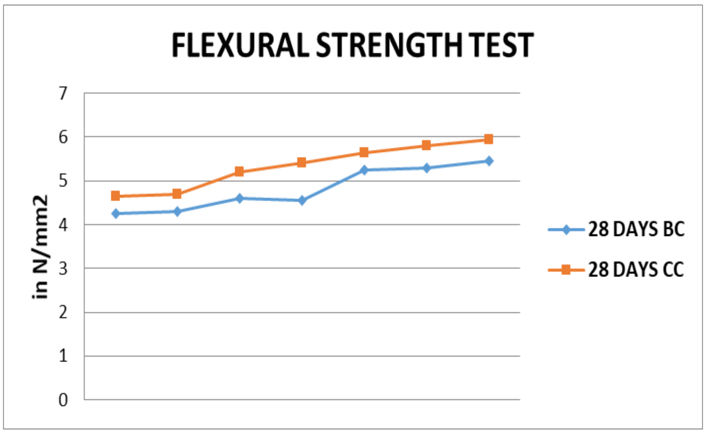

Fig. 8. Flexural strength for (BC: Bacterial Concrete & CC: Conventional Concrete)

5. CONCLUSIONS

The aforementioned experimental program led to the following deductions.

The techniques for creating self-healing concrete are provided in this study. The addition of bacteria to concrete is very beneficial since it raises the concrete's attribute level over that of regular concrete. Concrete fractures are filled up and repaired by bacteria through the production of calcium carbonate crystals that plug the fissures. Additionally, bacteria enhance the properties of traditional concrete, such as increasing its strength after seven and twenty-eight days, since more days are needed to build strength. The following conclusions were discovered.

(1) The material properties of the cement, fine aggregates and coarse aggregates are within the acceptable limits as per IS code recommendations so we can use the materials for research works in concrete.

(2) Slump cone value for the Self-healing concrete increases with increasing in the percentage of Self-healing so the concrete was not workable.

(3) Compaction factor value of Self-healing concrete decreases with increase in the percentage of Self-healing.

(4) The compressive strength results of concrete for (Bacterial concrete) is maximum for sample S-2 in 7days, it was found 27.68 N/mm^2 and for 28 days the results was 41.15 N/mm^2 and for (Conventional concrete) of the sample no S-2 was found that, the maximum strength results in 7 days was 34.56 N/mm^2 and in 28 days was 41.82 N/mm^2 and for sample S-7 of Self-healing concrete and the optimum results of concrete for (Bacterial concrete) is

maximum at 7 days curing was 22.55 N/mm^2 and at 28 days curing was 37.55 N/mm^2 the minimum value for (Conventional concrete) for sample S-7 of in 7 days was 31.65 N/mm^2 and for 28 days 37.55 N/mm^2 .

(5) Split tensile strength for the cylindrical specimens the results for (Bacterial concrete) is maximum for sample S-2 in 28days, it was found 5.71 N/mm^2 and minimum results for sample S1 was 4.82 and for (Conventional concrete) the maximum value of sample no S-3 was 5.81 N/mm^2 similarly the minimum strength results in 28 days was 4.22 N/mm^2.

(6) The flexural strength of Self-healing concrete (BC) for sample of S-6 was 5.45 N/mm^2 and maximum results for (cc for sample S-7 was 5.95N/mm^2) replacement for 28 days of curing.

So the replacement of 20% to 40% of Self-healing concrete is generally useful for better strength values in M30 grade of concrete.

REFERENCES

[1] Neville, A.M. (1996) Properties of concrete (4th edition). Pearson Higher Education, Prentice Hall, New Jersey.

[2] Neville, A.M. (2002) Autogenous healing - A concrete miracle? Concrete Int 24(11):76-82

[3] Edvardsen, C. (1999) Water permeability and autogenous healing of cracks in concrete. ACI Materials Journal 96(4): 448-454.

[4] Reinhardt, H.W., and Jooss, M. (2003) Permeabilitiy and self-healing of cracked concrete as a function of temperature and crack width. Cement and Concrete Res 33:981- 985.

[5] Li, V.C., and Yang, E. (2007) Self healing in concrete materials. In Self healing materials - An alternative approach to 20 centuries of materials science (ed. S. van der Zwaag), pp. 161– 194. Springer, the Netherlands.

[6] Worrell, E., Price, L., Martin, N., Hendriks, C., and Ozawa Meida, L. (2001) Carbon dioxide emissions from the global cement industry. Annual Review of Energy and the Environment 26: 303-329.

[7] Bang, S.S., Galinat, J.K., and Ramakrishnan, V. (2001) Calcite precipitation induced by polyurethane-immobilized Bacillus pasteurii. Enzyme Microb Tech 28: 404-409.

[8] Ramachandran, S.K., Ramakrishnan, V., and Bang, S.S. (2001) remediation of concrete using micro-organisms. ACI Materials Journal 98(1):3-9.

[9] Ghosh, P., Mandal, S., Chattopadhyay, B.D., and Pal, S. (2005) Use of microorganisms to improve the strength of cement mortar. Cement Concrete Res 35:1980-1983.

[10] De Muynck, W., Debrouwer, D., De Belie, N, and Verstraete, W. (2008) Bacterial carbonate precipitation improves the durability of cementitious materials. Cement Concrete Res 38: 1005-1014.

[11] De Muynck, W., Cox, K., De Belie, N., and Verstraete, W. (2008) Bacterial carbonate precipitation as an alternative surface treatment for concrete. Constr Build Mater 22: 875-885.

[12] De Muynck, W., De Belie, N., and Verstraete, W. (2010) Microbial carbonate precipitation in construction material: A review. Ecol Eng 36:118-136

[13] Van Tittelboom, K., De Belie, N., De Muynck, W., and Verstraete, W (2010) Use of bacteria to repair cracks in concrete. Cement Concrete Res 40: 157-166.

[14] Jonkers, H.M. (2007) Self healing concrete: a biological approach. In Self healing materials - An alternative approach to 20 centuries of materials science (ed. S. van der Zwaag), pp. 195–204. Springer, the Netherlands.

[15] IS 2386-3 (1963): Methods of test for aggregates for concrete, Part 3: Specific gravity, density, voids, absorption and bulking [CED 2: Cement and Concrete

[16] IS 4031-1 (1996): Methods of physical tests for hydraulic cement, Part 1: Determination of fineness by dry sieving [CED 2: Cement and Concrete]

[17] IS 4031-4 (1988): Methods of physical tests for hydraulic cement, Part 4: Determination of consistency of standard cement paste [CED 2: Civil Engineering]

[18] IS 4031-5 (1988): Methods of physical tests for hydraulic cement, Part 5: Determination of initial and final setting times [CED 2: Civil Engineering]

[19] IS 4031-11 (1988): Methods of physical tests for hydraulic cement, Part 11: Determination of density (CED 2): Cement and Concrete.

[20] Other Internet resources and journals

[21] Is code IS:456-2000.

[22] Books referred A.K. JAIN, M.G. SHAH, P.C VARGEE and M.S. SHETTY.