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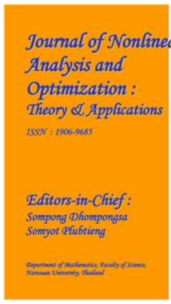

THE EFFECTS OF GGBS, LIME POWDER, AND METAKAOLIN ON THE DURABILITY OF SELF-COMPACTING CONCRETE OF M60 GRADE

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ABSTRACT

These days, environmental factors like pollution cause concrete to break down quite quickly. Water starts to percolate after the concrete breaks down. Inner reinforcement will corrode more readily as a result. significant failure of every reinforcing structure as a result of reinforce corrosion.

This study looks at the durability properties of partially cement-replaced self-compacting concrete (SCC) using different admixtures at different percentages, such as GGBS, metakaolin, and lime powder. We made five different combinations by replacing 25% of the cement with different proportions of metakaolin (MK), GGBS, and lime powder (LP). The weight of cement content determines the superplasticizer dose, which is fixed at 1%, and the W/C ratio is maintained at 0.34. In order to meet the EFNARC workability requirements, filling ability and passing ability were assessed prior to filling moulds using the V-Funnel, L-Box, Slump test, and J-Ring. Compressive strength (CS) of hardened SCC cubes was evaluated throughout a specified curing period (e.g., 28 or 60 days).

The results of the workability test indicated that GGBS alone, instead of cement, performed better since the workability qualities were somewhat lowered when the amount of MK and LP increased owing to mix densification. In the meanwhile, the CS shows an increase in the percentage of GGBS with MK and LP. The Nansu technique was used to create the M60 grade of concrete, according to EFNARC requirements. In order to examine the durability qualities of the concrete, HCl and H2SO4 were applied in an acidic atmosphere. In the meanwhile, test for sulphate attack using MgSO4 and Na2SO4. Water absorption and sorbtivity were also measured as part of the inquiry.

INTRODUCTION

From the very olden days, it is a saying like concrete is most common construction material due its durability, stiffness, resistance towards environmental obstacles, high strength in compression and moreover it is economical in financial standard. Concrete is produced with wide varieties of gravels, sand, water, cement and few chemical admixtures sometimes mineral admixtures in cement content. To attain proper workability, the usage super plasticizer, retarders, accelerators up to 2% is allowed. Hence to achieve a quality concrete one should know the fundamentals of concrete. In simple terms, Concrete could be a World transforming material with acquired properties at lowest price. Because looking back for two centuries in construction, where concrete involved in all sort of structures from boat hulls, schools, hospitals, monuments, bridges, dams, public buildings, rail terminals, ports, sports stadiums etc.

Since the abundant improvement in the life style of human being tends to rapid development in urbanization thus construction activity had a tremendous role in all sectors growth there comes a question how fast the civil works can be accomplish adopting new technique into construction world. Off course various research programs developed on speed work procedure with strength and durable qualities. Durability of concrete determines the resistance ability towards chemical attack, and weathering action throughout concrete life span. Durability of any material defines the life span of such material, therefore in production of concrete durability property of concrete stands crucial role in construction. The more quickly a fluid penetrates in concrete, it is high permeability and deterioration of concrete held point from inside of micro structure. Whereas the lower it anticipated of fluid into concrete it is high durable in nature. Permeability, which establishes the durability feature of concrete, is the extent to which a gas, a fluid, or a liquid absorbs into the concrete beneath a specific amount of pressure.

Even concrete do have some constraints despite its number of advantages. Few of them have concrete, which has low ductility, a relatively low tensile strength (TS), and is prone to cracking. Despite these limitations, concrete continues to be the material of choice for many purposes. Typically, concrete CS is at least ten times that of its tensile strength (TS) and five to six times that of its flexural strength (FS). The following are the main variables affecting CS:

- The most crucial element is the water-cement ratio.
- After mixing, concrete gradually gains strength as a result of the cement and water's chemical reaction.
- The strength after 28 days is typically measured, along with the cement's material properties, curing conditions, moisture content, and temperature.
- The higher strength at any given age, the longer the period of moist storage.
- homogenous blending of obtained water and concrete's component parts.

These SCC was discovered late 19’s century in Japan but this concrete came into existence this 20’s century. In late 19’s century Japan suffered with scarcity of skilled labor, therefore that was the first step to introduce Self compacting concrete into the construction industry. Hence after that a committee took the responsibility to investigate from the fundamentals on workability of concrete, in the University of Tokyo. For the first produced SCC which is used in the year 1988, and named it as “High Performance Concrete”, and later on developed that into “Self-Compacting High-Performance Concrete”. Here comes the concrete with aided self-consolidating character to it and named as Self compacting concrete. The SCC itself describe self- compaction of concrete while casting, these concrete flows each and every corner of form work even at congestion of reinforcement like beam-column joints without any external vibrations, easily flowable, whereas in conventional concrete over compaction leads to cause segregation and leaching. Compressive strength of self-compacting concrete gradual increases within 28 days comparatively conventional.

1.1. Self-Compacting Concrete

Urbanization is increasing, which leads to an increase in the development of enormous structures including high-rise buildings, tunnels, motorways, and other structures. completing such projects in accordance with the necessary criteria, such as doing so within a reasonable timeframe and budget. The SCC, which is compressed by its own weight and fills formwork notably in congested areas like beam-column connections and spread into all directions of agricultural works, enters into the picture as a result of the building sector looking for adaptable and fastest processes.

In other words, the definition of SCC is fresh concrete that spreads over formwork by weight alone without the use of vibrators. SCC is a non-segregating concrete that is capable of filling forms, cover reinforcement, and doing all of this without the need for vibration. This concrete allows for quick and attractive finishing during construction. This concrete is typically utilised in locations where vibrators are difficult to apply for compaction. SCC has three primary characteristics, including the capacity for filling and passing through the material and—most significantly—the capacity to resist segregation. Several experiments are carried out on fresh concrete to determine these qualities for SCC.

- The filling ability exam includes the slump test, T50 cm slump test, and V-funnel test.
- The L-box, U-box, and J-ring pass the ability test.
- Segregation resistance test with V-funnel at T5 min.

It is a delicate mixture that is highly reliant on the uniform mixing of concrete with all of its ingredients. The durability and toughened qualities of concrete are both enhanced by the addition of mineral admixtures. For circumstances with restricted access and sites of crowded reinforcements, SCC is the most practical alternative. In simple terms SCC could be an engineered material such that out of many problems like need of skilled labor, compaction of concrete in massive distribution of reinforced bars, passing ability to rid of honeycombs in column beam joints, high workability, enhanced resistance to chemical attacks and mechanical stress, lower permeability, non-segregation nature, durability of concrete etc. had solved by SCC with efficiency. Durability is a broad investigation of concrete's efficiency and useful life in all hostile conditions. But to obtain such qualities in SCC, comprises with Cement, FA, CA, Admixtures, and new constituents like copper slag, industrial by products, Metakaolin, and Water, super plasticizer. There are several nations doing SCC studies right now, and they fall into the following categories:

- Utilising rheometers to gather information on the flow behaviour of cement paste and concrete.
- Mixing techniques for SCC.
- Characterising SCC using laboratory test procedures.
- Evaluating the durability and hardened properties of SCC in comparison to standard concrete. and
- Construction-related concerns for SCC are just a few of the topics covered.

Materials opting in production of SCC should be suitable to concrete mix, and shouldn't be harmful such that shouldn't be detriment of quality it may cause corrosion of steel.

1.1.1 Design principles of Self Compacting Concretes

According to EFNARC guidelines for SCC, mix design is designed by adopting Nansu method. While designing mix design for SCC it is particular that the constituents of concrete is calculated by volume bases rather than mass.

- A water-to-powder volume ratio of 0.80 to 1.10.
- A total amount of 160 to 240 liters (400–600 kg) of powder per cubic meter.
- Normally, the mix's CA content ranges from 28 to 35 percentage points.
- The ratio of water to cement is chosen based on the specifications in EN 206. The average water content is 200 liters/m3 or less.
- The volume of the other components is balanced by the sand content.

1.1.2 Advantages of SCC

Few important Advantages actually choosing SCC is are as follow

- SCC enable freedom in designing of concrete structures.
- Construction works held by SCC can finish quickly comparatively to conventional concrete.
- Quality in construction is increased.
- Construction Cost spent for vibrators are avoided and sound pollution by vibrators too avoided.
- Permeability of concrete is decreased because of no pores observed in SCC.
- Reliability and Durability of concrete is high comparatively to conventionalconcrete.
- Thinner concrete sections, implies to reduce in cost of construction and improves activity area in the structure.
- In preparation of mix design of concrete can be obtain by adopting any standard methods with fulfilling EFNARC guidelines for SCC.

1.1.3 Disadvantages of SCC

Because of its limitations, SCC is remained as a choice in choosing concrete for construction works.

- In the preparation of mix design, it uses more trail batches and lab test comparatively to conventional concrete.
- SCC is chosen for high strength concrete, therefore which leads high in construction cost for small projects.
- The measurement and monitoring are more precise.
- There is no universally accepted approach for SCC mix design.

1.1.4 Applications of SCC

Major application of SCC in Construction industry is as follows

- Construction of Structures where massive distribution of reinforcement.
- Mostly used in Retrofication and Rehabilitation of buildings, Repair works in constructions.
- In construction of Retaining walls, Raft foundation and pile foundation.
- Recently, usage of SCC developed more in pre caste than site constructions.

1.2. Objectives and scope

From the research data there are many papers, projects which concludes that SCC is rapid growing concrete for future activities in construction industry. Therefore, in practical point of view developing such concrete in economic considerations with sufficient durable and strength quality in it is the main objective.

Thereafter to decline in cost analysis, waste materials of industry which is not harmful for Human's utilization is suggested to use in application of construction activities. Lime powder, Metakaolin two major mineral admixtures deals in this project while GGBS acts as a pozzolana material in cement content.

LITERATURE REVIEW

In this section, the previous research works and the incline utilization of SCC in construction activities happened and meant to be occur in future projects are discussed. An over view of SCC and constituent's usage development in production of concrete in precast activities. Most commonly usage material is concrete in globe wide for construction industry however, SCC meant to be revolutionary material in late 19's century. Now due to adequate fall of resources research programs turned invention a new era of building materials still SCC is a turning point where a world forming material in constructional projects.

2.1. History and Improvement

In 1800 year, the invention of concrete and usage of it developed with wide variety of benefits at economic price with durable and stiffness. Later on, in late 19's lack of skilled labor in construction area occurred in japan. Therefore, to overcome that issues invention of SCC happened and named it as "High Performance Concrete". And after few researches on it with aided property of consolidating by its own weight developed it to a "High Performance Self Consolidating Concrete".

In 1988 for the first time in the "University of Tokyo", the lab test on fresh concrete is done and utilized and named it as "SCC" or "Self- Consolidating Concrete". Hence still there is no standard method mix design, a committee in Europe is took the responsibilities and issued a code after research which entitled as "The European Guidelines for SCC". And the usage of SCC spread throughout EUROPE countries in beginning of 20's century.

2.2. Earlier researchers

There may have been numerous research studies conducted recently on assessing the durability characteristics of SCC using partial cement replacements for admixtures and the use of industrial waste items to produce concrete in an environmentally friendly and cost-effective manner.

According to Rizwan A. Khan (2015), the SCC mix that contains 20% fly ash (FA) and 10% MK exhibits the greatest results in CS having long-lasting characteristics. Using metakaolin in concrete performs high durability comparatively to lime- powder based concrete.

According to Biswadeep Bharali (2015), the incorporation of GGBS needs a high dosage of superplasticizer in order to get satisfactory workability, but the presence of FA in SCC increases the workability of fresh concrete. So, when FA and GGBS are replaced together, cement exhibits increased strength due to an increase in substitution %. He conveyed using fly ash improves workability meanwhile GGBS improves compressive strength.

Jagadeesh (2017) came to the conclusion that using FA instead of cement decreased the mix's strength when compared to GGBS. Furthermore, traditional SCC mix with mixed FA and GGBS substitution withstands all stresses and yields the best outcomes.

According to Srihari et al. (2015), adding MK to concrete reduces its workability. However, by boosting the superplasticizer and altering the w/b ratio, that might be improved. He claimed that adding MK to concrete instead of cement creates (C-S-H) gel, which strengthens concrete by obstructing pores already present in hardened concrete and increases CS.

According to B H V Pai (2014), the inclusion of GGBS enhances the best results in CS, TS, and FS. This is because it helps meet the acceptable workability criteria of SCC. The high concentration of SF (50.19%) makes it possible for the SF-based SCC mix to have inadequate strength.

According to S A Kristiawan et al. (2016), the incorporation of FA to replace some cement will lessen the deterioration of SCC caused by sulfuric acid assault as evaluated by CS reduction and diameter change. At a later age, the amount of the lessened degradation is more obvious. The ability of FA to change

According to Udit A. Chavda et al. (2018), using admixtures like FA and silica fume (SF) can boost the strength of SCC. As a consequence, it was discovered that just 15% FA is necessary to achieve the optimum amount of SCC; if additional FA is added, the strength progressively starts to decrease in both CS test and TS test.

Imad R. Mustafa (2017) analyses the current literature on SCC and finds that there have been multiple investigations on partial cement substitution with additives. The use of FA enhances the workability of new concrete while lowering the hardened qualities of SCC. Additionally, this will result in future research to determine the best mix design strategy for SCC being actively promoted.

According to Sathish Raja et al. (2016), industrial waste materials can be used successfully as substitute components in SCC. It is also acknowledged that certain items exhibit various characteristics in both their fresh and hardened states. Additionally, it is abundantly clear that the partial substitution of materials considerably enhances the concrete's durability properties.

MATERIALS USED

3.1. Cement:

For flexibility in modifying the amount of pozzolanic ingredient in concrete mixtures, ordinary Portland cement (OPC) is utilized. Cement 53 grade with a specific gravity of 3.12 is employed in this experiment.

Figure .1 Cement 53 grade

3.2. Sand (FA):

For this experiment, river sand has a specific gravity of 2.53, and a bulk density of roughly 1765 kg/m3 is used.

Fig.2 River sand

3.3. Gravel (CA):

In the present Studies, 10 mm crushed stone aggregate with a specific gravity of 2.6 and a bulk density of roughly 1523 kg/m3 is employed.

Fig.3 10mm Coarse Aggregate

3.4. Mineral Admixture:

GGBS: The JSW steel facility in Allahabad sold GGBS, which had a specific gravity of 2.3 and was a light yellow tint.

Fig.4 GGBS

Metakaolin: Comparatively, the presence of MK enhances the durability qualities of concrete. Adhipathi Minerals Kothuru carries MK.

Fig.5 Metakaolin

Lime powder: G e n e r a l l y , Lime powder is finer than cement is used in this investigation and i t i s available in Hyderabad.

Fig.6 Lime Powder

3.5. Super plasticizer:

About 1% of the cement composition is used in master ease 3709.

3.6. Water:

In this investigation, tap water is used. It is particular that the pH value of water maintained in between 6 to 8 for achieving homogenous mix.

3.7 Acids and Sulphates:

(i)H2SO4 (ii) HCl

(a) (b)

(i)Na2SO4 (ii) MgSO4

(c)

(d)

EXPERIMENTAL INVESTIGATION

In this investigation studies the Durability properties of SCC of M60 grade when cement content was partially substituted with GGBS, LP and MK. Here, at various percentage content of mineral admixtures maintaining 25% of cement content replacement five mixes are studied as revealed in table 1. Whereas Mix M1 perform as conventional concrete (CC) for comparison between mixes with 25% GGBS and 75% cement content in it.

4.1 Mix Design for M60 grade for SCC

Mix design method used in this project is Nansu method, one of the benefits among SCC could withdraw mix design of concrete by any standard Mix Design methodology. Trial and error method applied to obtain final mix proportions in mix design. In this project at 9th trail test the final mix design is obtained with 25% pozzolana content is allowed for acceptable workability. While using Nansu method in mix design it is particular that to check weather that fulfill EFNARC guidelines for SCC. Not only Nansu method, for concrete like SCC it should withstand the acceptable criteria in guidelines.

4.2 Final design of mix

In this investigation M60 grade concrete with proportions 1(cement) :1.751(FA) :1.395(CA). As indicated in Table 1, a total of 5 distinct mixes were created by partially substituting different amounts of admixtures for cement. Among them M1 acts as the CC. Specimen used in this were 45 cubes of 100 mm side and After curing of age 28 days.

Table.1 Mix Proportions of different mixes.

Mix	Proportions	Cement (Kg/m^3)	Pozzolona			FA (Kg/m^3)	CA (Kg/m^3)
			GGBS (Kg/m^3)	*LP (Kg/m^3)*	*MK (Kg/m^3)*		
M1	75%C+25%GGBS	436	145.5	0	0	1019	812
M2	75%C+15%GGBS+10%LP	436	87.3	58.2	0	1019	812
M3	75%C+15%GGBS+10%MK	436	87.3	0	58.2	1019	812
M4	75%C+10%GGBS+15%LP	436	58.2	87.3	0	1019	812
M5	75%C+10%GGBS+15%MK	436	58.2	0	87.3	1019	812

4.4 Mixing

Mixing can be defined as the phase of concrete where the cement paste aid to bind the coarse aggregate and fine aggregate with homogenous proportion of constituents. The equipment utilized for mixing is pan mixing, maximum quantity of concrete can be produced in that equipment is 75-90 kg/m3. While mixing procedure it should be sure that the batch must be less than the limit of pan mixing such that divide batching into two or more parts. By assuming 15% of wastage in every parts of batch.

Fig.8 Mixing Pan

EXPERIMENTAL RESULTS AND DISCUSSIONS

5.1 Testing Procedure

As a result, tests on both freshly laid concrete and hardened concrete are required for the SCC. Concrete must therefore possess the passing ability, filling capacity, and resistance against segregation in order to attain appropriate workability. According to EFNARC criteria for SCC, these investigations are performed. After various trial and error tests the final mix proportions fixed as per mix design the proportion of mixes as shown in table 1.

5.2 Test on Fresh Concrete

Table 2 Test results on Fresh concrete

Property	M1	M2	M3	M4	M5
V-funnel (sec)	10	11	12.5	14	16
J- ring (mm)	4	4	6	5	7
L-box (ratio)	0.9	0.86	0.81	0.75	0.7
Slump (mm)	650	630	615	590	570

5.3 Test on Hardened Concrete

Durability of concrete is generally performed for acid attack, sulphate attack, permeability, sorptivity, water absorption, alkali aggregates reaction, drying shrinkage, abrasion resistance, impact resistance, rapid chloride ion penetration and corrosion. But in this investigation test conducted on hardened concrete are as follow.

- Acid Attack with HCl and H2SO4
- Sulphate Attack with MgSO4 and Na2SO4
- Sorptivity with Water as test fluid
- Water Absorption

Off-course for comparing Compressive test is done, in two phases before subjected to durability tests and after tests with individual samples of same mixes. Mix M1 treat as conventional concrete in the investigation with 25% GGBS as pozzolana material in cement content. The compressive test results of all mixes are shown in table 3.

5.3.1 Test on Compressive Strength

Table 3 Test result for Compression Test at 28 days.

Mix	Proportions	Compression test (28 days)			Average (MPa)
		1	*2*	*3*	
M1	75%C+25%GGBS	72.88	71.92	72.5	72.43
M2	75%C+15%GGBS+10%LP	84.2	83.6	83.4	83.73
M3	75%C+15%GGBS+10%MK	63.5	63.9	62	63.13
M4	75%C+10%GGBS+15%LP	71.6	72.8	72.2	72.20
M5	75%C+10%GGBS+15%MK	47.6	47.1	46.4	47.03

5.3.2 Acid attack

i. H2SO4: Specimens subjected to Acid environment at ages 28 days and 60 days, following table 4 and table 5 shows weight loss and strength loss for mixes. Mix M1 treated as conventional concrete for comparing to other mixes.

Table 4 Percentage loss of weight and Percentage of loss in Strength after acidic environment (H2SO4) at 28 days

MIX	M1			M2			M3			M4			M5		
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Before	8.21	8.33	8.34	8.33	8.34	8.21	8.22	8.26	8.24	8.19	8.31	8.23	8.21	7.96	8.30
After	8.01	8.05	8.18	8.05	8.18	8.19	8.06	8.09	8.04	7.88	8.00	8.11	7.79	7.66	8.00
%Loss of wt	2.38	3.29	1.90	3.29	1.90	0.17	1.86	2.08	2.43	3.73	3.67	1.43	5.12	3.73	3.65
% of loss in wt (Avg)	2.4			1.8			2.1			2.9			4.2		
f_{ck}	72.4			83.7			63.1			72.2			47.0		
f^{l}_{ck}	52.1			59.6			38.8			40.6			38.6		
% of loss in strength	28.06			28.80			38.53			43.79			17.95		

fck =Average Compressive Strength after 28 days water curing

flck = Average Compressive Strength after 28 days curing in Acidic environment

Fig.14 Comparison of Percentage of loss in weights in mixes

CONCLUSIONS

1. According to the investigation's findings, mix M2, which consists of 10% LP and 15% GGBS, has a CS rise of around 15.5%. The structure's densification is to blame for this.
2. As shown in mix M4, the compressive strength diminishes as the quantity of lime powder increases.
3. The test findings indicate that, after 28 days, the percentage loss in weight for M2 mix in an acidic environment with H2SO4 is lower than that of M1 mix.
4. The test findings demonstrate that, even after 60 days, the M2 mix has a lower percentage of strength loss in an acidic environment containing H2SO4 than the M1 mix.
5. The test findings indicate that, after 28 days, the percentage weight loss for M4 mix in an acidic environment with HCl is lower than that of M1 mix.
6. The percentage strength loss in an acidic environment with HCl is higher for the M2 mix with an allowed compressive strength loss, and it is marginally lower after 60 days when compared to the M1 mix.
7. At 28 days, the percentage weight loss for the M3 mix is lower than the M1 mix in the event of a sulphate attack using MgSO4.
8. However, test findings indicate that mix M2 has a considerable proportion of strength loss after 60 days when compared to M1. This results from MgSO4 alkali reactions with concrete ingredients filling up structural cavities.
9. The test findings indicate that, after 28 days, the M2 mix experiences less sulphate assault with Na2SO4 than the M1 mix.
10. However, the test findings indicate that mix M3 has a lower percentage of strength loss after 60 days than mix M1. This results from the filling of structural gaps with concrete elements via Na2SO4 alkali reactions. 11. Sorptivity data indicates that all other mixes are allowed limit only, with the exception of mix M4. 12.In comparison to other mixes, mixes M1 and M4 exhibit superior performance in the water absorption test findings.

REFERENCES

1. Rizwan A. Khan, Durability Properties of Self Compacting Concrete containing Fly ash, Lime powder and Metakaolin, JOURNAL OF MATERIALS AND ENGINEERING STRUCTURES 2 (2015) 206–212, December 2
2. Biswadeep Bharali, Experimental Study on SCC using GGBS and Fly Ash, IJCEM vol 2, issue 6, September 2015
3. M Jagadeesh, N R Gowthami Reddy and T Naresh Kumar, Experimental Investigation on Durability Properties of SCC by partial replacement of fly ash and GGBS in OPC, IJCRT issue December 2017 vol.5
4. S Srihari and Seshagiri Rao M V, Properties of SCC with Metakaolin replacing sand with GBFS , IJRET vol 04 issue 13 December 2015

5. B H V Pai, M Nandy and A Krishnamoorthy, Experimental studies on SCC containing industrial by-products, EUROPEAN SCIENTIFIC JOURNAL, April 2014 edition vol.10, No.12
6. S A Kristiawan, Sunarmasto and G P Tyas, Degradation of SCC due to Sulfuric acid attack: Experiment investigation on the effect of High-volume Fly ash content, Materials Science and Engineering,107 2016
7. Rajdip paul and debashis bhattacharya, Full Length Research Article SELF COMPACTING CONCRETE: A REVIEW, International Journal of Development Research Vol 5, Issue, 04, pp. 4262-4264, April, 2015
8. Udit A Chavda and Dr. K. B. Parikh, Self-Compacting Concrete: A Review, International Journal for Research in Applied Science & Engineering Technology (IJRASET), Vol 6, Issue I, January 2018
9. Imad R. Mustafa, Dr. Dilshad K. Jaf and Dr. Sinan Abdhulkhaleq Yaseen, Literature Survey on Self-Compacting Concrete, International Research Journal of Engineering and Technology (IRJET), Vol 4, Issue 12, 2017
10. K. Sathish Raja and Dinesh A, Study on Self-Compacting Concrete- A Review, International Journal of Engineering Research & Technology (IJERT), Vol 5, Issue 02, February, 2016
11. P. Kannan, C.F. Jerin, and Dr. K. Murali, A Review on Self-Compacting Concrete, International Journal of Advanced Research in Engineering & Management (IJAREM), Vol 1, Issue 07, October 2015
12. Parathibha Aggarwal, Rafat Siddique, Yogesh Aggarwal and Surinder M Gupta, Leonardo Electronic Journal of Practices and Technologies, Issue 12, January- June 2008
13. Partha Rasalia and Abbas Jamani, International Research Journal of Engineering and Technology (IRJET), Vol 5, Issue 07, July 2018