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Effect of Sulphate Attack on Self Compacting Concrete

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Abstract: Many current structures are characterized by the complexity of architecture (various shapes and bends) and a high concentration of reinforcement which often makes it difficult to use concrete with conventional plasticity. Recent researches have been conducted in order to adopt concrete to these structures. The resulting concrete formulations are characterized by better workability, while remaining stable with mechanical properties and durability. This new type of concrete can fit in place under the influence of gravity, hence the term self compacting concrete "SCC".

The external attack of sulphate salts is considered as one of the major problems affecting concrete durability. Sulphates are highly soluble salts in the form of sodium sulphate, calcium sulphate, potassium sulphate, and magnesium sulphate. Sulphate attack is a process in which sulphates react with various phases of hydrated cement paste leading to deterioration of the concrete matrix through spalling, softening, and mass loss, which may lead to expansion and loose strength and elasticity. It is recognized as a complex process due to the effect of The aim of this study to demonstrate the change in strength in SCC when the cement is replaced with lime powder and to determine the sulphate attack on the self compacting concrete.

Compressive strength characteristics for 7days and 28days of the self compacting concrete are determined in which cement is partially replaced with lime powder (0%, 10%, 20%, 30%, 40%) and cured in the sodium sulphate solution.

To attain the planned objectives of the present investigation, M20 grade self compacting concrete is taken and values of cement replaced with limestone at the percentages of 0%,10%,20%,30% were considered. The total of 48 cubes,48 cylinders were casted.24 cubes and 24 cylinders are cured in normal water and 24 cubes and 24 cylinders are cured in sodium sulphate solution. and determined the compressive strength and split tensile strength values. The developments of compressive and tensile strengths of self compacting concrete at the age of 7and 28 days are investigated. Under the influence of external sulphate attack. The parameters comparing the SCC with normal concrete are increased at the 20% of lime powder replacement after that the parameters decreases gradually.

Keywords: *lime powder, compressive strength, split tensile strength, self compacting concrete M20 etc.*

Introduction

Self-Compacting Concrete (SCC) is a fluid mixture, which is suitable for placing difficult conditions and also in congested reinforcement, without vibration. In principle, a self – compacting or self – consolidating concrete must:

Have a fluidity that allows self – compaction without external energy Remain homogeneous in a form during and after the placing process and Flow easily through reinforcement.

Self – consolidating concrete has recently been used in the pre – cast industry and in some commercial applications, however the relatively high material cost still hinders the wide spread use of such specialty concrete in various segments of the construction industry, including commercial and residential construction.

Compared with conventional concrete of similar mechanical properties, the material cost of SCC is more due to the relatively high demand of Cementation materials and chemical admixtures including high – range water reducing admixtures (HRWRA) and viscosity enhancing admixtures (VEA). Typically, the content in Cementation materials can vary between 450 and 525 Kg/m3 for SCC targeted for the filling of highly restricted area sand for repair applications. Such applications require low aggregate volume to facilitate flow among restricted spacing without blockage and ensure the filling of the formwork without consolidation. The incorporation of high volumes of finely ground powder materials is necessary to enhance cohesiveness and increase the paste volume required for successful casting of SCC.

Self-Compacting Concrete (SCC)

Concrete that is able to flow and consolidate under its own weight, completely fill the formwork of any shape, even in the presence of dense reinforcement, while maintaining homogeneity and without the need for any additional compaction SCC has more powder content and less coarse aggregate. Fillers used can be fly ash, ground granulated blast furnace slag, condensed silica fume, rice husk ash , lime powder, chalk powder & quarry dust.SCC incorporates high range water reducers (HRWR, Super plasticizers) & freq constituently, viscosity modifying agent in small amount.

Characteristics of SCC

If SCC should not segregate- it must have mortar rich in fines & is also able to transport the coarse aggregate & keep them in viscous suspension Cement cannot be the only finer/filler material Mineral admixtures are used to enhance the deformability & stability of concrete Chemical admixtures are a must for achieving excellent flow at low water content. VMA reduces bleeding & improves the stability of the concrete mixture. Compared to Conventional Concrete, SCC has higher powder content in the order of 450-600 Kg/m^3 Lower water/cement ratio. Typical range of water is 160 to 185 kg/ m3 & water/binder ratio, by volume in the range of 0.7 to 1.25.Volume of paste 0.36 to 0.43Lower coarse/fine aggregate ratio Use of super plasticizers & VMA compatible with cement in small percentages. [7] Proposed a principle in which another NN yield input control law was created for an under incited quad rotor UAV which uses the regular limitations of the under incited framework to create virtual control contributions to ensure the UAV tracks a craved direction. Utilizing the versatile back venturing method, every one of the six DOF are effectively followed utilizing just four control inputs while within the sight of un demonstrated flow and limited unsettling influences. Elements and speed vectors were thought to be inaccessible, along these lines a NN eyewitness was intended to recoup the limitless states. At that point, a novel NN virtual control structure which permitted the craved translational speeds to be controlled utilizing the pitch and the move of the UAV. At long last, a NN was used in the figuring of the real control inputs for the UAV dynamic framework. Utilizing Lyapunov systems, it was demonstrated that the estimation blunders of each NN, the spectator, Virtual controller, and the position, introduction, and speed following mistakes were all SGUUB while unwinding the partition Principle.

Benefits and Advantages

At present self – compacting concrete (SCC) can be classified as an advanced construction material. The SCC as the name suggests, does not require to be vibrated to achieve full compaction. This offers benefits and advantages over conventional concrete. Improved quality of concrete and reduction of onsite repairs. Faster construction times. Lower overall costs. Facilitation of introduction of automation into concrete construction. Improvement of health and safety is also achieved through elimination of handling of vibrators. Substantial reduction of environmental noise loading on and around a site. Possibilities for utilization of “dusts”, which are currently waste products and which are costly to dispose of Better surface finishes. Easier placing. Thinner concrete sections. Greater Freedom in Design. Improved durability, and reliability of concrete structures. Ease of placement results in cost savings through reduced equipment and labor requirement. SCC makes the level of durability and reliability of the structure independent from the existing on – site conditions relate to the quality of labor, casting and compacting systems available. The high resistance to external segregation and the mixture self – compacting ability allow the elimination of macro – defects, air bubbles, and honey combs responsible for penalizing mechanical performance and structure durability.

Aims and Objectives

The main objectives of project are as follows:

1. To obtain the fresh SCC properties of normal self compacting concrete and partially replaced SCC with lime stone powder (slump flow, U-box, V-funnel, L-box tests).
2. To evaluate the mechanical properties of self compacting concrete partially replaced with lime stone powder.
3. To determine the strengths of the self compaction concrete replaced by lime stone powder with different proportions (0%, 10%, 20%, and 30%).
4. To compare the strength characteristics of self compacting concrete placed in 5% of sodium sulphate and normal water.

Scope of the Present Work:

The project is proposed to cast the specimens of self compacting concrete with partial replacement of lime stone powder of (0%,10%,20%,and30%) proportions. cubes (150*150*150*),cylinders(150 mm dia *300 mm height) by using self compacting concrete with partial replacement of lime stone powder ,which will give a better understanding on the properties of self compacting concrete with lime stone powder. Each proportion of concrete consists of 12 cubes and 2 cylinders using lime stone powder. Total number of specimens prepared using lime stone powder is 65.

Investigation and laboratory testing on high strength concrete with recycled aggregate. Analyze the results and recommendation for further research area.

Literature Review

For several years beginning in 1983, the problem of the durability of concrete structures was a major topic of interest in Japan. The creation of durable concrete structures requires adequate compaction by skilled workers. One solution for the achievement of durable concrete structures independent of the quality of construction work is the employment of self- compacting concrete, which can be compacted into every corner of a formwork, purely by means of its own weight and without the need for vibrating compaction. The necessity of this type of concrete was proposed by Okamura in 1986. Studies to develop self-compacting concrete, including a fundamental study on the workability of concrete, have been carried out by Ozawa and Maekawa at the University of Tokyo.The prototype of self- compacting concrete was first completed in 1988 using materials already on the market.

(Al-NajafAl Ashraf, Iraq, Civil, Engineering/University of Babylon)[1] (2001)

The Internal sulfate attack is considered as very important problem of concrete manufacture in Iraq and Middle East countries. Sulfate drastically influences the properties of concrete. This experimental study is aimed at investigating the effect of internal sulfates on fresh and some of the hardened properties of self compacting concrete (SCC) made from locally available materials and reinforced by steel fibers. Tests were conducted on fifteen mixes, three varied steel fiber contents (0, 0.75 and1.5) (%by Vol.) with five SO3 levels (3.9,5, 6, 7 and 8) (% by wt. of cement). The last four SO3 levels are outside the limits of the Iraqi specifications (IQS NO.45/1984). The results indicated that sulfate passively influenced the fresh and hardened properties of the plain and the reinforced SCC. However, regarding the effect on the hardened properties, the SCC reinforced with steel fiber showed similar to better sulfate resistance over plain SCC, the resistance enhanced with increasing steel fiber content. The results of the present study refer to that there might be a possibility of using reinforced SCC with unacceptable SO3 (with regard to Iraqi specifications) if high steel fiber content and long curing period are employed and if the SO3 is limited to 6 (% by wt. of cement).

P. Thongsanitgarn1, W. Wongkeo1, S. Sinthupinyo2, A. Chaipanich1[3](1983) In this study limestone powders with different particle sizes of 5, 10 and 20 µ were used to replace a part of Portland cement in different replacement levels

1. Sulphate Attack on Concrete

Sulphate attack is a chemical breakdown mechanism where sulfate ions attack components of the cement paste. The compounds responsible for sulphate attack are water-soluble sulphate-containing salts, such as alkali-earth

(calcium, magnesium) and alkali (sodium, potassium) sulphates that are capable of chemically reacting with components of concrete.
It combines with the C-S-H, or concrete paste, and begins destroying the paste that holds the concrete together. As sulphate dries, new compounds are formed, often called ettringite. These new crystals occupy empty space, and as they continue to form, they cause the paste to crack, further damaging the concrete.

Sulphate sources
This is rarer but, originates from such concrete- making materials as hydraulic cements, fly ash, aggregate, and admixtures, Portland cement might be over-sulphated, presence of natural gypsum in the aggregate. Admixtures also can contain small amounts of sulphates.
External sources of sulphate are more common and usually are a result of high-sulphate soils and ground waters, or can be the result of atmospheric or industrial water pollution. Soil may contain excessive amounts of gypsum or other sulphate.
Ground water is transported to the concrete foundations, retaining walls, and other underground structures. Industrial waste waters.

Nature of reaction: (chemical, Physical):
Sulphate attack processes decrease the durability of concrete by changing the chemical nature of the cement paste, and of the mechanical properties of the concrete.

1. **Chemical process:** The sulphate ion + hydrated calcium aluminates and/or the calcium hydroxide components of hardened cement paste + water= <u>ettringite</u> (calcium sulphoaluminate hydrate)
C3A.Cs.H18 + 2CH +2s+12H = C3A.3Cs.H32
C3A.CH.H18 + 2CH +3s + 11H = C3A.3Cs.H32

The sulphate ion + hydrated calcium aluminate and/or the calcium hydroxide components of hardened cement paste + water = <u>gypsum</u> (calcium sulphate hydrate)
$Na_2SO_4+Ca(OH) +2H_2O = \underline{CaSO_4.2H_2O} +2NaOH$
$MgSO_4 + Ca(OH)_2 + 2H_2O = \underline{CaSO_4.2H_2O} + Mg(OH)_2$

Two forms of Chemical reaction depending on Concentration and source of sulphate ions .Diagnosis Composition of cement paste in concrete.

2. **Physical process:**
The complex physic -chemical processes of "sulphate attack" are interdependent as is the resulting damage.
Physical sulphate attack, often evidenced by bloom (the presence of sodium sulphates Na_2SO_4 and/or $Na_2SO_4.10H_2O$) at exposed concrete surfaces. It is not only a cosmetic problem, but it is the visible displaying of possible chemical and micro structural problems within the concrete matrix. Both chemical and physical phenomena observed as sulphate attack, and their separation is in appropriate.

4. Research Conducted By The Authors Of This Paper
The Following EFNARC standards ,the authors of this paper are conducting research to determine the durability of self compacting concrete with partial replacement of cement by Quarry and limestone (dust) powder by (10%,20%,and 30%) and tested to determine compressive strength, split-tensile strength, and flexural strength at 28 days. Experimental work also includes testing of properties like Density variation, compressive strength, water sorptivity for 7, 28, 60, 90, 120 days with respect to control self compacting concrete. The typical results for self compacting concrete properties were found to be good for cement replacement by limestone powder by 10%. The properties of all the replacements were satisfying the recommended values given by EFNARC.

Lime Powder

Most cement plants consume much energy and produce a large amount of undesirable products, which affect the environment. but also to increase the concrete durability, more recently limestone is also used as a filler material to improve the workability and stability of fresh concrete and for a high flow able concrete, such as self-compacting concrete.

Use of Lime Powder in SCC

Lime powder is the material that improves the hydration rate of cement compounds and consequently increases the strength at early ages. The incorporation of limestone powder with Portland cement has many advantages on early compressive strength, durability and workability. It is well known, there are a wide range of cementitious mortars based on cement and components similar to those of concrete. The composition of mortars could sometime consist of more than one type of cement (i.e. special cement, like ultra-fine alumina cement) together with additions (i.e. silica fume, slag or fly ash), aggregates (normal, lightweight and special types, fillers), admixtures such as super plasticizer (SP), air entrainers and accelerators, polymer additives and fine polymer The use of industrial by- products, such as FA, SF, offers a low-priced solution to the environmental problem of depositing industrial waste.

5. Test On Materials

Cement: Cement is a binding material invented by Joseph Aspdin in 1824.it is manufactured from calcareous materials, such as limestone or chalk, and argillaceous materials such as shale and clay.

Coarse Aggregate: If the size of aggregate is bigger than 4.75mm, then the aggregate is consider as coarse aggregate.

Fine Aggregate: According to IS 383, most of the aggregate which will pass through 4.75 mm sieve and entirely retained on 75 µ sieve is considered as fine aggregate.

Water: Water is the main ingredient used to mix all the contents. Potable water is used as usage of any other water may contain salts and cause decrease in strength of concrete.

Lime powder: Limestone was firstly ground in a laboratory ball mill to attain a suitable fine powder. The specific surface area of limestone powder was measured in accordance with ASTM standard C240.

Super plasticizer: Super plasticizer is essential for the creation of SCC. The job of SP is to impart a high degree of flow ability and deformability, however the high dosages generally associate with SCC can lead to a high degree of segregation. Glenium B233 is utilized in this project, which is a product of BASF. Super plasticizer is a chemical compound used to increase the workability without adding more water spreads the given water in the concrete throughout the concrete mix resulting to form a uniform mix. SP improves better surface expose of aggregates to the cement gel. Super plasticizer acts as a lubricant among the materials. Generally in order to increase the workability the water content is to be increased provided a corresponding quantity of cement is also added to keep the water cement ratio constant, so that the strength remains the same.

Mix Design is carried out in B.I.S Method (Bureau of Indian Standards)

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining with the object of producing concrete of certain minimum strength and durability as economically as possible.
Mix design forM20 grade concrete according to BIS method

As per IS 10262:2009(Revised) Stipulation of proportioning

Grade designation= M-20
Type of cement = OPC 53 grade

Maximum nominal size of aggregates = 20mm Water/cement ratio = 0.55 (mild-M20)

Target mean strength for mix proportioning [f' ck = f ck + k.s]
Target mean strength = 20+1.65 x 4=26.6N/mm^2 Characteristics strength at 28 days = 20Mpa

Selection of water content
Max. water content = 186lts.
corrected water content = (186×(30÷100))+186=241

Calculation of cement content water/cement ratio = 0.5 cement content = 241lts/0.5
C=484kg/m^3

Calculation of coarse and fine aggregate
From zone one and coarse (20mm) at w/c ratio 0.5
Volume of coarse aggregate = 0.4

Corrected volume = 0.01/0.05 x 0.03=0.006
=0.6+0.006
Coarse aggregate = 0.606m^3
Fine aggregate = 1-0.606=0.394m^3

Calculations:
Volume of concrete = 1m^3

- absolute Vol.of cement = 484/3.12 x 1/1000
  = 0.151m^3
- volume of water = 242x 10^-3
  =0.242 m3
- volume of materials (except aggregates)
  = 0.242+0.151= 0.393
- absolute total aggregates = 1-0.393 = 0.603
- weight of coarse aggregate

= 0.603 x 0.3 x 2.77 x 1000
= 668.1kg/m3

- weight of fine aggregate

=0.603 x 0.6 x 2.6 x 1000
= 940.6kg/m3

- total density = cement + coarse aggregate + fine aggregate + water = 2108kg/m3

Due to the addition of super plasticizer water quantity is reduced to 15%ie; water used is 200 kgs/cumec

Cement	Fine aggregate	Coarse aggregate	Water	Super plasticizer
500	940	668 (30% of 20mm) (70% of 10mm)	200	2.5

MIX RATIO:-
Cement: fine aggregate: coarse aggregate = 1:1.88:1.336
Design for 0% Lime Powder
Design for 10% Lime Powder:

Cement = 450kg/m3
Water = 200kg/m3
Fine aggregate = 940kg/m3
Coarse aggregate = 668kg/m3
Recycled aggregate = 50kg/m3

Design for 20% Lime Powder:-
Cement – 400kg/m^3 Water – 200kg/m^3
Fine aggregate – 940kg/m^3
Coarse aggregate = 668kg/m^3
Lime powder = 100kg/m^3
Design for 30% Lime Powder:-
Cement – 350kg/m^3 Water – 200kg/m^3
Fine aggregate – 940kg/m^3
Coarse aggregate = 668kg/m^3
Lime powder = 150kg/m^3

6. Results and Analysis

Tests on Cement
Table. Showing results on cement tests

Tests on Aggregates

TESTS ON CEMENT	VALUES
Standard consistency	32%
Initial setting time	40 MIN
Final stetting time	8 hours
Finess modulus	7%
Compression strength	53.8MPa
Soundness	2mm
Specific gravity	3.12

Table. Showing results on aggregate tests

	Fine aggregate	Coarse aggregate
Specific gravity	2.6	2.77
Bulk density	1.6 gm/cc	1.65 gm/cc
Fineness modulus	3.07	6.7
Moisture content	0%	0%
Absorption rate	0.5%	0.35%

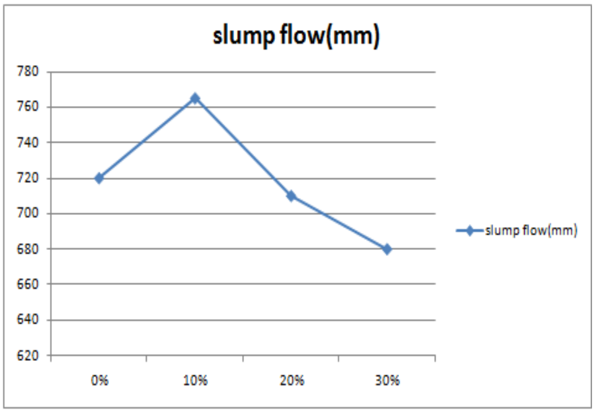
Lime Powder

Basic components (%)	Lime powder
Cao	38-48%
Sio2	15-18%
Al2O3	3-8%
Fe2O3	1-1.5%
MgO	0.5-3%
alkalies	1-1.5%
SO3	-
Cl	-
Loss in ignition	30-32%
Free Cao	-

Tests on Fresh Concrete

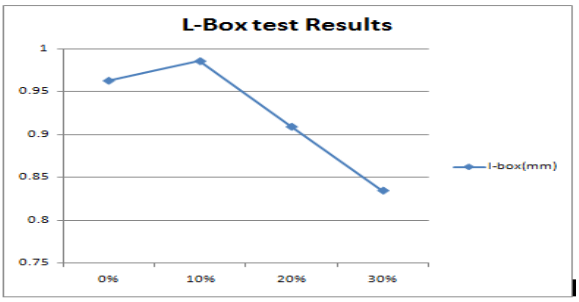
Workability tests Slump flow test:

	Lime 0%	Lime 10 %	Lime 20%	Lime 30%
slump	720mm	765mm	710mm	680mm

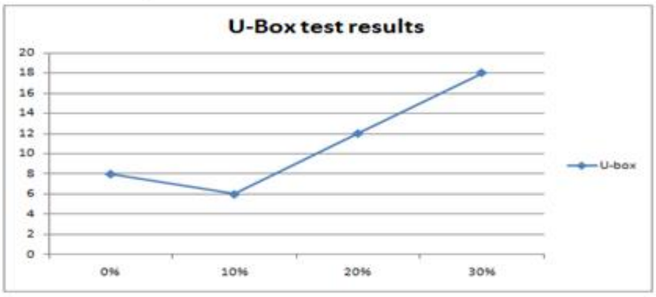


L-Box Test

Lime%	U-Box(mm)
0%	8
10%	6
20%	12
30%	18

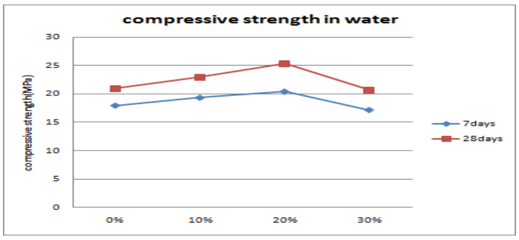


U Box Test



Test On Hardend Concrete
Compression Test
Compressive strength of cubes in water

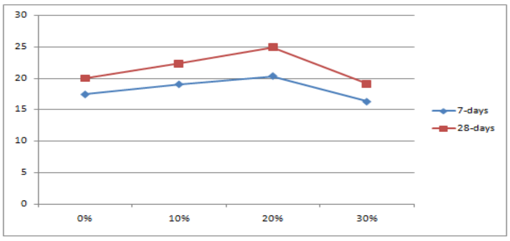
	7days	28days
0%	18	21
10%	19.4	23
20%	20.5	25.4
30%	17.2	20.7



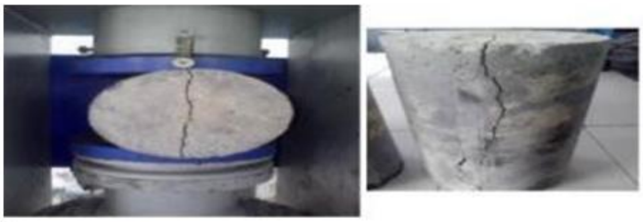
Compressive Strength of cubes in Sulphate

LIME	0%	10%	20%	30%
(h1/h2)	0.963	0.986	0.909	0.834

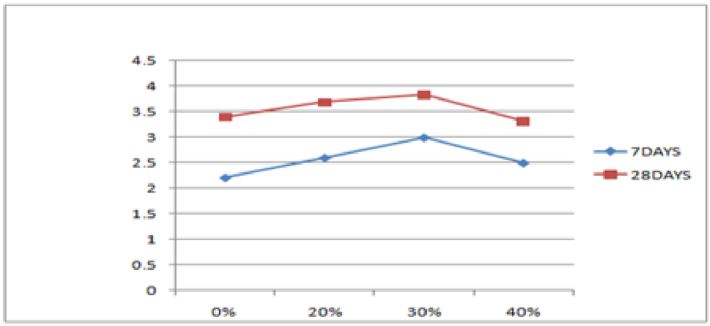
Lime%	7days	28days
0%	17.43	20
10%	19	22.3
20%	20.3	24.9
30%	16.3	19.1



Split Tensile Test

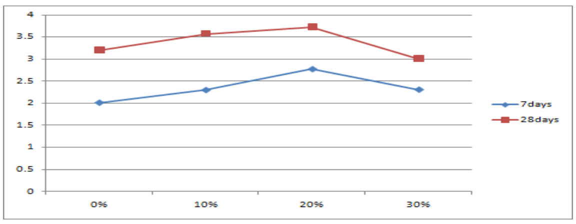


Lime%	7days	28days
0%	2.21	3.4
10%	2.6	3.68
20%	3	3.83
30%	2.5	3.31



Tensile strength of cylinders in sulphate

Lime%	7days	28days
0%	2.01	3.2
10%	2.3	3.58
20%	2.78	3.73
30%	2.31	3.01



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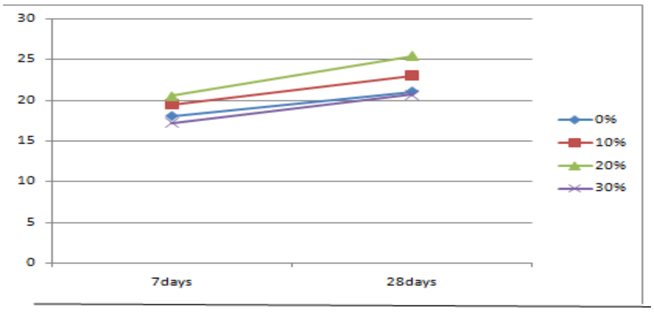
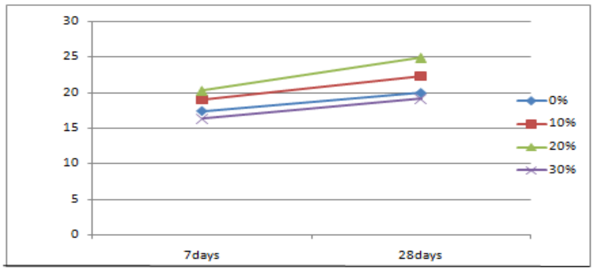
Compressive Strength Vs Duration of Immersion



Compressive strength of cubes (lime) in water



Compressive strength of cubes (lime) in Sodium Sulphate solution

7. Conclusion

The conclusions are as follows:

In this project, the review and research of current usage to the replacement of self compacting concrete by partial replacement of lime stone powder was discussed into different sectors, such as construction of bridge, building and tunnel construction .Total of four batches of SCC mixes required by the scope of the project. The investigation and laboratory testing on replacement of SCC with partial replacement by lime stone powder specimens such as compressive test, flexural test and elastic modulus of elasticity. However, not all the specimens had achieved to the high strength requirement.

In this investigation, the self compacting concrete properties were found to be good for cement replacement by limestone powder by 10%.as the percentage of limestone powder increases, the workability properties of SCC decreased with reduction in strength. The flow properties the replacements were satisfyingthe recommended values given by EFNARC. The compressive strength of replacement of 10% lime was 5 percent higher than the control SCC.

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