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CORRISION STUDIES ON SELF COMPACTING CONCRETE AND COMPARING WITH NORMAL CONCRETE

G.RAMADEVI[1], S.S.S.R.KRISHNA DUVVURI[2], K.JAGADESWARI[3]

[1](Civil engineering, Vignan Institute of Technology, Visakhapatnam)
[2](Civil engineering,M.tech)
[3](Civil engineering, Vignan Institute of Technology, Visakhapatnam)

ABSTRACT : Self-compacting concrete (SCC) can be placed in the form and it can pass through obstructions by its own weight without the need of vibration. It was first developed in Japan in 1988. It gained wider acceptance in Japan, Europe and USA due to its inherent distinct advantages. Although there are visible signs of its gradual acceptance in other countries, Durability is a major concern for concrete structures exposed to aggressive environments. Durability of reinforced concrete structures is influenced by many environmental phenomena. So developing SCC is necessary at this stage in order to increase the durability of the structure. Since then various investigations have been done on this concrete and it is proved that SCC is more durable than normal concrete. Reinforced concrete structures are very durable and capable of withstanding against adverse environmental conditions. However, failures in the structures do still occur as a result of premature reinforcement corrosion. In the present work different grades of self-compacting concrete were developed and their flow properties are verified by EFNARC specifications. After getting these mixes compressive strengths are found for these grades and conforming to achieving target strength. Durable property like Sorptivity was studied. The importance of this property is allied to the factor that this is the first phenomenon of transport of aggressive agents that takes place in concrete. Sorptivity, which is an index of moisture transport into unsaturated specimens, has been recognised as an important index. In addition to the above property corrosion studies were also carried. In this research the ability of chloride ions to penetrate in to the concrete must then be known for design as well as quality control purposes. Corrosion is a primary cause of premature deterioration of reinforced concrete which is exposed to dicing chemicals and sea water. Steel reinforcement in concrete is generally protected against corrosion because of the high alkaline environment of the surrounding cement paste. The cement paste forms a tightly adhering oxide layer over the steel bars and creates a protective environment with a high pH. These studies were carried on potential dynamic polarization studies. After getting the corrosion current, the corrosion rate was also determined.

KEYWORDS: Normal concrete, Self compacting concrete, flow properties of self-compacting concrete compressive strength, Sorptivity testes, potential resistance, corrosion current, corrosion rate

I.INTRODUCTION

Self-compacting concrete was first developed to improve durability of concrete structures in 1988. Since then, various investigations have been carried out. It is first used in practical structures in Japan by large construction companies. To make this a standard concrete several rational mix-design methods and self-compatibility testing methods have been carried out. It is a desirable achievement in the construction industry towards the development of self-compacting concrete in order to overcome problems associated with concrete casted in site. Self-compacting concrete (SCC) when taken in comparison with normally vibrated concrete (NC) possesses enhanced qualities and improves productivity and working conditions due to the elimination of compaction. In To achieve optimum strength and durability in concrete structures compaction is the key element. But complete compaction was difficult to obtain because of increasing the reinforcement with bars of smaller diameters and deficiency of skilled construction workers, leading to poor quality concrete. All these factors do not affect Self-compacting concrete .Due to its high fluidity and resistance to segregation it can be pumped longer distances. Self-compacting concrete is cast so that no additional inner or outer vibration is necessary for the compaction. It flows smoothly like honey and posses a very smooth surface level after placing of concrete. The composition of SCC is same as that of normal concrete but some chemicals and mineral admixtures are used and to attain self flow ability. Usually, the chemical admixtures used are high range water reducers (super plasticizers) and viscous modifying agents (VMA), which change the rheological properties of SCC .Mineral admixtures are used as an extra fine material, along with cement ,and replace cement in some cases. Because of the addition of a high quantity of fine particles, the internal material structure of SCC shows some resemblance with high performance concrete having compatibility in fresh stage and no initial defects in early stage.

LITERATURE REVIEW

A new type of concrete, which can be compacted into every corner of a formwork purely by means of its own weight, was proposed by Okamura[1]., He started a research project in 1986 on workability and flowing ability of this special type of concrete, which is later named as self-compacting concrete. The Self-Comp actability of this concrete can be largely affected by the characteristics of materials and the mix proportions. In his study, Okamura(1997) has fixed the coarse aggregate content to 50% of the solid volume and thefine aggregate content to 40% of the mortar volume, so that Self-Comp actability could be achieved easily by adjusting the water to cement ratio and super plasticizer dosage only.Later **Nan su et al [2]**. Proposed A simple mix design method for self-compacting concrete the amount of aggregates required is determined, and the paste of binders is then filled into the voids of aggregates such that the concrete obtained has ability to flow, ability of self-compacting and other desired properties of SSC. The amount of aggregates, binders and mixing water, as well as type and dosage of super plasticizer (SP) to be used are the major factors influencing the properties of SCC. Slump flow, V-funnel, L-flow, U-box and compressivestrength tests were carried out to examine the performance of SCC, and the results indicate that the proposed method could produce successfully SCC of high quality. The method involved determines Aggregate Packing Factor (PF) and influence on the strength, flow ability and Self-compatibility ability.**M.K. Gopalan [3].** In his work he measured the Sorptivity of three grades of cement concrete and six grades of fly ash mixes. The effect of curing was also studied by treating the samples in two curing conditions (fog curing and dry curing). Relationship between strength, curing conditions and fly ash content has been presented for Sorptivity. He concluded that the addition of fly ash to a concrete influenced the Sorptivity of the hardened concrete which strongly depended on the curing condition provided. When fog cured concretes of identical strengths were considered, the Sorptivity of the fly ash concrete was found to be lower than that of cement concrete. Under “drying,” the fly ash concrete had higher Sorptivity than cement concrete.

I. EXPERIMENTAL INVESTIGATION

The experimental program can be identified in two stages, first, to develop SCC mixes for M20, M30 and M60 grades which satisfy specifications given by EFNARC to qualify SCC and develop simple mix design for producing SCC with OPC. Then, in the second stage durable property like Sorptivity and corrosion of steel embedded in concrete was also studied for the same above grades. The same studies were carried on normal vibrated concrete for the same grades. Finally the results were compared**.**

The experimental program consisted of arriving at mix proportions, weighing the ingredients of concrete accordingly, mixing them (in a standard concrete mixer of rotating drum type of half bag capacity) and then testing (for the fresh properties of SCC). If fresh properties satisfy the EFNARC specifications, 18 Standard cubes of dimensions 150mmx150mmx150mm were caste to check whether the target compressive strength is achieved at 7- days and 28days curing. If either the fresh properties or the strength properties are not satisfied, the mix is modified accordingly. Standard cube moulds of 150X150X150mm made of cast iron were used for casting standard cubes. The standards moulds were fitted such that there are no gaps between the plates of the moulds. If any small gaps are found they must be fitted with plaster of Paris. The moulds are applied with oil or grease and then for kept ready casting. After 24 hours of casting, the specimens were removed from the moulds and transferred to curing tank in which they were immersed in water for the desired period of curing. For Sorptivity studies of Self-Compacting Concrete, a total of 9 cubes were cast. The same no. of cubes with normal concrete also.

But for corrosion studies cubes of dimensions 50X50X50mm were used. A rod of diameter 8mm was dipped in the centre of the cube. A total of 18, 9 for self compacting and 9 for normal concrete were casted. After 28 days of curing these cubes were dipped in Nacl solution of 5% concentration for a period of one week.

Materials used:

· 53 Grade ordinary Portland cement
· Fine Aggregate
· Coarse Aggregate
· Super Plasticizer (complast 430)
· Viscosity modifying agent VMA (Glenium)
· Micro silica

The mix design of Self compacting concrete was done by Nansu and the following proportions were obtained

Grade of concrete	M20	M30	M60
cement	210	220	700
Fine aggregate	944	991.13	850.3

Coarse aggregate	842	867.3	795.65
SP(Super plasticizer)	5.633	4.494	15.85
fly ash	300	231.8	289.26
Micro silica	0	0	35
VMA	0	0	1.75
water	238.66	196.533	269.86

Tests for Fresh Properties of Self-Compacting Concrete:

The main objectives of these tests are principally, to find tests which identify the three key fresh properties of SCC – filling ability, passing ability and resistance to segregation - for mix design purposes in the lab and for compliance purposes on site; and to recommend a range of results for the chosen tests to identify suitable SCC;

Tests recommended for European standardisation as reference methods:

Slump flow test (total spread and T50 time): To assess the filling ability,
This test is suitable for laboratory test and at site

- **L-box test**: To assess the passing ability and suitable for laboratory tests
- **J-ring test**: To assess the passing ability and suitable for laboratory tests
- **V-funnel test**: partially this test indicates filling ability and blocking and suitable for laboratory tests

S.NO	METHOD	PROPERTY
1	Slump flow test	Filling ability
2	T50cm Slump flow	Filling ability
3	V-funnel test	Filling ability
4	V-Funnel at T5 minutes	Segregation Resistance
5	L-Box test	Passing ability
6	J-Ring	Passing ability

Results obtained for different test on different grades

Method	Range of values	unit	Values obtained		
			M20	M30	M60
Slump flow test	650-800	mm	650	670	710
T50cm slump flow	2-5	sec	2	3.5	4
V-funnel test	6-12	sec	5	7.2	6.8
V-funnel at T5 minutes	6-15	sec	6	8.0	7.4
L-box test	0.8-1	h2/h1	0.87	0.9	1
J-ring	0-10	mm	12	9	7

Tests conducted on SCC and Normal concrete:

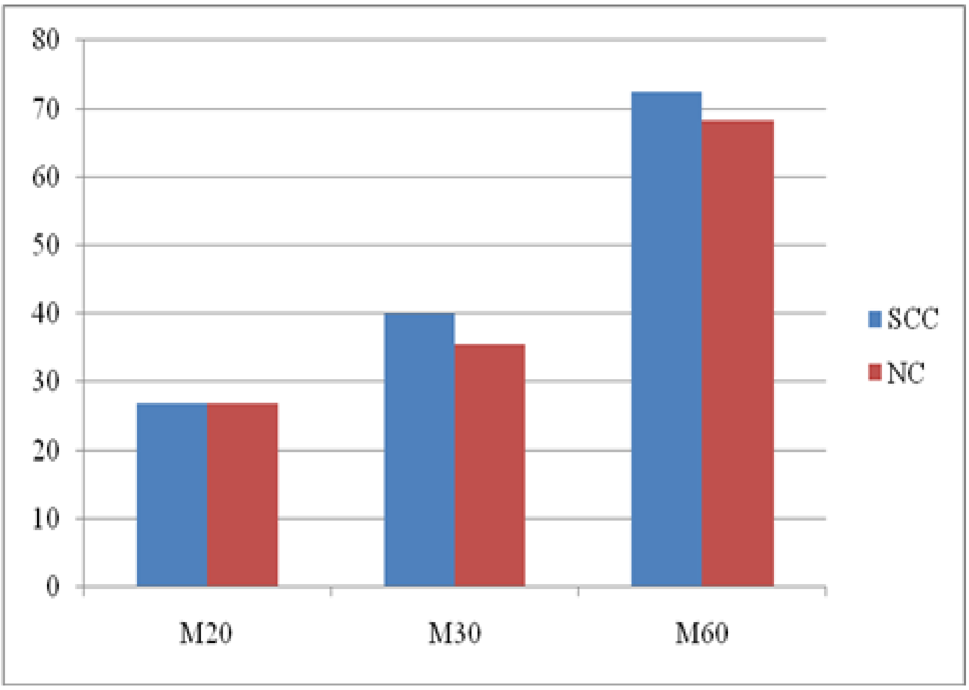
1. Compressive strength: In order to find compressive strength cubes of dimensions 150x150x150mm were casted. For that purpose moulds of required dimensions are used. Care should be taken that there should not have any gaps .If there are any gaps they should be filled with plaster of pairs. After 24hrs of casting the cubes are removed from the mould, and they are placed in water for curing for a period of 28days.

   After 28days of curing the cubes are removed from the curing tank. Then the cubes should be kept outside to dry. After drying the cubes are ready for testing. They are tested for compression in compression testing

Machine of capacity 200 tones .The specimen was placed in the machine in such a manner that the load was applied to opposite sides of the cubes as caste that is, not top and bottom. The axis of the specimen was carefully aligned at the centre of the loading frame. The load applied was increased continuously at a constant rate until the resistance of the specimen to the increasing load breaks down and no longer can be sustained. The maximum load applied on the specimen was recorded

COMPRESSIVE STRENGTHS FOR DIFFERENT GRADES IN COMPARISON WITH NORMAL CONCRETE

GRADE	COMPRESSIVE STENGTH	
	SELF COMPACTING CONCRTE	NORMAL CONCRETE
M20	26.88	26.80
M30	39.83	35.55
M60	72.5	68.2



Results Showing in Bar graph

2. Sorptivity test:

In order to test Sorptivity cubes of specimens 150x150x150mm were casted. After 28days of curing the specimens are removed from the curing tank and they are dried until the weight change is negligible.

After drying the initial weight of the cube was measured. Then the specimens are kept in tubs filled with water. The level of the water should be 10mm from the bottom of the cube. The cube should squeeze water from the bottom by capillary action. After a predefined time the cubes are removed from the tubs. Then they are taken for weight registration .Before taking weight the superficial should be removed with wet cloth .Immediately after weighting, the samples were replaced in the recipient till it reachs the following measuring time. The procedure was repeated, consecutively, at various times such as 15 min, 30 min, 1 h, 2 hrs., 4 hrs., 6 hrs., 24 hrs., 48 hrs. and 72 hrs. until the last reading.

The Sorptivity coefficient (k) was obtained by using the following expression:

$W/A = k \sqrt{t}$

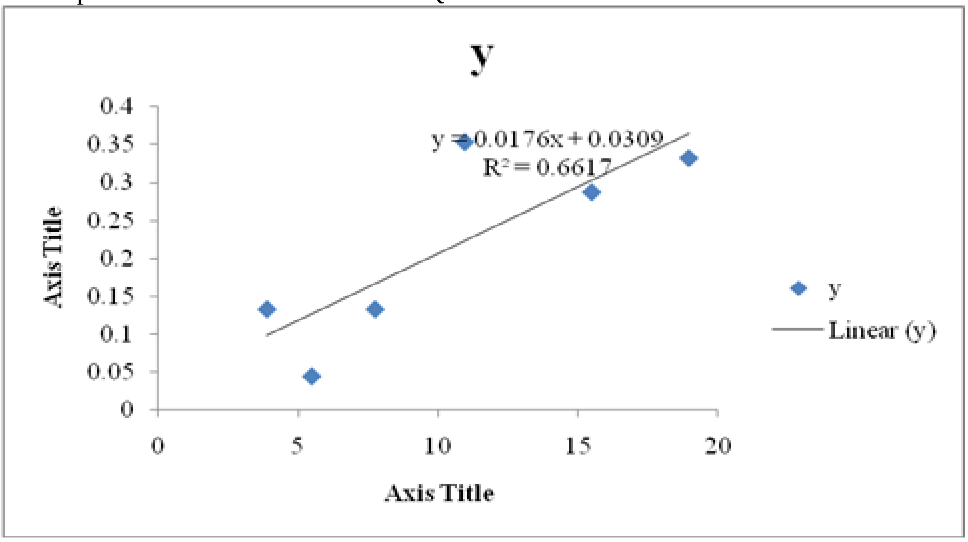
Where W = the amount of water adsorbed in (kg);

A = the cross-section of specimen that was in contact with water (m2);

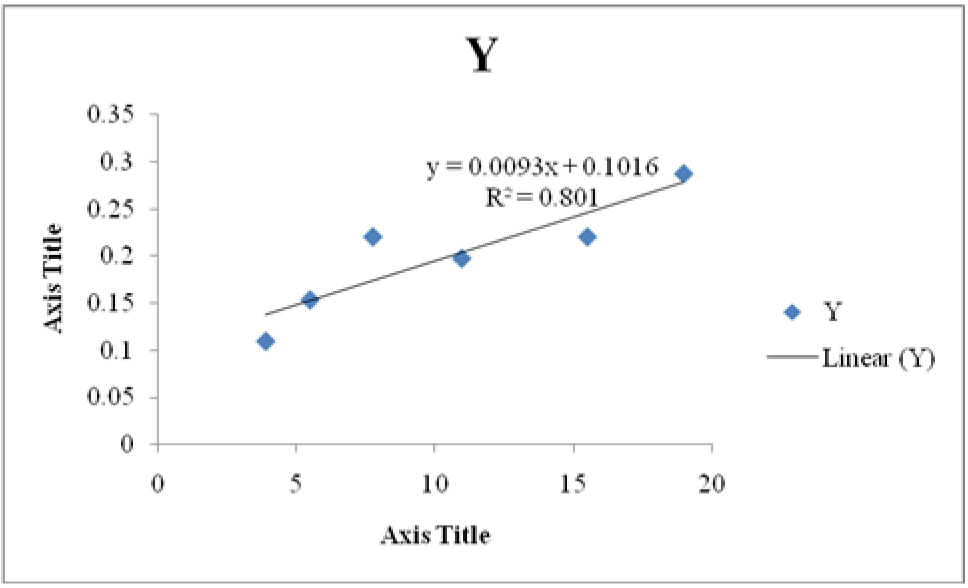
t = time (min);

k = the Sorptivity coefficient of the specimen (kg/m2/min 0.5).

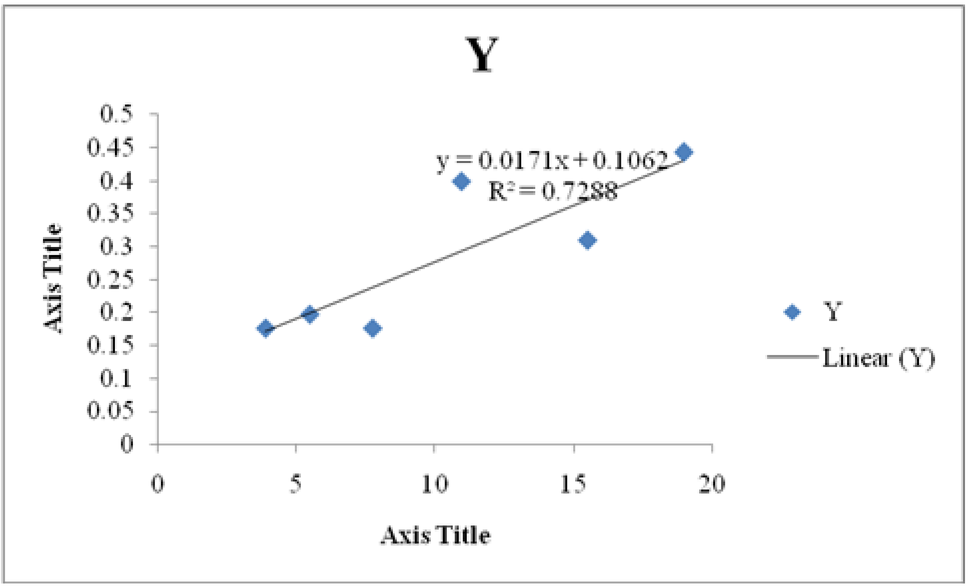
To determine the Sorptivity coefficient, *Q/A* was plotted against the square root of time ($\sqrt{t}$), then, *k* was calculated from the slope of the linear relation between *Q/A* and $\sqrt{t}$



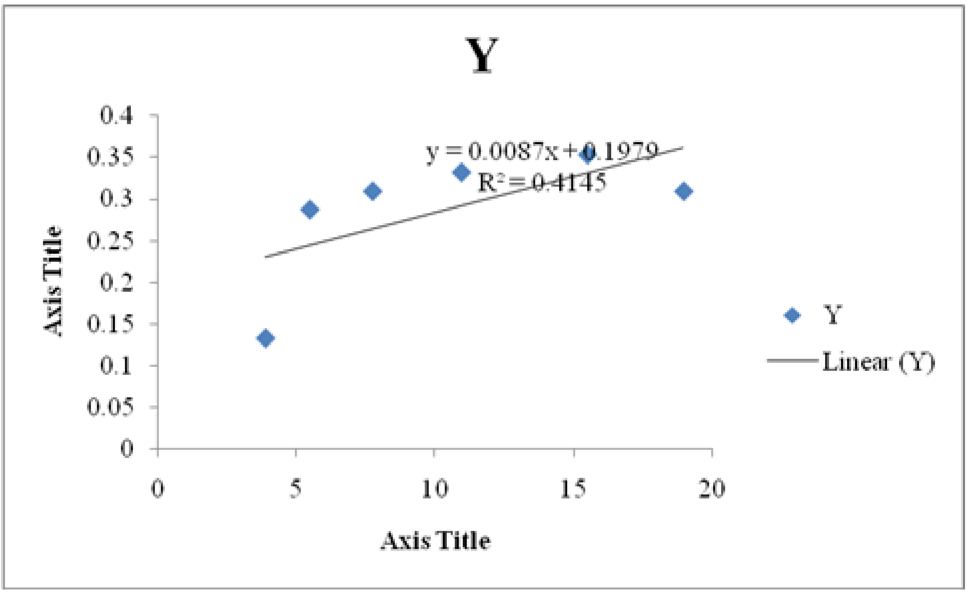
GRAPH FOR M20 NORMAL CONCRETE



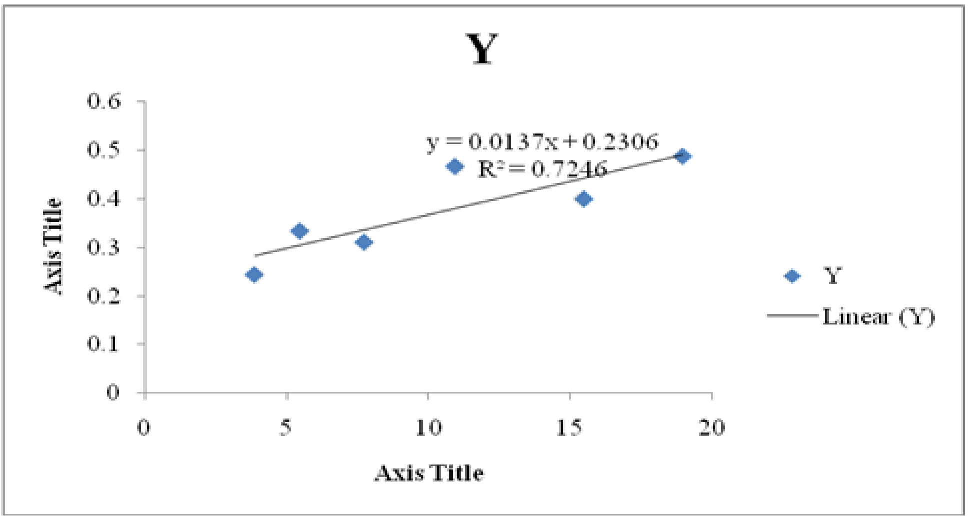
GRAPH FOR M20 SELF COMPACTING CONCRETE



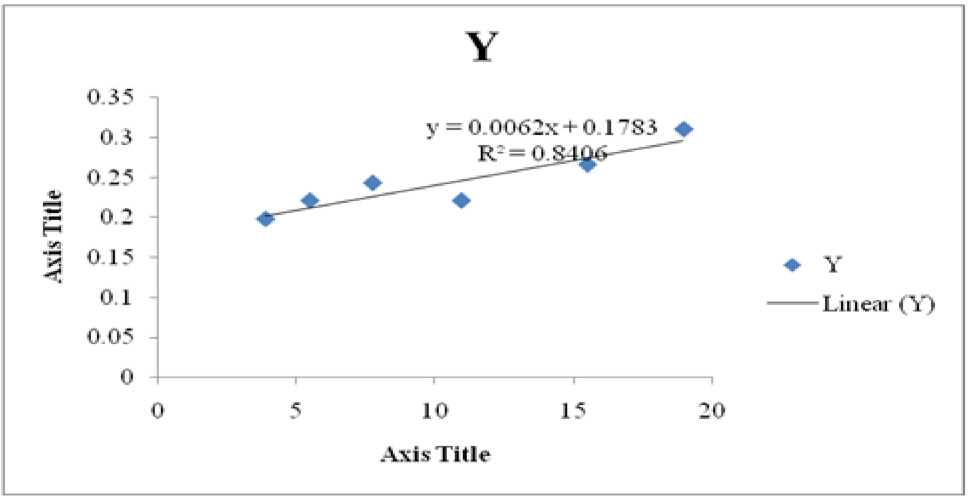
GRAPH FOR M30 NORMAL CONCRETE



GRAPH FOR M30 SELF COMPACTING CONCRETE



GRAPH FOR M60 NORMAL CONCRETE



GRAPH FOR M60 SELF COMPACTING CONCRETE

The following are the Sorptivity coefficients for different grades .they are tabulated as follows

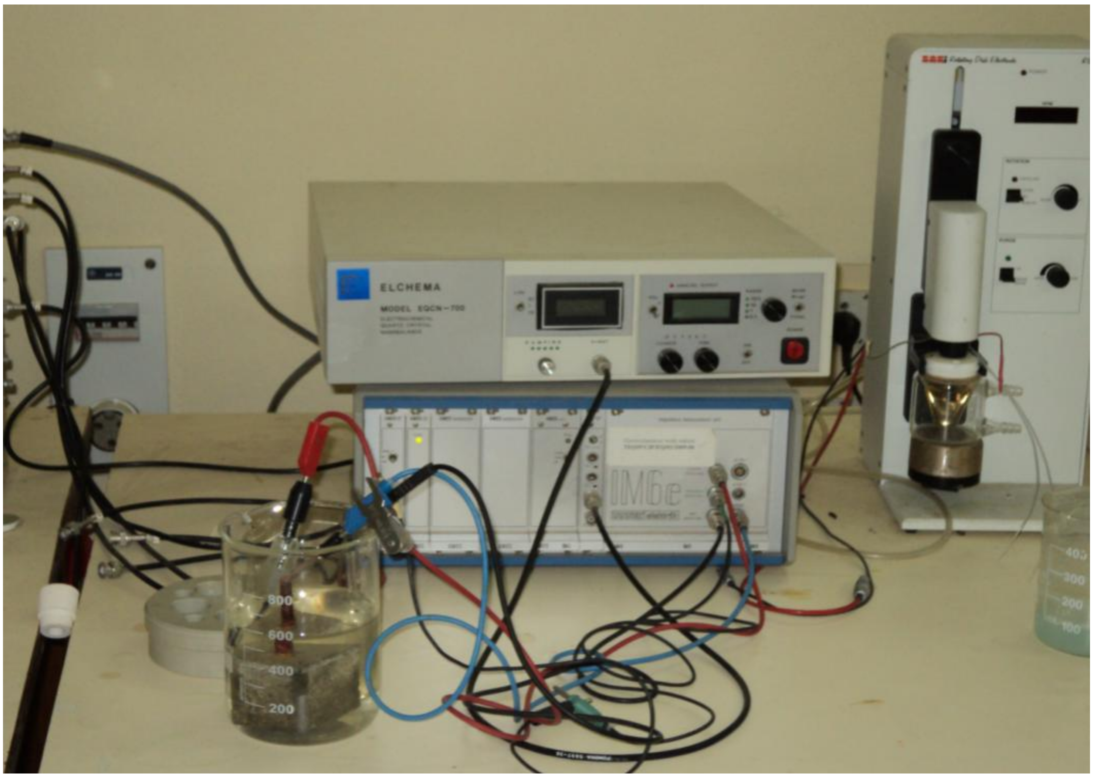
GRADE	Sorptivity coefficient	
	Normal concrete	Self compacting concrete
M20	0.0176	0.0093
M30	0.0171	0.0087
M60	0.0137	0.0062

SORPTIVITY COEFFICIENTS FOR DIFFERENT GRADES IN COMPARISON WITH NORMAL CONCRETE

3. Corrision Studies:

The corrosion resistance was measured by using potential dynamic polarization studies.

The accelerated corrosion behavior of steel bars embedded in concrete can be found by using these studies. The test specimen is made with concrete of size 50x50x50mm and a steel bar is embedded at its center. In order to accelerate the corrosion the specimen is kept Nacl solution for a period of one week .The concentration of the solution is 5%. The experiment starts by keeping the range of the potential resistance from -700mv to +700mv.A 500ml solution of Naclof the same concentration was taken and the specimen was dipped in to the solution. The total analysis is system operated and software used was Thales software. The current required to maintain the fixed potential was plotted against potential resistance and the typical curves drawn.



EQUIPMENT USED TO FIND CORROSION CURRENT

Graphs for different specimens are shown below. By observing these graphs we can say that there is a initial decrease of both current and potential. After getting some potential resistance there is an increase in both current and potential .The blue line in the graph represents cathodic potential and red line represents anodic. The potential goes on increasing with current up to certain stage .After some time we can notice that there will not be much increase in current .At that we can stop the experiment. Tangents are drawn for the cathodic and anodic curves in order to get the exact point of potential resistance and current. The values are tabulated accordingly.

CALCULATION OF CORROSION RATE FROM CORROSION CURRENT:

After getting corrosion current from graph the corrosion rate can be obtained by using the formula

$$CR = Icorr\ K\ EW\ /\ d\ A$$

where

CR= corrosion rate. Its units are given by the choice of K (see table below)

Icorr = The corrosion current in amps

K=A constant that defines the units of corrosion rate

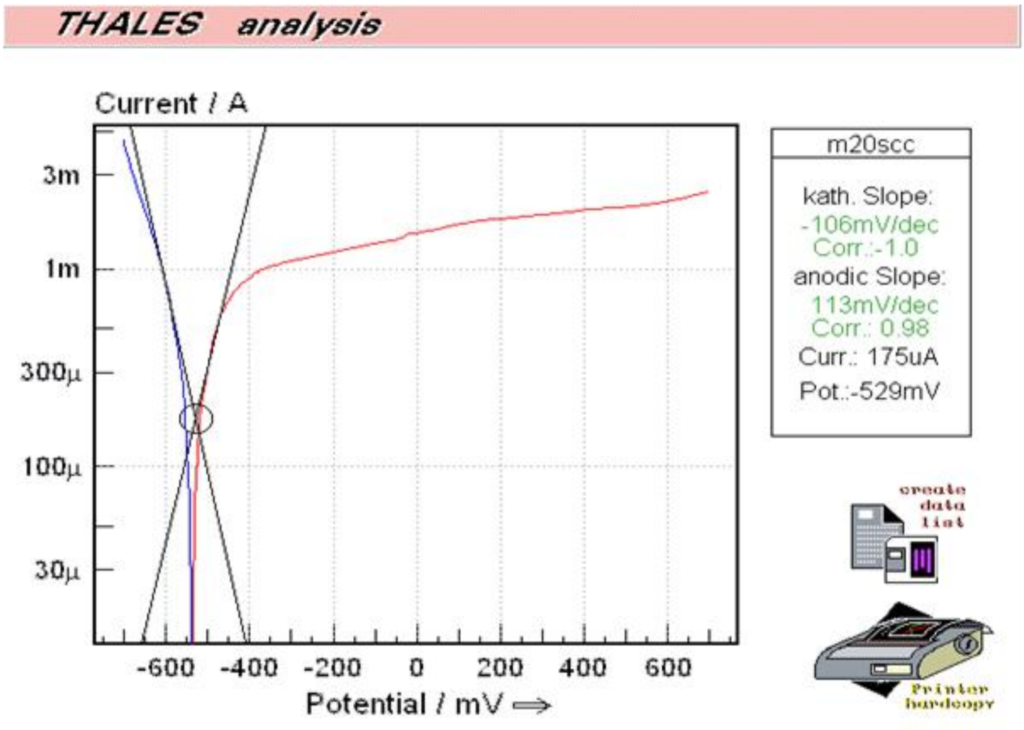
EW=equivalent weight in grams/equivalent

D=density in kg/cubic cm

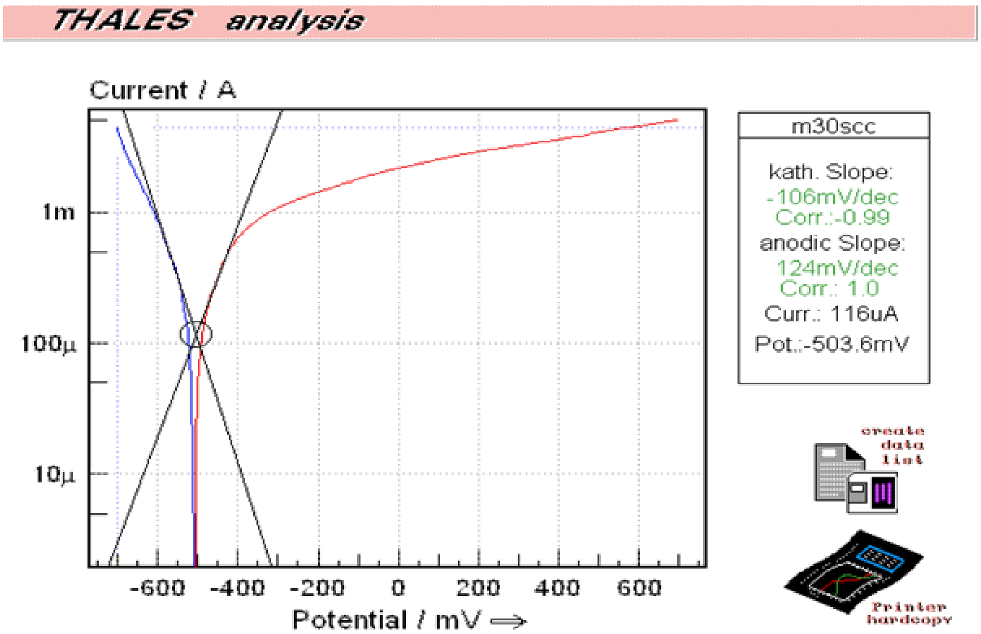
A=sample area in sq.cm

Corrosion Rate Constants

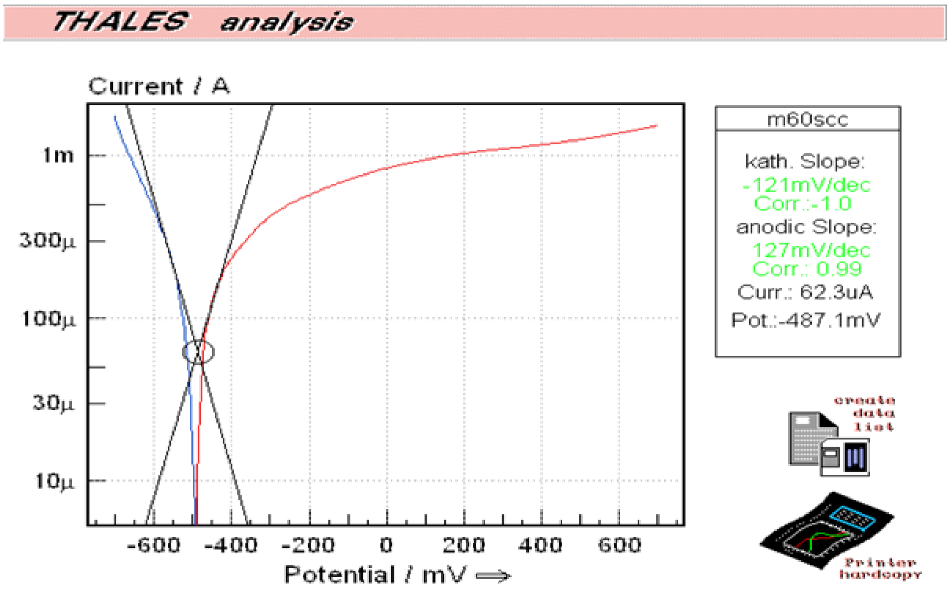
Corrosion Rate Units	K	Units
mm/year (mmpy)	3272	mm/(amp-cm-year)
milli-inches/year (mpy)	1.288×10^5	milliinches(amp-cm-year)



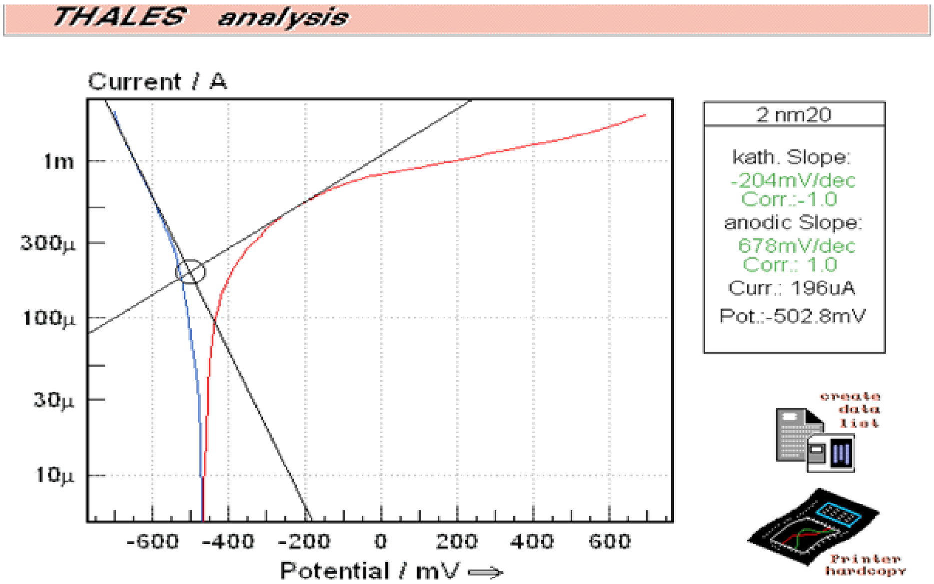
GRAPH M20SCC



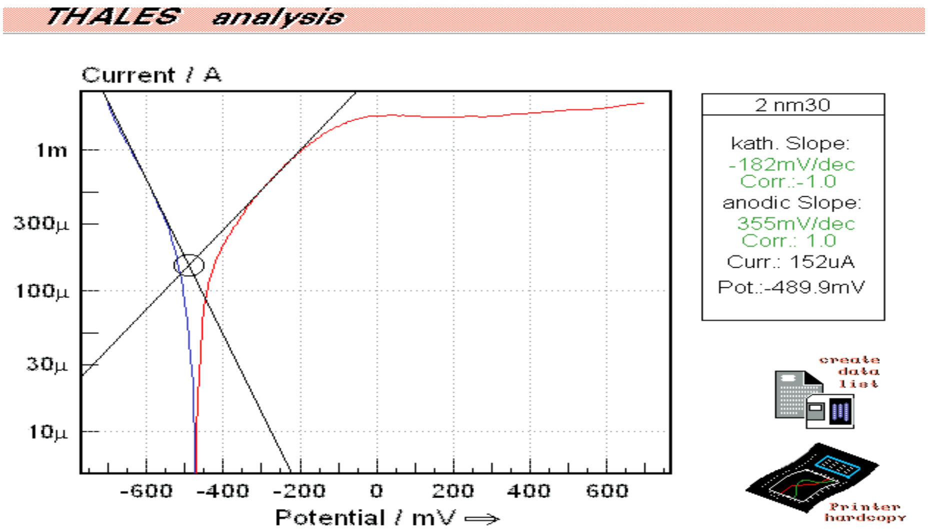
GRAPH FOR M30 SCC



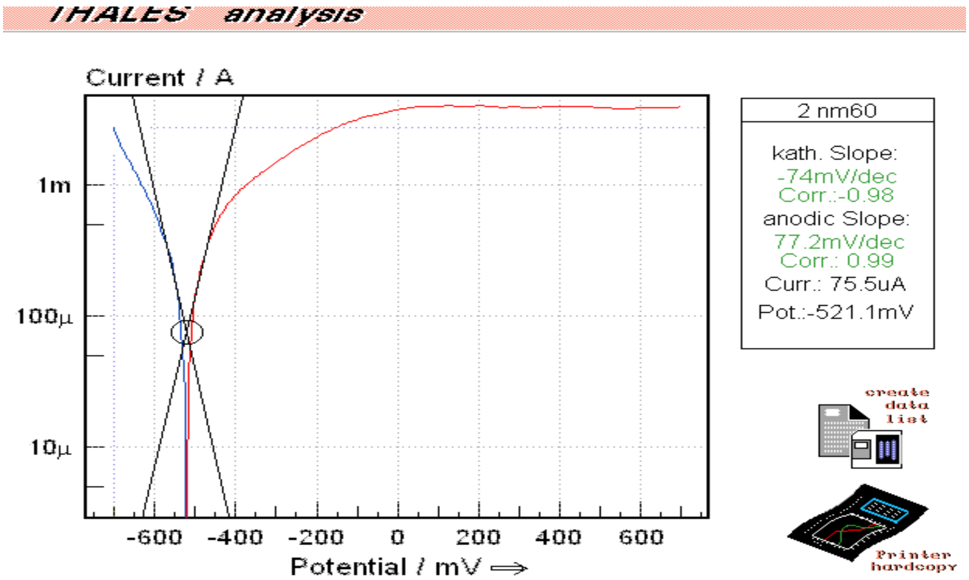
GRAPH FOR M60 SCC



GRAPH FOR M20 NORMAL CONCRETE



GRAPH FOR M30 NORMAL CONCRETE



GRAPH FOR M60 NORMAL CONCRETE

CORROSION CURRENT FOR DIFFERENT GRADES IN COMPARISON WITH NORMAL CONCRETE

Grade	Potential resistance		Corrosion current	
	SCC	NORMAL CONCRETE	SCC	NORMAL CONCRETE
M20	- 529mv	-502.8mv	175(µA)	196(µA)
M30	-503.6mv	--489.9mv	I16(µA)	155(µA)
M60	-487.1mv	-521.1mv	62.3(µA)	75.5(µA)

CORROSION RATES FOR DIFFERENT GARDES IN COMPARISON WITH NORMAL CONCRETE

GRADE	CORROSION RATE	
	SCC	NORMAL CONCRETE
M20	**0.081mm/year**	**0.091mm/year**
M30	**0.054mm/year**	**0.072mm/year**
M60	**0.029mm/year**	**0.035mm/year**

CONCLUSIONS

The following conclusions were made

1. The compressive strengths are found to be slightly more for self-compacting concrete when compared with normal concrete
2. .The Sorptivity coefficient is found to be less for SCC when compared to normal concrete because of increase in the powder content which ultimately reduces the voids.
3. .The Sorptivity coefficient is found to decrease as the grade of the concrete increases which means the porosity of the concrete decreases as the grade increases.
4. .As the grade of the concrete increases the corrosion potential is shifted towards more positive values (anodic)and the corrosion curve density decreasing.
5. when compared to SCC ,normal concrete corrodes more because of the increase in voids
6. The corrosion rate decreases with increase in the grade of the concrete as the corrosion rate is directly proportional to the corrosion current

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