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AN APPLICATION OF INDUSTRIAL WASTE IN MANUFACTURING OF SELF COMPACTING CONCRETE

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***Abstract*—Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete. In India, HINDALCO'S Aluminium refinery in Belgaum, Karnataka and many other places like Chhattisgarh generates a voluminous quantity of industrial waste in the form Red mud. This is largely dumped at sites, which are referred to as red mud pounds. The volume of waste generated is large and its alkalinity has the potential to contaminate valuable surface and groundwater resources. The dumping of red mud causing big threat for the society and it is disturbing the eco systems of the environment.So the objective of this research was comparing the Compressive strength value of Self-compacting by blending or by replacing the cement by Red mud. Cube specimens (15cmx15cmx15cm) were tested for compressive strength after 28 days of standard curing; in order find out if self-compacting concrete by blending or by replacing the cement by Red mud would show an increase in strength.**

***Keywords*— self-compacting concrete (SCC), NVC (Non-vibrated concrete), SQC (Super quality concrete), ready-mixed concrete (RMC), Pre-stressed Concrete Institute (PCI). etc …**

I. INTRODUCTION

Dietz, J. and J. Ma.:- Development of self-compacting concrete (SCC) is a desirable achievement in the construction industry in order to overcome problems associated with cast-in-place concrete. Self compacting concrete is not affected by the skills of workers, the shape and amount of reinforcing bars or the arrangement of a structure and, due to its high-fluidity and resistance to segregation it can be pumped longer distances (Bartos, 2000).

[2] Dhir, R. K. and T. D. Dyer:- The concept of self-compacting concrete was proposed in 1986 by professor Hajime Okamura (1997), but the prototype was first developed in 1988 in Japan, by professor Ozawa (1989) at the University of Tokyo. Self-compacting concrete was developed at that time to improve the durability of concrete structures. Since then, various investigations have been carried out and SCC has been used in practical structures in Japan, mainly by large construction companies.

[3] Detwiler, R. J., R. Wenk, and P. Monteiro:- Investigations for establishing a rational mix-design method and self-compactability testing methods have been carried out from the viewpoint of making it a standard concrete. Self-compacting concrete is cast so that no additional inner or outer vibration is necessary for the compaction. It flows like "honey" and has a very smooth surface level after placing. With regard to its composition, self-compacting concrete consists of the same components as conventionally vibrated concrete, which are cement, aggregates, and water, with the addition of chemical and mineral admixtures in different proportions

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[4] Dehn, F., K. Holschemacher, and D. Weisse:- Usually, the chemical admixtures used are high-range water reducers (super-plasticizers) and viscosity modifying agents, which change the rheological properties of concrete. Mineral admixtures are used as an extra fine material, besides cement, and in some cases, they replace cement. In this study, the cement content was partially replaced with mineral admixtures, e.g. fly ash, slag cement, and silica fume, Red Mud admixtures that improve the flowing and strengthening characteristics of the concrete.

1.2 Motive for Development of Self-Compacting Concrete

Ozawa and Maekawa:- The motive for development of self-compacting concrete was the social problem on durability of concrete structures that arose around 1983 in Japan. Due to a gradual reduction in the number of skilled workers in Japan's construction industry, a similar reduction in the quality of construction work took place. As a result of this fact, one solution for the achievement of durable concrete structures independent of the quality of construction work was the employment of self-compacting concrete, which could be compacted into every corner of a formwork, purely by means of its own weight (Figure 1.1). Studies to develop self-compacting concrete, including a fundamental study on the workability of concrete, were carried out by researchers Ozawa and Maekawa (Bartos, 2000) at the University of Tokyo. **[9]**

Aitcin:- During their studies, they found that the main cause of the poor durability performances of Japanese concrete in structures was the inadequate consolidation of the concrete in the casting operations. By developing concrete that self-consolidates, they eliminated the main cause for the poor durability performance of the concrete. By 1988, the concept was developed and ready for the first real-scale tests and at the same time the first prototype of self-compacting concrete was completed using materials already on the market. The prototype performed satisfactorily with regard to drying and hardening shrinkage, heat of hydration, denseness after hardening, and other properties and was named “High Performance Concrete.” At almost the same time, “High Performance Concrete” was defined as a concrete with high durability due to low water-cement ratio by professor Aitcin (Ouchi et al., 1996). Since then, the term high performance concrete has been used around the world to refer to high durability concrete. Therefore, Okamura (1997) has changed the term for the proposed concrete to “Self-Compacting High Performance Concrete.”

1.3 Construction Issues

Since the development of the prototype of self-compacting concrete in 1988, the use of selfcompacting concrete in actual structures has gradually increased. The main reasons for the employment of self-compacting concrete can be summarized as follows:

- To shorten construction period.
- To assure compaction in the structure - especially in confined zones where vibrating compaction is difficult.
- To eliminate noise due to vibration - effective especially at concrete products plants.

By employing self-compacting concrete, the cost of chemical and mineral admixtures is compensated by the elimination of vibrating compaction and work done to level the surface of the normal concrete (Khayat et al., 1997). However, the total cost for a certain construction cannot always be reduced, because conventional concrete is used in a greater percentage than self-compacting concrete. SCC can greatly improve construction systems previously based on conventional concrete requiring vibrating compaction. Vibration compaction, which can easily cause segregation, has been an obstacle to the rationalization of construction work. Once this obstacle has been eliminated, concrete construction could be rationalized and a new construction system, including formwork, reinforcement, support and structural design, could be developed (Figure 1.2).

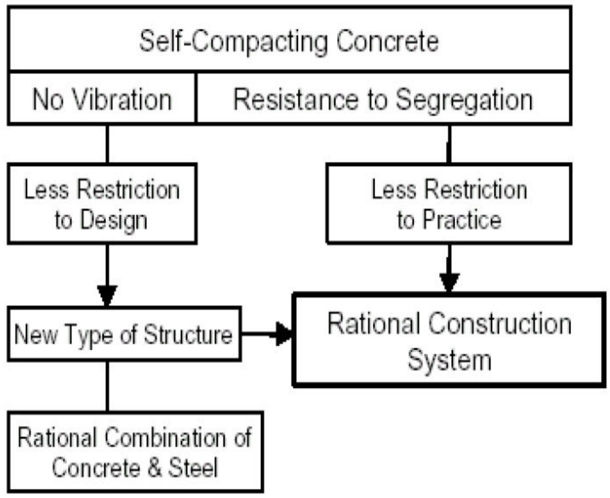

Figure 1.2 Rational construction system proposed by Ozawa (Ouchi et al., 1996).

1.4 Existing Tests for Fresh SCC Mixes

Fresh SCC must possess at required levels the following key properties:

Filling ability: this is the ability of the SCC to flow into all spaces within the formwork under its own weight.

Passing ability: this is the ability of the SCC to flow through tight openings such as spaces between steel reinforcing bars, under its own weight.

Resistance to segregation: the SCC must meet the required levels of properties A & B whilst its composition remains uniform throughout the process of transport and placing. Many tests have been used in successful applications of SCC. However, in all the projects the SCC was produced and placed by an experienced contractor whose staff has been trained and acquired experience with interpretation of a different group of tests. In other cases, the construction was preceded by full-scale trials in which a number, often excessive, of specific tests was used (Ouchi et al., 1996). The same tests were later used on the site itself. Below is a brief summary of the more common tests currently used for assessment of fresh SCC:

U-type test: Of the many testing methods used for evaluating self-compactability, the U-type test (Figure 1.3) proposed by the Taisei group is the most appropriate, due to the small amount of concrete used, compared to others (Ferraris, 1999). In this test, the degree of compatibility can be indicated by the height that the concrete reaches after flowing through obstacles. Concrete with the filling height of over 300 mm can be judged as self-compacting. Some companies consider the concrete self-compacting if the filling height is more than 85% of the maximum height possible.

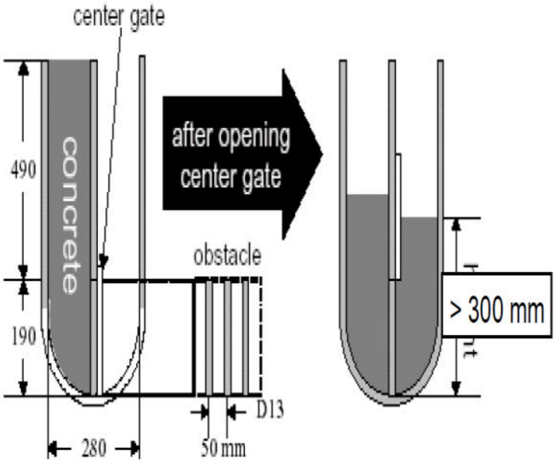

Figure 1.3 U-type test (Ouchi and Hibino, 2000).

Slump Flow test: The basic equipment used is the same as for the conventional Slump test. The test method differs from the conventional one by the fact that the concrete sample placed into the mold is not rodded and when the slump cone is removed the sample collapses (Ferraris, 1999). The diameter of the spread of the sample is measured, i.e. a horizontal distance is determined as opposed to the vertical distance in the conventional Slump test. The Slump Flow test can give an indication as to the consistency, filling ability and workability of SCC. The SCC is assumed of having a good filling ability and consistency if the diameter of the spread reaches values between 650mm to 800mm.

II. LITERATURE SURVEY

Hajime Okamura:- 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 (1997). In 1986, he started a research project on the flowing ability and workability of this special type of concrete, later called self-compacting concrete. The self-compactability 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 the fine aggregate content to 40% of the mortar volume, so that self-compactability could be achieved easily by adjusting the water to cement ratio and superplasticizer dosage only. A model formwork, comprised of two vertical sections (towers) at each end of a horizontal trough, was used by professor Okamura to observe how well self-compacting concrete could flow through obstacles. Figure 2.1 shows the ends of small pipes mounted across the horizontal trough and used as obstacles. The concrete was placed into a right-hand tower, flowed through the obstacles, and rose in the left-hand tower.

The obstacles were chosen to simulate the confined zones of an actual structure. The concrete in the left-hand tower rose to almost the same level as in the right-hand tower. Similar experiments of this type were carried out over a period of about one year and the applicability of selfcompacting concrete for practical structures was verified. This research was started at the suggestion of professor Kokubu (Okamura, 1997) from Kobe University, Japan, one of the advisors of Hajime Okamura.

Figure 2.1 Small pipes used as obstacles in formwork (Okamura, 1997).

Kazumasa Ozawa:- After Okamura began his research in 1986, other researchers in Japan have started to investigate self-compacting concrete, looking to improve its characteristics. One of those was Ozawa (1989) who has done some research independently from Okamura, and in the summer of 1988, he succeeded in developing self-compacting concrete for the first time. The year after that, an open experiment on the new type of concrete was held at the University of Tokyo, in front of more than 100 researchers and engineers. As a result, intensive research has begun in many places, especially in the research institutes of large construction companies and at the University of Tokyo. Ozawa (1989) completed the first prototype of self-compacting concrete using materials already on the market. By using different types of superplasticizers, he studied the workability of concrete and developed a concrete which was very workable. It was suitable for rapid placement and had a very good permeability. The viscosity of the concrete wasmeasured using the Vfunnel test (see Chapter 1). Other experiments carried out by Ozawa (1989) focused on the influence of mineral admixtures, like fly ash and blast furnace slag, on the flowing ability and segregation resistance of self-compacting concrete. He found out that the flowing ability of the concrete improved remarkably when Portland cement was partially replaced with fly ash and blast furnace slag. After trying different proportions of admixtures, he concluded that 10-20% of fly ash and 25-45% of slag cement, by mass, showed the best flowing ability and strength characteristics.

Subramanian and Chattopadhyay:- Subramanian and Chattopadhyay (2002) are research and development engineers at the ECC Division of Larsen & Toubro Ltd (L&T), Chennai, India. They have over 10 years of experience on development of self-compacting concrete, underwater concrete with antiwashout admixtures and proportioning of special concrete mixtures. Their research was concentrated on several trials carried out to arrive at an approximate mix proportion of self-compacting concrete, which would give the procedure for the selection of a viscosity modifying agent, a compatible superplasticizer and the determination of their dosages. The Portland cement was partially replaced with fly ash and blast furnace slag, in the same percentages as Ozawa (1989) has done before and the maximum coarse aggregate size did not exceed 1”. The two researchers were trying to determine different coarse and fine aggregate contents from those developed by Okamura.

The coarse aggregate content was varied, along with water-powder (cement, fly ash and slag) ratio, being 50%, 48% and 46% of the solid volume. The U-tube trials were repeated for different water-powder ratios ranging from 0.3 to 0.7 in steps of 0.10. On the basis of these trials, it was discovered that self-compactability could be achieved when the coarse aggregate content was restricted to 46 percent instead of 50 percent tried by Okamura (1997). In the next series of experiments, the coarse aggregate content was fixed at 46 percent and the sand content in the mortar portion was varied from 36 percent to 44 percent on a solid volume basis in steps of 2 percent. Again, the water-powder ratio was varied from 0.3 to 0.7 and based on the U-tube trials a sand content of 42 percent was selected. In order to show the necessity of using a viscosity-modifying agent along with a superplasticizer, to reduce the segregation and bleeding, the mixture proportion developed by the two researchers was used to cast a few trial specimens. In these trials, viscosity-modifying agent was not used. The cast specimens were heavily reinforced slabs having 2400x600x80 mm and no vibration or any other method of compaction was used.

However, careful qualitative observations revealed that the proportions needed to be delicately adjusted within narrow limits to eliminate bleeding as well as settlement of coarse aggregate. It was difficult to obtain a mixture that was at the same time fluid but did not bleed. This led to the conclusion that slight changes in water content, or granulometry of aggregate may result either in a mixture with inadequate flowing ability, or alternatively one with a tendency for coarse aggregate to segregate. Therefore, it became necessary to incorporate a viscositymodifying agent in the concrete mixture. Viscosity-modifying agents can be a natural polymer such as guar gum, a semi-synthetic polymer such as hydroxy propyl methyl cellulose, or water-soluble polysaccharides, including those derived from a microbial source such as welan gum. Experiments involving three types of gums were being carried out by the two researchers. One commonly used thickener in cementbased systems, namely hydroxy propyl methyl cellulose (HPMC), a low priced gum known as guar gum and a special product called welan gum were selected for studying their suitability for use in self-compacting concrete. On a first consideration, a1l these qualified as viscosity modifying agents. However, some of these substances, with the exception of welan gum, had shortcomings. Guar gum had to be made into a suspension in water after heating to 60°C and stirring for about one hour. This solution lost its suspending power after twelve hours. HPMC was not compatible with the naphthalene formaldehyde super-plasticizer and entrained excessive air, causing a reduction in strength (Figure 2.3). Welan gum is suitable for use in self-compacting concrete because it combines with most types of super-plasticizer and has superior suspending power, compare to guar gum and hydroxyl propyl methyl cellulose (HPMC).

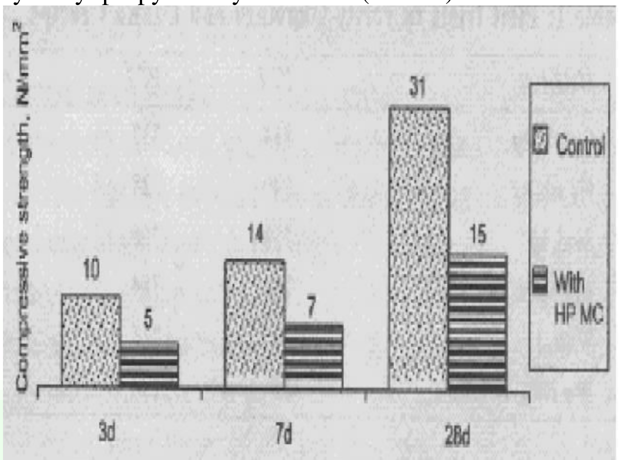

Figure 2.3 Compressive strength of SCC with and without HPMC (Subramanian and Chattopadhyay, 2002).

III. AGGREGATE-CEMENT BONDING CHARACTERISTICS

Bonding between aggregate and cement paste is an important factor in the strength of concrete, especially the compressive strength, and regarding the fracture properties of concrete. Bond is due, in part, to the interlocking of the aggregate and the paste owing to the roughness of the surface of the former (Neville, 1993). A rougher surface, such as that of crushed particles, results in a better bond, usually obtained with softer, porous, and mineralogical heterogeneous particles. Generally, texture characteristics, which permit no penetration of the surface of the particles, are not conducive to good bond. In addition, bond is affected by other physical and chemical properties of aggregate, related to its mineralogical and chemical composition (Bijen and Rooij, 1999). So, aggregate shape, surface structure and hardness are all factors affecting the strength of the aggregate-matrix bond. However, today little is known about these phenomena, and relying on experience is still necessary in predicting the bond between the aggregate and the surrounding cement paste.

The determination of the quality of bond of aggregate is rather difficult and no accepted tests exist. Generally, when bond is good, a crushed concrete specimen should contain some aggregate particles broken right through, in addition to the more numerous ones pulled out from their cavities. An excess of fractured particles, however, might suggest that the aggregate is too weak (Neville, 1993). Because it depends on the paste strength, as well as on the properties of aggregate surface, bond strength increases with the age of concrete.

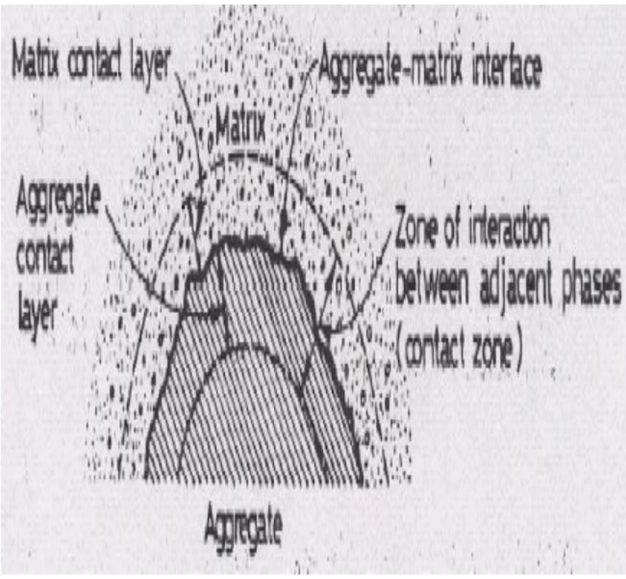

Figure 3.l Aggregate-matrix interface (Avram et al., 1981).

Another kind of interaction force between aggregate and matrix is that of chemical nature. Here, layers of a certain thickness are affected in the aggregate and the matrix and the forces developed are internal cohesive forces inside these layers, due to chemical reactions (Subramanian, 1999). Owing to the new products formed by reactions which take place at the aggregate surface, the interface between aggregate and matrix becomes diffuse and the reaction products are generated on the surface of aggregate crystals. As a rule, forces developed in the aggregate-matrix contact region are both physical (adhesion and interlocking) and chemical (due to reaction products and to the epitaxial growth) in nature. Physical forces, which predominate in inert aggregates, essentially depend on aggregate topography and roughness (Avram et al., 1981).

Thus, concrete prepared with polished aggregates such as feldspar or mica will always break at the aggregate-matrix interface, however strong the matrix is made. In those areas where the maximum value of the force that the aggregate surface can stand is exceeded, microcracks will start to develop. The fine voids developed over the aggregate surface represent structural breaks in the continuity and are, at the same time, an opportunity for the accumulation of a liquid interface phase. If concrete is submitted to freezing-thawing actions or to aggressive chemical agents, the liquid phase changes its volume, fact which leads to an additional stress on the aggregate-matrix interface and hence to microcracks. Studies showed that here an important part is played by the type of cement used (Neville, 1993). Cements, which subsequent to hydration generate idiomorphic crystals in the contact region, are less resistant to aggressive actions than cements which produce a gel-like mass (Figure 3.2), wherein a fine crystallization process is initiated.

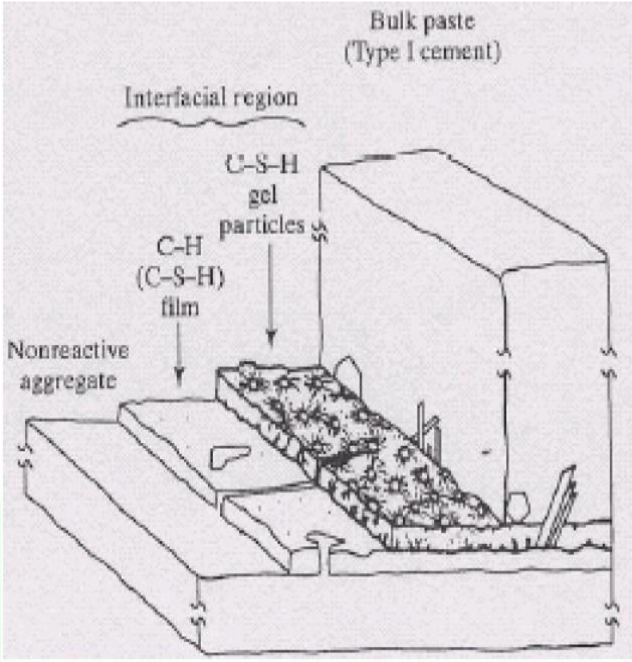

Figure 3.2 Interfacial region between aggregate and cement paste (Mindess et al., 2003).

Because, most aggregates show certain physical and chemical interaction with the cement matrix, they can be divided into two classes (Avram et al., 1981):

- Those producing a strong contact layer on the matrix surface while the aggregate surface is left practically unchanged and,
- Those producing weaker contact layers both on the aggregate and on the matrix surfaces.

IV. EXPERIMENTAL PROCEDURE AND TEST RESULTS

4.1. GENERAL

The main aim of this experimentation is to find out the effect of addition of red mud, which is a waste product from the aluminium industries, and foundry waste sand, which is a waste product from foundry, on the properties of self compacting concrete containing three admixtures. In this experimentation combinations of admixtures which is taken super plasticizer + VMA.

4.2. MATERIALS USED

In the experimentation OPC (Ordinary Portland Cement) was used. Locally available sand and coarse aggregates were used. The specific gravity of sand was found to be 2.55 and was Zone II sand. The specific gravity of coarse aggregates used was found to be 2.61. The coarse aggregates were 12mm and downsize. The mix proportion adopted in the experimentation was 1:1:0.5 with a water/binder ratio 0.35. The flyash/cement ratio used was

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1:3.5 (ERMCO Guidelines, 2005). The flyash used in the experimentation is pozzocrete 60, was obtained from DIRK INDIA PRIVATE LTD. The chemical composition of flyash is shown in the table 4.1(a).

Table 4.1(a) Chemical composition of flyash. (Chemical Test/ Analysis by DIRK INDIA PRIVATE LTD. Nashik)

Oxides	Percentages by mass
SiO_2+Al_2O_3+ Fe2O_2	70 min
SiO_2	35 min
MgO	05 max
SO_3	03 max
Na_2O	1.5 max
Total chlorides	0.05 max

The red mud used in the experimentation was obtained from HINDALCO, Belgaum, Karnataka. The fineness of red mud was found to be 35 m^2/gm with particle size of 75 microns and its density is found to be 3gm/cc. The chemical composition of red mud is shown in table 6.1(b).

Table 4.1(b) Chemical composition of red mud (Mauskar, 2006)

Chemical Composition	Bauxite Residue (%)	Typical values Worldwide (%)
Fe2O_3	51	30-60
Al_2O_3	15	10-20
CaO	13	2-8
SiO_2	10	3-50
Na_2O	0.20	2-10
TiO_2	5	3-5

A viscosity modifying admixture called GLENIUM STREAM 2 was used to induce the flow without segregation. GLENIUM STREAM 2 is dosed at the rate of 50 to 500ml/100Kg of cementitious material. Other dosages may be recommended in special cases according to specific job site conditions. GLENIUM STREAM 2 consists of a mixture of water soluble polymers which is absorbed on to the surface of cement granules thereby changing the viscosity of water and influencing the rheological properties of the mix. It also resist the segregation due to aggregation of the polymer chains when the concrete is not moving. GLENIUM STREAM 2 is a chloride free admixture. It should be added to the concrete after all the other components of the mix. This is particularly important in order to obtain maximum efficiency. It is a colourless free flowing liquid and manufactured by BASF Construction Chemicals (India) Pvt. Ltd., Pune. A high performance concrete super-plasticizer based on modified polycarboxylic ether was used in the experimentation. The trade name of the superplasticizer is GLENIUMTM SKY 569. It greatly improves the cement dispersion. It is manufactured by BASF Construction Chemicals (India) Pvt. Ltd., Pune. Optimum dosage of GLENIUMTM SKY569 should be determined in trial mixes. As a guide a dosage range of 300ml to 1200ml per 100kg of cementitious material is normally recommended.

4.3. EXPERIMENTAL PROCEDURE AND RESULT

4.3.1. Slump Flow Test

The consistency and workability of self compacting concrete were evaluated using the the slump flow test. Because of its ease to operation and portability, the slump flow test is the most widely used method for evaluating concrete consistency in the laboratory and at construction sites. In this study , the diameter of the concrete flowing out of the slump cone was obtained by calculating the average of two perpendicularly measured diameters for determining the above mentioned properties of concrete. The results from table 6.3.1 shows that the self compacting concrete was complying with the requirements found in the literature. Thus, self compacting concrete was assumed to having a good consistency and workability after gradually adjusting the chemical admixtures in the mix.

Table 4.3.1 Slump flow test results

W/C Ratio	0.35	0.40	0.45	0.50	0.60
Spread diameter (mm)	655	670	685	700	740

4.3.2. Compressive Strength

Self compacting concrete has also shown an increase in compressive strength, with an average of 65 percent. The values used for plotting the graph in Graph 4.1 were the minimum and maximum values obtained for each water cement ratio. The average values (Table 4.3.2) of compressive strength for each water-cement ratio are shown in Graph 4.2.

Table 4.3.2 Compressive Strength – 28 days

W/C Ratio	Types of Concrete			
	Normal Concrete		Self compacting concrete	
	Compressive Strength	Average Strength	Compressive Strength	Average Strength
	MPa	MPa	MPa	MPa
0.35	32.33	31.44	40.00	40.59
	31.40		41.33	
	30.60		40.44	
0.40	25.62	25.60	36.14	34.24
	24.54		34.24	
	26.90		32.32	
0.45	22.23	21.21	29.06	29.91
	20.27		30.81	
	21.14		29.88	
0.50	17.03	17.7	22.21	22.79
	18.57		21.85	
	17.71		24.43	
	14.81		18.1	

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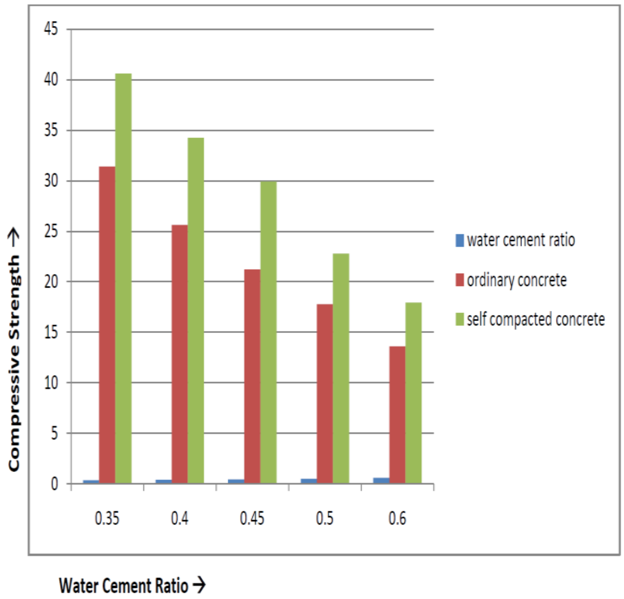
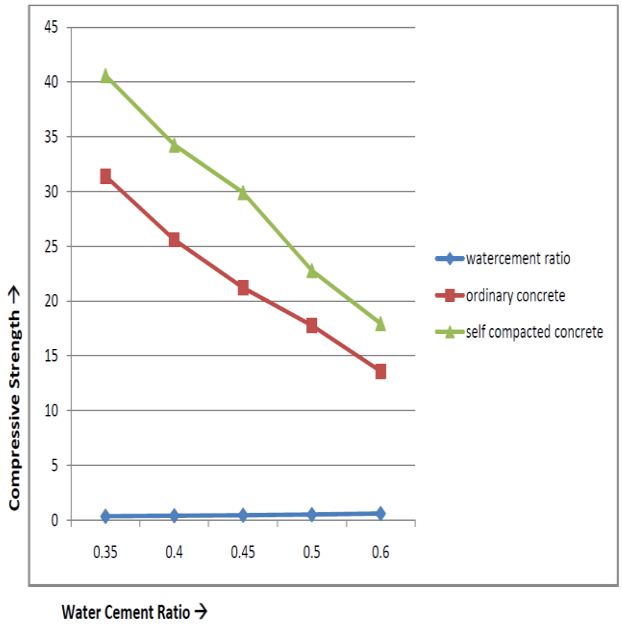
0.60	13.99 11.99	13.6	16.99 18.77	17.95



Graph 4.1 Variation of compressive strength with water-cement (W/C) ratio



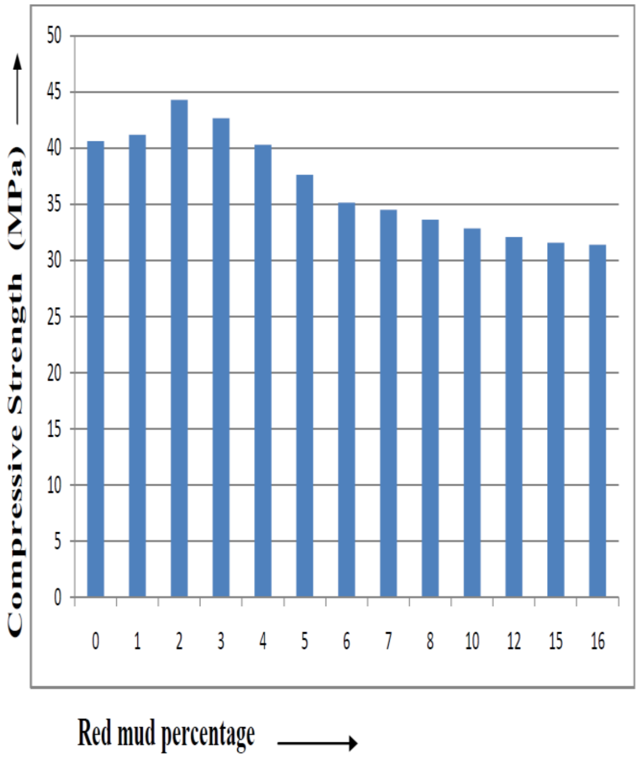
Graph 4.2 Variation of compressive strength average with water-cement

RESULTS

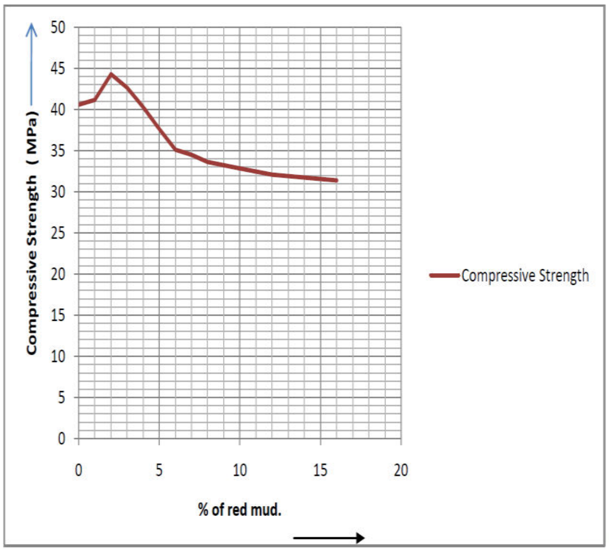
The following Table No.4.15 gives the overall results of compressive strength of self compacting concrete containing the combination of admixtures (SP+VMA) for various percentage addition of red mud

Table 6.15 Variation of Compressive Strength w.r.t. Red Mud Percentage

Percentage addition of red mud	Average Compressive strength (MPa)	Percentage (%) increase or decrease of compressive strength w.r.t. ref mix (0 % of red mud)
0	40.59	
1	41.18	+1.45
2	44.29	+9.11
3	42.66	+5.10
4	40.29	-0.74
5	37.62	-7.32
6	35.11	-13.50
7	34.51	-14.98
8	33.62	-17.17
10	32.84	-19.09
11	32.08	-20.97
15	31.56	-22.25
16	31.38	-22.69



Graph 4.3The variation of compressive strength of SCC containing red mud



Graph 4.4 Variation of compressive strength of SCC containing red mud

V. CONCLUSION

The following experimental studies can be conducted in future with respect to self compacting concrete-

- The effect of addition of red mud/foundry waste sand on the durability characteristics of self compacting concrete containing more than three admixtures.
- The effect of high temperature on the properties of self compacting concrete containing more than three admixtures with red mud/foundry waste sand.
- The effect of addition of red mud/foundry waste sand on the shrinkage and the creep properties of self compacting concrete containing more than two admixtures.
- Similarly there are lot more mineral admixtures which are the wastage of the industry. The other type of ingredients /wastages used for manufacturing of concrete to reduce the problems of environmental attack.

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