WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Experimental Study on Smart Dynamic Concrete by Using GGBS

[1] Allu Damodara Rao, [2] M Harish

[1] P.G Student, [2] Assistant Professor-
[1,2] Swamy Vivekananda Engineering College

A B S T R A C T :

Low Fines Self-Compacting Concrete (SCC) is widely used in the construction industry because its benefits are clear and helpful for making money. However, in everyday concrete work, SCC is still not used much.

Usually, when a concrete producer makes SCC, they design the strength higher than needed. This happens because a lot of fine materials are needed to keep the SCC stable. These fine materials are often cement and pozzolanic materials that are easy to get from the plant. Having too much cement and fine materials makes the concrete more expensive. If the total amount of fine materials is reduced, the cost of the concrete can go down, as long as the SCC still works properly.

This project is about making a mix of Low Fines SCC by replacing some of the cement with GGBS. A new chemical additive, which is a hyper plasticizer with a built-in viscosity modifier, is used to keep the SCC properties. The mix with less fine materials still has the same good properties as SCC. It is found to be more cost-effective than regular concrete that needs vibration. Also, using GGBS helps reduce environmental impact by using industrial waste instead of cement.

Keywords: Self-Compacting Concrete (SCC), GGBS, Fly ash

1. Introduction

1.1. SCC History

Concrete has evolved over the years to address challenges in the construction industry and reduce environmental impact. One notable advancement is self-compacting concrete (SCC), which is designed to flow and compact on its own without the need for external vibration. SCC offers advantages such as high fluidity, stability, and ease of placement, making it ideal for complex structures. It also reduces labor costs, accelerates construction, and simplifies the casting process in confined spaces.
However, SCC typically relies on Portland cement, which contributes significantly to carbon emissions. To mitigate this, researchers and industry professionals have explored the use of supplementary cementitious materials (SCMs) as partial substitutes for Portland cement. These materials, such as fly ash, rice husk ash, silica fume, and calcined clay, are often by-products from industrial and agricultural processes. By incorporating these materials, the construction industry can reduce its environmental footprint while maintaining the structural performance of concrete.
which, ordinarily, would be discarded as waste, have been recycled, valorised, and utilised as alternative binders in cementitious systems. Examples of such materials include steel slag, rice husk ash, fly ash, coconut shell ash, waste granite, silica fume, AND calcined clays, etc.

1.2. Motive For Development of SCC

1.3. For many years starting in 1983, the issue of how long concrete structures last was a big concern in Japan. To make concrete structures last longer, it's important to have skilled workers who properly compact the material. But over time, there have been fewer skilled workers in Japan's construction industry, which has led to lower quality in building work. One way to make concrete structures durable without relying on the skill level of workers is to use SCC. This type of concrete can fill all the corners of a formwork just by its own weight, without needing to be vibrated. The need for this kind of concrete was first suggested by Okamura in 1986. Research on developing self-compacting concrete, including studies on how well it works, was done by Ozawa and Maekawa at the University of Tokyo. This concrete was called "Self-Compacting High Performance Concrete."

1.4. Reasons For Introducing SDC

Along these lines, these concrete materials offer strong mechanical strength and good durability, as well as the necessary fresh properties. However, according to statistics from the European Ready Mix Concrete Organisation (ERMCO), the mechanical needs of regular concrete used in everyday construction are much lower than what standard self-compacting concrete (SCC) provides. Because of this, SCC is often made with more strength and durability than needed to meet the fresh workability requirements, which makes it more expensive than regular concrete. This is one of the main reasons why SCC isn't widely used in the ready-mixed concrete industry, though it's not the only reason. One of the key issues is the difficulty in making strong SCC with low amounts of fine materials like cement and filler, even when using viscosity-modifying admixtures (VMAs) available today.

On the other hand, the properties of locally available materials such as cement, aggregates, and filler are not always ideal for making SCC.
As a result, a lot of lab testing is needed to adjust the mix design to get stable concrete. Also, small changes in the moisture levels of aggregates and filler can greatly impact the stability of SCC, requiring several mix adjustments.

Furthermore, using extra fine materials (filler) can sometimes require new storage silos and more control in the plant.
This, combined with the high amount of cement usually needed, raises production costs. Therefore, using SCC as a regular, everyday concrete is difficult, especially in the ready-mixed concrete industry today. In response to this, the development of Smart Dynamic Concrete (SDC) has been proposed. This concept uses new types of VMAs that allow designing concrete with self-compacting properties without adding extra fine materials. This keeps the total fine content (cement plus filler) between 350–420 kg/m³, ensuring the needed stability. Using this new family of VMAs, called RheoMATRIX, along with special super plasticizers made for SCC, helps make concrete more cost-effective and can help SCC become more widely used in the ready-mixed concrete industry.

2. Workability SCC

2.1. Materials Used

The Different Types of Materials Used In This Investigation Given Below Are

2.1.1. Cement

Portland Pozzolana Cement is made by mixing pozzolanic materials with other cement ingredients. It includes OPC clinker, gypsum, and pozzolanic materials in specific amounts. The pozzolanic materials can be fly ash, volcanic ash, calcined clay, or silica fumes. These materials make up between 15% and 35% of the cement's total weight. Portland Pozzolana Cement (PPC) used in the study meets the standards set by IS 1489:1991.

2.1.2. Fine Aggregates

The SCC mixes were prepared by using the clean dry river sand as fine aggregate conformed to IS: 383- 1970. Sand specific gravity is 2.67.

2.1.3. Coarse Aggregates

Coarse aggregate used was pulverized granite stone conforming to IS: 383-1970 with maximum grain size of 12.5 mm. The specific gravity of the coarse aggregate is 2.56.

2.1.4. Water

In general, water that is safe to drink can be used to mix concrete; however, impurities in the water can affect the concrete's properties. These impurities can influence how long it takes for the concrete to set, its strength, and how much it shrinks, which can lead to corrosion of the steel reinforcing bars. Therefore, in this study, locally available clean drinking water was used.

2.2. Influence Of Admixtures on Concrete Properties

2.2.1. Mineral Admixtures and Blended Cements

There are some non-living materials that also have pozzolanic or hidden hydraulic properties. These materials are very fine in texture and are used in the concrete mix to make the concrete better (they are called mineral additives), or they can be used instead of regular cement to make blended cement.

2.2.1.1. Fly Ash

Fly ash is a by-product from coal-fired electric generating plants and can be used to replace up to 50% of Portland cement by mass. The characteristics of fly ash vary depending on the type of coal used. Generally, silicious fly ash behaves pozzolanic, while calcareous fly ash memiliki sifat hidraval laten.

2.2.1.2. Ground Granulated Blast Furnace Slag (GGBFS Or GGBS)

A by-product from steel production can replace up to 80% of Portland cement by mass. It has latent hydraulic properties.

2.2.1.3. Silica Fume

Silica fume is a by-product made when making silicon and ferrosilicon alloys. It is like fly ash, but its particles are 100 times smaller. Because of this, it has a larger surface area compared to its size, which makes it react more quickly in a pozzolanic way. Silica fume helps make concrete stronger and more durable, but it usually needs superplasticizers to keep the concrete mix workable.

2.3. Chemical Admixtures

Chemical admixtures are substances in powder or liquid form that are added to concrete to give it properties that cannot be achieved with ordinary concrete mixes. These are usually added during the batching or mixing process in quantities less than 5% by mass, and they help reduce confusion and frustration caused by the mixing process. The most common types of admixtures are:

I. Accelerators speed up the hydration (hardening) of concrete. Typical materials used are calcium chloride ($CaCl_2$) and sodium chloride (NaCl).

II. Retarders slow down the hydration process and are used in large or complex pours where premature setting before the pour is complete is not desirable. A typical retarder is table sugar, or sucrose ($C_{12}H_{22}O_{11}$).

III. Air entrainers add tiny air bubbles to the concrete, which reduces damage during freeze-thaw cycles and increases the durability of the concrete. However, entrained air is a trade-off with strength, as each 1% of air may result in a 5% decrease in compressive strength.

IV. Plasticizers (water-reducing admixtures) increase the workability of fresh concrete, allowing it to be placed more easily with less consolidating effort.

V. Super plasticizers (high-range water-reducing admixtures) are a class of plasticizers that significantly improve workability with fewer adverse effects. Plasticizers can also be used to reduce the water content of concrete while maintaining workability, which improves its strength and durability.

VI. Pigments are used to change the color of concrete for aesthetic purposes.

VII. Corrosion inhibitors are used to minimize the corrosion of steel and steel bars in concrete.

VIII. Bonding agents are used to create a bond between old and new concrete.

IX. Pumping aids improve pumpability, thicken the paste, and reduce the tendency for water to separate out of the paste.

2.4. Test Methods

It's important to understand that there isn't a standard method yet for testing self-compacting concrete (SCC) for shrinkage cracking. The main factors that affect how well SCC fills a space are called plastic viscosity and yield value. Among the tests, slump flow and T50 show the strongest connection to these factors, and they also give consistent and reliable results. Plus, the equipment used for slump flow is commonly used in real-world concrete work, and the process is easy to follow. Because of this, slump flow along with T50 was chosen as the main test method to check the filling ability of SCC.

2.4.1. Slump Flow Test

The slump flow test is used to check how well self-compacting concrete flows horizontally without any blocks in its way. It was first created in Japan for testing concrete that is used underwater.

1. The method is based on the slump test, which measures how much the concrete settles. The diameter of the circle made by the concrete is a way to see how well it can fill spaces.

2. This is a simple and quick test, but if you want to measure the T50 time, two people are needed. It can be done on-site, but the base plate is quite large, and you need a flat, level surface.

This test is the most commonly used one and is good at showing how well the concrete can fill spaces. However, it doesn't tell you how well the concrete can flow between reinforcing bars without getting stuck, but it might show how well it resists segregation.

Some say that the test doesn't fully represent real-world conditions because it lets the concrete flow freely without any restrictions.

But it's still useful for checking the consistency of ready-mixed concrete delivered to a site from one load to another.

The standard slump test is used to measure the plasticity of fresh concrete.

The slump flow test, on the other hand, measures how easily the concrete flows. The test involves measuring the average diameter of the spread of the fresh concrete after it flows out of an upside-down slump cone. It shows how well self-compacting concrete can deform under its own weight.

Fig. 1 - (a) Slump Flow; (b) Flow Measuring.

3. Mix Design

3.1. Mix Design

Mix design is about figuring out the right mix of materials for making concrete that works for a specific job. The goal is to find the best mix of ingredients that gives the concrete the needed qualities, like how easy it is to work with, how strong it is, how long it lasts, and how cheap it is to make. This is done by carefully choosing the materials and their amounts.

The main things to consider when making a mix design are:

i. Workability – how well the concrete can be mixed, placed, and shaped
ii.Strength – how strong the concrete needs to be
iii.Durability – how long the concrete will last
iv.Economy – making it as cheap as possible without losing quality

3.2. Tests Performed For Materials

For preparing the mix design basic requirement is the specific gravity of cement and aggregates.
Test procedure for finding out the specific gravity of aggregate is:

3.2.1. Test performed for Cementitious materials:

Specific Gravity of cement	= 3.15
Fineness of Cement	= 8%
Specific Gravity of GGBS	= 2.82

3.2.2. Test performed for Aggregates:

Test for Fine Aggregate	
Specific Gravity	= 2.69
Fineness Modulus	= 3.21
Test for Coarse Aggregate	
Specific gravity of 10mm Coarse	= 2.78
Specific Gravity of 20mm Coarse	= 2.85
Gradation of Aggregate	
20mm retained and 25mm passing	
10mm retained and 12.5mm passing	
0.075mm retained and 4.75mm passing	

Table 1 - Physical Properties of Materials.

Material Name	Physical Properties	Value
Cement	Specific Gravity & Fineness	3.15 & 8%
GGBS	Specific Gravity	2.82
Fine Aggregate	Specific Gravity & Size	2.69 0.075mm<aggregate<4.75mm
Coarse Aggregate (20mm)	Specific Gravity & Size	2.85 20mm<aggregate<25mm
Coarse Aggregate (10mm)	Specific Gravity & Size	2.78 10mm<aggregate<12.5mm

Table 2 - Chemical Properties of Materials.

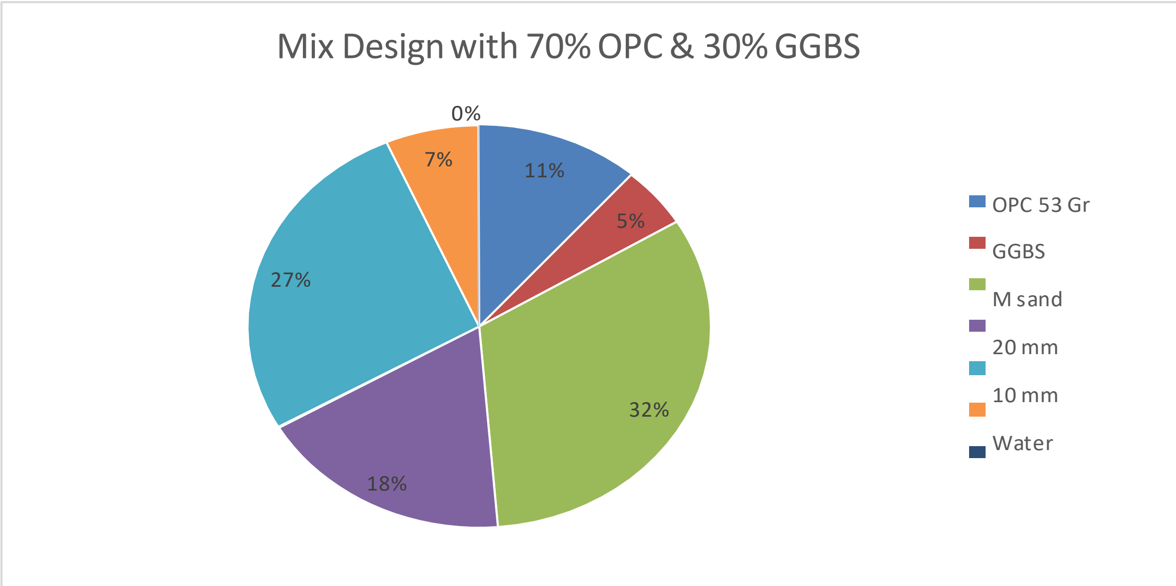
S No	Chemical Compound	GGBS	OPC (Cement)
1	SiO2	35.50	19.80
2	Al2O3	12.00	4.20
3	Fe2O3	0.40	2.98
4	CaO	42.00	60.60
5	MgO	8.00	2.18
6	Na2O	-	-
7	K2O	-	-
8	P2O5	-	-
9	Loss on ignition	0.10	0.98
10	Insoluble Residue (Other than SiO2)	0.30	0.85

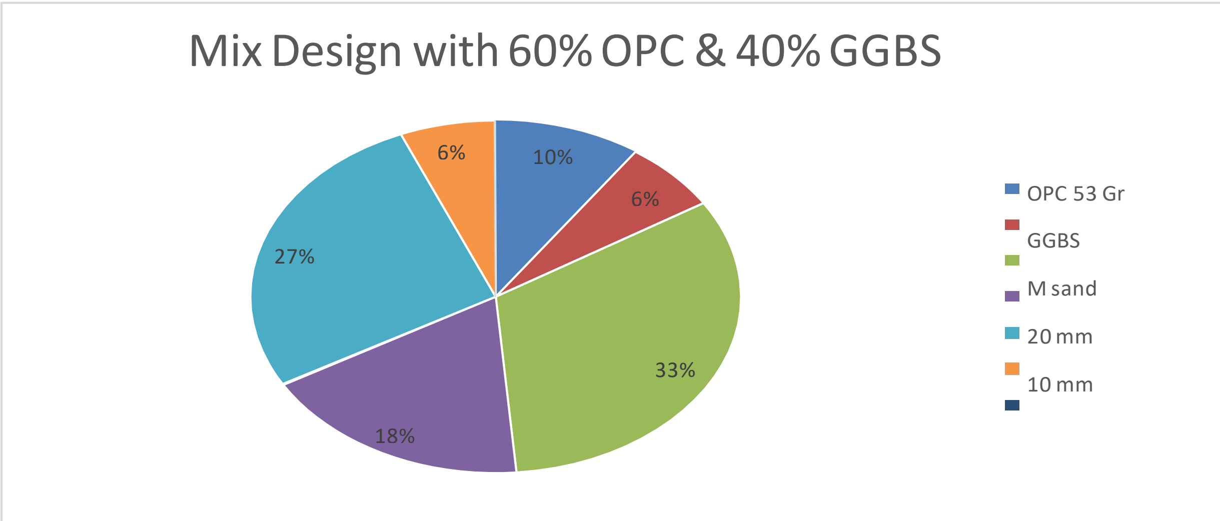
4. Mechanical Characteristics Of SDC

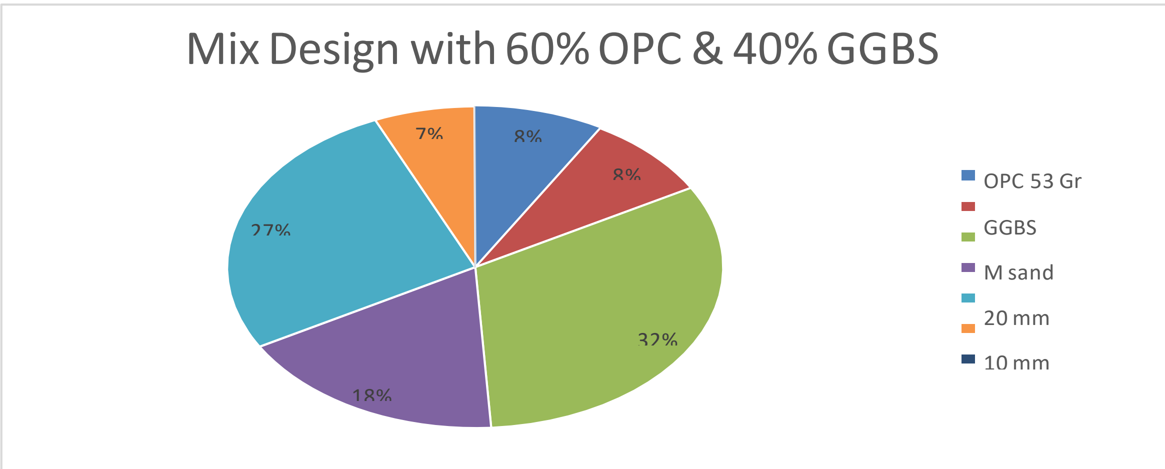
Trail Mix	Cement (Kg/m3)	GGBS (kg/m3)	Aggregate (Kg/m3)			Water (kg/m3)	Admixture (%)	Flow (mm)	Problem faced
			Fine	20 mm	10 mm				
Mix-1	280	120	854	418	626	152	1.0	380	Sticky
Mix-2	280	120	798	440	660	160	1.1	600	**Good**
Mix-3	240	160	810	448	672	164	1.2	610	Segregation
Mix-4	240	160	810	448	672	156	1.2	610	**Good**
Mix-5	210	210	805	445	666	168	1.2	610	Bleeding
Mix-6	210	210	805	445	666	164	1.2	630	**Good**

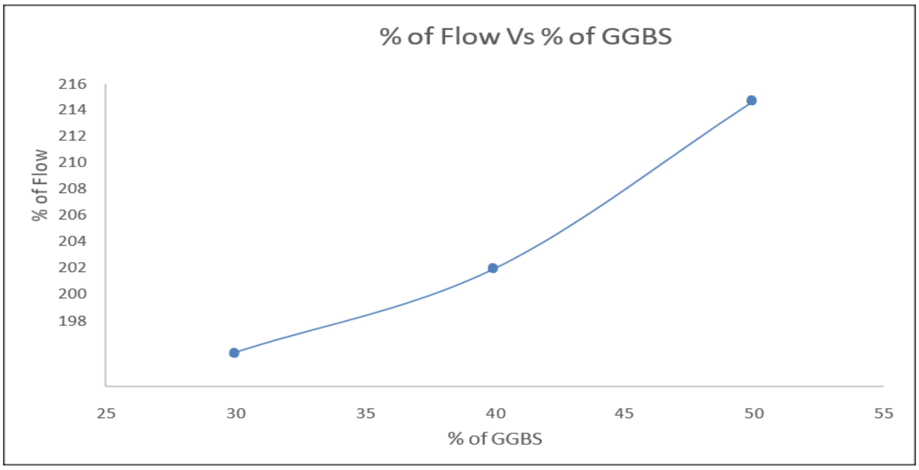
All these 6 mix designs give us ample information about the behavior of low fines SCC inclusive of the cost dynamics. From the experiments and results the following are observed:

In the above trial mixes Mix 2, 4 & 6 were satisfy the flow and strengths.


Mix Design with 70% OPC & 30% GGBS
0%
7%
11%
5%
27%
32%
18%
OPC 53 Gr
GGBS
M sand
20 mm
10 mm
Water


Mix Design with 60% OPC & 40% GGBS
6%
10%
6%
27%
33%
18%
OPC 53 Gr
GGBS
M sand
20 mm
10 mm


Mix Design with 60% OPC & 40% GGBS
7%
8%
8%
27%
32%
18%
OPC 53 Gr
GGBS
M sand
20 mm
10 mm

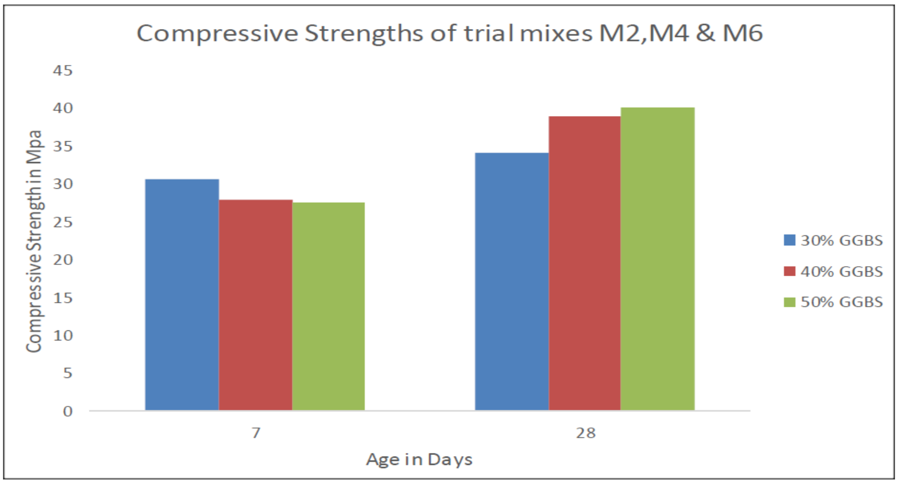


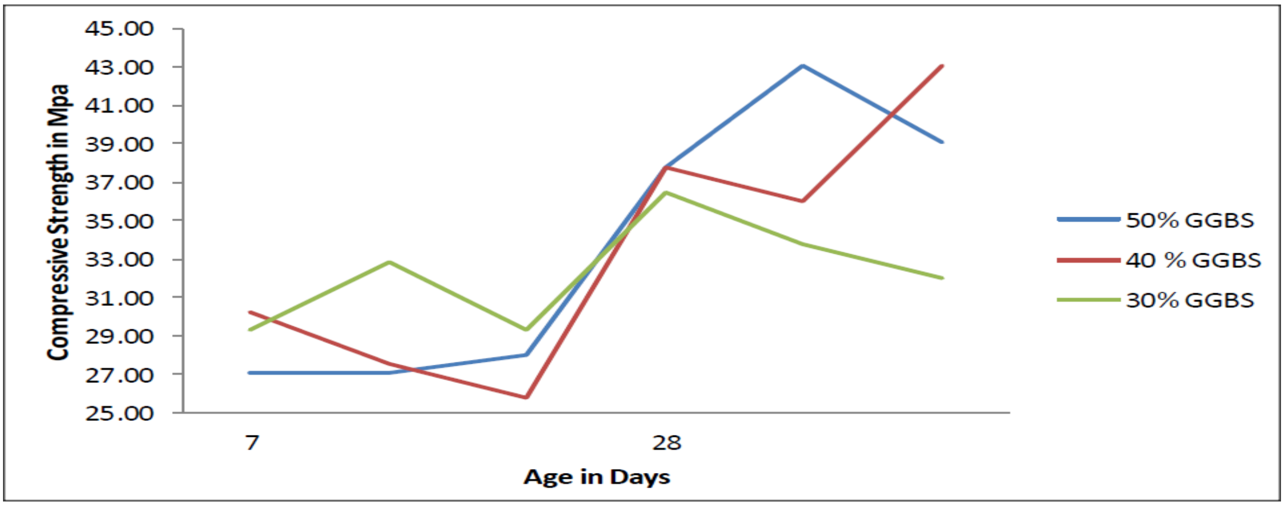
4.1.1. Mechanical Characteristics

The compressive strength of the concrete was tested using three cubes that are each 15cm by 15cm by 15cm in size. After pouring the concrete into the molds, the cubes were left there for 24 hours. During this time, the temperature was kept around 27 plus or minus 2 degrees Celsius, and the humidity was maintained at least at 90%. After 24 hours, the cubes were taken out of the molds and placed in clean, fresh water. They stayed in the water until they were taken out for testing.

Test Results of Compressive Strength

Trials	Compressive Strength (MPa)	
	7 Days	28 Days
Mix – 2	30.52	34.07
Mix – 4	27.85	38.96
Mix – 6	27.41	40.00





Compressive Strength Vs Age

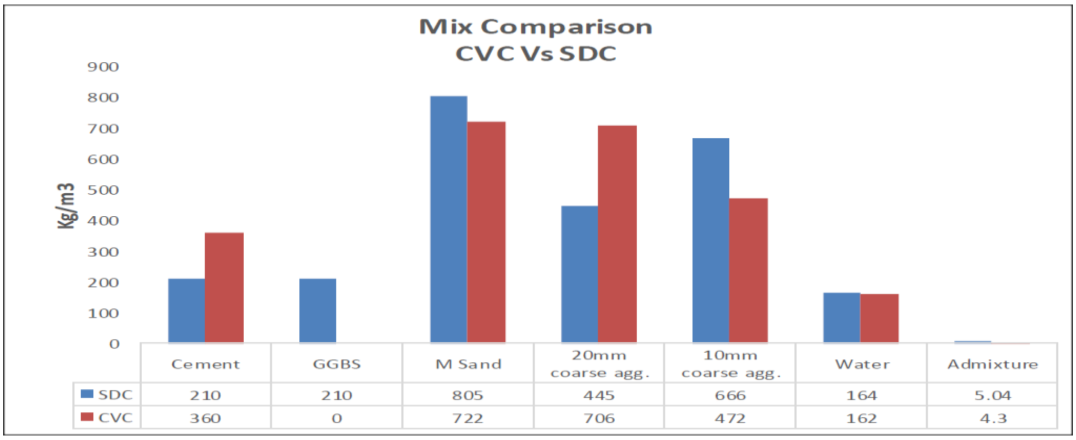
5. Cost Analysis

Self Compacting Concrete has been limited because of high costs, especially for materials like cement, and has mainly been used in special projects. Regular uses, like those requiring 25 to 30 Mpa concrete, have not been cost-effective because they need a lot of fine materials to make the self-compacting concrete.

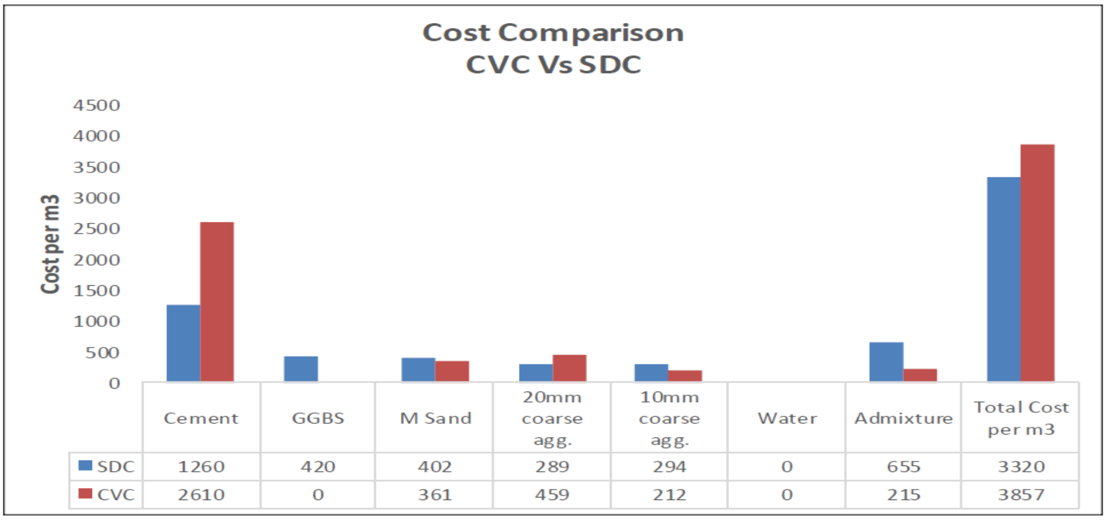
A new type of Viscosity Modifying Admixture, called RheoMATRIX, makes it easier to use Self Compacting Concrete in regular applications. This new material allows for less fine content, which reduces costs. This new type of concrete, named Smart Dynamic Concrete, helps expand the use of Self-Compacting Concrete in the Ready-Mixed Concrete industry. It cuts down on extra costs from using fine materials and lets you use less binder, like cement, or lower-grade cement, or more supplementary materials, while still meeting strength requirements.

Material	SDC Mix (Kg/m3)	Cost (Rs)	CVC Mix (g/m3)	Cost (Rs)
Cement	210	1260	360	2610
GGBS	210	420	0	0
M Sand	805	402	722	361
20mm coarse agg.	445	289	706	459
10mm coarse agg.	666	294	472	212
Water	164	….	162	….
Admixture	5.04	655	4.3	215
Total Cost per m3		**3320**		**3857**

By comparing the costs of CVC and SDC, it is possible to lower the cost to 537 per 1m³. This makes SDC a feasible option for concrete plants where the cost is reliable when compared to CVC. SDC works through a special action in concrete that helps save fine particles (<0.125mm), resulting in a concrete mix that is both stable and very fluid. This type of concrete is self-leveling, so it can be placed without needing to be compacted



later. This increases the speed of placing concrete by up to three times and saves up to 40% of the work time. Also, the natural chemical strength of SDC makes it easier to produce standard concrete because it is less affected by changes in water demand.



6. Conclusion

1. From the trial mixes M2, M4, and M6, it can be concluded that a cementitious content of 420 kg/m³ with an admixture percentage of 1.2% gives a slump flow of 630mm and achieves compressive strength that is suitable for M30 grade concrete.

2. When looking at mechanical properties such as compressive strength, the results are comparable to conventional concrete.

3. When analyzing the cost of both Smart Dynamic Concrete (SDC) and conventional concrete (CVC), it is found that using SDC saves 537/- per cubic meter of concrete.

4. Smart Dynamic Concrete brings economic, environmental, and user-friendly benefits to concrete and has the potential to push the construction industry towards more advanced practices.

5. Based on the above findings, it can be recommended to use SDC in the concrete industry as it is reliable in terms of both cost and strength when compared to conventional concrete.

6. Smart Dynamic Concrete combines the benefits of traditionally vibrated concrete and self-consolidating concrete. This approach allows for unique mix design optimization by reducing the amount of fine materials used.

As shown in the table, it is observed that the strength achieved in M30 grade concrete using GGBS with a silicon dioxide content of 35.50% is higher.

REFERENCES

1. European guidelines for Self Compacting Concrete, May 2005 (EFNARC).
2. H. Okamura and M. Ouchi wrote about Self-Compacting Concrete, covering its development, current state, and future, in a paper published by RILEM in 1999.
3. Vilas.V.Karjinni, Shrishail B.Anadinni and Dada S.Patil studied the characteristic properties of high performance SCC with mineral admixtures, published in The Indian Concrete Journal in September 2009.
4. Rashid Jaffer, Roberta Magarotto & Joana Roncero researched on Smart Dynamic Concrete, showing that using fines lower than 380 kg/m3 is possible with an innovative Viscosity Modifying Admixture called RheoMATRIXc in 2010.
5. Tahir Kemal Erdem, Kamal H Khayat, and Ammar Yahia did an experimental study on the relationship between the rheology of self-consolidating concrete and the corresponding concrete equivalent mortar in 2009.
6. P.T. Santosh Kumar studied the effect of water/cement ratio and aggregates on the strength and workability of SCC in 2009.
7. S. Girish, R.V. Ranganath and Jagadish Vengala researched on how powder and paste affect the flow properties of SCC and showed that flow properties of SCC.
8. Rafat Siddique studied the properties of self-compacting concrete with class F-fly ash and showed that mixes prepared with fly ash in the range of 15% to 35% are effective.
9. Nadar Ghafoori & Mary Barfield studied the effects of hauling time on air-entrained self-consolidating concrete in 2010.
10. Selcuk Turkel & Ali Kandemir researched on the fresh and hardened properties of SCC made with different aggregates and mineral admixtures in 2009.
11. Aggelos S. Georgiadis, Kosmas K. Sideris and Nikolaos S. Anagnostopoulos researched on the properties of SCC made with limestone filler or VMA in 2009.
12. Dr. S.C. Maiti and Raj K Agarwal studied the use of chemical and mineral admixtures to improve the mechanical properties in 2007.
13. Khurana, R.S., Magarotto, R. and Moro, S. improved the concept of 'Smart Dynamic Concrete: an innovative approach for the construction industry' in July 2010.
14. Rashid Jaffrey, Roberta Magarotto & Joana Roncero researched on Smart Dynamic Concrete using fines lower than 380 kg/m3 is feasible by means of an innovative Viscosity Modifying Admixture called RheoMATRIXc in 2010.
15. A.M. Neville wrote about the properties of concrete in his book, "Properties of Concrete", 4th edition, published by Prentice Hall/Pearson, Harlow in 2000.
16. M.S. Shetty wrote a book titled "Concrete Technology", published by S. Chand & Company Ltd., New Delhi.