

STUDY ON SELF COMPACTING CONCRETE USING ADMIXTURE

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Dedication

to

Parents, Family And Teachers

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ABSTRACT

Self-compacting concrete using admixture is a specific type of concrete that can flow only by its own weight and can fill any space while keeping its homogeneity. This work summarizes the experiments for evaluating the performance of self-compacting concrete including slump flow tests as well as the recent achievements of the fresh and hardened properties of self-compacting concrete such as slump flow, segregation resistance, compressive strength and tensile strength. Also, the previous researches of durability is surveyed including sulfate resistance, inner frost resistance, freezing and thawing. The effect of dosage amount of water-binder ratio, water cement ratio and super plasticizer on the properties of self-compacting concrete are revealed based on the survey of previous literatures. Particular emphasis is placed on the availability and economic effectiveness of partial replacement of certain amount of cement by mineral admixtures, ordinary Portland cement.

Keywords: Self-compacting concrete, fresh properties, Hardened properties, Durability, super plasticizer, Fly Ash; Mix Design, Compressive Strength.

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LIST OF ABBRIVATION AND SYMBOLS

SU	Sonargaon University
SCC	Self-Compacting Concrete
ASTM	American Society For Testing And Materials
CA	Coarse Aggregate
PCC	Portland Composite Cement
BS	The British Standard
SCFRC	Self-Compacting Fiber Reinforced Concrete
EFNARC	European Federation of National Associations Representing For Concrete
NVC	Normal Vibrated Concrete
HPC	High Performance Concrete
JRMCA	Japanese Ready-Mixed Concrete Association
CRI	Concrete Research Institute
NCC	Normal Compacting Concrete
DEPA	Danish Environmental Protection Agency
EN	The European Standard
WW	Wood Waste
SSD	Saturated Surface dry

CHAPTER 1

Introduction

1.1 : Background and Motivations

Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. The invention of SCC is considered one of the most important developments in the construction industry. SCC is produced with low water-cement ratio providing the potential for high early strength, earlier remodeling and faster use of elements and structures. It is able to flow under its own weight due to its highly fluid nature and achieving a full compaction even in a formwork with complicated shapes and dense reinforcement. The elimination of vibration improves the productivity, shortens construction time, increases the safety of working environment and reduces the labor and equipment cost. The improved construction practice and performance, combined with the health and safety benefits, make SCC a very attractive solution for both precast concrete and civil engineering construction. Self-Compacting Concrete (SCC), which flows under its own weight and does not require any external vibration for compaction, has revolutionized concrete placement. SCC, was first introduced in the late 1980's by Japanese researchers [1], is highly workable concrete that can flow under its own weight through restricted sections without segregation and bleeding. Such concrete should have a relatively low yield value to ensure high flow ability, a moderate viscosity to resist segregation and bleeding, and must maintain its homogeneity during transportation, placing and curing to ensure adequate structural performance and long term durability. The successful development of SCC must ensure a good balance between deformability and stability.

Researchers have set some guidelines for mixture proportioning of SCC, which include

- (i) reducing the volume ratio of aggregate to cementations material [1-2];
- (ii) increasing the paste volume and water-cement ratio (w/c);
- (iii) carefully controlling the maximum coarse aggregate particle size and total volume;
- (iv) using various viscosity enhancing admixtures (VEA) [1].

For SCC, it is generally necessary to use super plasticizers in order to obtain high mobility. Adding a large volume of powdered material or viscosity modifying admixture can eliminate segregation. The powdered materials that can be added are fly ash, silica fume, lime stone powder, glass filler and quartzite filler. Since, self-compatibility is largely affected by the characteristics of materials and the mix proportions, it becomes necessary to evolve a procedure for mix design of SCC. Okamura and Ozawa have proposed a mix proportioning system for SCC [3]. In this system, the coarse aggregate and fine aggregate contents are fixed and self-compatibility is to be achieved by adjusting the water /powder ratio and super plasticizer dosage. The coarse aggregate content in concrete is generally fixed at 50 percent of the total solid volume, the fine aggregate content is fixed at 40 percent of the mortar volume and the water /powder ratio is assumed to be 0.9-1.0 by volume depending on the properties of the powder and the super plasticizer dosage. The required water /powder ratio is determined by conducting a number of trials. One of the limitations of SCC is that there is no established mix design procedure yet. This paper describes a procedure specifically developed to achieve self-compacting concrete. In addition, the test results for acceptance characteristics for self-compacting concrete such as slump flow, J-ring, V-funnel and L-Box are presented. Further, the strength characteristics in terms of compressive strength for 7-days, 14-days and 28-days are also presented.

1.2: Research Objectives and Overview

It is a concrete that can be compacted by its own weight and fills every corners in the formwork and the placing can be done without vibrating compaction. In the plastic state it is very homogenous, cohesive and very flow able.

1.3: Organization of the thesis

Concrete is a versatile material extensively used in construction applications throughout the world. Properly placed and cured concrete exhibits excellent compressive-force-resisting characteristics and engineers rely on it to perform in a myriad of situations. However, if proper consolidation is not provided, its strength and durability could be questionable. To help alleviate these concerns, Japanese researchers in the late 1980's developed a concrete mixture that deformed under its own weight, thus filling around and encapsulating reinforcing steel without any mechanical consolidation.

- Self-Compacting Concrete offers new possibilities and prospects in the context of durability and strength of concrete.
- As a result of the mix design, some properties of the hardened concrete can be different for SCC in comparison to normal vibrated concrete.
- Mix design criterions are mostly focused on the type and mixture proportions of the constituents.
- Adjustment of the water/cement ratio and super plasticizer dosage is one of the main key properties in proportioning of SCC mixtures.

1.4: AIM AND OBJECTIVES

The aim of this study of self-compacting concrete using ordinary Portland cement is to obtain self-compacting concrete satisfying EFNARC guidelines and make comparison of self-compacting concrete to normally compacted concrete in terms of workability and compressive strength.

The above aim will be accomplished by fulfilling the following research objectives:

- FRESH STATE (Filling ability and Passing ability)
 - HARDENED STATE (Compressive strength)
1. Obtaining specific experimental data to understand fresh and hardened properties of self-compacting concrete.
 2. Developing SCC using Portland Composite cement in varying dosages satisfying European standards and to study their behavior.
 3. Determining whether the properties observed in (1) are structurally sufficient for its application according to relevant standard as a construction material.
 4. Assessing the implication of its usage as a construction material in the built environment.

1.5 : SCOPE OF STUDY

For this study, concrete with varied percentages of Portland composite cement were used in producing self- compacting concrete in terms of filling ability and passing ability and were compared with normally compacted concrete.. The key parameter in the study is:

1. The workability characteristics using compressive strength test characteristics at 07, 14 and 28 days.

1.6: SIGNIFICANCE OF STUDY

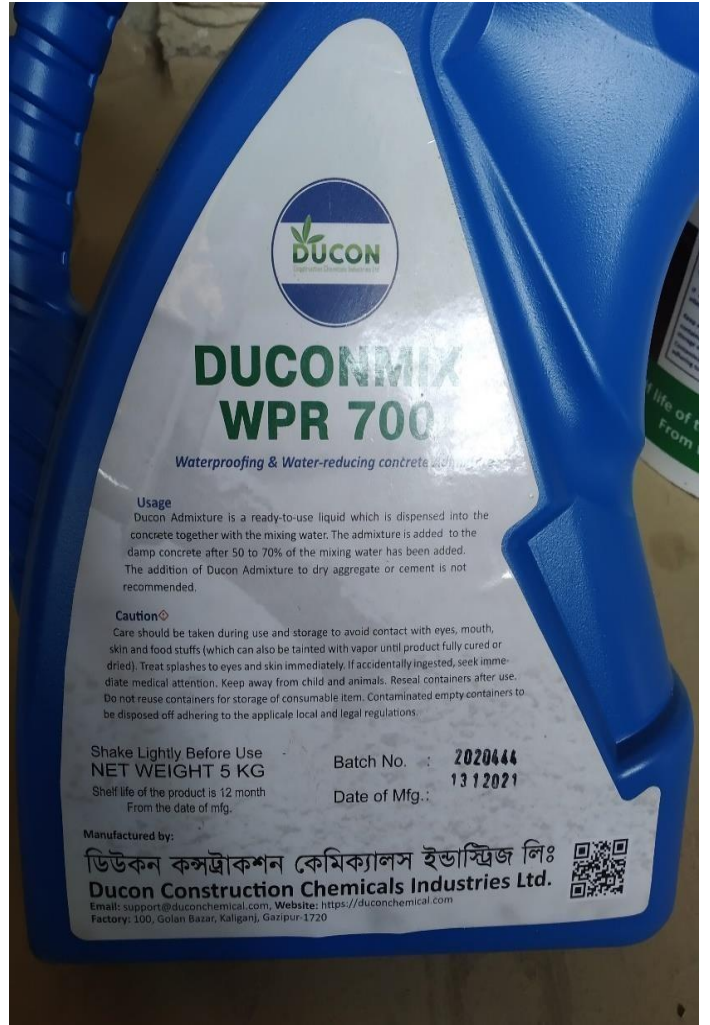
1. To produce concrete of high and significant strength and durability to be used for all construction structures.
2. To minimize maintenance, labor cost, and cost due to the vibrators required.

1.7: CONSTITUENTS OF SCC

With regard to its composition, SCC consists of the same components as conventionally vibrated concrete, which are

- Cement
- Aggregates
- Water
- Sand
- Chemical Admixture. (We used a readymade chemical admixture for this test)

CHEMICAL NAME: "Duconmix WPR 700" Admixture for healthy and durable construction.



1.8 : SOME INFORMATION ABOUT SCC

1. Self Compacting Concrete was first developed in Japan in the year 1980.
2. Prof. H. Okamura of University of Tokyo, Japan; is mainly responsible for initiating and initial development of this concrete and is now regarded as the Father of SCC.
3. The need for the development of SCC arose from the skilled labor and man power in Japan during 1980's.
4. It is a greatest technological advancement and the most revolutionary development in concrete technology over the years, at least from 1980 till date.
5. Though SCC was first developed to overcome the deficiency of the skilled man power, subsequently it is observed that SCC not only reduces the requirement of man power, but it also results in more durable concrete with the excellent user friendly characteristics.
6. It has a big role to play because of the sustainable benefits in construction both quantitatively and qualitatively.
7. It is now used in many countries such as Canada, Sweden, Netherlands, USA, Austria, Korea etc.

CHAPTER 2

Literature Review

2.1 : Introduction

Ozawa et al. (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. They found out that on partially replacement of OPC by fly ash and blast furnace slag the flowing ability of the concrete improved remarkably. He concluded that the best flowing ability and strength characteristics 10-20% of fly ash and 25-45% of slag cement by mass.

Domone and His-Wen (1997) performed a slump test for high workability concrete. A beneficial correlation between the slump values and flow was obtained from the laboratory test. It showed satisfying value of the slump flow.

Bui et al. (2002) discussed a speedy method in order to test the resistance to segregation of Self-compacting concrete. Extensive test programmer of SCC with different water-binder ratios, paste volumes, combinations between coarse and fine aggregates and various types and contents of mineral admixtures was carried out. The test was helpful in concluding the method along with the apparatus used for examining the segregation resistance of SCC in both the directions (vertical and horizontal).

Xie et al. (2002) presented the preparation technology of high strength self- compacting concrete (SCC) containing ultrapulverised fly ash (UPFA) and super plasticizer (SP). Various parameters of concrete were selected namely good workability, high mechanical properties and high durability and SCC was developed. There was low slump loss in the fresh SCC mixture. The workability of high strength SCC containing UPFA and SP can be evaluated by the method of combining slump flow and L-box test. Slump flow was 600/750 mm. Flow velocity of L-box test was 35-80 mm/sec

Lachemi and Hossain (2004) presented the research on the suitability of four types of Viscosity Modifying Agent (VMA) in producing SCC. Fresh and hardened properties of SCC were studied by adding different VMA to SCC. The deformability through restricted areas can be evaluated using v-funnel test. In this test, the funnel was filled completely with concrete and the bottom outlet was opened, allowing the concrete to flow out. The time of flow from the opening of outlet to the seizure of flow was recorded. Flow time can be associated with a low deformability due to high paste viscosity, higher inter particle friction or blockage of flow. Flow

time should be below 6 sec for the concrete to be considered as SCC. All the mix performed well with no significant segregation and jamming of aggregate was noticed.

Cengiz (2005) used fly-ash with SCC in different proportional limit of 0%, 50% and 70% replacement of normal Portland cement (NPC). He investigated the strength properties of self compacted concrete prepared using HVFA (high volume fly ash). Concrete mixtures made with water cementations material ratios ranged from 0.28 to 0.43 were cured at moist and dry curing conditions. He investigated the strength properties of the mix and developed a relationship between compressive strength and flexural tensile strength. The study proved that it is possible to convert an RCC (zero slump) concrete to a workable concrete with the use of suitable super plasticizer.

Kumar (2006) reported the history of SCC development and its basic principle, different testing methods to test high flow ability, resistance against segregation, and passing ability. Different mix design methods using a variety of materials has been discussed in this paper, as the characteristics of materials and the mix proportion influences self-compact ability to a great extent, also its applications and its practical acceptance at the job site and its future prospects have also been discussed. Orimet test was performed, the more dynamic flow of concrete in this test simulates better the behavior of a SCC mix when placed in practice compared with the Slump-flow variation. The Orimet/J-ring combination test shows great promise as a method of assessing filling ability, passing ability and resistance to segregation.

Khatib (2008) investigated the properties of self-compacting concrete prepared by adding fly ash (FA). FA was used as a replacement for Portland Cement (PC). PC was replaced 0-80% by fly ash. For all the mixes water binder ratio was maintained as 0.36. Strength properties as well as the workability, shrinkage, absorption and ultrasonic pulse velocity were studied in this research. From the observations it was concluded that 40% replacement of FA resulted in strength of more than 65 N/mm² at 56 days. On increasing the amount of fly ash the high absorption values were obtained and absorption of less than 2% was exhibited.

Miao (2010) conducted a research on developing a SCC with cement replacement up to 80% in all the mixes and examining its fresh properties. Result show that the fly ash acts as a lubricant material; it does not react with super plasticizer and produce a repulsive force and the super plasticizer may only act on the cement. As a result, the larger the amount of fly ash contained, lesser the super plasticizer needed.

Heba (2011) presented an experimental study on SCC with two cement contents; the work involved three types of mixes, the first considered different percentages of fly ash, the second used different percentages of silica fumes and the third used mixtures of fly ash and silica fume. It was concluded that higher the percentages of fly ash the higher the values of concrete compressive strength until 30% of FA, however the higher values of concrete compressive strength is obtained from mix containing 15% FA

2.2: Literature Review Overview

Ducon Construction Chemicals Industries Ltd

Ducon Construction Chemicals Industries Ltd is leading manufacturer of high-performance construction chemicals, concrete admixtures in Bangladesh, concrete waterproofing in Bangladesh and other products for building construction in Bangladesh and Malaysia. Epoxy flooring in Bangladesh. Concrete Admixtures in Bangladesh. We offer performance construction chemicals range including concrete admixtures, concrete waterproofing, grouts & anchors, repair mortars, bonding agents, adhesives, floor coatings, curing and sealing compounds, dry shake hardeners, joint fillers, sealants, densities, waterproofing, repair, Epoxy flooring in Bangladesh and other products used in residential, commercial and industrial applications. German Technology, formulation and manufacturing process we are using for ensuring German Quality. Concrete Admixtures in Bangladesh are the special ingredients that are included during concrete mixing to enhance the properties and performance of completely fresh concrete admixture company in Bangladesh.

2.2.1 : Ducon Products & Services are Engineered

- Provide material for high performance & durability.
- Cost-effective, optimal reliability & trust worthy.
- Contribute the environment friendly & sustainability

2.2.2 : Industry Covered

We offer performance construction chemicals range including admixtures, grouts & anchors, repair mortars, bonding agents, adhesives, curing & sealing compounds, joint sealants, waterproofing, Epoxy & PU floor coating and other products used in residential, commercial and industrial, small and big projects applications.

2.2.3 : About Ducon Construction Chemicals Industries Ltd.

Ducon Construction chemical Industries Ltd manufacturing and supplying Concrete Admixtures, Waterproofing, Epoxy & Polyurethane Resin Floor Coating, Construction chemicals in Bangladesh and Malaysia, Concrete admixtures. We are using German technology, raw materials, formulation and machineries for ensuring best quality. We have our own R&D and Q&C lab for continuous improving quality. Quality products and quality application, both are important for our sector. So we maintain Ducon Training Center for Best application ever. We trained our distributor, applicator and contractor in Bangladesh and Malaysia. Ensuring Best quality products, best service, best application, Easy delivery process with best price company in Bangladesh and Malaysia. Ducon Construction Chemicals Industries Ltd is leading developer and manufacturer of high-performance professional construction Chemicals products for building construction. We offer performance construction chemicals range including admixtures, grouts & anchors, repair mortars, bonding agents, adhesives, flooring coatings, curing and sealing compounds, dry shake hardeners, joint fillers, sealants, densifiers, waterproofing, repair, Epoxy and PU floor coating and other products used in residential, commercial and industrial applications. Using advanced and latest sustainable polymer chemistry,



Figure 2.1: Mixed Concrete With Admixture

Ducon materials are formulated with a wide variety of high-quality Raw materials based on epoxy, polyurethane, latex, cement, bituminous and acrylic technology. Every product is tested for high performance, sustainable, environment friendly and durability. We invest in the continue research and development necessary to bring you some of the most innovative products on the market. Constantly we strive to excellence on the few parameters through innovation on our products. We believe continuous development is the key to success.

We working closely with our customers, clients, channel partners and applicator to identify what they need most, what is the challenge, and what is the limitation whether it is innovative products development, greater efficiency or application expertise. Together with the customer, client, channel partners, applicator we want to make sure that every interaction is a step is journey to excellence. Our service is based on our close relationships with architects, engineers, contractors, specifies, consultants, channel partners and construction chemicals suppliers who offer high quality products and technical support. Our expert application technology provides support where extraordinary results are required.

New Construction related Chemicals ideas enter our world of cement and resinous material every day. We make a good relationship with scientist and researcher globally, our team of chemists are continually developing and testing innovative and environmentally friendly products for the construction chemicals industries. Not only test our products internally, we rely outside testing at project site providing their performance results as proof of validity. We match precise engineering with premium raw materials, Machineries, testing equipment and performance additives in a controlled environment to ensure consistency and quality.

CHAPTER 3

Methodology

3.1 : Introduction

Concrete is a construction material composed of cement, fine aggregates (sand) and coarse aggregates mixed with water which hardens with time. Portland cement is the commonly used type of cement for production of concrete. Concrete technology deals with study of properties of concrete and its practical applications. In a building construction, concrete is used for the construction of foundations, columns, beams, slabs and other load bearing elements. There are different types of binding material is used other than cement such as lime for lime concrete and bitumen for asphalt concrete which is used for road construction.

Concrete is one of the most frequently used building materials. Its usage worldwide, ton for ton, is twice that of steel, wood, plastics, and aluminum combined. Globally, the ready-mix concrete industry, the largest segment of the concrete market, is projected to exceed \$600 billion in revenue by 2025. This widespread use results in a number of environmental impacts. Most notably, the production process for cement produces large volumes of greenhouse gas emissions, leading to net 8% of global emissions. Significant research and development is being done to try to reduce the emissions or make concrete a source of carbon sequestration. Other environmental concerns include widespread illegal sand mining, impacts on the surrounding environment such as increased surface runoff or urban heat island effect, and potential public health implications from toxic ingredients. Concrete is also used to mitigate the pollution of other industries, capturing wastes such as coal fly ash or bauxite tailings and residue.

Various types of cements are used for concrete works which have different properties and applications. Some of the type of cement are Portland Pozzolana Cement (PPC), rapid hardening cement, Sulphate resistant cement etc.



Figure 3.1: Picture of Concrete blocks using Duconmix-WR 700 made by BWDB

3.2 : Methodology Overview

Components of concrete are cement, sand, aggregates and water. Mixture of Portland cement and water is called as paste. So, concrete can be called as a mixture of paste, sand and aggregates. Sometimes rocks are used instead of aggregates.

The cement paste coats the surface of the fine and coarse aggregates when mixed thoroughly and binds them. Soon after mixing the components, hydration reaction starts which provides strength and a rock solid concrete is obtained.

3.3 : Summary

Grade of concrete denotes its strength required for construction. For example, M30 grade signifies that compressive strength required for construction is 30MPa. The first letter in grade “M” is the mix and 30 is the required strength in MPa.

Based on various lab tests, grade of concrete is presented in Mix Proportions. For example, for M30 grade, the mix proportion can be 1:1:2, where 1 is the ratio of cement, 1 is the ratio of sand and 2 is the ratio of coarse aggregate based on volume or weight of materials.

The strength is measured with concrete cube or cylinders by civil engineers at construction site. Cube or cylinders are made during casting of structural member and after hardening it is cured for 28 days. Then compressive strength test is conducted to find the strength.

Regular grades of concrete are M15, M20, M25 etc. For plain cement concrete works, generally M15 is used. For reinforced concrete construction minimum M20 grade of concrete are used

Table 3.1: Compressive Strength for Normal Strength Concrete.

Concrete Grade	Mix Ratio	Compressive Strength	
		MPa	psi
Normal Grade of Concrete			
M5	1 : 5 : 10	5 MPa	725 psi
M7.5	1 : 4 : 8	7.5 MPa	1087 psi
M10	1 : 3 : 6	10 MPa	1450 psi
M15	1 : 2 : 4	15 MPa	2175 psi
M20	1 : 1.5 : 3	20 MPa	2900 psi

Table 3.2: Compressive Strength for Standard Strength Concrete.

Concrete Grade	Mix Ratio	Compressive Strength	
		MPa	psi
Standard Grade of Concrete			
M25	1 : 1 : 2	25 MPa	3625 psi
M30	Design Mix	30 MPa	4350 psi
M35	Design Mix	35 MPa	5075 psi
M40	Design Mix	40 MPa	5800 psi
M45	Design Mix	45 MPa	6525 psi

Table 3.3: Compressive Strength for High Strength Concrete.

Concrete Grade	Mix Ratio	Compressive Strength	
		MPa	psi
High Strength Concrete Grades			
M50	Design Mix	50 MPa	7250 psi
M55	Design Mix	55 MPa	7975 psi
M60	Design Mix	60 MPa	8700 psi
M65	Design Mix	65 MPa	9425 psi
M70	Design Mix	70 MPa	10150 psi

3.4 : How to Make Concrete?

Concrete is manufactured or mixed in proportions w.r.t. cement quantity. There are two types of concrete mixes, nominal mix and design mix. Nominal mix is used for normal construction works such as small residential buildings. Most popular nominal mix are in the proportion of 1:2:4. Design mixed concrete are those for which mix proportions are finalized based on various lab tests on cylinder or cube for its compressive strength. This process is also called as mix design. These tests are conducted to find suitable mix based on locally available material to obtain strength required as per structural design. A design mixed offers economy on use of ingredients. Once suitable mix proportions are known, then its ingredients are mixed in the ratio as selected. Two methods are used for mixing. Hand Mixing or Machine Mixing. Based on quantity and quality required, the suitable method of mixing is selected. In the hand mixing, each ingredients are placed on a flat surface and water is added and mixed with hand tools. In machine mixing, different types of machines are used. In this case, the ingredients are added in required quantity to mix and produce fresh concrete. Once the it is mixed adequately it is transported to casting location and poured in formworks. Various types of formworks are available which as selected based on usage. Poured concrete is allowed to set in formworks for specified time based on type of structural member to gain sufficient strength.

After removal of formwork, curing is done by various methods to make up the moisture loss due to evaporation. Hydration reaction requires moisture which is responsible for setting and strength gain. So, curing is generally continued for minimum 7 days after removal of formwork.

3.5 : Types of Concrete Construction

Concrete is generally used in two types of construction, i.e. plain concrete construction and reinforced concrete construction. In PCC, it is poured and casted without use of any reinforcement. This is used when the structural member is subjected only to the compressive forces and not bending. When a structural member is subjected to bending, reinforcements are required to withstand tension forces structural member as it is very weak in tension compared to compression. Generally, strength of concrete in tension is only 10% of its strength in compression. It is used as a construction material for almost all types of structures such as residential concrete buildings, industrial structures, dams, roads, tunnels, multi storey buildings, skyscrapers, bridges, sidewalks and superhighways etc.

Example of famous and large structures made with concrete are Hoover Dam, Panama Canal and Roman Pantheon. It is the largest human made building materials used for construction.

3.6 : Steps of Concrete Construction

The construction steps are:

1. Selecting quantities of materials for selected mix proportion
2. Mixing
3. Checking of workability
4. Transportation
5. Pouring in formwork for casting
6. Vibrating for proper compaction
7. Removal of formwork after suitable time
8. Curing member with suitable methods and required time

3.7 : Experimental Work

We make a total of 30 cylinders for this test. We used 20 kg of cement as material, 0.72 cft of sand, 1.43 cft of khoa and we used **Duconmix WPR 700** concrete admixture As chemical admixture. For every 50 kg of cement 200g of admixture has to be used, So 0.67 kg of cement is used for each cylinder and we used 200 mg of chemical or 0.4% chemical to make the first 9 cylinders. We used 0.5% or 250ml chemicals for the next 9 cylinders and 300ml or 0.6% chemicals for the last 9 cylinders. 8.6 liters of water has been used for this purpose. We make three cylinders without chemicals. Cylinder size is 4in x 8in. The ratio was 1:1.5:3

3.7.1 : Estimate of Materials

Cylinder size = 8" x 4"

Total Volume = $\pi r^2 h$ x

Nos

$$= 3.1416 \times \frac{\pi \times 2^2 \times 8}{12} \times 30$$

$$= 1.75 \text{ cft}$$

Dry Volume = 1.75 x 1.5 = 2.625 cft

Ratio = 1:1.5:3 & Sum of Ratio = 1+1.5+3 = 5.5

Materials

- Cement = $\frac{2.63}{5.5} \times 0.8 = 0.382 \times 50 = 19.13 \text{ kg or } 20 \text{ kg}$

- Sand $\frac{2.63}{5.5} \times 1.5 = 0.72 \text{ cft}$

=

3. Khoa $\frac{2.63}{5.5} \times 3 = 1.43$ cft
=

Water Cement Ratio = 0.45

So, $0.45 = \frac{w_{\text{of water}}}{w_{\text{of cement}}}$

➤ $0.45 = \frac{w_{\text{of water}}}{20}$

➤ Water = 0.45×20
= 8.6 lit.

3.8 : Materials

- Ordinary Portland Cement (Type III).
- Brick Aggregate.
- Sand.
 - Sylhet Sand 25 %
 - Local Sand 75 %
- Readymade Chemical Admixture (Duconmix WPR 700).
- Water.

3.8.1 : Ordinary Portland Cement

Ordinary Portland cement is one of the most widely used type of Cement. Types, properties, constituents, manufacture, uses and advantages of Ordinary Portland Cement is discussed. In 1824 Joseph Aspdin gave the name as Portland cement as it has similarity in color and quality found in Portland stone, which is a white grey limestone in island of Portland, Dorset.

3.8.1.1 : Constituents of Ordinary Portland Cement

The principal raw materials used in the manufacture of Ordinary Portland Cement are:

1. Argillaceous or silicates of alumina in the form of clays and shale's.
2. Calcareous or calcium carbonate, in the form of limestone, chalk and marl which is a mixture of clay and calcium carbonate.

The ingredients are mixed in the proportion of about two parts of calcareous materials to one part of argillaceous materials and then crushed and ground in ball mills in a dry state or mixed in wet state. The dry powder or the wet slurry is then burnt in a rotary kiln at a temperature between 1400 degree C to 1500 degree C. the clinker obtained from the kiln is first cooled and then passed on to ball mills where gypsum is added and it is ground to the requisite fineness according to the class of product.



Figure 3.2: Portland Cement

The above constituents forming the raw materials undergo chemical reactions during burning and fusion, and combine to form the following compounds called **BOGUE COMPOUNDS**. The proportions of the above four compounds vary in the various Portland cements. Tricalcium silicate and dicalcium silicates contribute most to the eventual strength. Initial setting of Portland cement is due to tricalcium aluminate. Tricalcium silicate hydrates quickly and contributes more to the early strength.

The contribution of dicalcium silicate takes place after 7 days and may continue for up to 1 year. Tricalcium aluminate hydrates quickly, generates much heat and makes only a small contribution to the strength within the first 24 hours. Tetracalcium alumino-ferrite is comparatively inactive.

All the four compounds generate heat when mixed with water, the aluminate generating the maximum heat and the dicalcium silicate generating the minimum. Due to this, tricalcium aluminate is responsible for the most of the undesirable properties of concrete.

Cement having less C3A will have higher ultimate strength, less generation of heat and less cracking. Table below gives the composition and percentage of found compounds for normal and rapid hardening and low heat Portland cement.

Portland Cement	Normal	Rapid hardening	Low heat
(a) Composition: Percent			
Lime	63.1	64.5	60
Silica	20.6	20.7	22.5
Alumina	6.3	5.2	5.2
Iron Oxide	3.6	2.9	4.6
(b) Compound: Percent			
C3S	40	50	25
C2S	30	21	35
C3A	11	9	6
C3A	12	9	14

3.8.1.2 : Properties of Ordinary Portland Cement

Properties	Values
Specific Gravity	3.12
Normal Consistency	29%
Initial Setting time	65min
Final Setting time	275 min
Fineness	330 kg/m ²
Soundness	2.5mm
Bulk Density	830-1650 kg/m ³

3.9 : Types of Ordinary Portland Cement

3.9.1 : AS per ASTM 150 (American Standards)

- **Type I** Portland cement is known as common or general-purpose cement. It is generally assumed unless another type is specified.
- **Type II** provides moderate sulfate resistance, and gives off less heat during hydration.
- **Type III** has relatively high early strength. This cement is similar to type I, but ground finer.
- **Type IV** Portland cement is generally known for its low heat of hydration.
- **Type V** is used where sulfate resistance is important. This cement has a very low (C_3A) composition which accounts for its high sulfate resistance

3.9.2 : Uses of Ordinary Portland Cement

1. It is used for general construction purposes where special properties are not required such as reinforced concrete buildings, bridges, pavements, and where soil conditions are normal.
2. Used for most of concrete masonry units

3.9.3 : Advantages of Ordinary Portland Cement

1. It has great resistance to cracking and shrinkage but has less resistance to chemical attacks.
2. Initial setting time of OPC is faster than PPC so it is recommended in projects where props are to be removed early.
3. Curing period of OPC is less than PPC and curing cost reduces. Hence recommended where curing cost prohibitive. Disadvantages

3.9.4 : Disadvantages of Ordinary Portland Cement

1. It cannot be used for mass concreting as it has high heat of hydration as compared to PPC.
2. The durability of concrete made using OPC is less than that of the concrete made using PPC.

3. It produces comparatively less cohesive concrete than PPC, hence concrete pumping becomes a little difficult.
4. OPC has lower fineness, hence has higher permeability and as a result it has lower durability.
5. OPC is costlier than PPC.

3.10 : Coarse Aggregate (Brick Chips):

By definition, coarse aggregate retains on No, 4 sieve. For our project work, we have used aggregate which passed through 1 inch sieve and retained on No 4 sieve as coarse aggregate. Brick chips are the coarse aggregate in most mixes.

We have collected fresh coarse from the local market. The main problem we have faced that aggregates were either gap graded or uniformly graded. There were different qualities of aggregates found in the market. These qualities are based on the quality of brick in the artificial and also the method of production of aggregates. The aggregates we have collected were mainly bricks chips.

3.11 : Maximum Size of Aggregate

Investigation was carried out to study the effects of maximum aggregate size (MAS) of brick coarse aggregate (10 mm) on fresh and hardened properties of concrete. Previous researches were conducted on the MAS of 12.5 mm, 19 mm, 25 mm, 37.5 mm and 50 mm (T. Uddin, 2017). This is the continuation of the previous work of lower MAS. For investigation, first class bricks were collected and broken into pieces to make coarse aggregate according to the gradation requirements of ASTM C 33. The aggregates were tested for specific gravity, absorption capacity, unit weight, and abrasion resistance. Cylindrical concrete specimens of diameter 100 mm and length 200 mm were made for MAS of 10 mm with varying sand to aggregate volume ratio (s/a) (0.40, 0.45 and 0.50), W/C ratio (0.45, 0.50, and 0.55), and cement content (375 kg/m³ and 400 kg/m³). A total of 18 different cases were considered and a total of 144 concrete specimens were made for testing. The specimens were tested for splitting tensile

strength at the age of 28 days, and compressive strength, stress-strain curve, and Young's modulus at the age of 7 days and 28 days. Ultrasonic Pulse Velocity (UPV) through the specimens was measured using Portable Ultrasonic Non-destructive Digital Indicating Tester (PUNDIT). The rebound number on the specimen surface was also measured using a Schmidt hammer. Results have revealed that for a higher cement content, smaller sized brick coarse aggregate (10.0 mm) give lower compressive strength and splitting tensile strength. But for a lower cement content, and lower W/C ratio, these properties tend to increase with an increase in maximum size of aggregate up to 37.5 mm. The compressive strength of concrete increases with an increase in s/a ratio from 0.40 to 0.45. Moreover, the UPV is lower for the MAS of 10.0 mm of brick coarse aggregate. Based on the experimental results, relationship between compressive strength and w/c ratio, tensile strength and w/c ratio, UPV, cement content and s/a ratio are proposed for MAS of 10.0 mm of brick aggregate



Figure 3.3: Picture of Brick Aggregate

3.12 : Fine Aggregate (Sand)

Fine aggregate is the inert or chemically inactive material, most of which passes through a 4.75 mm sieve and contains not more than 5 percent coarser materials. They may be classified as follows:

- Natural Sand: Fine aggregate resulting from the natural disintegration of rocks and which has been deposited by streams agencies.

Sand consists of small angular or rounded grain of silica. Sand is commonly used as the fine aggregate in cement concrete. Both natural and artificial sands are used for this purpose. Functions of sands:

- It fills the voids existing in the coarse aggregate.
- It reduces shrinkage and cracking of concrete.
- By varying the proportion of sand concrete can be prepared economically for any required strength.
- It helps in hardening of cement by allowing the water through its voids.
- To form hard mass of silicates as it is believed that some chemical reaction takes place between silica of sand constituents of cement.

In our country, fine aggregate are found in two forms namely, local sand and Sylhet sand. Local sand easily is available and less costly. On the other hand, Sylhet sand is collected in from river in the sylhet region and supplied throughout the country. Sylhet sand is bit costly. We have used only Sylhet sand particles those passed through the No.4 sieve as fine aggregate, as we had to maintain the combined aggregate gradation within the proposed band gradation “5-10-14-18”.


3.13 : Readymade Chemical Admixture (Duconmix WPR 700).


3.13.1 : Duconmix WPR 700: is improved compressive strengths and also its water reducing and waterproofing admixture in Bangladesh by Ducon construction chemicals Industries ltd Bangladesh and Malaysia. German formulation and technology ensuring best quality. Its available best price in Bangladesh, Malaysia and many others countries. It is used for Waterproofs concrete during the construction stage, Improves workability, Avoids cracking, Protect concrete from corrosion.

It can be used in all types of concrete and mortar or plaster that is used in all types of residential, commercial and infrastructural construction for waterproofing admixture in Bangladesh. Additionally, it can be used in concrete applications constantly or intermittently in contact with water such as sea walls, tunnels, basements, structural and pre-cast concrete in exposed superstructures from the best waterproofing admixtures company in Bangladesh.

Concrete Admixture

দীর্ঘস্থায়ী
কম্প্রসিভ স্ট্রেন্থ বৃদ্ধি করে
১০০% ওয়াটারপ্রুফিং করে
ড্যাম্প এবং মরিচা প্রতিরোধ করে
সেগরিগেশন, ব্লিডিং এবং পোরাস কমায়ে
কার্যোপযোগিতা, পাম্প ক্ষমতা
এবং মসূনতা বৃদ্ধি





Green Construction Solutions

Green Construction Solutions
f <https://www.facebook.com/grcsbd/>
01717917191, 01711484788

Figure 3.4: About Ducon Concrete Admixture

3.13.2 : BENEFITS

- Liquid
- Improved compressive strengths
- Water-reducing
- Work ability
- Self-Compacting
- Reduces segregation
- Improved surface finish
- Low dosage required
- Waterproofing admixture – Resistance to water penetration
- Increased durability.

3.13.3 : RECOMMENDED USE

DUCONMIX WPR 700 is used in all types of concrete and mortar that is used for improved compressive strengths in Bangladesh in all types of residential, commercial and industrial construction. Also, it can be used with plastering concrete mortar, sea walls, tunnels, basements, structural and pre-cast concrete in exposed superstructures.

3.13.4 : DOSAGE

For a 50kg bag of cementitious material, 200g DUCONMIX WPR 700 is recommended. Besides, DUCONMIX WPR 700 should be determined with trial mixes. Higher dosages may be required when certain combinations of materials and conditions are present or water reduction in excess of 15% is required. Because of variations in concrete materials, job site conditions, and/or applications, dosages outside of the recommended range may be required.

3.13.5 : To produce waterproof concrete followings to be remember:

- Make sure water cement ratio is in the range of 0.40 to 0.60.
- Keep water content as below as possible.
- Place concrete as early as possible and make sure it's compacted.

3.13.6 : Over dose effects:

- Increase in air entrainment.
- Loss of workability.
- Increase plastic shrinkage.
- Extension can be occurred in initial and final setting.
- Bleeding or segregation can be occurred.

3.13.7 : APPLICATION

DUCONMIX WPR 700 is a ready-to-use liquid which is poured into the concrete together with the mixing water. Generally, DUCONMIX WPR 700 added to the damp concrete after 50 to 70% of the mixing water has been added. The addition of waterproofing admixture in Bangladesh to dry aggregate or cement is not recommended.

3.13.8 : TYPE

ASTM C494: Types A & D

3.13.9 : COLOR

Dark Brown Liquid

3.13.10 : PACKAGING: DUCONMIX WPR 700 is available in 5kg, 10kg, 20kg & 250kg drums or bulk

3.14 : Water

Combining water with a cementations material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and makes it flow more freely. A lower water-to-cement ratio yields a stronger, more durable concrete, whereas more water gives a free-flowing concrete with a higher slump. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure. Hydration involves many different reactions, often occurring at the same time. As the reactions proceed, the products of the cement hydration process gradually bond together the individual sand and brick particles and other components of the concrete to form a solid mass. The water used in making concrete specimen was of good drinkable quality. As the quality of water effects the strength of concrete .The water cement ratio adopted was 0.50, 0.55, and 0.60. The strength of concrete depends upon water cement ratio. Greater the water cement ratio, lesser will be the strength of concrete.

Table 3.4: Classification of Aggregate Based on Particle Size

Aggregate Fraction	Size Range
Coarse Aggregate	Retained on No.4
Fine Aggregate	Passing No.4 Retained on No.100

3.15 : Laboratory Investigation & Test Procedure

The aim of the experimental program is to compare the properties of self-compacting concrete made with normal coarse and fine aggregate and self-compacting concrete having different percentage of Chemical. The basic is carried out on materials used for casting concrete samples are discussed in this chapter. At the end, the various tests conducted on the specimens are discussed

3.16 : Steps of Investigation

Investigation procedures included different steps like sieving, casting of concrete, curing, testing. These steps were handled very carefully as quality control of concrete mixtures depends on these.

3.17 : Sieving of Aggregate

Coarse aggregates those are found in the local market are doing not fulfill the aggregate gradation band “5-10-18-22” or “5-10-14-18” proposed for better concrete properties. Those coarse aggregates only contain the definite size of particles. They are not properly gradated. To get a well-gradated aggregate gradation, we had to sieve the particles according to their sizes. Sieve sizes that we used for the purpose were 1 inch, 3/4 inch, 1/2 inch, 3/8 inch, and No. 4. We stockpiled those aggregates according to their sizes.



Figure 3.8 Aggregate Sieve Analysis

3.18 : Casting of concrete

Casting of concrete included several steps. Mixing machine was used for mixing the ingredients of concrete properly. Slump tests were carried out. Concrete paste was casted in the mold. No vibrator was used for compacting the concrete paste in the mold. The molds were removed one day later. Then samples were put in a water tub for curing.

3.19 : Curing

Curing is the process in which the concrete is protected from loss of moisture and kept within a reasonable temperature range. This process results in concrete with increased strength and decreased permeability. Curing is also a key player in mitigating cracks, which can severely affect durability. Water curing is carried out by supplying water to the surface of concrete in a way that ensures that it is kept continuously moist. The water used for this purpose should not be more than about 5°C cooler than the concrete surface. Spraying warm concrete with cold water may give rise to thermal shock that may cause or contribute to cracking. Alternate wetting and drying of the concrete must also be avoided as this causes volume changes that may also contribute to surface crazing and cracking. Different types of curing procedures exist such as ponding, sprinkling and wet covering. Our samples were dipped into the water tub fully. Curing with water was carried through whole time; we took out the samples just before the testing.



Figure 3.9: Curing of Concrete

3.20 : Testing

After the completion of curing, test of compressive strength were done. Testing was done on 7days, 14 days & 28 days. Strength of the samples is a valuable criterion of the potential quality of the concrete. Strength at early stages is desirable during the first stages of concrete operation to aid in establishing the proper mix. Strength at the later stages is more indicative of the actual strength of concrete in the structure and is therefore more valuable for reference purposes.

3.21 : Preparation of Specimen

Total 30 cylinder specimens were casted. Cylinder specimen is of 4" diameter and 8" height





3.22 : Test Procedures

All the test procedures are discussed below.

3.23 : Slump Test

Slump test indicates the flow ability property. The slump test with its simple and rapid procedure is used to evaluate the deformability of mix-concrete in the absence of obstacles. The filling ability by measuring the horizontal flow diameter. The segregation resistance in this test can be detected visually. Because of its simplicity, the slump test can be done either on site or in the laboratory with inverted or upright Abram's cone.



Figure 3.11: Slump Test

3.24 : Compressive Strength Test

Cylindrical specimens of size 4" diameter and 8" height were cast for conducting compressive strength test for each mix. The test method conforms to the ASTM standard requirement of specification C39 for cylinder. This test was carried at the end of 7 days, 14 days, and 28 days of curing. Calibration equation was used at the time of testing to measure actual load. The compressive strength of any mix was taken as the average of strength of specimens.



Figure 3.12: Compression Test

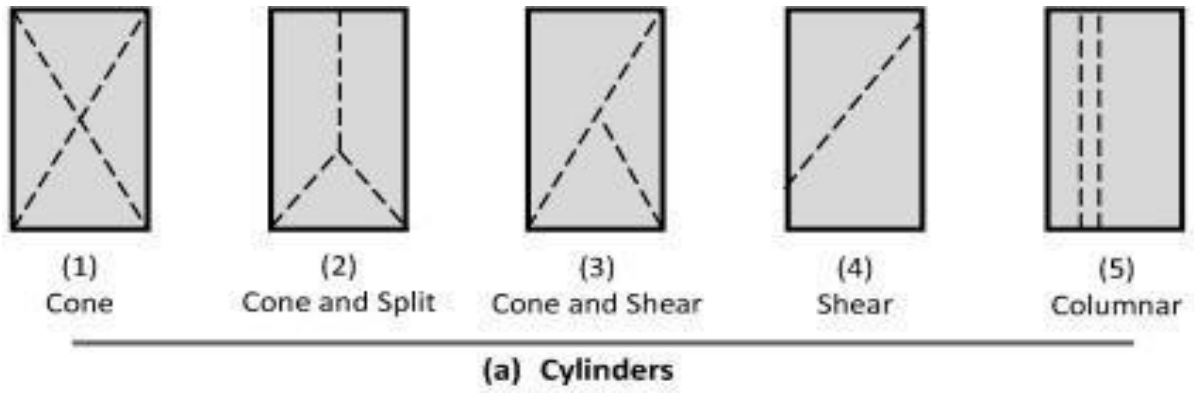


Figure 3.13: Failure Type of cylinder.

CHAPTER 4

Result & Discussion

4.1 : Introduction

For self-compacting concrete we have used admixtures in different ratio. We have determined the FM for course aggregate and fine aggregate. And we determined the compressive test for all the cylinders, first curing for 7 days, then curing for 14 days, then curing for 28 days, and the results we got after all the tests are mentioned below. We have performed compressive strength tests on cylinders using admixtures and without admixtures.

4.2 : Specific Aim 1

Table 4.1: Sieve analysis of coarse aggregate

Sieve number	Sieve Size (mm)	Wt retained (gm)	% retained	Cumulative % retained
3/4"	19	410	41.00	41.00
3/8"	9.5	500	50	91.00
#4	4.75	90	9	100
#8	0	0	0	100
#16	0	0	0	100
#30	0	0	0	100
#50	0	0	0	100
#100	0	0	0	100
pan				
Total		1000 gm		=732

$$\text{Fineness Modulus (FM)} = (732/100) = 7.32$$

Table 4.2: Sieve analysis of Fine aggregate

Sieve number	Sieve Opening	Materials Retained (gm)	% Materials Retained	Cumulative % retained
#4	4.75	0	0	0
#8	2.36	1	0.2	0.2
#16	1.19	2	0.4	0.6
#30	0.59	4	0.8	1.4
#50	0.30	188	37.6	39
#100	0.15	251	50.2	89.2
pan		54	10.8	
Total		500 gm		= 130.4

$$\text{Fineness Modulus (FM)} = (130.4/100) = 1.304$$

Sieve number	Sieve Opening	Cumulative % Passing	Cumulative % retained
#4	4.75	97	03
#8	2.36	85	15
#16	1.19	70	30
#30	0.59	50	50
#50	0.30	30	70
#100	0.15	10	90
pan			
Total			= 258

$$\text{Fineness Modulus (FM)} = (258/100) = 2.58$$

4.3 : Summary We have made cylinders using admixture with Course aggregate and fine aggregate for compressive test. We use number one brick chips as course aggregate and Sylhet sand for fine aggregate. Let's test the sieve analysis of the course aggregate and from this we get the result of the aggregate's fineness modulus **7.32** from which we can understand that it is a slightly better quality course aggregate than the average type. After Sieve analysis of fine aggregate we get FM which is **1.304** which is average quality FM. we hope to get very good quality compressive stress from the cylinders we have made with all these aggregates.

4.4 : Compressive Strength

Calculation:

Compressive Strength of Concrete = Maximum Compressive Load / Cross sectional Area.

Such as,

Maximum Compressive Load = 70 KN

Cross Sectional Area of Cylinder = 12.56 sq.in

So, Compressive Strength of Concrete = Maximum Compressive Load / Cross sectional Area.

4.5 : RESULT ON COMPRESSIVE STRENGTH TEST

Table 4.3: Compressive Strength of Cylinder in 7 Days (KN)

Specimen No	Area(in ²)	Admixture Dosage (SCC)	Without Admixture	Crushing Load (KN)	Compressive Strength (Psi)
01.	12.56	No Admixture	Yes	66	1180.9116
02.	12.56	200 gm	No	80	1431.408
03.	12.56	200 gm	No	83	1485.0858
04.	12.56	200 gm	No	81	1449.3006
05.	12.56	250 gm	No	78	1395.6228
06.	12.56	250 gm	No	77	1377.7302
07.	12.56	250 gm	No	72	1288.2672
08.	12.56	300 gm	No	64	1145.1264
09.	12.56	300 gm	No	65	1163.019
10.	12.56	300 gm	No	50	894.63

NOTE: Looking at all the data in table 4.3, we realize that after 7 days, the maximum value of compressive strength is 1485.0858 Psi & Crushing load is 83

KN. Which we got using 200 gm admixtures.

Table 4.4: Compressive Strength of Cylinder in 14 Days (KN)

Specimen No	Area(in ²)	Admixture Dosage (SCC)	Without Admixture	Crushing Load (KN)	Compressive Strength (Psi)
11.	12.56	No Admixture	Yes	100	1789.26
12.	12.56	200 gm	No	127	2272.3602
13.	12.56	200 gm	No	133	2379.71
14.	12.56	200 gm	No	128	2290.2528
15.	12.56	250 gm	No	113	2021.8638
16.	12.56	250 gm	No	115	2057.649
17.	12.56	250 gm	No	116	2075.5416
18.	12.56	300 gm	No	101	1807.1526
19.	12.56	300 gm	No	99	1771.3674
20.	12.56	300 gm	No	103	1842.9378

NOTE: Again looking at all the data in table 4.4, we realize that after 14 days, the maximum value of compressive strength is 2379.71 Psi & Crushing load is 133 KN. Which we got using 200 gm admixtures.

Table 4.5: Compressive Strength of Cylinder in 28 Days (KN)

Specimen No	Area(in ²)	Admixture Dosage (SCC)	Without Admixture	Crushing Load (KN)	Compressive Strength (Psi)
21.	12.56	No Admixture	Yes	123	2200.7898
22.	12.56	200 gm	No	177	3166.9902
23.	12.56	200 gm	No	173	3095.4198
24.	12.56	200 gm	No	184	3292.2384
25.	12.56	250 gm	No	133	2379.7158
26.	12.56	250 gm	No	143	2558.6418
27.	12.56	250 gm	No	139	2487.0714
28.	12.56	300 gm	No	113	2021.8638
29.	12.56	300 gm	No	122	2182.8972
30.	12.56	300 gm	No	118	2111.3268

NOTE: And finally looking at all the data in table 4.5, we realize that after 28 days, the maximum value of compressive strength is 3292.2384 Psi & Crushing

load is 184 KN. Which we got using 200 gm admixtures.

4.6 : Result Analysis (CS): We test the compressive strength of each cylinder and do 7 days 14 days and 28 days curing. Then we do the tests. For each test we get a crushing value and a compressive strength (Psi). From the tests that are done after each curing, we can see that if admixtures are used at 200 mg (per 50 kg cement), the compressive strength increases a lot and if some more admixtures are used, the compressive strength decreases a bit. Similarly, 7 days and 14 days. At the end of 28 days we test and from this we understand that 200 mg admixture has the highest strength to use, which applies to every curing.



CHAPTER 5

Limitations & Recommendations

5.1: LIMITATIONS

As with any construction material, self-compacting concrete faces the following limitations:

- Material selection is more strict.
- Construction costs increase, compared with regular concrete.
- Many trial batches and laboratory tests are required to use a designed mixture.
- Higher precision is required when measuring and monitoring.
- There is no internationally accepted test standard for self-compacting concrete mix.
- For better results, no more than 200 ml of admixture (DUCON WPR 700) can be used for every 50 kg of cement.
- All number one materials need to be used for best results.

5.2: RECOMMENDATIONS

Self-compacting concrete should preferably be manufactured using appropriate cements for this purpose depending on the type and quantity of admixtures they contain or otherwise with common cement type CEM I, concrete admixtures meeting the regulation (Article 30 of this Code) and using, where required, an appropriate inert filler as an aggregate to correct the granule size of finer diameter sands that pass through a 0.063 mm screen. One way or the other, a sufficient quantity of fines (particles passing through a 0.125 mm screen) shall be achieved to obtain the property of self-compact ability. The total quantity of fines less than 0.125 mm supplied by the cement, the concrete admixtures and the aggregates required to manufacture self-compacting concrete is in the order of 23% by weight of the concrete mass. This may be determined, when necessary, with greater accuracy by means of the corresponding characteristic tests. As in conventional compacting concrete, other components such as water recycled from concrete plants, pigments, shrinkage reducing admixtures based on glycol or fibres may be used in self-compacting concrete when necessary, applying the same limitations and specifications as for conventional concrete.

CHAPTER 6

Conclusions

6.1 : Conclusions:

The comparative analysis of the characteristics and of the proportions of the components of several compositions have contributed to the definition of a SCC composition methodology, aiming at the converging towards a rational process of SCC development. The study also confirms that there is a vast diversity of compositions of the self-compacting concrete, and that there is not a single composition for a given application or requirement, which is a reason for investing in the optimization of the compositions for a higher efficiency and economy. It has also been verified that SCC thus produced has features that overcome the traditional concrete, such as the quality of the surfaces' finishing the value obtained for the resistance to compression considering the quantity of concrete used, the saving in labor work and energy in its production

Considering the obtained experimental results, in laboratory and in industry, compositions based on the proportions of the materials in volume should continue to be developed, diversifying the materials to use. It is important to analyse and to deepen, in future developments, the relationship between its properties in the hardened status, namely the resistance to compression, and which is the influence of the characteristics of the component materials. It is also important to promote, in the future, the development of compositions based on this methodology and, besides the involvement of Laboratory and, in this case, of Prefabrication Industry, to try to involve other actors from the construction industry, namely Designers and Construction Companies.

On the basis of the experimental results obtained, in laboratory and in industry, compositions based on the proportions of the materials in volume should continue to be developed, diversifying the materials to use. It is important to analyze and to deepen in future developments the relation between its properties in the hardened condition, namely the resistance to compression, and which is the influence of the characteristics of the constituent materials. It is critical, then, to promote the development of compositions on the basis of this methodology and, besides the involvement of Laboratories and, in this case, of the Prefabrication Industry, to try to involve other actors from the construction industry, namely Designers and Construction Companies.

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