Development of Ductile Concrete without Coarse Aggregates by Using Steel and Basalt Fibers

By

Ulugbek Sultanov

FINAL PROJECT REPORT

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

September 2013

Universiti Teknologi PETRONAS
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Perak Darul Ridzuan

CERTIFICATION

CERTIFICATION OF APPROVAL

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Approved by,

____

Project Supervisor DR. NASIR SHAFIQ

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

September 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ULUGBEK SULTANOV

ABSTRACT

The current project work is based on developing RPC (Reactive Powder Concrete) which can satisfy all the standards and requirements of concrete technology industry. The standards and requirements must be met in terms of providing good compression and tensile resistance strength. The scope of the study is mostly depended on the performance of ingredients of the RPC which are fine aggregates, admixtures, steel and basalt fibers. Nowadays construction industries of all over the world look at the RPC with suspicious mind set, because they think RPC qualification is not confirmed yet, and they do not want to risk too much by using it. Thus in order to get strong acknowledgement in industries, it is needed to make many qualified researches, experiment works and it is strongly required to obtain the good results. In the following project work it is tried to prove that RPC is competitive to HPC (High Performance Concrete), by making good RPC mixes, and experimenting them to get the results.

The methods of conducting this research are based on the experimental analysis of the RPC and the analysis of the results obtained. The first stage of methodology is the creating the special mix design for producing RPC. The next comes the selection and preparation of materials. Then the testing works on the concrete in its fresh state. After fresh concrete testing the curing process (which has 56 maximum curing days), comes. And the last stage of the activity is testing the hardened concrete in terms of compression and tensile strength.

The results for slump flow test, V funnel test, Compression and tensile tests were obtained and tabulated in this project work. As a conclusion from the results obtained it is possible to say that the performance of steel fibers is superior compare to the performance of the basalt fiber within the RPC mixture. Because RPC with steel fibers gives good characteristics in workability, flow ability, compression resistance and tensile resistance.

ACKNOWLEDGEMENT

First and foremost, pray to god the Al-Mighty for His bless and love, giving me all the strength to complete the final year project. After everything had been planned, efforts were made, the project managed to be finished within the time frame. Without the help and guidance from other people, this study would not be able to complete successfully. Hence, on this page I would like to express my gratitude to those parties who had directly or indirectly involved in helping me for this project.

I would like to dedicate this project as a token of gift to my beloved parents, Yunus Sultanov and Mashkura Sultanova for their support and pray.

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ABBREVIATIONS AND NOMENCLATURES

1. **RPC** – Reactive Powder Concrete

2. **HPC** – High Performance Concrete

3. **SCC** – Self Compacting Concrete

4. **HSC** – High Strength Concrete

CHAPTER 1

INTRODUCTION

Project background:

1.1 ***Clear and concise background of study***: The most popular engineering material is concrete. It is used for buildings, industrial structures, bridges and dams. Every day the quality of concrete is improving, to achieve better characteristics, lower prices and to be environmentally acceptable. The project is about creating "Reactive Powder Concrete" (RPC) or it is possible to call it "Self-Compacting Concrete" (SCC), and showing its qualification and worthiness to be used in the construction and manufacturing industries. RPC content defers from the content of the high performance concrete (HPC). The components for the RPC mixture are cement, fine aggregate, steel fibers, silica fume and super-plasticizer. They are carefully selected to achieve the optimal mixture. The significant components of the ordinary concrete which are reinforcement re-bars, and coarse aggregates, are not utilized in the project mixture. That differs the RPC from the ordinary high performance concrete. Reactive Powder Concrete (RPC) is a developing composite material that will allow the concrete industry to optimize material use, generate economic benefits, and build structures that are strong, durable, and sensitive to environment. A comparison of the physical, mechanical, and durability properties of RPC and HPC (High Performance Concrete) shows that RPC possesses better strength (both compressive and flexural) and lower permeability compared to HPC. High-Performance Concrete (HPC) is not just a simple mixture of cement, water, and aggregates. HPC has achieved the maximum compressive strength in its existing form of microstructure. However, at such a level of strength, the coarse aggregate becomes the weakest link in concrete. In order to increase the compressive strength of concrete even further, the only way is to remove the coarse aggregate. This philosophy has been employed in Reactive Powder Concrete (RPC)[1]. Reactive Powder Concrete (RPC) was developed in France in the early 1990s and the world's first Reactive Powder Concrete structure, the Sherbrooke Bridge in Canada, was erected in July 1997. Reactive Powder Concrete (RPC) is an ultra high-strength and high ductility cementitious composite with advanced mechanical and physical properties. It consists of a special concrete where the microstructure is optimized by precise gradation of all particles in the mix to yield maximum density. It uses extensively the pozzolanic properties of highly refined silica fume and optimization of the Portland cement chemistry to produce the highest strength hydrates[1].

Composition of Reactive Powder Concrete:

RPC is composed of very fine powders (cement, sand, quartz powder and silica fume), steel fibres (optional) and superplasticizer. The superplasticizer, used at its optimal dosage, decreases the water to cement ratio (w/c) while improving the workability of the concrete. A very dense matrix is achieved by optimizing the granular packing of the dry fine powders. This compactness gives RPC ultra-high strength and durability[6]. Reactive Powder Concretes have compressive strengths ranging from 200 MPa to 800 MPa.

1.2 ***Problem statement:*** Large amount of reinforced steel re-bars usage and waste in the high performance concrete forming process.

1.2.a ***Problem identification:*** As it is well known that the pure concrete possesses a low ductility characteristic. Thus in order to obtain such kind of characteristic the reinforcement steel bars (re-bars) are mostly used in the concrete manufacturing process. Re-bars have the ductile characteristic in themselves. However the steel is considered a quite expensive material and it is well known as a heavy material, it can give an extra weight to the concrete blocks. The need to create tensile stress withstanding concrete in the concrete technology sphere in order to replace the use of the steel re-bars in the tensile areas of concrete beams.

1.2.b ***Significance of project*****:** This project work is based on the proofing that RPC can satisfy all the requirements of concrete technology industry, and RPC can reduce the percentage of using steel materials (re-bars) in concreting process. The durability characteristics of RPC are of particular importance as its primary marketing strategy is " an ultra hig performance material for resistance to hazardous environment" Cavill and Rebentrost (2005). The use of RPC in reinforced applications has been limited mainly due to view held that the relatively high cost of materials and dedicated production rationale required made it uneconolical. As such few investigations into the comparative static performance of RPC and HSC (High Strength Concrete) in reinforced beam elements have been undertaken.

1.3 ***Objective and scope of study:***

1.3 a ***Objective*****:** The aim of the project is to achieve the good resistance of RPC to the max tensile stress applied. The objective of this project is mainly to study the performance of the fiber self-compacting concrete incorporated with cement replacement materials. The sub objectives of the project are listed as following:

- To enhance the ductility of self compacting concrete by adding steel fiber.
- To design the mixture of the SCC with different type of materials: cement, water as well as chemical additive which is super plasticizer.
- To study the effect of fiber and SCC mixture with different percentage.

1.3 b ***Scope of study:*** This project work is mostly based on the performance of the steel fibers, fine aggregates, and other admixtures within the concrete under tensile stress.

1.4 ***The relevancy of the project:*** Definitely the chosen project topic is relevant to my area of study which is civil engineering area, it takes many disciplines of the industrial works, the concrete technology and manufacturing is considered as main subject in the civil engineering. Because mostly –used construction material is considered cement and its product concrete. The improvement or innovations in the concrete technology and manufacturing will definitely benefit the civil engineering sphere. Since a lot of concrete is used in the construction work, it is important to find out the better improvement for the quality of the concrete for cost saving and future use. Nowadays, numerous types of high rises and mix buildings have been constructed because the land cost is expensive. In fact, high rise building is more risky and need better concrete for the durability of the building. SCC has special characteristic which is high in ductility, thus the durability of the concrete is also high. Another important aspect is that this material will help to save the construction cost as SCC doesn't need any labor workers for compaction. Besides, it reduces noise levels at construction site, thus, environmental pollution can be prevented.

1.5 ***Feasibility of the project within the scope and time frame:*** The project will be done in two semesters that includes three area of study which are research, development of application and also beta-testing and improvement of the full prototype. The project will involve some experimental works in order to check the good mixture of fiber. Further testing will be carried out for the better outcome. Based on the description above, it is very clear that this project will be feasible to be carried out within the time frame.

CHAPTER 2

LITERATURE REVIEW

2.1 ***Number of references:*** 6 units

2.2 Critical analysis of literature:

From the report *Self-Consolidating Concrete* by Frances Yang, SCC itself is standing for Self-Consolidating Concrete, or Self-Compacting Concrete and sometimes is called as High-Workability Concrete, Self-Leveling Concrete, or Flowing Concrete. Those terms above are used to specify this highly workable concrete only requires little to no vibration for compaction. It is an innovative concrete that can be compacted into every corner of the formwork by means of its self-weight only does not requires vibration for placing and compaction. It is in want of a standard definition, but may be nominally considered a concrete mix of exceptional deformability during casting, which still meets resistance to segregation and bleeding. The normal consolidated concrete which experience inadequate vibration in heavily congested areas basically will lead to surface shrinkage and inadequate bond with the rebar. SCC has low and can be used to make “super-flat” floors without post-pour leveling[2].

It had becoming a major issue regarding to the problem of the durability of concrete structures in Japan early 1983 as the skilled worker started to decrease gradually in the industry. In order to create the durable concrete structure, sufficient amount of labor were required for compaction activity. The only solution to achieve high durable concrete structures was not rely to the quality of construction but to have self-compacting concrete, which can be compacted into every side of a formwork, merely by means of its own weight and vibrating compaction automatically by itself. The SCC idea was proposed into scientific world in Japan in 1986 by Professor Hajime Okamura from Tokyo University. K. Ozawa developed the first prototype in 1988 as a response to the growing problems associated with concrete durability and the high demand for skilled workers. SCC becomes well known throughout the world and it has been the subject of multitudinous investigations so that it can be adapted into the production of modern concrete[1]. Meanwhile, the numerous productions of additives have been developed as well as sophisticated plasticizers and stabilizers tailor-made for the precast. In comparison with other high-performance concretes, these concretes have their own special characteristics and differ from other normal concretes and can be only by systematic optimization both of the individual constituents and of the composition.

One article [7] describes the most important benefits of RPC:

- RPC is a better alternative to High Performance Concrete and has the potential to structurally compete with steel.
- Its superior strength combined with higher shear capacity results in significant dead load reduction and limitless structural member shape.
- With its ductile tension failure mechanism, RPC can be used to resist all but direct primary tensile stresses. This eliminates the need for supplemental shear and other auxiliary reinforcing steel.
- RPC provides improve seismic performance by reducing inertia loads with lighter members, allowing larger deflections with reduced cross sections, and providing higher energy absorption.
- Its low and non-interconnected porosity diminishes mass transfer making penetration of liquid/gas or radioactive elements nearly non-existent. Cesium diffusion is non-existent and Tritium diffusion is 45 times lower than conventional containment materials.

Another article [8] states:
"The relatively high cost, required production control, and lack of industry knowledge have generally precluded its widespread use in more common engineering applications. Overseas and more recently in Australia, RPC has made its way into many niche markets in applications where these high characteristic strengths (compressive strength 200MPa, flexural strength 40MPa) and superior durability properties can be fully utilized. Examples include prestressed beams forming part of bridge structures. The use of RPC enables not only superior mechanical performance of the structure it also ensures a significant extended service life due to its inherent material properties". Generally RPC mixtures incorporate a combination of cement and silica fume to form the binding medium. Collepardi et al.(1996); Coppola et al. (19970 investigated the effect of cement and silica fume type on the relative performance of RPC. The findings showed that choice of binder type greatly affects the water demand of the RPC mixture and the early stage strength development. The use of a low calcium aluminate (C_3A) Portland cement and a white silica fume was recommended.

One of the studies on RPC was that the comparison of strengths of different types of RPC, and there were made some experimental procedures on them, here are the results of the testing:

Table 2.1: Material Specification and Composition

Material and specification RPC	Plain RPC	Steel fiber reinforced RPC	Recron fiber reinforced
Cement	1	1	1
Silica fume	0.32	0.32	0.30
Quartz sand	--	0.36	0.36
Sand (150-600 µm)	1.50	1.50	1.50
Super plasticizers	0.032	0.035	0.03
Steel fibers	--	0.20	0.25
Water/Cement	0.20	0.22	0.079
Comp. strength (7 days) (N/mm^2)	96	138	77
Comp.strength (28 days) (N/mm^2)	106	151	84
Flexural strength (N/mm^2)	13.5	29	18

Ductility of Concrete

Ductility is the strain ability of the materials can take before rupturing. It is the ability of a section to deform beyond its yield point without a significant strength loss. A material with high ductility will be able to be drawn into long, thin wires without breaking. A material with low ductility is instead brittle, and though it may be strong, once it deforms enough, it will simply rupture. Ductility can be expressed in terms of displacement, rotation, or curvature ratios [4].

Factors Affecting Ductility

1. The higher tension steel area causes a less ductile behaviour for the section [22].
2. Increase in the steel yield strength also causes a less ductile behaviour for the section [22].
3. Increase in concrete strength causes lessen in ductility [22].
4. The compression reinforcement carries part of the compression force that would be carried by the concrete in a singly reinforced beam, the required depth of the neutral axis is decreased and the section reaches a much higher curvature (higher ductility) before the concrete reaches its maximum useable strain [22].

Use fibres in normal or high strength concrete to increase ductility are also one of the solutions. Such concrete is known as Ductile Concrete.

"The Qinghai-Tibet railway lies in the west area of China at an altitude of more than 4,000 meters. The 576-km railway is being built on frozen earth. The bad climate and sandstorms of the tundra require the concrete of the bridge to have superior mechanical properties and high durability. By adding Portland cement, silica fume, superfine fly ash, and super plasticizers, reactive powder concrete (RPC) is used in the sidewalk systems of bridges with compressive strength of 160 MPa. The research shows that RPC has high strength, excellent frost durability, and impermeability. Therefore, RPC is the best choice for the Qinghai-Tibet railway." [6]

Figure 2.1 Portland cement

Figure 2.2 Basalt fiber

Figure 2.3 Superplasticizer

Figure 2.4 Silica fume

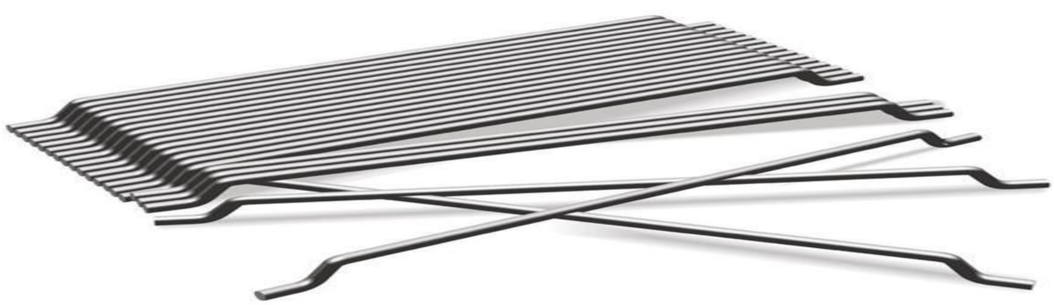

Figure 2.5 Steel fibers

Fibers

Low tensile strength of concrete is due to the propagation of single internal crack. If the crack restrained locally by extending into other matrix adjacent to it, the initiation of crack is retarded and higher tensile strength of concrete is achieved. This restrained can be achieved by adding small length fibres to concrete. In addition to increase the tensile strength, addition of fibres enhance fatigue resistance, energy absorption, toughness, ductility and durability.

Super plasticizer

Superplasticizers causes a significant increase in flow ability with little effect on viscosity. This can be explained through the experiment where the addition of 0.3 to 1.5 percent (by weight of cement) conventional superplasticizer to a concrete mix with 50-70 mm slump increases slump to 200-250 mm [5]. This means, it exhibited enormous increases in slumps at the recommended dosage. The new generation of superplasticizers is based on polycarboxylated ethers, which act as powerful cement dispersants that require less mix water to provide dramatic increase in flow [5]. At the recommended dosage rates the compressive strengths of test cylinders cast from superplasticized concretes were equal to or greater than the strengths of cylinders cast from the control mix even though no at-tempt was made in these tests to reduce the water-cement ratio. This was true for cylinders compacted by vibration as well as those not compacted by vibration.The requirements for superplasticizer in self-compacting concrete are summarized below :

a) High dispersing effect for low water/powder (cement) ratio: less than approx. 100% by volume
b) Maintenance of the dispersing effect for at least two hours after mixing
c) Less sensitivity to temperature change

Silica Fume

Silica fume is also referred as microsilica or condensed silica fume. It is produced in electric arc furnaces as a by-product of the production of silicon metals and ferrosilicon alloys which is ultra-fine non-crystalline mineral composition consist of amorphous glassy spheres of silicon dioxide. Silica fume has very small particle size and large surface area and high content of silica dioxide (SiO_2) make it highly reactive pozzolan[2].

In order to reduce the cement content or as an additive material which can increase the performance of concrete, silica fume is used as supplementary cementitious materials. Because of the cost is expensive, it is used in small amounts which is between 5% and 10% by mass of the total cementing material. It also has a

spherical shape like fly ash but has extremely small particle size which is 100 times smaller than the average cement particle.
The benefit seen from adding Silica Fume is the result of changes to the microstructure of the concrete due to:

1. Physical Contribution:

- Adding Silica Fume brings millions of very small particles to concrete mixture.
- Just like fine aggregates fills in the spaces between coarse aggregate particles, Silica Fume fills in the spaces between cement grains.
- This phenomenon is frequently referred to as particle packing or micro-filling.

2. Chemical Contribution:

- It is very high amorphous silicon dioxide content because of that silica fume is a very reactive Pozzolanic material in concrete.
- As the Portland cement in concrete begins to react chemically it releases Calcium hydroxide.
- The Silica Fume reacts with this Calcium hydroxide to form additional binder material called Calcium Silicate hydrate (C-S-H), which is very similar to the Calcium hydrate formed from the Portland cement.

	Fibred	Fibred
Portland Cement	1	1
Silica fume	0.325	0.324
Sand	1.43	1.43
Quartz Powder	0.3	0.3
Superplasticizer	0.018	0.021
Steel fibre	0.275	0.218
Water	0.2	0.23

Table 2.2: RPC mixture designs from literature [3].

2.4 Relevancy and recentness of the literature:

As it is mentioned above most of the researches on RPC or SCC have started around 80's and 90's of 20th century, thus the references are taken from the research papers and engineering journals which were written within 1980-2010.

CHAPTER 3

METHODOLOGY

3.1 Methodology:

This project will be conducted according to this methodology to meet the objectives. In order to find the performance of fibre self-compacting concrete, detailed review as well as brief research about the topic is focused on the selected papers which concentrate on the design mixture itself. The issues relevancy between the selected papers and our project's objective need to be taken into account to ensure the credibility of this project.

For the other sub objective which is to outline the study of mixture and strength of concrete, literature reviews as well as brief research about the topic are carried out on several resources such as books, journals and also internet.

3.2 Project activities:

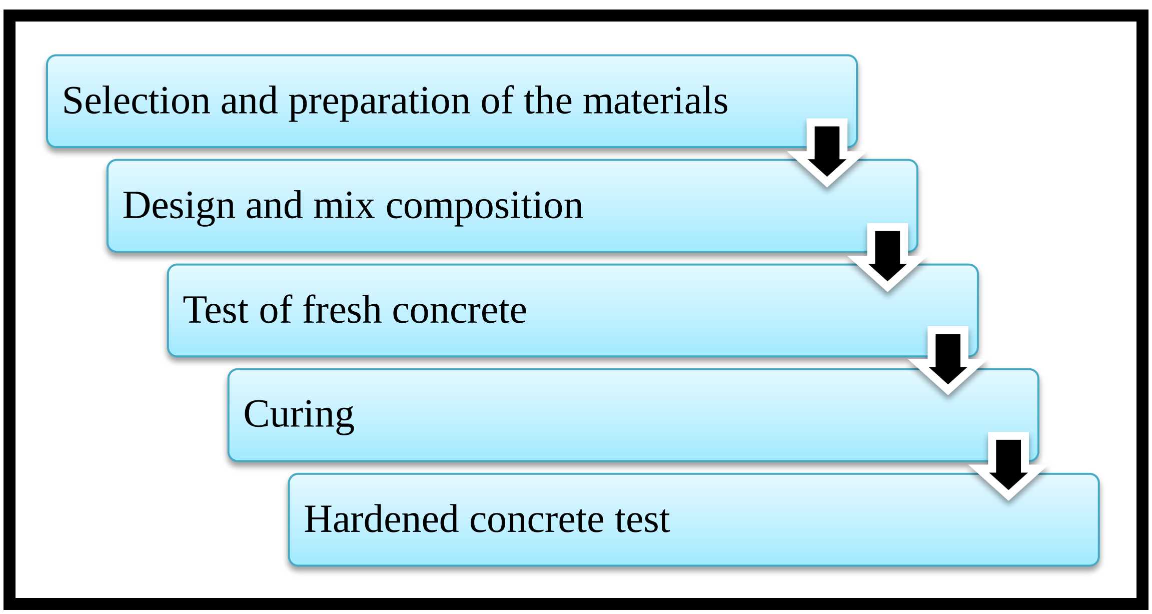

Figure 3.1: Project flow

Mix design often use volume as a key parameter because of the importance of the need to over fill the voids between the aggregate particles. The mix composition is chosen to satisfy all performance criteria for the concrete in both the fresh and hardened states.

Curing is important for all concrete but especially so for the top-surface of elements made with SCC. These can dry quickly because of the increased quantity of paste, the low water/fines ratio and the lack of bleed water at the surface. Initial curing should therefore commence as soon as practicable after placing and finishing in order to minimize the risk of surface crusting and shrinkage cracks caused by early age moisture evaporation.

- Mix design:

Mix design procedures:		
Curing days	Cubes (0.1m x 0.1m x 0.1m) for Compression test	Cylinders (0.1m d x 0.3m h) for Tensile stress
After 3 days	3	-
After 7 days	3	-
After 28 days	3	3
After 56 days	3	3
	Total samplings	18
Total volume	{ 12(0.1mx0.1mx0.1m) +6π(0.05mx0.05m)0.3} = 0.03m cube	

Table 3.1: Mix design procedures

a) The general content of mix:

I. **CEMENT**
II. **WATER**
III. **SAND**
IV. **STEEL FIBER**
V. **BASALT FIBER**
VI. **SILICA FUME**
VII. **SUPER PLASTICIZERS**

b) Firstly it is very important to mention that there are 2 groups of mix:

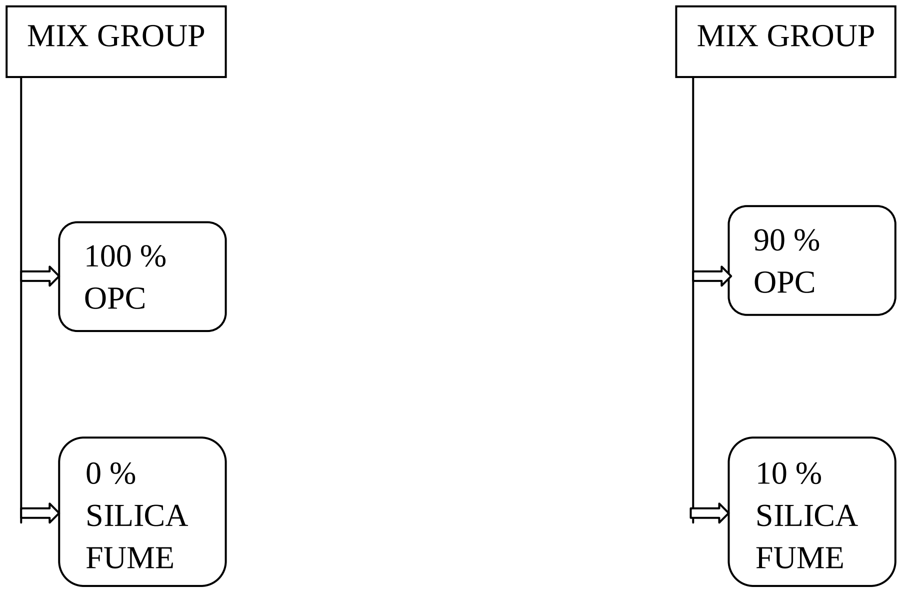

Figure 3.2: Mix groups

c) The general numbers:

- General weight of 1 m cube of concrete = 2400kg;
- General weight of cement per 1m cube concrete = 800kg/m3;
- Weight of test concrete sample = 0.03x 2400kg = 72 kg;
- General weight of sand per 1 m cube of concrete = 1400kg/m3;
- General weight of water per 1 m cube of concrete = 1400kg/m3;

- Mix group 1: 100% OPC
  1) Cement = 800kg/2400kg x 72 kg = 24 kg;
  2) Sand = 1400kg/2400kg x 72 kg = 42 kg;
  3) Water = 200kg/2400kg x 72 kg = 6 kg;
  4) Steel fiber and Basalt fiber = *1% by wt of cement;
  *1.5% by wt of cement;
  * 2% by wt of cement;
  5) Super plastesizer = 1% by wt of cement;

For Mix Group 1:

№	*OPC (kg)*	*SAND (kg)*	*WATER (kg)*	*STEEL FIBER (kg)*	*BASALT FIBER (kg)*	*Super plasticizer (kg)*	*SILICA FUME (kg)*
1	*24*	*42*	*6*	*0*	*0*	*0.24*	*0*
2	*24*	*42*	*6*	*0.24*	*0*	*0.24*	*0*
3	*24*	*42*	*6*	*0.36*	*0*	*0.24*	*0*
4	*24*	*42*	*6*	*0.48*	*0*	*0.24*	*0*
5	*24*	*42*	*6*	*0*	*0.24*	*0.24*	*0*
6	*24*	*42*	*6*	*0*	*0.36*	*0.24*	*0*
7	*24*	*42*	*6*	*0*	*0.48*	*0.24*	*0*

Table 3.2: Mix group 1

For Mix group 2:

	OPC (kg)	***SAND (kg)***	***WATER (kg)***	***STEEL FIBER (kg)***	***BASALT FIBER (kg)***	***Super plastisizer (kg)***	***SILICA FUME (kg)***
1	***21.6***	***42***	***6***	***0***	***0***	***0.24***	***2.4***
2	***21.6***	***42***	***6***	***0.24***	***0***	***0.24***	***2.4***
3	***21.6***	***42***	***6***	***0.36***	***0***	***0.24***	***2.4***
4	***21.6***	***42***	***6***	***0.48***	***0***	***0.24***	***2.4***
5	***21.6***	***42***	***6***	***0***	***0.24***	***0.24***	***2.4***
6	***21.6***	***42***	***6***	***0***	***0.36***	***0.24***	***2.4***
7	***21.6***	***42***	***6***	***0***	***0.48***	***0.24***	***2.4***

Table 3.3: Mix group 2

- Mix group 2: 90% OPC + 10% SF
  1) Cement = 800kg/2400kg x 72 kg x 0.9 = 21.6 kg;
  2) Sand = 1400kg/2400kg x 72 kg = 42 kg;
  3) Water = 200kg/2400kg x 72 kg = 6 kg;
  4) Steel fiber and Basalt fiber = *1% by wt of cement;
     *1.5% by wt of cement;
     * 2% by wt of cement;
  5) Super plastesizer = 1% by wt of cement;
  6) Silica fume = 10 % by wt of cement;

3.3 Key milestone:

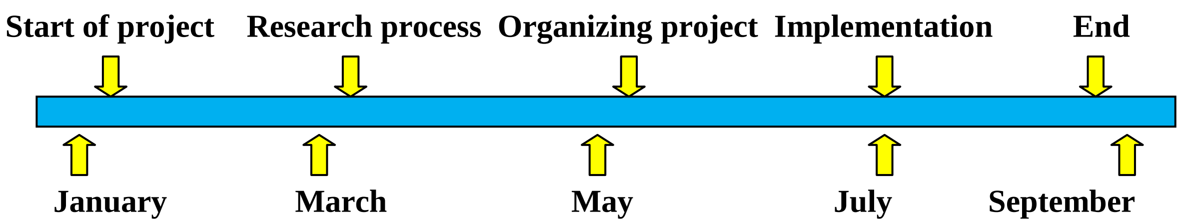

Figure 3.3 Key milestone

3.4 Gantt chart:

No	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1.	Project work continues																
2.	Submission of Progress Report																
3.	Project work continues																
4.	Pre-SEDEX																
5.	Submission of Draft Report																
6.	Submission of Dissertation (soft bound)																
7.	Submission of Technical Paper																
8.	Oral Presentation																
9.	Submission of Project Dissertation (hard bound)																

Table 3.4 Gantt chart

3.5 Tool (eg. Equipment, hardware, etc) required:

- **Slump flow test (ASTM 1611)**

Apparatus:

1. Abram's cone - standard Abram's con as defined in ASTM C143/C143M
2. Slump flow board - a non-absorbent rigid plate. A circle 500mm in diameter should be marked at the center in order to measure the T_{50} value

Figure 3.4: Abram's cone

Figure 3.5 : Slump flow board

- **Slump T_{50} test**

Apparatus:

1. Same as slump flow test apparatus
2. Stop watch

Figure 3.6: Slump flow and slump T_{50} test

V-funnel

Apparatus:

1. V shaped funnel
2. Stopwatch

Figure 3.7: V shaped funnel

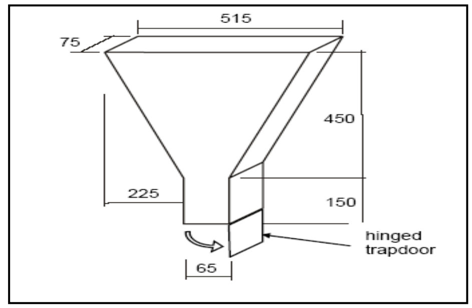

Figure 3.8 : V-funnel dimension

Compressive strength test

Apparatus: Compression Testing Machine (it complies with the requirement of BS 1610)

Figure 3.10 : Compression machine (ADR 1500)

Tensile and flexural strength test

Figure 3.11: Tensile strength test

CHAPTER 4

RESULTS AND DISCUSSION

4.1 **Data gathering:**

COMPRESSION TEST { Gr 1 }														
			3 days curing			7 days curing			28 days curing			56 days curing		
mix №	Cast date	Sample	Load kN	Stress kN/m2	Weight (g)	Load kN	Stress kN/m2	Weight (g)	Load kN	Stress kN/m2	Weight (g)	Load kN	Stress kN/m2	Weight (g)
			17-Jun			21-Jun			12-Jul			9-Aug		
1	14-Jun	1	435.1	43.51	2255.8	494.1	49.41	2180	576.1	57.61	2217.8	790.6	79.06	2215.9
		2	431.6	43.16	2209.7	488.9	48.89	2245	600.3	60.03	2187.5	795.9	79.59	2214.7
		3	448.8	44.88	2294.8	491.7	49.17	2231.7	582	58.2	2297.6	794.8	79.48	2214.8
	average		438.5	43.85	2253.43	491.567	49.157	2218.9	586.133	58.613	2234.3	793.767	79.377	2215.133
			23-Jun			27-Jun			18-Jul			15-Aug		
2	20-Jun	1	616.8	61.68	2136.8	651.1	65.11	2278.6	751.1	75.11	2288.1	860.2	86.02	2278.9
		2	589.7	58.97	2264	715.2	71.52	2145.4	702.3	70.23	2272.5	864.8	86.48	2276.8
		3	620.4	62.04	2189.4	587.2	58.72	2238.7	736.8	73.68	2289	835.7	83.57	2282.5
	average		608.97	60.9	2196.73	651.167	65.117	2220.9	730.067	73.007	2283.2	853.567	85.357	2279.4
			21-Jun			25-Jun			16-Jul			13-Aug		
3	18-Jun	1	473.4	47.34	2164.6	427.8	42.78	2200.5	571.9	57.19	2110.6	649.8	64.98	2116.8
		2	472.2	47.22	2050.8	517.3	51.73	2082.8	568.3	56.83	2115	648.6	64.86	2115
		3	456.8	45.68	2165.8	471.4	47.14	2197.3	575.8	57.58	2117	647.1	64.71	2118.5
	average		467.47	46.75	2127.07	472.167	47.217	2160.2	572	57.2	2114.2	648.5	64.85	2116.767
			23-Jun			27-Jun			18-Jul			15-Aug		
4	20-Jun	1	603	60.3	2134	715.6	71.56	2232.8	861.1	86.11	2119.9	1000.2	100.02	2122
		2	586.5	58.65	2202.6	753.4	75.34	2270.9	836.6	83.66	2118	1003.4	100.34	2123.4
		3	617.2	61.72	2189	760.3	76.03	2249.6	859.4	85.94	2122	1002.7	100.27	2122.5
	average		602.23	60.22	2175.2	743.1	74.31	2251.1	852.367	85.237	2119.97	1002.1	100.21	2122.633
			24-Jun			28-Jun			19-Jul			16-Aug		
5	21-Jun	1	129.6	12.96	2113.7	95.5	9.55	2044	135.4	13.54	2058.6	250.7	25.07	2054.8
		2	111	11.1	2043.6	104.7	10.47	2145.9	153.7	15.37	2102.4	253.8	25.38	2053.7
		3	118.3	11.83	2234.8	112.3	11.23	2087.2	148.9	14.89	2095	253.7	25.37	2051.6
	average		119.63	11.96	2130.7	104.167	10.417	2092.4	146	14.6	2085.33	252.733	25.273	2053.367
			24-Jun			28-Jun			19-Jul			16-Aug		
6	21-Jun	1	305.7	30.57	2206.6	498.4	49.84	2261.8	545.4	54.54	2224	678.5	67.85	2225.8
		2	300.9	30.09	2226.7	512.7	51.27	2259.8	560.7	56.07	2230	687.4	68.74	2224.9
		3	310.6	31.06	2198.7	506.8	50.68	2254.9	558.2	55.82	2231	679.3	67.93	2217.4
	average		305.73	30.57	2210.67	505.967	50.597	2258.8	554.767	55.477	2228.33	681.733	68.173	2222.7
			28-Jun			2-Jul			23-Jul			20-Aug		
7	25-Jun	1	115.7	11.57	2176.2	132.7	13.27	2026.8	195.7	19.57	2136.6	248.9	24.89	2142.6
		2	120.3	12.03	2134.9	213.2	21.32	2239	195.3	19.53	2237.1	246.6	24.66	2143.7
		3	124.5	12.35	2207.1	179.4	17.94	2176.3	198.9	19.89	2240	243.9	24.39	2145.7
	average		120.17	11.98	2172.73	175.1	17.51	2147.4	196.633	19.663	2204.57	246.467	24.647	2144

Table 4.1: **Compression Test Results for Gr 1 Mix**

Table 4.1 illustrates the compression test results for group 1 mix. As it is possible to see here the first column shows the number of mixes and the second column presents the casting date of each mix. Next four columns represent the results after curing dates 3,7,28, and 56 days.

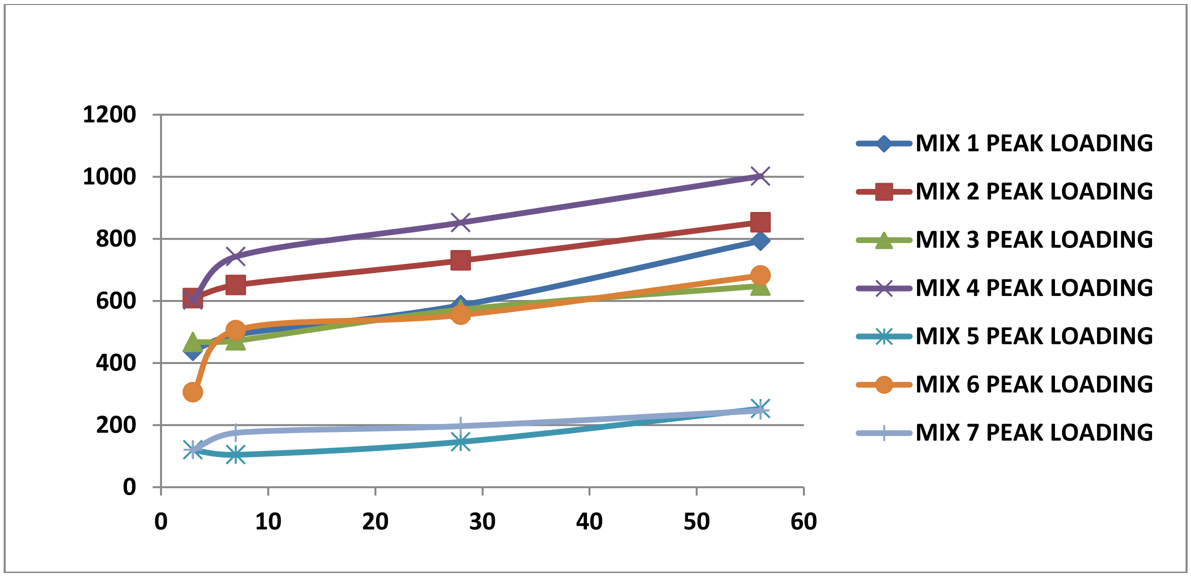

Figure 4.1: **Peak Compression Loading for Gr 1 Mix**

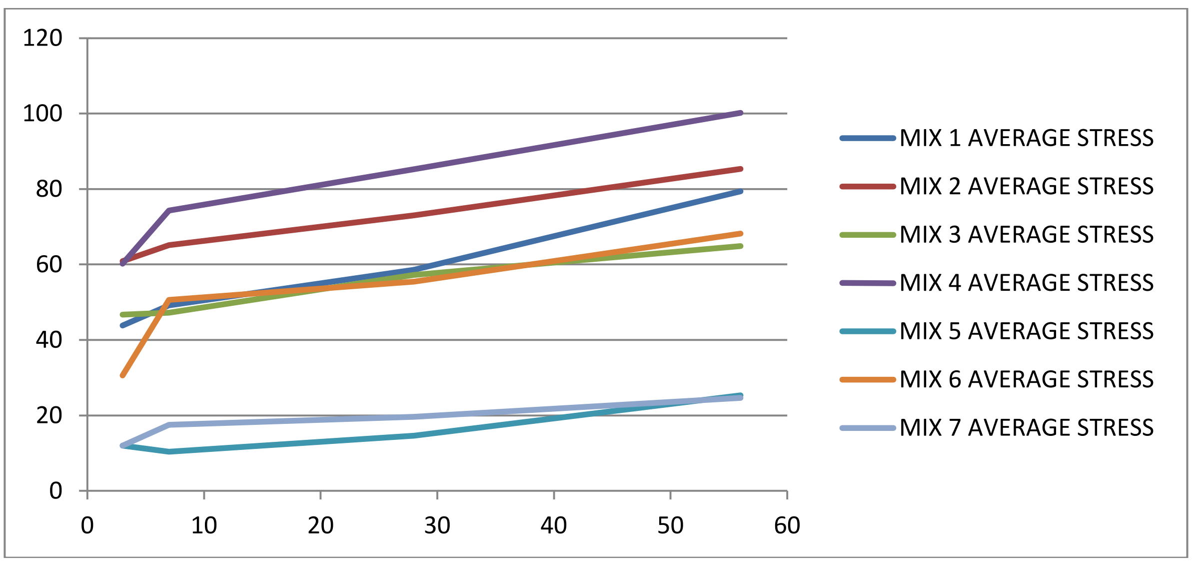

Figure 4.2: **Average Compression Stress for Gr 1 Mix**

The illustrated two graphs show the clear picture of the behavior of 7 mixes in compression loading. As Figure 4.1 shows mix 4 is good in compression loading while mix 7 is quite poor. The figure 4.2 presents that mix 4 is good in compression stress resistance compare to mix 7.

TENSILE TEST { Gr 1 }								
			28 days curing			56 days curing		
mix №	Cast date	Sample	Load kN	Stress kN/m2	Weight (g)	Load kN	Stress kN/m2	Weight (g)
			12-Jul			9-Aug		
1	14-Jun	1	79.3	2.524	3476.5	220.6	7.0226	3475.9
		2	101.8	3.241	3464.4	224.6	7.1499	3456.8
		3	115.6	3.681	3467.9	223.9	7.1276	3467.1
	average		98.9	3.149	3469.6	223.033	7.1	3466.6
			18-Jul			15-Aug		
2	20-Jun	1	198.5	6.319	3135.6	437.9	13.94	3145.9
		2	154.3	4.913	3155.4	436.7	13.902	3142.4
		3	178.5	5.682	3143.8	436.4	13.892	3143.8
	average		177.1	5.638	3144.93	437	13.911	3144
			16-Jul			13-Aug		
3	18-Jun	1	201.6	6.418	3278.9	578.9	18.429	3276
		2	205.8	6.551	3267.5	574.8	18.298	3274.9
		3	203.6	6.481	3275.3	576.7	18.359	3276.4
	average		203.67	6.484	3273.9	576.8	18.362	3275.8
			18-Jul			15-Aug		
4	20-Jun	1	208	6.62	3366.4	689.7	21.956	3376.9
		2	209.7	6.676	3365.9	684.8	21.8	3367.8
		3	207.9	6.618	3376.8	689.3	21.943	3387.2
	average		208.53	6.638	3369.7	687.933	21.9	3377.3
			19-Jul			16-Aug		
5	21-Jun	1	65.9	2.098	3137.5	178.2	5.6728	3146.9
		2	64.8	2.063	3136.8	176.9	5.6314	3145.7
		3	69.4	2.209	3134.4	179.6	5.7174	3145.2
	average		66.7	2.123	3136.23	178.233	5.6739	3145.9
			19-Jul			16-Aug		
6	21-Jun	1	79.9	2.543	3101.5	190.7	6.0707	3104.8
		2	71.1	2.264	3053.3	193.4	6.1567	3106.9
		3	75.8	2.413	3106	196.8	6.2649	3107.5
	average		75.6	2.407	3086.93	193.633	6.1641	3106.4
			23-Jul			20-Aug		
7	25-Jun	1	85.4	2.719	3126.9	214.8	6.8379	3126.6
		2	87.5	2.785	3157.8	215.9	6.873	3123.7
		3	83.9	2.671	3146.2	213.7	6.8029	3124.6
	average		85.6	2.725	3143.63	214.8	6.8379	3125

Table 4.2: **Tensile Test Results for Gr 1 Mix**

In the above shown table the tensile test results are given, first column is number of mixes, next is casting dates, and the last 2 testing after curing days 28 and 56.

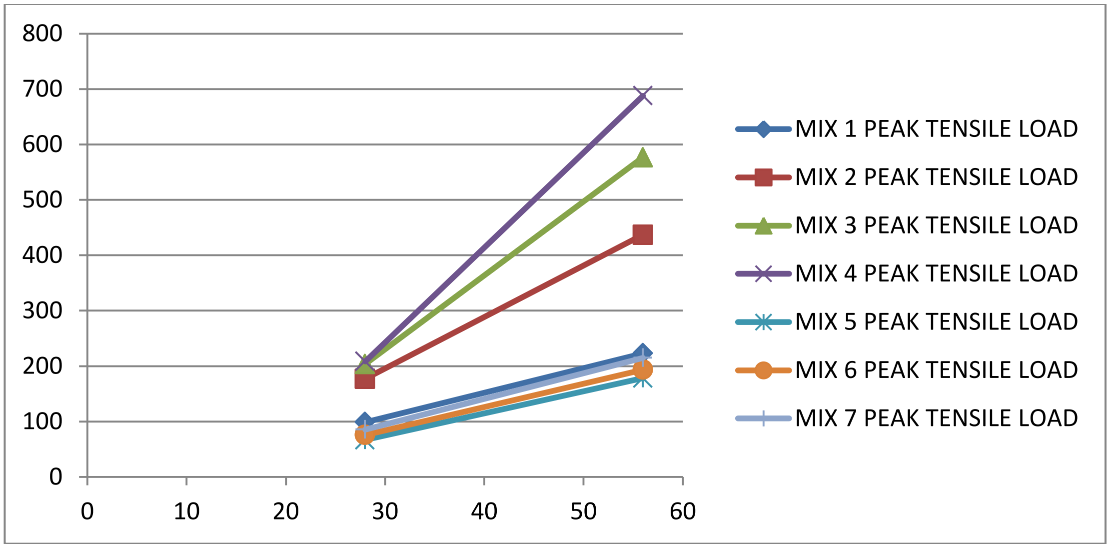

Figure 4.3: **Peak Tensile Loading for Gr 1 Mix**

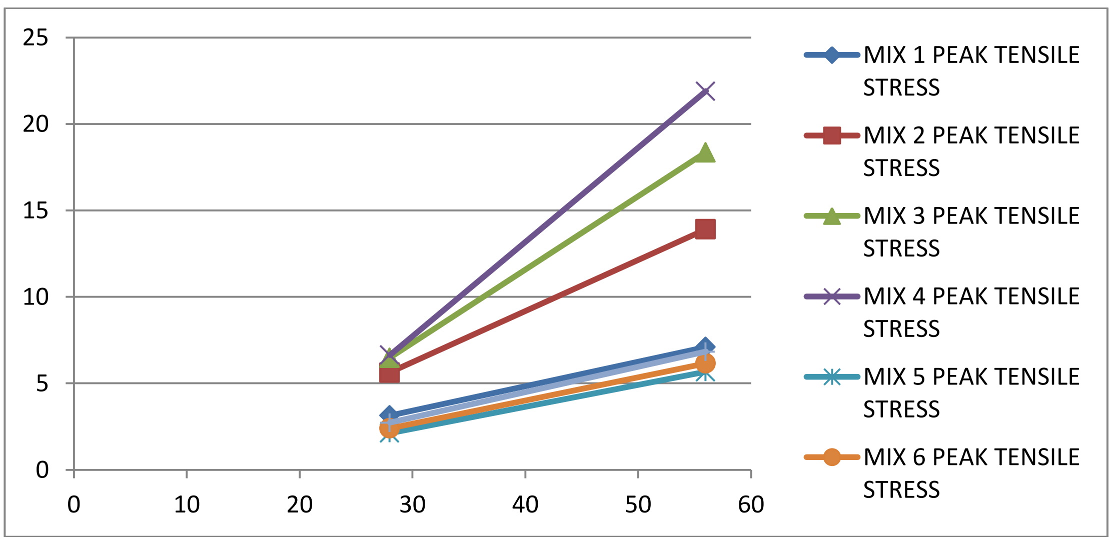

Figure 4.4: **Average Tensile Stress for Gr 1 Mix**

Figure 4.3 and 4.4 represent the graphical illustration of the tensile test results. Here in both figures mix 4 is showing good performance while mix 5 is vice verse.

MIX GROUP 1			
mix №	Cast date	SLUMP TEST RESULTS	V-FUNNEL TEST RESULT
		Length of fresh concrete mass (cm)	Time taken (sec)
1	14-Jun	48	20
2	20-Jun	45	24
3	18-Jun	47	28
4	20-Jun	47.6	29
5	21-Jun	38	40
6	21-Jun	36	47
7	25-Jun	35	49

Table 4.3: **Slump and V-Funnel Test Results for Gr 1 Mix**

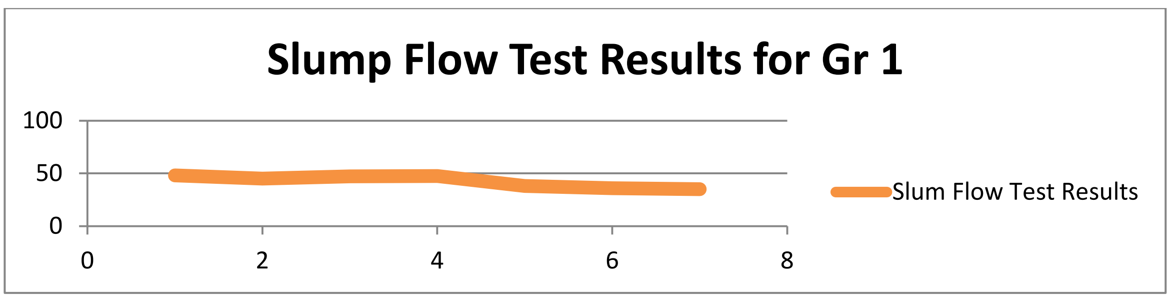

Figure 4.5: **Slump Flow Test Results for Gr 1 Mix**

Figure 4.6: **V-Funnel Test Results for Gr 1 Mix**

Test results of workability and flow ability characteristics of fresh concrete are shown above figures. As it is clear from slump flow test mix 1 is quite good in expansion while mix 7 is poor. The same scenario in V-Funnel test also mix 1 is pretty good than mix 7.

COMPRESSION TEST { Gr 2 }														
			3 days curing			7 days curing			28 days curing			56 days curing		
mix №	Cast date	Sample	Load kN	Stress	Weight	Load kN	Stress	Weight	Load kN	Stress	Weight	Load kN	Stress	Weight
			30-Jun			4-Jul			25-Jul			21-Aug		
1	28-Jun	1	253.2	25.32	2081.4	311.5	31.15	2135.1	444	44.4	2072	782.9	78.29	2065
		2	245.5	24.55	2126.4	310.7	31.07	2120.4	445.8	44.48	2076	783.2	78.32	2067.5
		3	250.4	25.04	2120.7	320.1	32.01	2123.5	445	44.5	2067	785.7	78.57	2064.9
	average		249.7	24.97	2109.5	314.1	31.41	2126.3333	444.9333	44.46	2071.667	783.9333	78.3933	2065.8
			4-Jul			8-Jul			29-Jul			26-Aug		
2	2-Jul	1	413.8	41.38	2234.7	442.8	44.18	2249.7	600.3	60.03	2179.1	720.6	72.06	2167.9
		2	420.3	42.03	2218	451.7	45.17	2238.9	611.8	61.18	2180	725.4	72.54	2165.3
		3	418	41.8	2230.1	452.3	45.23	2241.6	603.9	60.39	2143.8	723.9	72.39	2163.7
	average		417.3667	41.73666667	2227.6	448.9333	44.86	2243.4	605.3333	60.53333	2167.633	723.3	72.33	2165.633
			5-Jul			9-Jul			30-Jul			27-Aug		
3	3-Jul	1	437.1	43.71	2210.3	513.7	51.37	2231.7	712.4	71.24	2134.6	850.2	85.02	2139.2
		2	442.7	44.27	2224.5	502.3	50.23	2245.1	737.3	73.73	2145	853.9	85.39	2135.2
		3	448.7	44.87	2231	516.8	51.68	2261.8	703.8	70.38	2137.7	851.6	85.16	2136
	average		442.8333	44.28333333	2221.9333	510.9333	51.09333	2246.2	717.8333	71.78333	2139.1	851.9	85.19	2136.8
			6-Jul			10-Jul			31-Jul			28-Aug		
4	4-Jul	1	670.2	67.02	2231.8	705.6	70.56	2239.6	893.2	89.32	2246.8	984.9	98.49	2249.7
		2	669.7	66.97	2245.7	712.7	71.27	2234.7	891.7	89.17	2245.6	982.7	98.27	2246.9
		3	672.8	67.28	2239.4	707.9	70.79	2238.9	894.5	89.45	2241.8	985.7	98.57	2245.9
	average		670.9	67.09	2238.9667	708.7333	70.87333	2237.7333	893.1333	89.31333	2244.733	984.4333	98.4433	2247.5
			6-Jul			10-Jul			31-Jul			28-Aug		
5	4-Jul	1	304.6	30.46	2167.8	350.6	35.06	2146.8	480.6	48.06	2153.9	573.9	57.39	2168.3
		2	314.7	31.47	2174.2	361.8	36.18	2154.2	482.7	48.27	2154.7	572.8	57.28	2175.9
		3	309.3	30.93	2158.2	352.7	35.27	2138.9	481.9	48.19	2153.8	575	57.5	2189
	average		309.5333	30.95333333	2166.7333	355.0333	35.50333	2146.6333	481.7333	48.17333	2154.133	573.9	57.39	2177.733
			7-Jul			11-Jan			1-Aug			29-Aug		
6	5-Jul	1	178.2	17.82	2045.7	232	23.2	2057.9	259.2	25.92	2041.2	370.4	37.04	2047.8
		2	184.8	18.48	2067.8	203.6	20.36	2059	260.3	26.03	2053.2	382.7	38.27	2045.8
		3	195.8	19.58	2052.1	228.4	22.84	2062.7	264.8	26.48	2048.9	379.9	37.99	2043.8
	average		186.2667	18.62666667	2055.2	221.3333	22.13333	2059.8667	261.4333	26.14333	2047.767	377.6667	37.7667	2045.8
			10-Jul			14-Jul			4-Aug			1-Sep		
7	8-Jul	1	278.4	27.84	2143.7	301.7	30.17	2143	390.6	39.06	2142.9	470.8	47.08	2145.9
		2	264.8	26.48	2184.6	312.4	31.24	2135.8	395.9	39.59	2145.8	472.9	47.29	2187.9
		3	283.5	28.35	2173.9	306.3	30.63	2138.7	367.9	36.79	2145.6	469.9	46.99	2156.8
	average		275.5667	27.55666667	2167.4	306.8	30.68	2139.1667	384.8	38.48	2144.767	471.2	47.12	2163.533

Table 4.4: **Compression Test Results for Gr 2 Mix**

The above shown table 4.4 illustrates the compression test results for group 2 mix. As it is possible to see here the first column shows the number of mixes and the second column presents the casting date of each mix. Next four columns represent the results after curing dates 3,7,28, and 56 days. The blue line means the averaged value of 3 above given test result values.

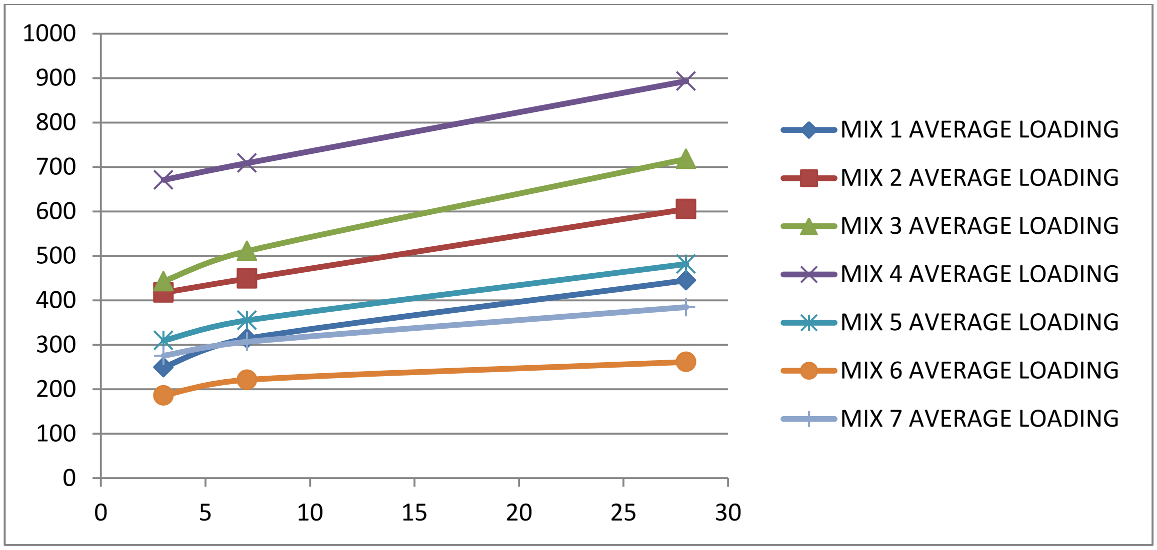

Figure 4.7: **Average Compression Loading for Gr 2 Mix**

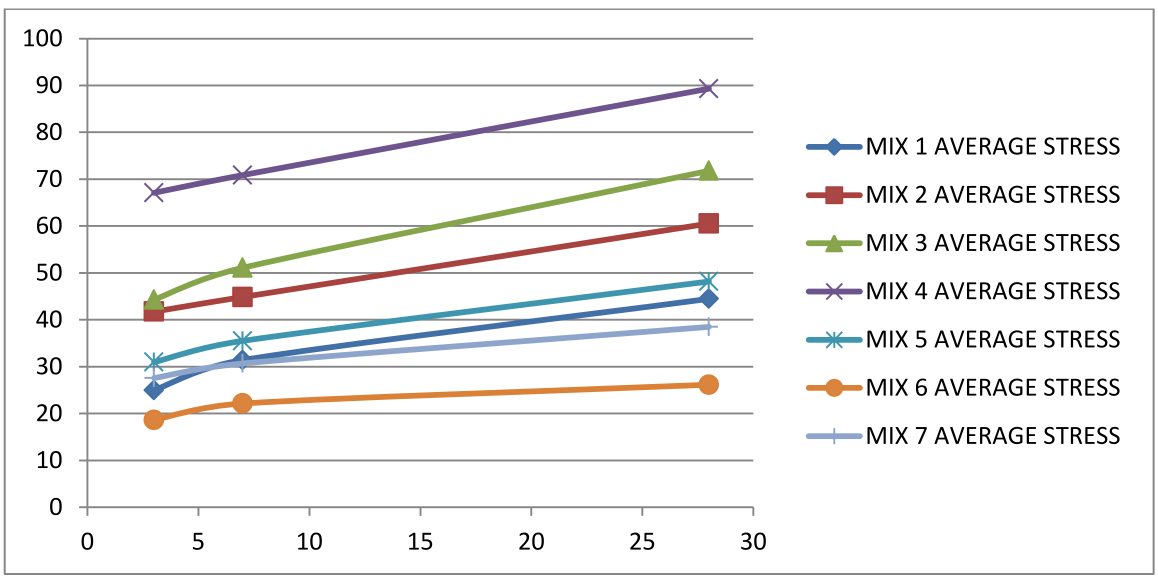

Figure 4.8: **Average Compression Stress for Gr 2 Mix**

The illustrated two graphs show the clear picture of the behavior of 7 mixes in compression loading. As Figure 4.7 shows mix 4 is good in compression loading while mix 6 is quite poor. The figure 4.8 presents that mix 4 is good in compression stress resistance compare to mix 6. It shows that mix 4 with steel fibers inside is superior than mix 6 with basalt fibers.

TENSILE TEST { Gr 2 }								
			28 days curing			56 days curing		
mix №	Cast date	Sample	Load kN	Stress	Weight	Load kN	Stress	Weight
			25-Jul			21-Aug		
1	28-Jun	1	99.2	3.158	3453.5	190.6	6.067552	3456.9
		2	121.8	3.877	3424.4	194.6	6.194887	3474.8
		3	111.6	3.553	3448.9	189.9	6.045268	3469.1
	average		110.8667	3.529324377	3442.2667	191.7	6.102569	3466.9333
			29-Jul			26-Aug		
2	2-Jul	1	175.5	5.587	3142.6	437.9	13.94009	3145.9
		2	167.3	5.326	3147.4	436.7	13.90189	3142.4
		3	178.5	5.682	3143.8	436.4	13.89234	3143.8
	average		173.7667	5.532	3144.6	437	13.91144	3144.0333
			30-Jul			27-Aug		
3	3-Jul	1	196.6	6.259	3256.9	525.9	16.74148	3289
		2	197.8	6.297	3257.5	528.8	16.83379	3272.9
		3	195.6	6.227	3253.3	529.7	16.86245	3275.4
	average		196.6667	6.261	3255.9	528.1333	16.81257	3279.1
			31-Jul			28-Aug		
4	4-Jul	1	206	6.558	3364.4	652.7	20.77802	3326.9
		2	204.7	6.516	3369.9	651.8	20.74937	3328.8
		3	211.9	6.746	3362.8	657.3	20.92446	3321.2
	average		207.5333	6.607	3365.7	653.9333	20.81728	3325.6333
			31-Jul			28-Aug		
5	4-Jul	1	57.9	1.843	3157.5	163.2	5.195	3132.9
		2	53.8	1.713	3161.8	161.9	5.154	3127.7
		3	51.4	1.636	3152.4	168.6	5.367	3129.2
	average		54.367	1.731	3157.233	164.567	5.239	3129.933
			1-Aug			29-Aug		
6	5-Jul	1	75.9	2.543	3119.5	176.7	5.62506	3114.8
		2	74.1	2.264	3099.3	179.4	5.711011	3118.9
		3	75.8	2.413	3115	187.8	5.978417	3115.5
	average		75.267	2.407	3111.267	181.300	5.771	3116.400
			4-Aug			1-Sep		
7	8-Jul	1	76.4	2.432114093	3116.9	201.8	6.424092	3167.6
		2	73.5	2.339795626	3119.8	208.9	6.650113	3163.7
		3	79.9	2.543532932	3116.2	204.7	6.51641	3162.6
	average		76.600	2.438	3117.633	205.133	6.530	3164.633

Table 4.5: **Tensile Test Results for Gr 2 Mix**

In the above shown table the tensile test results are given, first column is number of mixes, next is casting dates, and the last 2 testing after curing days 28 and 56.

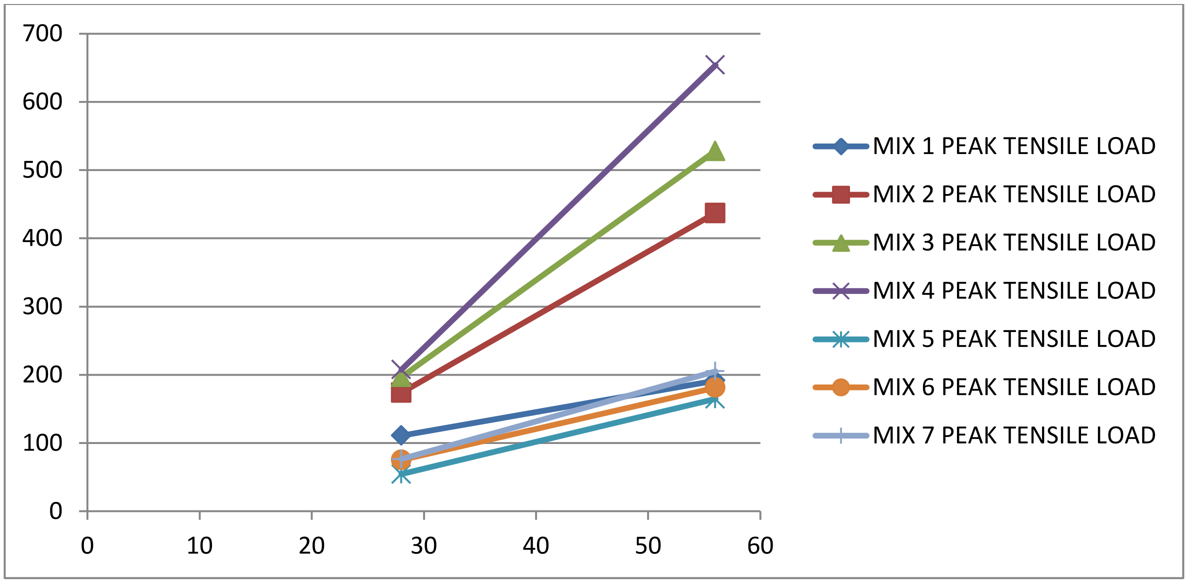

Figure 4.9: **Peak Tensile Loading for Gr 2 Mix**

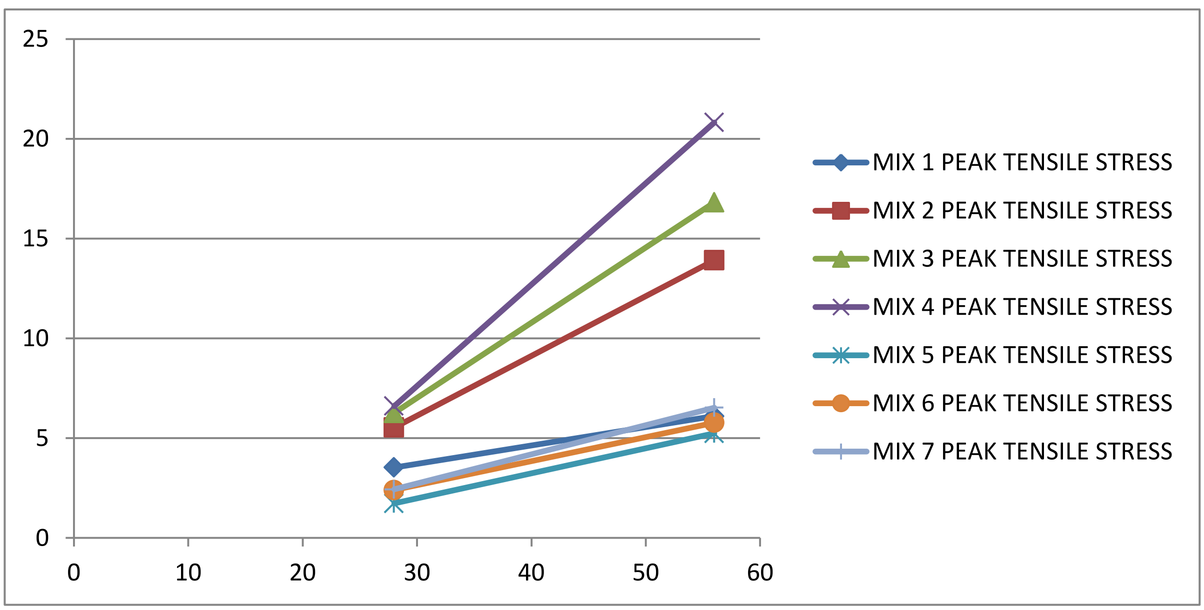

Figure 4.10: **Average Tensile Stress for Gr 2 Mix**

Figure 4.9 and 4.10 represent the graphical illustration of the tensile test results. Here in both figures mix 4 is showing good performance while mix 5 is very poor. Here also it is possible to see in mix 4 the effect of steel fiber on the strength of the concrete.

MIX GROUP 2			
mix №	Cast date	SLUMP TEST RESULTS	V-FUNNEL TEST RESULT
		Length of fresh concrete mass (mm)	Time taken (sec)
1	28-Jun	45	18
2	2-Jul	43	23
3	3-Jul	41	26
4	4-Jul	40	29
5	4-Jul	37	37
6	5-Jul	34	39
7	8-Jul	32	42

Table 4.6: **Slump and V-Funnel Test Results for Gr 2 Mix**

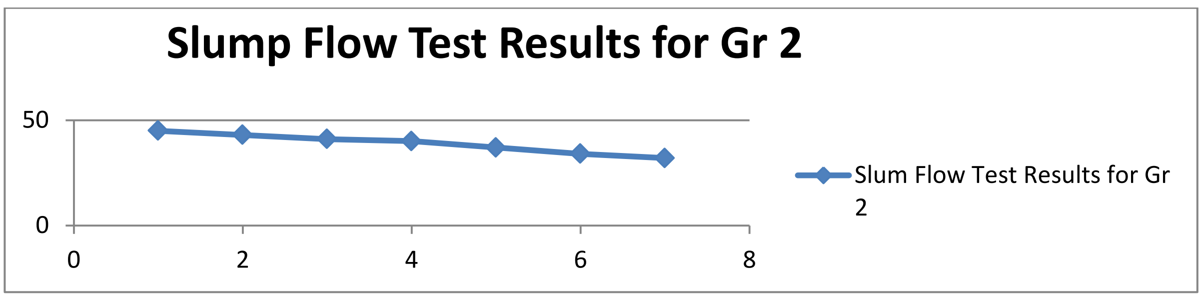

Figure 4.11: **Slump Flow Test Results for Gr 2 Mix**

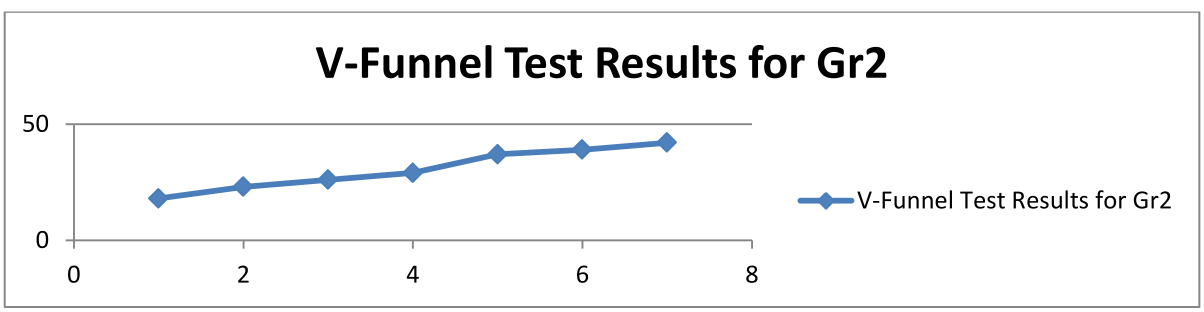

Figure 4.12: **V-Funnel Test Results for Gr 2 Mix**

Test results of workability and flow ability characteristics of fresh concrete are shown above figures. As it is clear from slump flow test mix 1 is quite good in expansion while mix 7 is poor. The same scenario in V-Funnel test also mix 1 is pretty good than mix 7.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Relevancy to the Objectives:

As a matter of fact the whole the project work high lightened above, directly describes the chosen objectives of the project. As it was mentioned before the objectives of this project work are :

- To achieve the good resistance of RPC to the max tensile stress applied.
- To study the performance of the basalt and steel fiber concrete incorporated with cement replacement materials.
- To enhance the ductility of self compacting concrete by adding steel fiber.
- To design the mixture of the SCC with different type of materials: cement, water as well as chemical additive which is super plasticizer.
- To study the effect of fiber and SCC mixture with different percentage

It is possible to state clear that steel fiber performance in ductile RPC is better than basalt fiber in RPC. Thus this research paper recommends to use steel fibers in producing ductile RPC concretes.

5.2 Suggested Future Work for Expansion and Continuation:

In fact it is possible to say that the topic which is chosen and discussed here, has nowadays a very significant place in the modern research process of this world. Because if the RPC is accepted by the concrete technology industries and people, it will bring a dramatic change to the concrete and construction industries. It means RPC can compete with reinforced concrete, and other concrete materials. From my point of view I can give the following suggestions for expansion and continuation of the project:

- ✓ As much as possible steel replaceable materials should be tested and utilized in developing ductile concrete.
- ✓ The capabilities of the developed RPC should be frequently advertized and demonstrated for the concrete technology industries so in order to get their trust and people’s believe in RPC.
- ✓ It is required to take some risk and responsibilities by constructing structures from RPC, so RPC may prove that it possesses the same characteristics as High Performance Concrete.

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