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Analysis of Ultra high Performance Concrete - Properties, Applications and Future Scope

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Abstract: Ultra-High Performance Concrete (UHPC) is an advanced construction material characterized by exceptional strength, durability, and ductility. This thesis presents a detailed analysis of UHPC including its properties, applications, and future scope in modern infrastructure. New types of concrete such as High Strength Concrete (HSC), High Performance Concrete (HPC), very high performance concrete (VHPC), Self Compacting Concrete (SCC), Ultra High Performance Concrete (UHPC) and Ultra- High Strength Concrete (UHSC) are being constantly developed in order to meet the increasing demand for improved mechanical properties and durability
***Keywords*: High Performance Concrete (HPC), durability, advanced cementitious materials (ACM), Ultra-High Performance Concrete, Ultra- High Strength Concrete (UHSC)**

I. INTRODUCTION

The relatively high initial cost of UHPC has restricted its wider use in the construction industry. Under relatively mild service environments, properly designed reinforced concrete (RC) structures show excellent performance in terms of durability and structural behavior. However, this is no longer the case when they are subjected to severe mechanical or aggressive environmental conditions. Premature deterioration of reinforced concrete structures, such as bridges, has been a persistent and frustrating problem to those responsible for maintaining those structures as well as to those using them. The deterioration typically consists of concrete delamination and spalling due to various mechanisms, including corrosion of embedded steel reinforcement, de-icing salt–induced scaling, freezing and thawing cycles, or reactive aggregates. The rate of this deterioration is mainly dependent on the permeability of the concrete to moisture and aggressive substances. This decay shortens the lifetime of infrastructure and increases the costs of their long term maintenance. New types of concrete such as High Strength Concrete (HSC), High Performance Concrete (HPC), very high performance concrete (VHPC), Self Compacting Concrete (SCC), Ultra High Performance Concrete (UHPC) and Ultra-High Strength Concrete (UHSC) are being constantly developed in order to meet the increasing demand for improved mechanical properties and durability.

II. OBJECTIVES

1.Review the literature concerning concrete mixture design.
2.Investigate the influences of water-cement ratio (by mass), silica fume, silica flour, sand and steel fibre on concrete properties.
3. Determine the optimized designs that maximized 28 day compressive strength or had minimum cost
4.Monitoring creep rates which are determined from packing density distributions of nano scale particles

III. LITERATURE REVIEW

A brief review of work already done in the fie

Author Name	Work	Result
Vandamme and Ulm (2009)	Monitoring creep rates which are determined from packing density distributions of nano scale particles	Slow the creep rate, increase concrete's durability and prolong the life of structures from a nanoscopic perspective.

Aïtcin and Mehta (1990)	In order to increase the compressive strength of concrete.	Concrete failure will always initiate in the weakest part of one of these three phases.
Acker and Behloul (2004)	UHPC is characterized	Achieve a greater percentage of the ultimate load capacity of its components.
Schmidt and Fehling (2005)	By enhancing homogeneity and increasing the packing density through optimization of the granular mixture and elimination of coarse aggregates.	Producing a very dense and strong structure of the hydration products using very low water-cement ratio.
Tang (2004)	UHPC has been used for producing special pre-stressed and precast concrete members.	These outstanding properties make it a promising material for different concrete applications
Shah and Weiss (1998)	Applications include the production of nuclear waste storage facilities	Rehabilitation and retrofitting of concrete structures

IV. METHODOLOGY

Proposed Methodology during the tenure of research work

1) The targeted use of high performance materials like advanced cementitious materials (ACM) in new structures or conservation projects leads to enhanced performance and durability.
2) It is proposed to combine normal strength concretes and UHPFRC in composite structures in order to exploit the advantages of the two materials in an optimal way.
3) UHPFRC will used in the parts of a structure subjected to attack by detrimental substances and/or where high strengths or stiffness are required.
4) This concept of composite "UHPFRC-concrete" structures can be applied to new structures and to conservation projects.
5) Although numerous regulations and guidelines cover the composition and properties of concrete and its components, the actual process of concrete production, i.e. mixing, is, for all intents and purposes, left to the user. Due to the low water content with respect to the content of fines (<0.125mm) and the high dosage of admixtures, the production of HPC and VHPC/UHPC requires more mixing energy to homogenise the concrete components. It has to be pointed out that the traditional mix design methods that have been developed over the years for normal concrete cannot be used for HPC and VHPC/UHPC. The response surface methodology (RSM) was employed in this experimental design using Design-Expert Version 9.0 software. Seven components were considered in this project, namely: water, cement, silica fume, silica flour, fine sand, steel fibre, and super-plasticizer (SP). As discussed below, the amount of super-plasticizer was fixed, so only five independent parameters had to be determined: water-cement ratio (by mass), silica fume, silica flour, fine sand and steel fiber. The main reason that the amount of super-plasticizer was fixed is because the number of experiments was decreased to a relatively small number. There were 31 batches including 16 factorial points, 10 axial points, and 5 center points.
6) Selection of Materials, Proportions, and Constraints Mixture proportions by mass from

	Cement	Silica Fume	Sand	Steel Fibers	SP	Water

Kg in $1m^3$	1087	163	652	390	46	250
Mass Ratio to Cement	1	0.15	0.60	0.36	0.04	0.23

7) Particle size analysis of 4030 sand

	Mesh Size		
Typical Mean % Retained on Individual Sieves	ASTM	Microns	4030 Sand
	20	850	-----
	30	600	3.3
	40	425	36.4
	50	300	34.5
	70	210	16.2
	100	150	7.2
	140	106	2.1
	200	75	0.3
	270	53	-----
	PAN	PAN	-----

8) Material Tests

- Outline of concrete tests

S. N.	Test	Description
1	Compressive strength	To obtain the capacity of concrete to withstand axially directed pushing forces
2	Splitting tensile strength	To estimate the tensile strength
3	Air-content test for hardened concrete	To evaluate the resistance to freezing and thawing and chemical attack
4	Flow cone test	To obtain the spread value of paste

- Compressive Strength Test
- Splitting Tensile Strength Test
- Slump Cone Test

9) Material Tests

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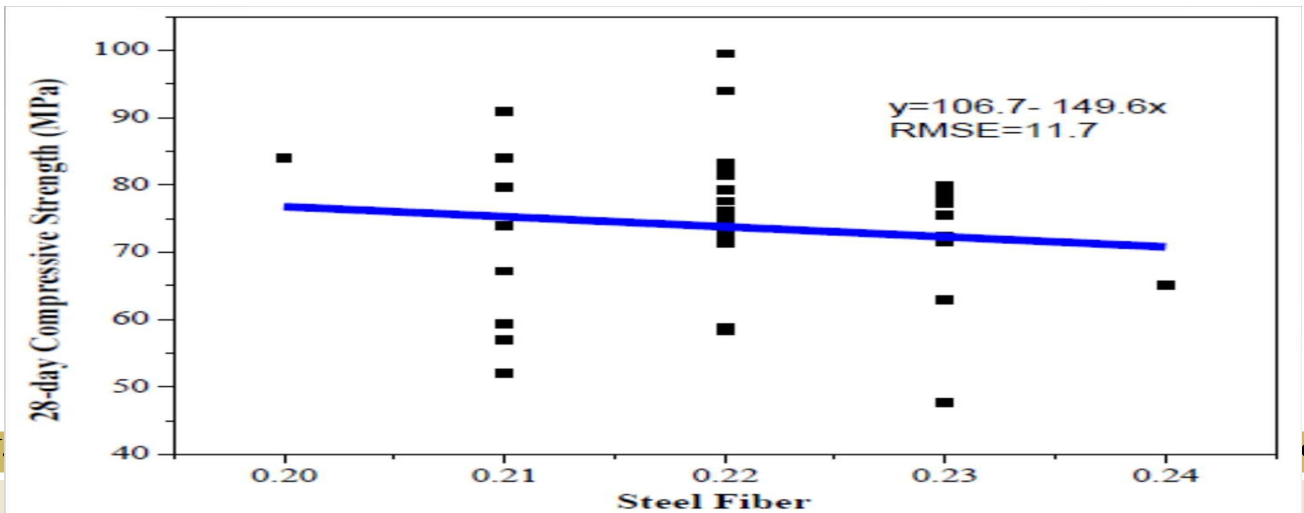
V. RESULT & DISCUSSION

28_{day} compressive strength verses steel fiber volume fraction

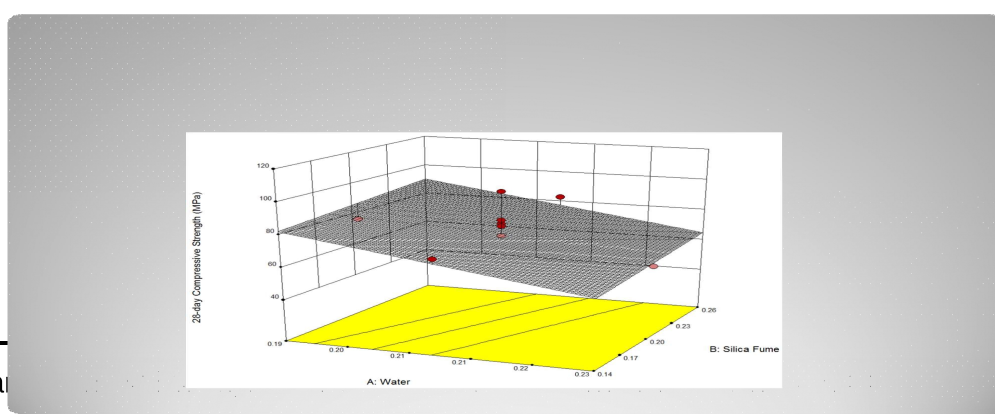


S. N						ob>F
1						
2	Linear vs Mean	1612.92	5	322.58	2.99	0.0301
3	2FI vs Linear	1132.06	10	113.21	1.08	0.4307
4	Quadratic vs 2FI	627.2	5	125.44	1.33	0.3259
5	Cubic vs Quadratic	467.31	5	93.46	0.99	0.5056
6	Residual	473.53	5	94.71		
7	Total	173142.82	31	5585.25		

28days Model Fitting

28days MODEL DIAGNOSTICS

Response surface of 28_{day} compressive strength



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S.N.	1st Scenario				
1	Water	Silica Fume	Silica Flour	Sand	Steel Fiber
	0.19	0.26	0.25	1.364	0.201
	7day Compressive Strength (MPa)		2 day Compressive Strength (MPa)		
	67.3		102.4		
2	2nd Scenario				
	Water	Silica Fume	Silica Flour	Sand	Steel Fiber
	0.19	0.26	0.073	1.39	0.209
	7day Compressive Strength (MPa)	28day Compressive Strength (MPa)	Air Content (%)		Cost (dollars/m^3)
	60.3	82	6.00		2423.3

Optimization results

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VI. CONCLUSION & FUTURE SCOPE

A. Conclusions

From these conclusions, it was observed that the highest optimization result for 28_{day} compressive strength was 102.4MPa. It was concluded that it would be very difficult to increase this strength using the current material and experimental methods. As a result, different materials or new methods would have to be investigated for making UHPC; this will be introduced in section 5.2. Also, it was concluded based on observations from this project that a high energy mixer should be used to improve results; more mixing energy would help to disperse all of the components, potentially increasing the workability.

Fig. Concrete cylinders curing in lime saturated water

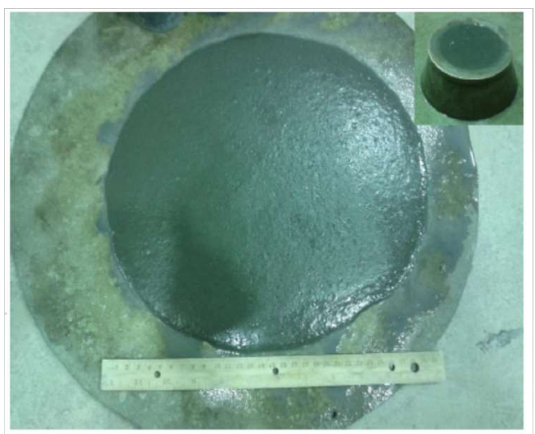

Fig. Concrete compressive strength test

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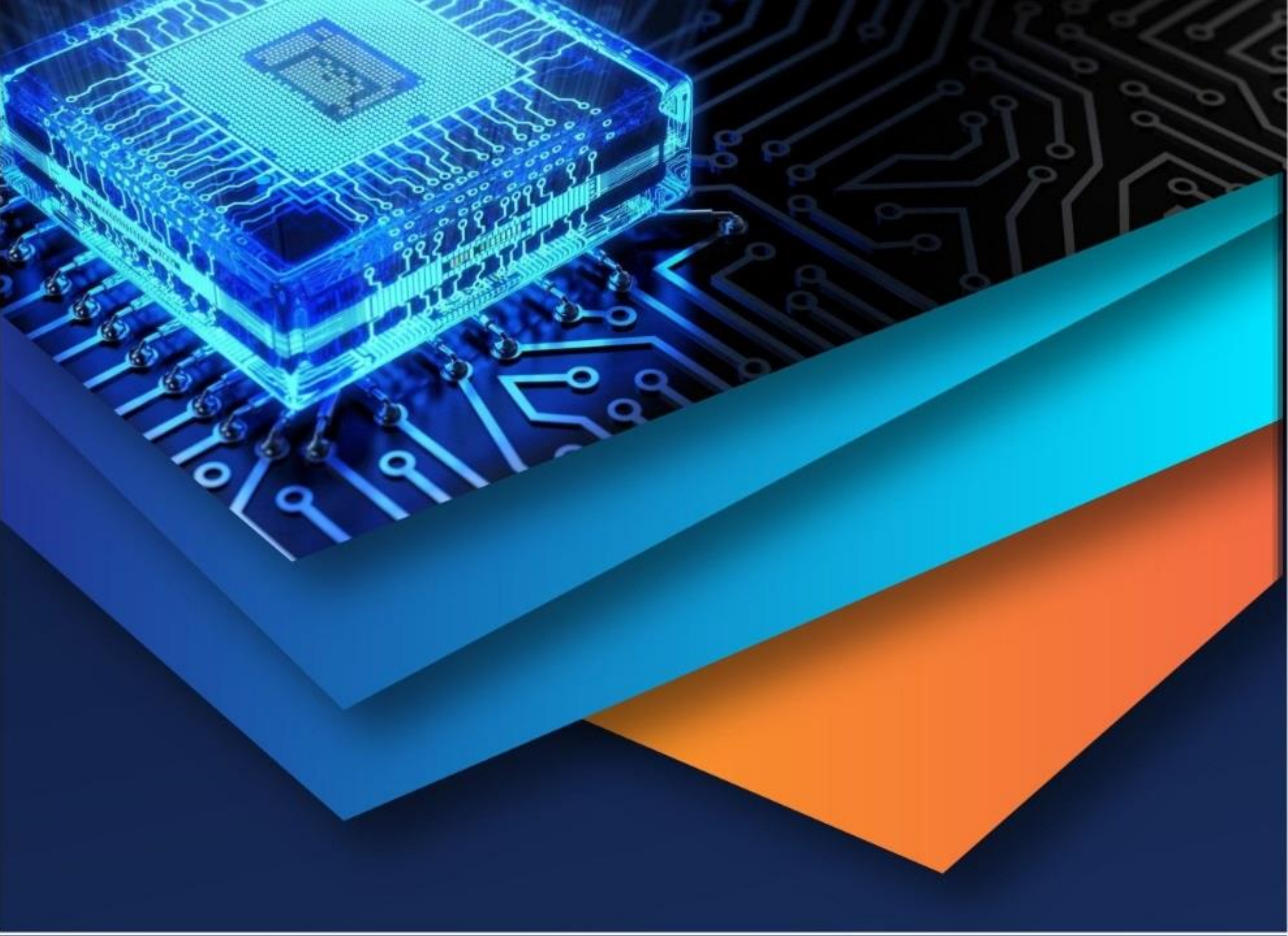

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