EXPERIMENTAL STUDY ON COMPRESSIVE BEHAVIOUR OF SILICA FUME AS PARTIAL REPLACEMENT OF CEMENT UNDER ULTIMATE LOADS

Preyadarshi.S[1], K.Shanmugam[2], Dr.R.Angeline Prabhavathy[3]

[1]Assistant Professor, Department of Civil Engineering, Vels Institute of Science Technology & Advanced Studies, Chennai, Tamilnadu

[2] Ph.D Student, Department of Civil Engineering, Hindustan Institute of Technology & Science, Chennai, Tamilnadu

[3] Professor, Department of Civil Engineering, Hindustan Institute of Technology & Science, Chennai, Tamilnadu

---

Abstract: ***Concrete is the most important material for construction in India by our project we are going to study about the replacement of cement by silica fume to check up the strength and durability of concrete for certain replacement and also it must be economy. Concrete is the mixer of cement, fine aggregate, coarse aggregate with w/c ratio. In this mixer we are going to replace cement by silica fume in some percentage to show concrete as high performance concrete. Similarly while replacement of cement into silica fumes it provides more compressive strength and low permeability to concrete within short period at mix design for M25 grade. Using Portland pozzolonic cement, portable fine aggregate, angular coarse aggregate with high range water reducing admixture.***

Keyword: Silica fume, Compressive Strength, Split Tensile Strength, Durability, Permeability, Conplast, High performance Concrete

---

I.INTRODUCTION

I.1 GENERAL

Concrete is one of the most important material uses for construction in India. So need of concrete is more, we have to get much more performance in concrete than normal concrete and it must also be economically. Concrete is normally ecofriendly so if there any replacement it must also be ecofriendly, so we used silica fume in concrete to get high performance concrete. Normally high performance concrete is used in the bridge, dam such like that place. But concrete is also used in residential building so we must use high performance concrete in residential building to get life structure of building more. The admixture (High Range Water Reducing Admixture) is also used to reduce water requirement. If there increase in water cement ratio, strength of concrete will decreases. If there no proper workability strength will also decreases, in such cases the high range water reducing admixture is used to get more strength in concrete by low water and high workability. If some percentage of silica fumes is replaced water quantity is required more in such cases admixture will be increased to get good workability. From this replacement of cement by silica fume and addition of super plasticizer the concrete will perform has high performance concrete.

I.2 OBJECTIVE

- To establish a feasible mix design to produce HPC.
- To obtain the mechanical properties of HPC including, compressive strength,
- Splitting tensile strength,
- To evaluate the strength of HPC gain with age.
- To obtain the relationship between splitting tensile strength and compressive strength.
- To obtain the relationship between modulus of rupture and compressive strength.
- To study the influence of silica fume dosage and water cement ratio mixing procedure to
- Show the compressive strength and workability of HPC.

II.LITERATURE SURVEY

Dr. P. Jeyabalan, Assistant Professor of Civil Engineering, and **B. N. Krishnaswami** Faculty in Civil Engineering, National Institute of Technology, Tiruchirappalli, Tamil Nadu.

Concrete is the second largest material consumed by the human being in the world next to water. Environmental attack can severely reduce the strength and life of the concrete. In the present study a series of 5 batches of concrete were cast containing fumed silica and the material properties were determined. These properties include compressive strength and permeability. The test results are compared with the values for high performance concrete without fumed silica as a reference mix. It is high reactive Ordinary Portland cement made for some purpose. Fumed silica is produced by the vapour phase hydrolysis of silicon Tetra chloride in a hydrogen oxygen flame. The combustion process creates silicon dioxide molecules, which condense to form particles. Fumed silica is being used in various fields such as pharmaceuticals, paints, adhesives and sealants, plastics, rubber and ink except for concrete. Properties of the fumed silica and silica fume have been shown in Table – 1. Since fumed silica is much finer than silica fume its influence in the paste aggregate interface was found to be the dominant factor in the development of increased strength.

Perumal, Sri Ramakrishna Mission Vidalia Polytechnic College and **R.Sundararajan**, Government College of Technology, India.

Maintenance, repair and rehabilitation of existing cement concrete structures involve a lot of problem leading to significant expenditure. In the recent past, there has been considerable attention for improving the properties of concrete with respect to strength and durability, especially in aggressive environments .High performance concrete (HPC) appears to be better choice for a strong and durable structure. Suitable addition of mineral admixtures such as silica fume (SF), ground granulated blast furnace slag and fly ash in concrete improves the strength and durability of concrete due to considerable improvement in the microstructure of concrete composites, e specially at the transition zone Very few studies have been reported in India on the use of SF for development of HPC and also durability characteristics of these mixes have not been reported. In order to make a quantitative assessment of different cement replacement levels with SF on the strength and durability properties for M60, M70 and M11 0 grades of HPC trial mixes and to arrive at the maximum levels of replacement of cement with SF, investigations were taken.

Tony Kojundic, Silica Fume Association, c/o Elemi Materials Inc. PO Box 266 Pittsburgh, PA 15230 (412)299-7229. tony@silicafume.org

This presentation will provide a fundamental look into the definition of high-performance concretes (HPC) of today, and the technology behind silica-fume to produce HPC for bridge applications. The presentation will highlight key structural and durability properties of HPC and the life-cycle cost savings from implementing HPC into our nation's transportation infrastructure. Included are HPC bridge applications from around the country and the latest evolving HPC designs employing the lessons learned from 20 years of bridge experiences. One such lesson is a universally accepted construction technique and curing practice to best utilize the properties HPC brings the project. The presentation also highlights many resources for information on HPC technology, application, and practice, provided by industry and the FHWA.Tony Kojundic is a founding Board member of the Silica Fume Association, and Business. Manager for Elemi Materials in Pittsburgh, PA. The Silica Fume Association operates under a co-operative agreement with the FHWA to help provide 'technology transfer' on High performance Concrete (HPC) to state and local transportation departments. He is active on numerous committees of the American Concrete Institute(ACI), the Transportation Research Board, the American Society of Testing and Materials, the National Concrete Bridge Council, and the Society of Petroleum Engineers. His ACI duties include secretary of the Silica-fume Concrete Subcommittee, and chapter author to the High-strength Concrete, Parking Structures, and Concrete Proportioning Committees. Through his employment at Elemi he's been directly involved with silica-fume concrete research and implementation into project applications for the past 20 years. A 1975 graduate engineer from West Virginia University, Tony has published a dozen or so papers on high-performance, durable concrete and has spoken at numerous engineering and transportation conferences around the country

III. MATERIALS AND METHODOLOGY

III.1 ORDINARY PORTLAND CEMENT

Portland Cement is manufactured by intergrading well-burnt OPC Clinker with 15 to 35 % Portland and required percentage of Gypsum to the fineness of not less than 300 m2 /Kg. Portland Cement is new generation cement. It contains high reactive Silica (HRS) to enhance ultimate performance of concrete. Portland is essentially a siliceous material in finely divided form with the presence of water, that react with Calcium hydroxide at ordinary temperature liberated during the hydration of Portland Cement to produce stable, cementitious compounds. These compounds contribute to strength and water tightness of Cement and are especially suitable for Dams and mass construction like foundation. Portland, also known as pozzolanic ash (pulvis puteolanus in Latin), is a siliceous or siliceous and aluminous material which reacts with calcium hydroxide in the presence of water at room temperature (cf. pozzolanic reaction). In this reaction insoluble calcium silicate hydrate and calcium aluminates hydrate compounds are formed possessing cementitious properties.

ADVANTAGES

- Higher durability of concrete structure due to less permeability of water.
- More resistance towards the attack of alkalies, sulphates, chlorides, chemicals.
- Better workability.
- Low heat of hydration.
- Less Cracks.
- More resistance towards leakages.
- Due to more fineness, OPC have better cohesion with aggregates and make more dense concreteness.
- Comparative lower Water-Cement ratio provides an added advantage for the further increase of compressive strength of the concrete.
- Portland Ordinary portland cement has a lower specific gravity and therefore weight for weight produce a higher yield of concrete.
- Better surface finish.

POZZOLANIC REACTION

The pozzolanic reaction is the chemical reaction that occurs in Portland cement containing pozzolans. It is the main reaction involved in the Roman concrete invented in Ancient Rome and used to build, for example, the Pantheon. At the basis of the pozzolanic reaction stands a simple acid-base reaction between calcium hydroxide, also known as Portlandite, or ($Ca(OH)_2$), and silicic acid (H_4SiO_4, or $Si(OH)_4$), and . Simply, this reaction can be schematically represented as follows $Ca(OH)_2 + H_4SiO_4 \rightarrow Ca^{2+} + H_2SiO_4^{2-} + 2\ H_2O \rightarrow CaH_2SiO_4 \cdot 2\ H_2O$ or summarized in abbreviated notation of cement chemistsCH + SH → C-S-HThe product of general formula ($CaH_2SiO_4 \cdot 2\ H_2O$) formed is a calcium silicate hydrate, also abbreviated as C-S-H in cement chemist notation, the hyphenation denotes the variable stoichiometry. The ratio Ca/Si, or C/S, and the number of water molecules can vary and the above mentioned stoichiometry may differ. Many pozzolans contain aluminates, or $Al(OH)_4^-$, that will react with calcium hydroxide and water to form calcium aluminates hydrates such as C_4AH_{13}, C_3AH_6 or hydrogarnet, or in combination with silica C_2ASH_8 or strätlingite (cement chemist notation). In the presence of anionic groups such as sulphate, carbonate or chlorine, AFm phases and AFt or ettringite phases can form.

Table 1: INITIAL AND FINAL SETTING TIME FOR CEMENT

Trial	Initial setting time (min)	Final setting time (hrs)	Remarks
01	45 minutes	9 hours	6mm penetration distance

SEIVE ANALYSIS

Cement is used as a building material for mortar and concrete. The fineness of cement has on important bearing on the rate of hydration and hence on the gain of strength. Fineness gives more cohesiveness and reduces bleeding. Rapid development of strength requires greater degree of fineness. Too much of fineness is undesirable because, finer cement deteriorates more quickly when exposed to air and likely to cause more shrinkage greater amount of gypsum is required for proper retardation.

Table 2: SIEVE ANALYSIS OF CEMENT

Type of cement	Name of sample	Weight of sample residue W_1 in g	Weight of sample W_2 in g	Weight of residue in percentage	Average percentage of residue	Remark
Ordinary Portland	1	100	21	21	19.3	75 µ IS sieve
	2	100	19	19		

cement	3	100	18	18		

III.2 FINE AGGREGATE

The fine aggregate shall consist of natural sand or, subject to approval, other inert materials with similar characteristics, or combinations having hard, strong, durable particles. Fine aggregate from different sources shall not be mixed or stored in the same pile nor used alternately in the same class of construction or mix, without permission from the Engineer.

Fig.1 Fine Aggregate

III.3 COARSE AGGREGATE

The largest proportion of the primary aggregate was used to manufacture concrete (36%), with a further 10% used to manufacture the cement that is also used in the concrete. Used in roads was the second largest category (26%), while 20% of aggregates were used in other construction uses & fills and another 2% were used for railway ballast. However materials that are suitable for use as aggregates can also be used to manufacture other products thus industrial and other uses amounted to 6% with the remainder split between the manufacture of mortar (4%), glass (1%) and use in agriculture (1%).

Fig.2 Coarse Aggregate

III.4 PORTABLE WATER

Almost any natural water that is drinkable and has no pronounced taste or odour can be used as mixing water for making concrete. Some water which may not be suitable for drinking may still be safe for mixing concrete. Pipe born drinking water supplies are generally safe for making concrete. Water of doubtful quality can be simply tested by making two sets of cubes or cylinders of the same mix, one with the doubtful water, and the other (used as a reference) set with distilled water, purified water, tap water, or other drinkable water of good quality. If the suspected water produces concrete of 28 day compressive strengths at least 90% of the strength of the companion (reference) set, it can be considered suitable.

III.5 SILICA FUME

Silica fume, also known as micro silica, (CAS number 69012-64-2, and EINECS number 273-761-1) is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete.

Fig.3 Silica Fume

PROPERTIES

Silica fume is an ultrafine material with spherical particles less than 1 µm in diameter, the average being about 0.15 µm. This makes it approximately 100 times smaller than the average cement particle. The bulk density of silica fume depends on the degree of densification in the silo and varies from 130 (undensified) to 600 kg/m3. The specific gravity of silica fume is generally in the range of 2.2 to 2.3. The specific surface area of silica fume can be measured with the BET method or nitrogen adsorption method. It typically ranges from 15,000 to 30,000 m2/kg.

III.6 HIGH RANGE WATER REDUCING ADMIXTURE(CONPLAST SP430)

- To produce pumpable concrete
- To produce high strength, high grade concrete M25 & above by substantial reduction in water resulting in low permeability and high early strength.
- To produce high workability concrete requiring little or no vibration during placing.

ADVANTAGES

- Improved workability - Easier, quicker placing and compaction.
- Increased strength - Provides high early strength for precast concrete with the advantage of higher water reduction ability.
- Improved quality - Denser, close textured concrete with reduced porosity and hence more durable.
- Higher cohesion - Risk of segregation and bleeding minimised; thus aids pumping of concrete
- Chloride free - Safe in prestressed concrete and with sulphate resisting cements and marine aggregates.

DESCRIPTION

Conplast SP430 is based on Sulphonated Naphthalene Polymers and supplied as a brown liquid instantly dispersible in water. Conplast SP430 has been specially formulated to give high water reductions up to 25% without loss of workability or to produce high quality concrete of reduced permeability.

IV. EXPERIMENTAL STUDY

IV.1 MAKING TEST CUBES FROM FRESH CONCRETE

The standard size of cube is 150 mm. Cubes of 100 mm size are not suitable for concrete having a nominal maximum aggregate size exceeding 20 mm. Cubes of 150 mm size are not suitable for concrete having a nominal maximum aggregate size exceeding 40 mm. The moulds for the specimens must be made of cast iron or cast steel. The inside faces must be machined plane. The cube mould is normally made in two halves to facilitate removal of the concrete cube without damage. Each mould has a base, which is a separate metal plate, preferably fastened to the mould by clamps or springs. When assembled, all the internal angles of the mould must be right angles. To comply with CS 11990, moulds are required to be within specified tolerances for dimensions, squareness and parallelism.

Fig.4 Mixing and Cube Mould

Fig.5 Casting and Curing

Fig.6 Testing of Cubes and Cylinders

IV.2 COMPRESSIVE STRENGTH

Table 3: COMPRESSIVE STRENGTH OF CUBE FOR 7 DAYS

SL NO:	SPECIMENS	LOAD (KN)	COMPRESSIVE STRESS (N/MM^2)
1	CONTROLLED SPECIMEN	415	18.4
2	2.5% REPLACEMENT OF SILICAFUMES	435	19.3
3	5% REPLACEMENT OF SILICAFUMES	545	24.2
4	7.5% REPLACEMENT OF SILICAFUMES	575	25.6
5	10% REPLACEMENT OF SILICAFUMES	690	30.7

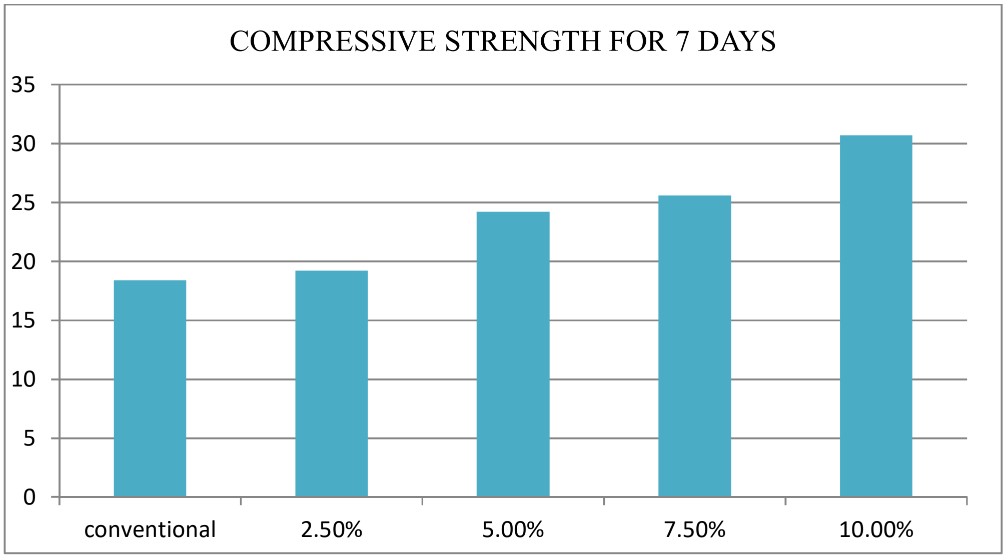

Chart.1 Compressive Strength for 7 days

Table 4: COMPRESSIVE STRENGTH OF CUBE FOR 14 DAYS

SL NO:	SPECIMENS	LOAD (KN)	COMPRESSIVE STRESS (N/MM^2)
1	CONTROLLED SPECIMEN	485	21.6
2	2.5% REPLACEMENT OF SILICAFUMES	550	24.4
3	5% REPLACEMENT OF SILICAFUMES	690	30.7
4	7.5% REPLACEMENT OF SILICAFUMES	775	34.4
5	10% REPLACEMENT OF SILICAFUMES	795	35.4

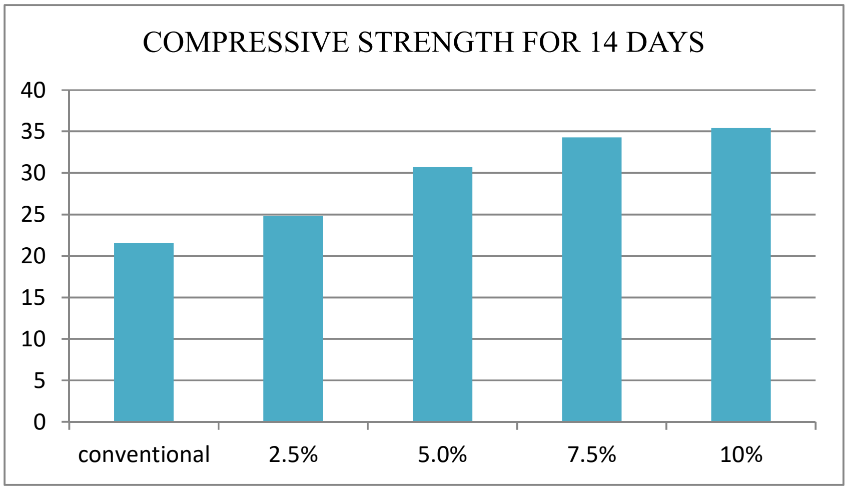

Chart.2 Compressive Strength for 14 days

Table 5: COMPRESSIVE STRENGTH OF CUBE FOR 28 DAYS

SL NO:	SPECIMENS	LOAD (KN)	COMPRESSIVE STRESS (N/MM^2)
1	CONTROLLED SPECIMEN	740	30.33
2	2.5% REPLACEMENT OF SILICAFUMES	690	30.7
3	5% REPLACEMENT OF SILICAFUMES	745	33.1
4	7.5% REPLACEMENT OF SILICAFUMES	795	35.3
5	10% REPLACEMENT OF SILICAFUMES	880	39.2

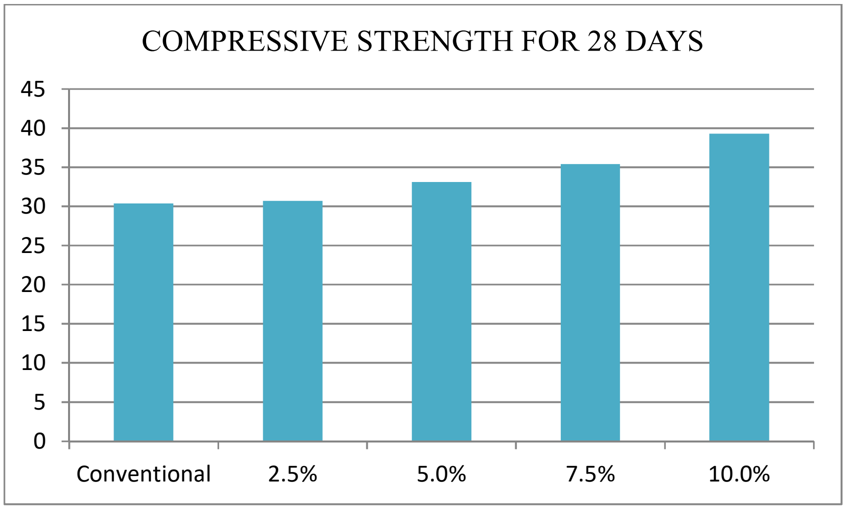

Chart.3 Compressive Strength for 28 days

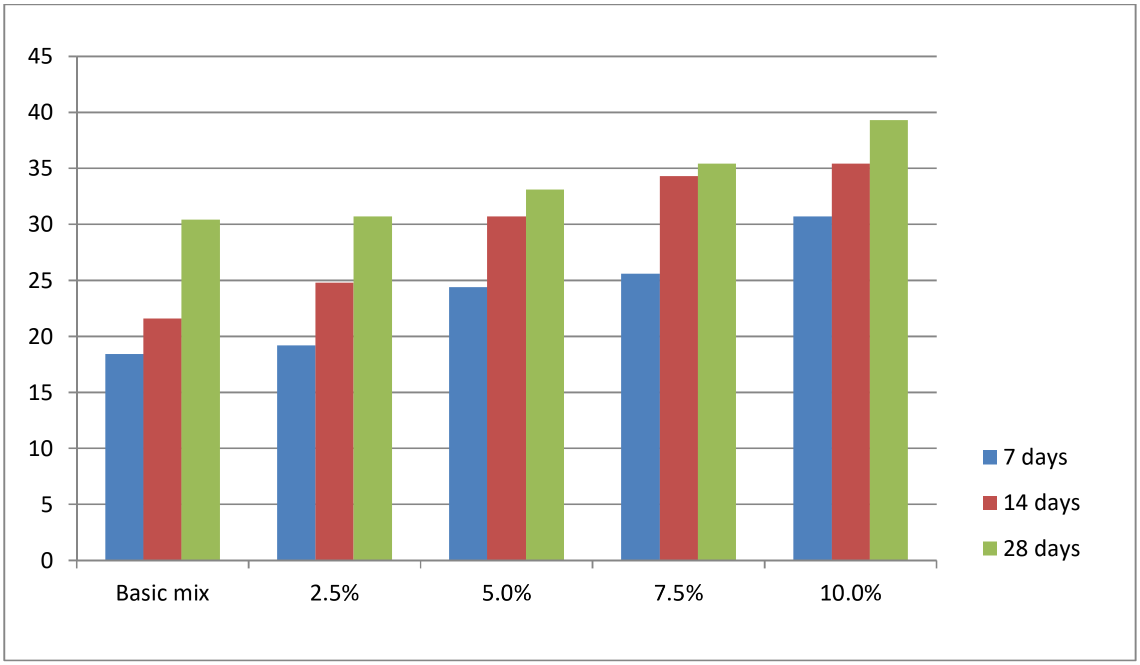

Chart.4 Comparison of 7, 14, 28 Days Compressive Strength

IV.3 SPLIT TENSILE STRENGTH

Table 6: SPLIT TENSILE STRENGTH OF CYLINDER FOR 28 DAYS

SL NO:	SPECIMENS	LOAD (KN)	COMPRESSIVE STRESS (N/MM^2)
1	CONTROLLED SPECIMEN	420	23.5
2	2.5% REPLACEMENT OF SILICAFUMES	435	24.6
3	5% REPLACEMENT OF SILICAFUMES	470	26.6
4	7.5% REPLACEMENT OF SILICAFUMES	520	29.4
5	10% REPLACEMENT OF SILICAFUMES	570	32.25

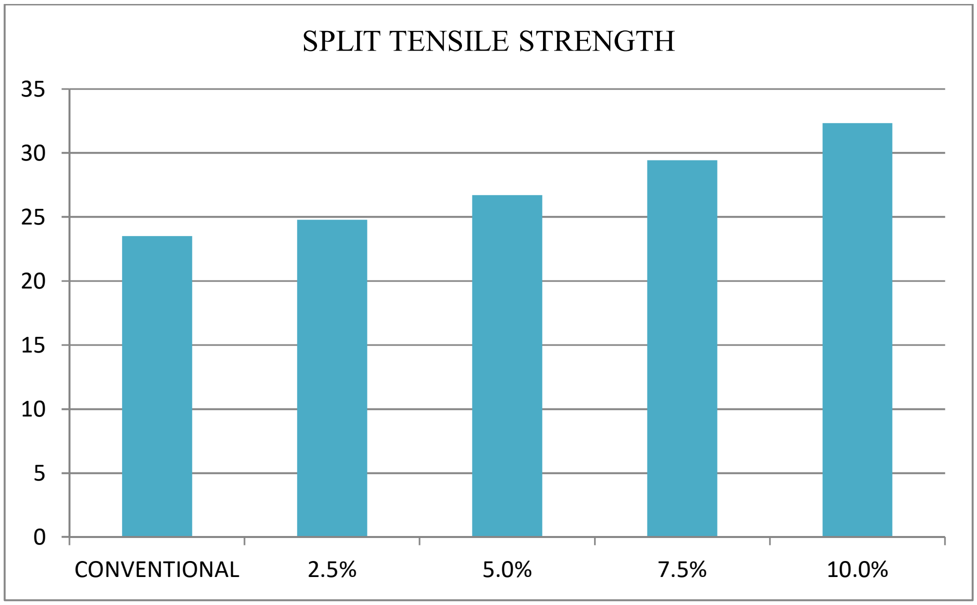

Chart.5 Split Tensile Strength

Table 7: Percentage of Materials

Materials	Cement %	Silica fume %	Cement (kg/m^3)	Silica fume (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	W/C Ratio
C	100	0	405	0	542	1234	0.46
SF 2.5%	97.5	2.5	394.88	10.12	542	1234	
SF 5%	95	5	384.75	20.25	542	1234	
SF 7.5%	92.5	7.5	374.63	30.37	542	1234	
SF 10%	90	10	364.51	40.49	542	1234	

V. CONCLUSION

Conclusions presented in this section are based on this particular research work. For clarity, the conclusions have been grouped into subsections, focusing on the laboratory tests. That included two different types; compression and split strength. Based on the results of this investigation, the following conclusions can be drawn

V.1 THE COMPRESSIVE STRENGTH

- It is possible to produce HPC using materials which are available at the local markets if they are carefully selected and achieving mix composition in grain size distribution that will achieve a minimum compressive strength of 35 MPa at 28 days. Such concretes can be produced with crushed basalt, sand and silica fume as the mineral admixture.
- Because of a larger amount OPC cement plus silica fume used in the HPC concrete mixtures along with a relatively low W/C ratio, the strength development of the concretes is much more rapid in the first 7 days.
- The compressive strength increases as the unit weight increases. Results indicated that the hardened unit weight for HPC ranges from 2511 to 2530 kg/m3, and 28 days compressive strength ranges from 122 to 132 MPa.
- The slump value for the UHPC mixes has an average about 80 – 150mm. This was achieved by adding the 5 % dosage of the super plasticizer.

V.2 THE SPLIT TENSILE CYLINDER STRENGTH

- As the compressive strength increases the splitting cylinder strength also increases.

- The ratio of the splitting cylinder strength to compressive strength decreases as increase the compressive strength increases.

V.3 THE SILICA FUME DOSAGE

- The use of the silica fume effectively increases the compressive strength of the concrete due to the improvement in the bond between the cement and the surface of the aggregate through the chemical reaction between silica fume and the CH resulting from the hydration of cement
- The use of silica fume is necessary for the production of HPC. The cube compressive strength studies indicate that the optimum percentage of silica fume is about 15%.
- An increase in silica fume content leads to a decrease in the slump of fresh concrete.
- The density of HPC increases as of silica fume content increases.

VI. REFERENCES

1. Varzinskas, Visvadas; Jurgis Kazimieras Staniškis, Alis Lebedys, Edmundas Kibirkštis, Valdas Miliūnas (2009). "Life Cycle Assessment of Common Plastic Packaging for Reducing Environmental Impact and Material Consumption". Environmental Research, Engineering and Management **50** (4) 57–65. Retrieved 21 September, 2012.
2. Mikell P.Groover, Fundamentals of Modern Manufacturing, John Wiley & Sons, 2002 U.S.A, ISBN 0-471-40051-3
3. Callister W.D. Jr., Materials Science & Engineering an Introduction, John Wiley & Sons, 2003 U.S.A, ISBN 0-471-22471-5
4. Lomborg, Bjørn (2001). The Skeptical Environmentalist Measuring the Real State of the World. p. 138. ISBN 978-0-521-80447-9.
5. "The History of Concrete". Dept. of Materials Science and Engineering, University of Illinois, Urbana-Champaign. Retrieved 8 January 2013.
6. Lancaster, Lynne (2005). Concrete Vaulted Construction in Imperial Rome. Innovations in Context. Cambridge University Press. ISBN 978-0-511-16068-4
7. Henry Cowan The Master builders, New York 1977, ISBN 978-0-471-02740-9
8. History of Concrete. Ce.memphis.edu. Retrieved on 2013-02-19. Robert Mark, Paul Hutchinson "On the Structure of the Roman Pantheon", Art Bulletin,
9. Nick Gromicko and Kenton Shepard. "The History of Concrete". The International Association of Certified Home Inspectors (InterNACHI). Retrieved 8 January 2013.
10. "Evaluation of Electrically Conductive Concrete Containing Carbon Products for Deicing". ACI Materials Journal. Retrieved 1 October 2012.
11. "Ready Mixed Concrete Production Statistics". NRMCA-National Ready Mixed Concrete Association. Retrieved 10 January 2013.
12. Garrett, P.R. (1992). Defoaming. Theory and Industrial applications. USA CRC Press.. ISBN 0-8247-8770-6.