HIGH PERFORMANCE CONCRETE USING QUATERNARY BLEND

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ABSTRACT-- Concrete is probably the most extensively used construction material in the world. The addition of SCMs in concrete has dramatically increased along with the development of concrete industry, due to the consideration of cost saving, energy saving, environmental protection and conservation of resources. However, environmental concerns both in terms of damage caused by the extraction of raw material and carbon dioxide emission during cement manufacture have brought pressures to reduce cement consumption by the use of supplementary materials. Use of these by products facilitates sustainable development. High Performance Concrete (HPC) is the latest development in concrete. It has become more popular these days and is being used in many prestigious projects. Blending of a large amount of waste materials such as fly ash, micro silica, rice husk ash (RHA), GGBS, etc. is being done in large extents in the manufacture of High Performance Concrete (HPC). A lot of work has been done on replacement of cement with fly ash and micro silica, which have shown good results with respect to strength and durability. The existing blending methodology of binary blending (mixing one Supplementary Cementitious Material (SCM) with cement) and ternary blending (mixing two SCMs with cement) has improved the performance of concrete. But there is a scope of further improvement by using quaternary blend which can further improve properties of concrete. The present paper deals with the study of properties namely workability and compressive strength of M80 grade HPC using quaternary mixes incorporating Cement, Fly Ash, Micro Silica and Ultrafine Slag along with PCE based super plasticizer.

Keywords- High Performance Concrete, Quaternary blend, Micro Silica, Ultrafine Slag, Sustainable Development

1. INTRODUCTION

Concrete presently is most widely used construction material in the world. The concrete has many good properties like ease in casting, good compressive strength, versatility and good durability. Simple as well as complicated structures can be casted by using concrete. Concrete produced should be strong enough to carry design load and durable enough so that structure constructed lives for its design life. Main constituent of concrete is cement which is produced from limestone. As per U.S Geological survey report world cement production was 3400 million tonnes in year 2011. It is expected that cement requirement will grow three fold to 3.2 billion tonnes by year 2015 [1]. The cement production is an expensive process and it also emits carbon dioxide (CO_2). The researchers have estimated that for production of 1 ton of cement, nearly 1.5 tonnes of earth minerals are consumed and 1 ton of CO_2 is emitted in the atmosphere due to burning of fuel and calcination of limestone [2].

One of the efficient methods to conserve the Mother Nature's resources and reduce the environmental impact is to use Supplementary Cementitious Materials (SCMs) by replacing OPC in concrete because most of SCMs are pozzolanic in nature and hence they are helpful in increasing later strength of concrete. Blending of SCMs with cement has many advantages such as saving in cement, recycling of waste products, increase in physical properties of concrete and reduce environmental impact through reduce green house gases production. Most of the SCMs are waste materials produced as by product or waste from different industries, which are pollutants when dumped into land or thrown into water bodies. So blending them in concrete becomes safe disposal method for them. Some SCMs are Fly ash, Ground Granulated Blast furnace Slag (GGBS), Micro Silica (Silica Fume) and Rice Husk Ash (RHA). [3]

Supplementary cementitious materials are materials, which in itself possesses little or no cementitious properties but, in the presence of moisture chemically react with calcium hydroxide to form compounds possessing cementitious properties. Different SCMs are fly ash, silica fume, GGBS, Rice husk ash, Metakaolin, etc

Fly ash improves the performance and quality of concrete. Fly ash affects the plastic properties of concrete by improve workability; reduce water demand and reducing heat of hydration. Due to spherical shape of particles, it can also increase workability of cement while reducing water demand. Fly ash possesses very less to no cementitious properties, but in presence of moisture it reacts with calcium hydroxide to form Calcium silicate hydrate (CSH) which adds to the strength. [4]

The specific gravity of Micro Silica is 2.22, but may become higher when the silica content is lower. The particles are extremely fine and having diameter ranging between 0.03 and 0.3μm. The high surface area of Micro Silica would increase the water demand. The use of Micro Silica can reduce bleeding and improved cohesion of the mix. The cohesiveness of concrete containing SF is good for pumping and for underwater concrete. [5]

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Ground granulated blast furnace slag has lower heat of hydration, hence generates less heat during concrete production and curing. As a result, GGBS is a desirable material to utilize in mass concrete placements where control of temperatures is an issue. Percentage replacements by weight of GGBS for cement have ranged from 10 to 90%. [6]
Ultrafine Slag is a new generation, ultrafine, low calcium silicate product, manufactured in India. It has distinct characteristics to enhance 'performance of concrete' in fresh and hardened stages. It can be considered and used as practical substitute for Silica Fume (Micro Silica) as per the results obtained. If the advantages of Ultrafine Slag are observed in the concrete mix design, the initial rate of strength development was found to be increased or similar as that of Silica Fume. [7]. Keeping all these things in view, an attempt has been made in the present paper to study of properties namely workability and compressive strength of M80 grade HPC using quaternary mixes incorporating Cement, Fly Ash, Micro Silica and Ultrafine Slag along with PCE based super plasticizer.

2. RESEARCH METHODOLOGY

2.1 *Materials*

The materials used in the research for producing HPC, along with their various properties have been given in Table 1.

Table 1 Materials

Material	**Sp.Gravity**	**Grade/Type**	**Source**
Cement	3.15	53 OPC	Ambuja Cement
Fly Ash	2.3	Class F	AshTech
Micro Silica	2.3	Densified	Elkem
Ultrafine Slag	2.9	-	Alccofine- 1203
Fine Aggregate	2.72	Zone II	Crushed Aggregate
Coarse Aggregate	2.84	57% - 20mm 43% - 10mm	Locally Available
Chemical Admixture	1.13	PCE based	Master Glenium by BASF

2.2 *Mix Proportions:*

Mix proportion of M80 grade HPC mix was obtained by making certain modifications in the mix proportion arrived at using the guidelines of IS Code method. The mix proportion was obtained without considering any replacement of cement by SCMs.
After several trials, a cement content of 650 kg/m^3 and water-binder ratio of 0.24 were finalized based on 28 days compressive strength gain of HPC mix and desired workability properties (slump flow). Thus, for making HPC mixes the mix proportion was as follows:
Cement (Binder) content - 650 kg/m^3
Water-binder ratio- 0.24,
Fine Aggregate- 695 Kg/m^3
Coarse aggregate- 981 Kg/m^3
Water- 154 Kg/m^3
Chemical Admixture- 1.25%

2.3 *Preparation of HPC Mix*

The required quantities of all the ingredients were taken by weigh batching. Mixing of the ingredients was done in a pan mixer as per the standard procedure. A reference mix was prepared using a water-binder ratio of 0.24 and suitable super plasticizer content was added in order to get desired workability.

The workability of the concrete was studied by conducting slump flow tests as per the standard procedure (Fig.1 & Fig.2). Standard cube specimens of 150mm x 150mm x 150mm size were casted using the procedure described in IS Code (IS: 516–1959) and were immediately covered with plastic sheet and kept there for 24 hours and then released in water tank for 28 days curing.

All the HPC mixes were prepared using the same mix proportion and water-binder ratio and considered for study of workability and strength properties of HPC mixes.

Fig.1

Fig.2

Slump Flow Test

2.4 *Testing of specimens*

After 7 days, 28 days and 56 days of curing period, the specimens were taken outside the curing tank and were tested under a compression testing machine of 3000KN capacity for compressive strength.

Fig.3 Compression Testing Machine

3. RESULT AND DISCUSSION

The results for slump flow test and compressive strength for 7days, 28 days and 56 days are given in Table 2 and Table 3 respectively.

Table 2 Slump Flow Results

Mix No.	Mix proportion				Workability (Slump Flow)		Admixture Dosage (%)
	Cement	Fly Ash	Alccofine-1203	Micro Silica	Initial	60 Min	
N1	100	-	-	-	690	360	1.3
T2	70	20	10	0	720	640	1.1
T3	70	20	0	10	690	390	1.35
Q4	70	20	5	5	700	530	1.2
T5	65	25	10	0	720	650	1.1
T6	65	25	0	10	650	380	1.3

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Q7	65	25	5	5	700	550	1.15
T8	65	20	15	0	730	660	1.1
T9	65	20	0	15	680	400	1.35
Q10	65	20	7.5	7.5	710	560	1.2
T11	60	25	15	0	720	670	1.1
T12	60	25	0	15	690	410	1.3
Q13	60	25	7.5	7.5	700	610	1.2

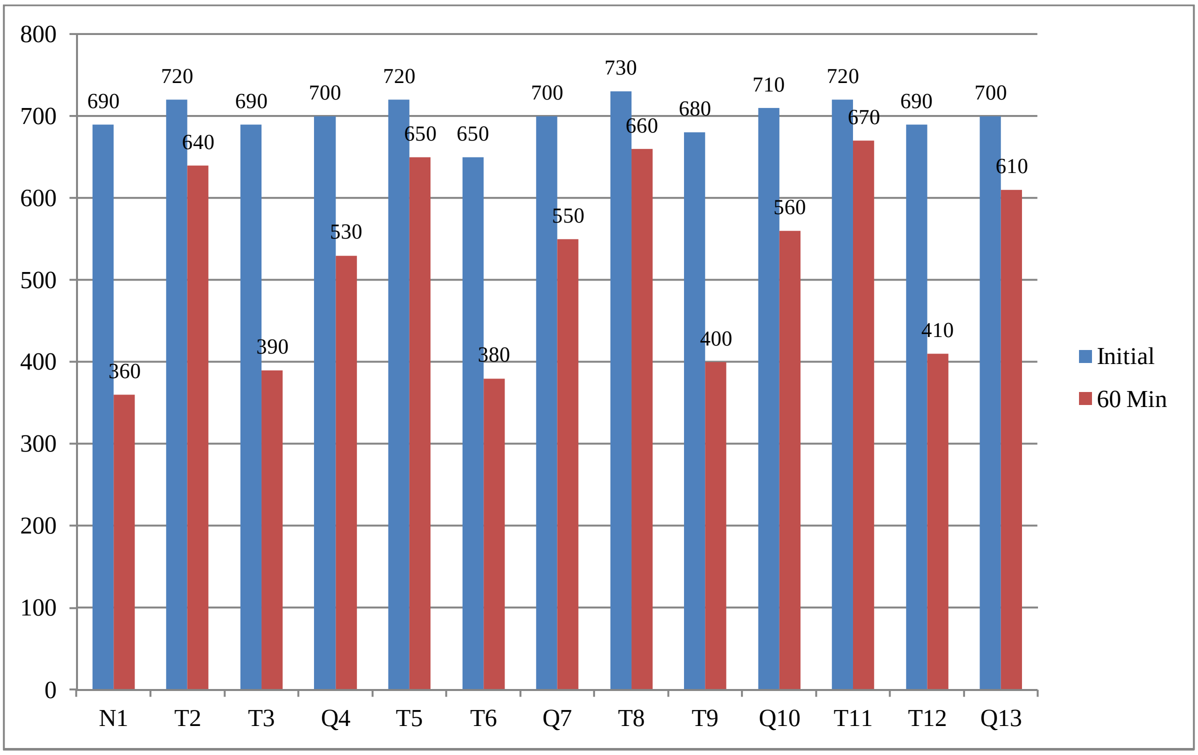

Fig.4 Workability

Table 3 Compressive Strength Results

Mix No.	Mix proportion of Binder				Strength @7days (MPa)	Strength @28days (MPa)	Strength @56days (MPa)
	Cement	Fly Ash	Alccofine-1203	Micro Silica			
N1	100	-	-	-	72.23	84.65	87.5
T2	70	20	10	0	60.46	82.23	88.74
T3	70	20	0	10	55.11	83.11	88.96
Q4	70	20	5	5	60.31	84.27	90.78
T5	65	25	10	0	59.68	81.29	90.11
T6	65	25	0	10	54.23	81.11	88.34
Q7	65	25	5	5	58.29	82.48	91.62
T8	65	20	15	0	57.63	82.2	89.46
T9	65	20	0	15	54.16	82.71	88.62
Q10	65	20	7.5	7.5	59.41	83.73	92.17
T11	60	25	15	0	57.72	80.78	91.33
T12	60	25	0	15	53.91	81.09	90.24
Q13	60	25	7.5	7.5	61.86	82.83	93.69

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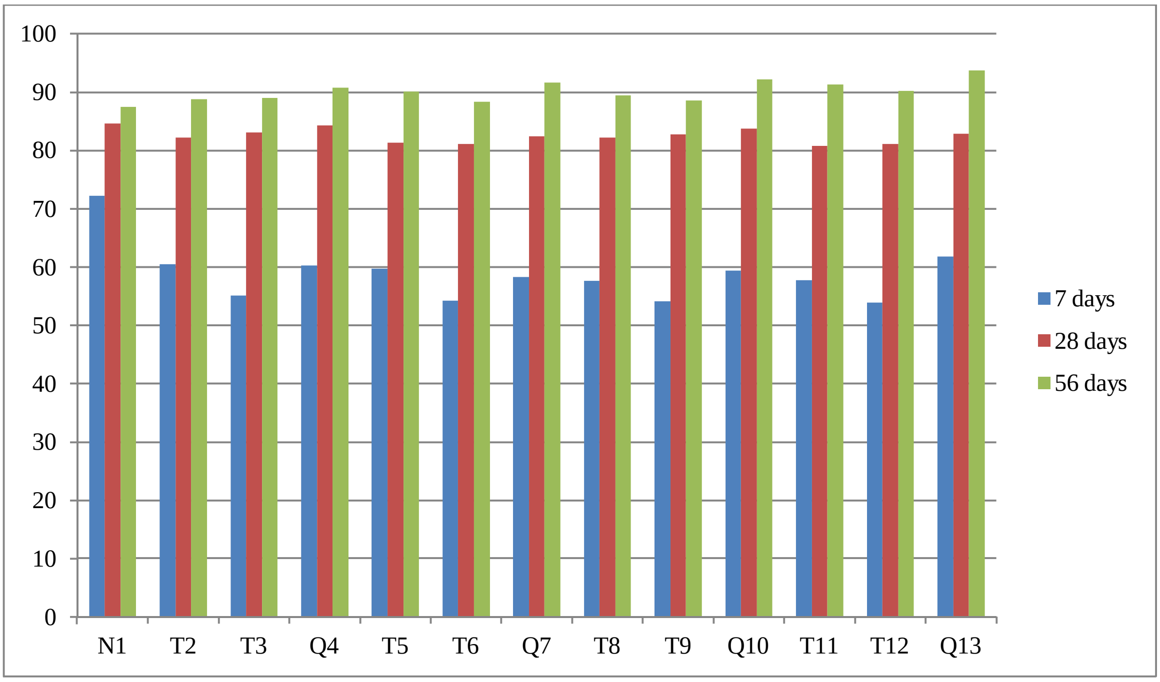

Fig.5 Compressive strength

The results show that for ternary mix of Micro Silica the superplasticizer dosage required for obtaining slump flow of 700 mm is higher than that in Ultrafine slag. The ternary mix of Ultrafine slag require less superplasticizer dosage for 700 mm slump flow. The quaternary mix required superplasticizer dosage between Micro Silica and Ultrafine Slag. For Micro Silica slump flow after 60 min retention shows drastic drop where as it is good in case of Ultrafine Slag and quaternary mix. Compressive strength results shows that quaternary mix has better early strength than ternary mixes of Micro silica and Ultrafine Slag. 56 days strength is also high in quaternary mix.

4. CONCLUSION

The quaternary mix gives better early strength than ternary blend. The quaternary blend solves problem of bleeding of ternary mix with Ultrafine slag and also the decrease in workability in case of ternary blend with Micro Silica. The quaternary mix also requires less quantity of superplasticizer than ternary blend of Micro Silica, so there is substantial saving in cost also. So quaternary blend is a blend is a better option than ternary blend, which has some limitations. And there is substantial saving in quantity of cement, so less production of cement is required so environmental degradation is reduced, thus it also helps in sustainable development.

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