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A Study of Composite Cements Performance in Concrete using Ultrafine Supplementary Cementitious Materials (Alccofine 1203 or Micro silica)

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Abstract:- Concrete is the unavoidable man-made material in the field of construction. The raw materials production are poisonous in nature. Concrete is the primary base material for construction. The construction work is contributing to global warming to great extent. During the production of cement, it contributes that 1 MT of cement production and emits 0.6-1Mt of Co2 emission. The cement and steel manufacturing process contributes nearly about 19 - 20% of CO2 emissions in India. This is one form factor to contribute towards global warming. The aim is to reduce negative impact in the construction industry by replacing the conventional OPC Cement usage through the Hybrid single component cement known as Composite Cement. The usage of standardized cementitious material with optimum content in the design mix makes us achieve the targeted performance of concrete with full proof. I.e. it helps in easy handling, variation of multiple raw materials, and avoids the manual errors in handling multiple materials during the execution. The optimum content can control the cost of construction of the overall project. The key to accepting this hybrid concrete is that we can standardize its performance easily. The modern hybrid characteristic is to meet the initial properties of blended concrete against OPC mixes. At present, the conventional blending of Flyash / Slag / Supplementary cementitious material at the site is a very low percentage in concrete (less than 25%) average. The uplift of acceptance of higher usage of SCM in concrete via Hybrid composite cement can have a better impact on the reduction of global warming. Considering the challenges we have offered the twin benefit of more economical and greener in construction aspect the acceptance level shall be lifted in coming days.

Technically in mass concrete, the designers have even started specifying the later strength at 90 days for Concrete i.e. especially structure like Rafts. Even now the durability aspects are being treated with the most care. A lot of SCM and geo-polymer concretes are being made to reduce the negative impact of concrete. The next era in concrete has been started.

Technical Edge

- **Ideal single component cement is suitable for both project and retail construction.**
- **This gives us the benchmark and easy to track the performance of concrete.**
- **The one component of cement makes us have easy application.**
- **It gives the scope to make all our structures more durable irrespective of the method of production. i.e. either manually or through batching plant**

Keywords:- *Composite cement, Optimisation, Triple bend, Durability of concrete, ternary concrete mix.*

I. INTRODUCTION

Modern concrete consist of cement, supplementary material, Mineral admixture, Coarse aggregate, fine aggregate, admixture and water. Cement is the key ingredient in concrete which defines the ultimate character and performance of the end product “Concrete”. As cement role is significant in this process, the ultimate performance of cement needs to be extracted. That is the performance of concrete from fresh concrete, harden concrete and durability needs to be analysed to meet the modern requirements. Keeping the cost with in the budget planed. This change in all the aspect will contribute both factor made mass construction and small projects. The benefit of the modern improvement shall be made available on ground. The small uplift of performance in cement can have a major impact on the construction industry.

This improvement of cement impacts gives a way to optimise the concrete cost of construction, with ultimate performance. Even all special modern day requirements needs such improved properties namely early setting, free flow, Special concrete such as SCC, fast rate of strength gain and high durability aspects etc. Technically it is achieved by working with the grading of cementitious content. I.e. we are trying and reducing the spacing or removing the void between the cementitious materials using ultrafine materials. Here we have compared the concrete behavior using standardised Chettinad Composite cement (Ternary blend (OPC, PFA and Slag)) with ultrafine materials either Micro silica (MS) or Ground granulated blast furnace slag (GGBS). This ready to use single component cement removes the manual error or variation while handing multiple

supplementary cementitious materials. This has the dual advantage of PFA and Slag with standardised properties hence it can be used for all purposes of construction. Both below the ground level and above the ground (super structures). In short it can give resistance against corrosion and chemical attack.

- **Combination 1:** Chettinad Composite cement with blend of Ground granulated blast furnace slag (GGBS), and Pulverised fuel ash (PFA/Flyash) with Alccofine 1203 (Ultrafine GGBS)

- **Combination 2:** Chettinad Composite cement with blend of Ground granulated blast furnace slag (GGBS), and pulverised fuel ash (PFA/Flyash) with Micro Silica (Alloy Manufacturing)

In commercial projects either ultrafine combination is used as per the environment, costing, and structural specification, based on the element, etc. In general construction sites, handling multiple binding materials was almost impossible without standardized composite cement because it is highly difficult to bench mark the behavior of 3 variables while we blend manually. Traditionally hence they follow ordinary Portland cement earlier. The modern hybrid blended cement make the ease to achieved complex properties of concrete along with durability.

- **Work:** In real time construction though we try to promote the blended mixes, most of the case prefers OPC Mixes to achieve high early strength. This project is to overcome the initial strength gain in blended "Composite Cement" using ultrafine material fine materials called "Alccofine" or "Micro silica". We have studied the concrete behaviour while using composite cement with various percentages of ultra-fine materials either Alccofine or Micro silica, 5% 7%, and 10% respectively. The results shows better performances with 10% blend with Alccofine and above 10% for micro silica.

II. LITERATURE REVIEW

A. Investigations on Composite Cement containing Indian fly ash and GranulatedBlast Furnace Slag by S K Chaturvedi, D Yadav*, S Vanguri*, V P Chatterjee*, A K Sahu** and A Pahuja**

In this paper the investigation reveals that Composite cement blends of clinker, fly ash and GBF slag were prepared and evaluated for physical properties and subjected to hydration studies.

- The compressive strength values of composite cement blends was marginally lower at Initial ages and improved at later ages compared to the reference samples.
- The reduction in compressive strength at initial ages may be attributed to dilution effect and the improvement in strength at later ages was due to synergetic effect of addition of fly ash and GGBS slag.
- Composite cements with performance equivalent to control PPC or PSC can be prepared by using mix of fly ash and GBFS in the range of 5-35% and 20-50% respectively.
- It is observed that the initial parameter of concrete using composite cement needs to improve to have better acceptance across all segment of construction.

B. Triple blend -Composite usage in Concrete – 2019 Evaluating strength parameters of triple blended concrete using composite cement.

Vasudev MV, Associate professor Dept. of civil, Pallavi P, Associate professor Dept. of civil and Mithun ,PG student Nitte Meenakshi Institute of technology.

Grade of Concrete – M30

Triple blend with different combination - F15G40

C100, C50G50, C35F30G35, C35F15G50, C35F25G40, C35F35G30, **C45F15G40**, C45F25G30, C55F15G30

The targeted fresh concrete workability in the range of 80 – 95 MM, Compressive strength for M 30 grade of concrete was in the range of 20 Mpa to 30 Mpa at 7 days and in the range of 30 Mpa to 40 Mpa at 28 days.

Mix of **M30 /C45F15G40** Vs CC 7 D – 15/30 and Tensile Strength reported as TS – 2.5/2.6.

The durability was reported **M30 /C45F15G40** Vs CC 28 D –40/46 **Permeability** – 15 / 19 mm TS – 3.6/4

Input observed: *50 -55% replacement can be supported in composite cement.*

C. Triple blend usage-Composite usage in Concrete – 2014 Triple blending of cement concrete with fly ash and ground granulated blast furnace slag

1K.V.Pratap, 2M.Bhasker, 3P.S.S.R.Teja They have studied the blending ratio between Flyash and GGBS. i.e. 20: 80, 40: 60, 60:40 & 80: 20. They have observed the rate of strength gain from 7th day to 28 day. Grade of Concrete – M60 (T.CEM = 590 Kg/Cum)

Better result observed with 40 Flyash: 60 GGBS. They have reported about 19.63 % increment in CS from 7 to 28 days. (52.52 – 43.9 = 8.62), 8.62/43.9 = 19.63

TS also has increment of 19.94% 7 Day 43.78 / 43.9 & 28 Day 68.55 /65.14 CSS – At 28 days (5.23% Higher than CC)

Input observed: *GGBS is contributing later strength gain i.e. 7 to 28 days. 18 -20%*

D. Use of Micro Silica in Concrete – 2016

Akshaykumar Hirapara, Kaushal Kathiriya & Brijesh Ramani U.G. Student

Jatinkumar B. Patel Assistant Professor Department of Civil Engineering SVBIT, Gandhinagar, Gujarat SVBIT, Gandhinagar, Gujarat

They have studied the usage of Micro Silica usage in concrete, the concrete grade was – M25 (T.CEM = 432.55 Kg/cum)
MS – Variation - M25 - 3%, 5%, 7%, 9%, 11%, 13% and 15%
Slump – Variation – 48 to 65 MM (48MM - 15% – CC)
MS - 11% (R) = 44.78 Mpa / 32 Mpa (At 28 days)

Compressive Strength is increase up to 25% to 30% more, compare to ordinary M25 grade concrete.

Input observed : *25 -30% improvement CS in Replacement 11% MS.*

E. Experimental Investigation on Durability Properties of Self Compacting Concrete by Partial Replacement of Fly Ash and GGBS E.sreenivasulu1, A. Ramakrishnaiah2
Total Cementitious – 453.2 Kg / Cum
Better flow observed with A4 Mix.
The CS is 30.63 Mpa at 28 days against 43.4 Mpa (CC).

Mix Designation	Proportions of Binding Materials
A1	100% cement
A2	90% cement + 10% fly ash
A3	85% cement + 10% fly ash + 5% GGBS
A4	80% cement + 10% fly ash + 10% GGBS
A5	75% cement + 10% fly ash + 15% GGBS

Table 1: Proportion of cementitious materials

- **Normal curing**
  In 60 days CS is 41.60 Mpa against 33 Mpa (CC).

- **Acid Attack**
  In 60 days CS is 48.06 Mpa against 37.93 Mpa (CC).
  Alkalinity Test

  In 90 days CS is 42.30 Mpa against 38.50 Mpa (CC).
  Alkalinity Test

  In 90 days CS is 41.36 Mpa against 35.53 Mpa (CC).
  Sulphate Attack

RCPT value A4 & CC Mix 28 D – 1088.7 / 1672.5(CC)

Mix 90 D – 785.89/1296.7 (CC)

- ***Input observed:***
  - *GGBS & Flyash blending to be increased to have better durability.*
  - *To compensated the higher blending the ultra-fine material is substituted. (Alccofine / MS)*
  - *It is reported and found suitable for special concrete also.*

F. Recent developments in the Indian concrete industry in the use of ggbs in concrete at rmc batching plants as partial replacement to opc cement and its effects on concrete durability.
Manjunatha L R- JSW Cement,Yoga nanda, M.V-JSW Cement and Sandhya R Anvekar-Visvesvaraya Technological University

- **Grade of concrete's:**
  They have arrived the mix from M 20 to M 50 grade. They have compared PFA mix with GGBS Mix.

- **Input observed:**
  - GGBS is can give better CS than Flyash.
  - It can be used in different location and ambient.
  - Early strength can be obtained by using higher binder content, as ggbs is hydrophobic in nature.

G. Experimental investigation on strength properties of self-Compacting concrete by partial replacement of fly ash and ggbs Pammi haripriya[1], p.Anil kumar[2]
In this paper they have used different combination of concrete mixes for self-compacting concrete. They have found the compressive strength, flow test and durability test Acid resistance, sulphate attack and alkalinity test.

- **Input observed:**
  - The compressive strength is better with 50 OPC: 50 Slag.
  - SCC – Special Concrete has been considered.
  - The concrete with 50% replacement can have better performance even under durability test (Acid resistance, sulphate attack and alkalinity test).
  - GGBS is supporting the all tough conditions.

H. Evaluation of Strength Behaviour of Self-Compacting Concrete using Alccofine and GGBS as Partial Replacement of Cement Dr.S. Kavitha and T. Felix Kala*
In this paper they have investigated the performance of Tertiary Concrete Mixes in special concrete "self-compacting concrete".

- **Input observed:**
  - They used ggbs 30% along with Alccofine (Early strength). They have varied the Alccofine percentage from 10, 10, 15 and 20 percentages. They have tested the SCC concrete performance and the initial strength.
  - The result obtained show that 10% addition of Alccofine has given the best performance impact. It

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also confirms Alccofine and ggbs combination can be used as performance enhancers.

I. Compressive strength of binary and ternary concrete made with opc 53-s

R. Muni naik1, N. Ramakrishna2, Prof. A.S. Rao3 M40 Grade using special grade cement 53-S Four mixes by replacing cement content of 0%, 20%, 30%, 40% with GGBS, Four mixes by replacing 0%, 20%, 30%, 40% cement content with Fly Ash (class C), and considered in the study three mixes using GGBS and Fly Ash without cement content viz(G25+F15)%, (G20+F20)%, (G15+F25)% one mix with only cement content(G0+F0)% was also done for compaction. The compressive strength tests are conducted on specimens cured for 7,28,56,91 days.

% of the GGBS	7days N/mm^2	28 days N/mm^2	56 days N/mm^2	91days N/mm^2
G0&F0	36.3	48.6	49.4	51
G25&F15	31	45	48.2	49.5
G20&F20	29.2	43.2	48.8	51.7
G15&F25	28.4	41.4	51.8	53.3

Table 2: compressive strength

M 40 – 420 kg of cem & CS

- **Input observed:**
  - Mix G 15&F25 showed better result. **i.e. replacement of 40 % is able to meet the requirement.**

III. METHODOLOGY - EXPERIMENTAL

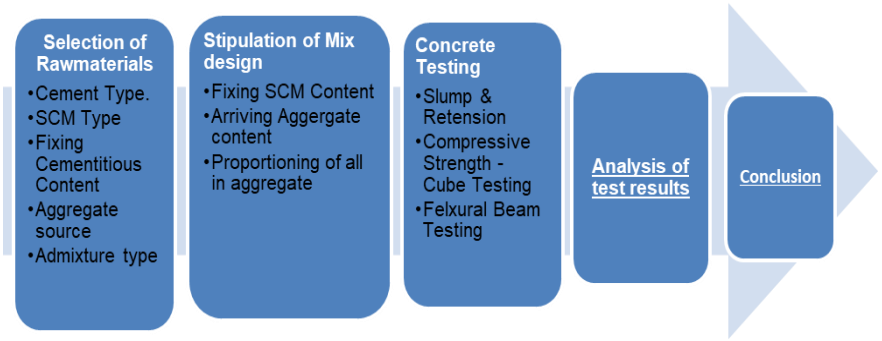

Table 3

A. Costing Table

Selection of cementitious material for M40 grade has been done consider the below aspects

- Costing : In general, the cementitious content of the concrete is fixed based on the guide as per IS 10262: 2019 fig or IS 456: 2000 Table 5. Considering the minimum cement content for grade we have used the ultra-fine material in various percentages (5% 7%, and 10%) to understand the impact in early age with minimum total cementitious content.
- Cost dynamic show the marginal variation between the blended cement mixes (Composite Cement) Vs Blended cement with ultrafine SCM.
- Blended mix with ultrafine SCM vs Ordinary Portland cement (OPC) mix show a potential saving of R.s. 168 per cum. This is about 5 – 5.5 % of Cost reduction against pure OPC Mix.

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B. Costing Table

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- Blended mix with ultrafine SCM vs Ordinary Portland cement (OPC) mix show a potential saving of R.s. 168 per cum. This is about 5 – 5.5 % of Cost reduction against pure OPC Mix.
- No much Price difference even after the inclusion of ultrafine material. Very importantly the initial properties have been achieved with minimal Cementitious content.

S.No	Trial Mix Reference Number	Cementitious Content Per Cum Kg/Cum					
	Duration	CEM	GGBS	MS/ Alccofine	T.CEM Kg/Cum	CC Cost	Mix Type
1	T0-OPC 53 /M40	440	0	0	440	3520	OPC Mix (OPC 53)
2	T1-CC40	440	0	0	440	3344	(CC)
3	T2-CC40CC&8AF	335	0	30	365	3296	CC + 8.23 % ACF
4	T3-CC40CC&10AF	330	0	35	365	3383	CC + 9.59 % ACF
5	T4-CC40CC&12AF	320	0	45	365	3685	CC + 12.35 % ACF
6	T5-CC40CC&08MS	335	30	0	365	3146	CC + 8.23 % MS
7	T6-CC40CC&10MS	330	35	0	365	3208	CC + 9.59 % MS
8	T7-CC40CC&12MS	320	45	0	365	3332	CC + 12.35 % MS

Table 4: Cementitious proportion and Costing of Binder

IV. REPLACEMENT LEVEL OF SCM WITH RESPECTIVE TO ITS PROPERTIES

- **Alccofine 1203:** From the existing other literature say the optimal usage of Alccofine 1203 is in the range of 10 -12 %. Alccofine 1203 more cementitious properties SCM.
- **Micro silica (MS):** The recommended blending is subjected to the application. As we are targeting for early strength the recommend dosage is 5 -10%. As in our case the blended cement has lower cementitious content the dosage of MS is taken on higher side, not exceeding the cost of Alccofine 1203 mix. The performance of fresh and harden concrete is compared.

Chemical Analysis of Cement & SCM						
S.No	Characteristic	Cement (%)	UF GGBS (%)	Silica Fume (%)	Metakolin (%)	Dirk 60 fly ash (%)
1	Calcium Oxide (CaO)	62.17	31.47	1.35	0.68	2.24
2	Silica (SiO.)	18.25	26.78	89.6	62.68	62.97
3	Alumina (Al.O.)	6.32	21.86	0.85	29.79	26.88
4	Ferric Oxide (Fe.O.)	7.69	10.09	1.99	1.32	3.6
5	MagnesiumOxide(MgO)	1.3	1.03	1	0.35	0.77
6	Sulphuric Anhy (SO.)	2.3	-	1.41	-	0.4
7	Sodium Oxide (Na.O)	0.37	0.06	0.05	0.25	0.26
8	Potassium Oxide (K.O)	0.2	0.1	0.11	0.61	0.91
9	Total loss of ignition	1.4	1.97	0.59	3.02	0.31
10	Manganese trioxide (Mn.O)	-	-	-	0.01	0.06
11	Titanium Oxide (TiO.)	-	-	-	1.01	1
12	Other Constituents	-	6.64	3.05	0.28	0.6

Table 3.2 Chemical composition of SCM

- **Impact of environment:** It is recommending using Alccofine 1203 all for the sub structure and superstructure. Alccofine 1203 is not preferred under corrosive environment however is overcome by using Composite cement. As Micro silica is preferred due silica rich in nature. Micro silica will have better resistance under corrosive environment. However as we have used the composite cement further details study would be recommended before we conclude the environment impact as whole.

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V. BEHAVIOR OF FRESH AND HARDEN CONCRETE

The workability (Slump value) and retention was better in terms of blending with Alccofine 1203. The blending of Micro silica was marginally lower. The better workability and retention was observed due to the composite cement properties. This has been studied with our earlier activity i.e. the study of only composite cement.

S.No	Trial Mix Reference Number	Workability (Slump Value - MM)			
	Duration	Control	Initial	60 Min	120 Min
1	T0-OPC 53 /M40 Control Mix	25	180	130	80
2	T1-CC M40 Composite Cement(CC) Control Mix	20	180	140	80
3	T2-CC40CC&8AF CC & Alccofine – 8%	25	190	130	80
4	T3-CC40CC&10AF CC & Alccofine – 10%	25	190	150	110
5	T4-CC40CC&12AF CC & Alccofine – 12%	25	190	130	80
6	T5-CC40CC&08MS CC & Micro silica – 8%	20	170	130	70
7	T6-CC40CC&10MS CC & Micro silica – 10%	20	170	140	90
8	T7-CC40CC&12MS CC & Micro silica – 12%	20	180	150	90

Table 4: Workability and Retention

VI. COMPRESSIVE STRENGTH

The Compressive strength was better in terms of blending with Alccofine 1203 the 90days result was higher than our targeted strength of M40 grade. We could able to achieve the strength of 2 grades (M60) strength at 90 days. The blending of Micro silica was marginally lower with the blend of 12%. The performance of micro silica is lower by 10% as compared to Alccofine 1203.

S.N	Trial Mix Reference Number	Compressive Strength Mpa				
	Age	1	3	7	28	90
1	T0-OPC 53 /M40 Control Mix	19.53	31.36	37.41	50	52
2	T1-CC M40 Composite Cement (CC) Control Mix	14.06	29.23	34.46	41.72	48.31
3	T2-CC40CC&8AF CC & Alccofine – 8%	28.12	33.54	45.11	54.83	57.21
4	T3-CC40CC&10AF CC & Alccofine –10%	37.13	43.27	48.44	55.66	59.54
5	T4-CC40CC&12AF CC & Alccofine – 12%	38.71	45.45	49.48	52.21	56.98
6	T5-CC40CC&08MS CC & Micro silica – 8%	23.9	29.16	40.95	50.12	53.73
7	T6-CC40CC&10MS CC & Micro silica – 10%	34.67	41.14	44.77	48.33	57.56
8	T7-CC40CC&12MS CC & Micro silica – 12%	36.7	44.24	46.96	50.92	54.09

Table 5: Compressive strength of composite cement with Alccofine and Micro silica.

VII. DURABILITY

The Durability was better in terms of blending with Alccofine 1203 the 90days result was higher than Mixes.

S.N	Trial Mix Reference Number	Durability			
		Water Penetration 28 Day	Water Penetration 90 Day	RCPT 28 Day	RCPT 90 Day
1	T0-OPC 53 /M40 Control Mix	13	13	4215	4212
2	T1-CC M40 Composite Cement(CC) Control Mix	11	10.7	447	430
3	T2-CC40CC&8AF CC & Alccofine – 8%	10	9	445	433
4	T3-CC40CC&10AF CC & Alccofine – 10%	7	6	416	405
5	T4-CC40CC&12AF CC & Alccofine – 12%	6	6	394	390
6	T5-CC40CC&08MS CC & Micro silica – 8%	11	10	490	484
7	T6-CC40CC&10MS CC & Micro silica – 10%	9	8	448	442
8	T7-CC40CC&12MS CC & Micro silica – 12%	6	6	410	400

Table 6: Durability (Water penetration & RCPT)

VIII. CONCLUSION

The objective of getting early strength with blended hybrid cement is achieved. The ultrafine supplementary cementitious material has been studied. The Alccofine 1203 having better cementitious properties while we blend with cement, possible due to its nature. It has better impact on improving the early strength. The micro silica impact is marginally lower result against Alccofine 1203. This could be the alternate for Alccofine 1203. In order to make the concrete more durable the cementitious content shall be increased by 10 – 20%. This can be studied in further trial as per the project requirement. This could be having better rate of strength again in later age. The cost is also available to increase the cementitious content as we have saving of 5% cost.

However the durability can't be compared with direct pricing, it is valued more than actuals. The objective of making even a hand mix concrete more durable at optimal cost is achieved with eco-friendly sustainable construction.

- Ultrafine materials are suitable for blending with composite or triple blend binders of concrete.
- Ultrafine material helps the triple blended concrete to overcome the higher early strength with lower cementitious material.
- Ultrafine material makes the concrete durable.

Future scope for the research work would be to derive minimum cementitious content table for various grades of concrete i.e. similar to our Minimum cementitious content given in IS 456, Table 5. This shall give the better clarity to real time designing.

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