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EFFECTIVE UTILIZATION OF INDUSTRIAL BY- PRODUCTS IN CONSTRUCTION INDUSTRY

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ABSTRACT

Now a days large number of studies are going on to improve the performance of concrete with the help of innovative chemical admixtures and supplementary cementitious materials .These materials used are majority by- products or industrial waste from other processes. This paper presents results of experimental investigations on effect of addition of industrial by products as partial replacement of cement on the mechanical properties of concrete. In this research the Ordinary Portland Cement (OPC) has been replaced by industrial waste/by products (namely fly ash, micro silica, metakaolin) accordingly in the range of 0%, 5%, 10%, 15% 20%, & 25% by weight. Concrete mixtures were prepared, tested and compared in terms of compressive strength to the conventional concrete. Experimental results showed that addition of supplementary cementitious materials increased strength of concrete up to certain percentages and then decreased. Use of metakaolin imparted highest strength compared to other two materials. This experimental study also compares the strength by adding replacement materials separately in varying proportions and also in combination to obtain three types of triple blend mix .Compressive strength obtained for the triple blend mixes are also compared.

KEYWORDS: Compressive Strength, Flexural Strength, Split Tensile Strength, Fly Ash, Micro silica, Metakaloin

INTRODUCTION

In many of the countries huge amount of waste materials are produced annually. Most of these waste materials or by products are not reusable or if they are, their recycling leads to wasting energy and pollution which in turn increase the risk of these materials to the environment. Generally obtained by products or waste materials may or may not be further processed for use in concrete .Majority of them are pozzolonic materials which by themselves do not have any cementitious property ,but when used with Portland cement react to form cementitious compounds .The main benefits of using alternative materials for cement replacement is to reduce the consumption of cement by a considerable amount and still shows ability to display cementitious property and thus reducing the overall cost in construction. Moreover replacement is a good strategy to achieve the two purposes of removing the waste materials and also obtaining the positive qualities of concrete. This project mainly emphasis on the comparison of mechanical properties and development of suitable concrete with partial replacement of cement by industrial wastes or by-products, (fly ash. Microsilica, metakaolin).

MATERIALS USED

Cement: Grade-53 Ordinary Portland Cement conforming to IS specifications was used in this study. Properties of cement used is tabulated below

Table 1: Properties of Cement

Sl No	Properties	Values obtained
1	Standard consistency	35%
2	Average compressive strength	53.1
3	Specific Gravity	3.15
4	Initial/Final setting time	127/320 min

Fine aggregate: Manufactured sand with specific gravity 2.63, fineness modulus 2.53 was used. The maximum size of fine aggregate was taken to be 4.75 mm.

Coarse Aggregate: Coarse aggregate with 20 mm nominal size and specific gravity 2.85, and fineness modulus 6.9 were used.

superplasticizer: A commercially available superplasticizer –Master Rheobuild 1125 was used as admixture

Replacement Materials Used

Fly ash also known as flue-ash is one of the residue generated in combustion of coal in thermal power plants. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. In this study low-calcium fly ash (Class F), having specific gravity 2.05 was used .Fly ash was collected from Mettur thermal power plant.

Microsilica also known as silica fume is an amorphus polymorph of silicon dioxide. It is an ultra fine powder collected as a by-product in the carbothermic reduction of high-purity quartz with carbonaceous materials like coal, coke, wood chips in electric arc furnaces in the production of the silicon and ferrosilicon alloy and consist of spherical particles with an average particle diameter of 150 nm. Commercially available micro silica were used to prepare specimens. Specific gravity of micro silica used was 2.35.

Metakaolin is white, amorphous, highly reactive aluminium silicate pozzolan forming stabile hydrates after mixing with lime stone in water and providing mortar with hydraulic properties. It is a dehydroxylated form of clay mineral (aluminium silicate) and is obtained by thermal activation of kaolin clay. Particle size is less than fly ash (FA) and greater than silica fume (SF).Metakaolin having specific gravity 2.6 was used for the study. Obtained from English India Clay Ltd, Thonnakal, Kerala

MIX PROPORTIONS

Mix proportions were made for each set of replacement materials. First was control mix (without any replacement material), and the other four mixes each contained cement replaced with fly ash, microsilica and metakaolin by weight.The proportions of cement replaced were 5%, 10%, 15%, 20% & 25%.The control mix without replacement materials was proportioned as per Indian standard Specifications IS: 10262-1982.M30 mix design is adopted in the experimental study .Average compressive strength f 37.83 MPa was obtained for the control specimen. Mix proportion for control specimen and replaced materials are given in the tables below

Table 2: Mix Proportion for 1 M^3 Control Mix

Cement	Coarse Aggregate	Fine Aggregate	Water	Admixture
384Kg	1240Kg	763Kg	153 *l*	2.88 Kg

Table 3: Mix Proportion for Cement Replacement by Fly Ash

For 1 M3 of Concrete	% Replacement of Fly Ash				
	5%	10%	15%	20%	25%
Cement(kg)	364.8	345.6	326.4	307.2	288
Water(litres)	153	153	153	153	153
Coarse aggregate(kg)	1231.86	1228.32	1224.77	1221.2	1217.7
Fine aggregate(kg)	757.85	755.67	753.48	751.3	749.12
Slump obtained(mm)	65	65	65	70	65

Table 4: Mix Proportion for Cement Replacement by Micro silica

For 1 M3 of Concrete	% Replacement of Micro silica				
	5%	10%	15%	20%	25%
Cement(kg)	364.8	345.6	326.4	307.2	288
Water(litres)	153	153	153	153	153
Coarse aggregate(kg)	1231.86	1228.32	1224.77	1221.2	1217.7
Fine aggregate(kg)	757.85	755.67	753.48	751.3	749.12
Slump obtained(mm)	65	65	65	70	65

Table 5: Mix Proportion for Cement Replacement by Metakaolin

For 1 M3 of Concrete	% Replacement of Metakaolin				
	5%	10%	15%	20%	25%
Cement(kg)	364.8	345.6	326.4	307.2	288
Water(litres)	153	153	153	153	153
Coarse aggregate(kg)	1231.86	1228.32	1224.77	1221.2	1217.7
Fine aggregate(kg)	757.85	755.67	753.48	751.3	749.12
Slump obtained(mm)	65	65	65	70	65

EXPERIMENTAL PROCEDURES

Concrete cubes of size 150mm ×150 mm× 150 mm were cast for testing compressive strength, 150×300 mm cylinders for splitting tensile strength, 500mmx100mmx100mm beams for testing flexural strength.The machine was first loaded with aggregates, cement and other replacement materials, mixed in dry condition. Half of total water was added immediately after the initial rotation of the drum. The remaining water was added along with super plasticizer just after drum is started. The period of mixing was not less than two minutes. After proper mixing concrete was tested for desired slump and after casting, all the test specimens were finished with a Steel trowel. The specimens were carefully placed, and allowed to settle. Later they were unmoulded and taken for curing after setting. Specimens were tested for 7 day and 28 day strength.

Triple Blend Mix

After obtaining the optimum percentages for cement replacement a new mix was developed by combining two replacement materials simultaneously. Three set of mix design was developed by combining fly ash, micro silica and metakaolin.

Type 1: partial replacement of cement by fly ash and micro silica (10+10) %

Type 2: partial replacement of cement by fly ash and metakaolin (10+10) %

Type 3: partial replacement of cement by micro silica and metakaolin (10+10) %

Compressive strength for 7 days and 28 days is determined

Table 6: Triple Blend Mix Fly Ash + Micro silica (10+10) %

Materials	Amount
concrete	$1m^3$
Cement (kg)	307.2
Fly ash (kg)	38.4
Micro silica (kg)	38.4
Water (litre)	153
Coarse aggregate (kg)	1217.13
Fine aggregate (kg)	748.79
Slump obtained (mm)	38
Superplasticizer added (% weight of total cementatious material)	.98

Table 7: Triple Blend Mix Fly Ash + Metakaolin (10+10) %

Materials	Amount
concrete	1 m3
Cement (kg)	307.2
Fly ash (kg)	38.4
Micro silica (kg)	38.4
Water (litre)	153
Coarse aggregate (kg)	1219.8
Fine aggregate (kg)	750.43
Slump obtained (mm)	45
Superplasticizer added (% weight of total cementatious material)	1

Table 8: Triple Blend Micro silica + Metakaolin (10+10) %

Concrete	Amount
concrete	1 m3
Cement (kg)	307.2
Fly ash (kg)	38.4
Micro silica (kg)	38.4
Water (litre)	153
Coarse aggregate (kg)	1223.92
Fine aggregate (kg)	752.95
Slump obtained (mm)	48
Superplasticizer added (% weight of total cementatious material)	.95

Standard cubes of size 150x150x150mm were casted and cured, compressive strength was determined. Cement is replaced by 20% with the addition of supplementary cementitious materials (fly ash, microsilica and metakaolin) to form a ternary blend using the above said mix proportions.

RESULTS AND DISCUSSIONS

A.Compressive Strength

Standard cubes casted were loaded to failure in compression testing machine .The cubes were tested for 7 day strength and 28 day strength. Load values obtained for each specimen was noted. These load values divided by surface area gives compressive strength of concrete. The test results are plotted in the figure given below.

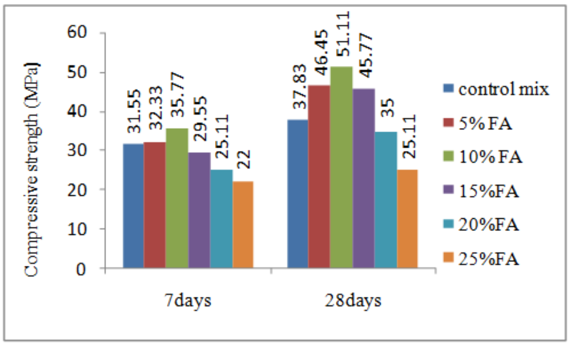

Figure 1: Comparison of Compressive Strength for Replacement by Fly Ash

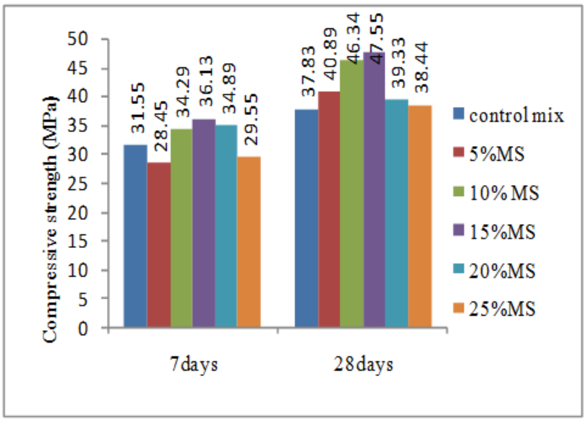

Figure 2: Comparison of Compressive Strength for Replacement by Micro silica

Figure 3: Comparison of Compressive Strength for Replacement by Metakaolin

It is clear from the graph that fly ash and metakaloin gave maximum strength at 10% replacement level and microsilica at 15% replacement level. A comparison of the strength obtained for different, materials used is given in the table below.

Table 9: Comparison of Compressive Strength Achieved for Different Materials

	28 Day Strength Achieved (MPA)			
Replacement %Age by Weight of Cement	**Control Mix**	**Fly Ash**	**Micro silica**	**Metakaolin**
0%	37.83	--	--	--
5%	--	46.45	40.89	52.13

10%	--	51.11	46.89	58.06
15%	--	45.77	47.55	55.9
20%	--	35	39.33	57.5
25%	--	25.11	38.44	55.78

Maximum compressive strength (58.06 MPa) achieved for 10% replacement of cement by metakaloin .Replacement of cement increased compressive strength appreciably upto 10% replacement level and then begin to decrease.

B. Split Tensile Strength

The tensile strength of concrete cylinders (control mix and with different replacement materials) were determined at 7 and 28 days. Variation of 28 day tensile strength of various mixes are plotted in the graphs below.

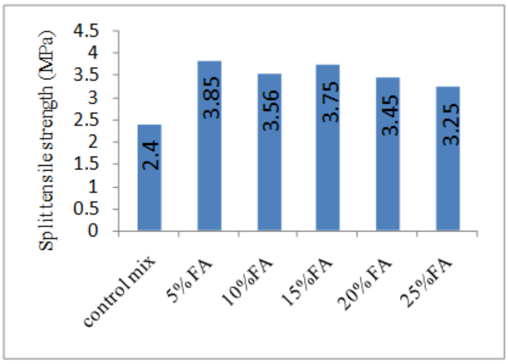

Figure 4: Comparison of Split Tensile Strength for Replacement by Flyash

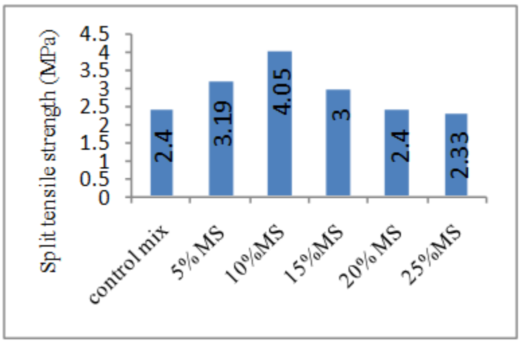

Figure 5: Comparison of Split Tensile Strength for Replacement by Micro silica

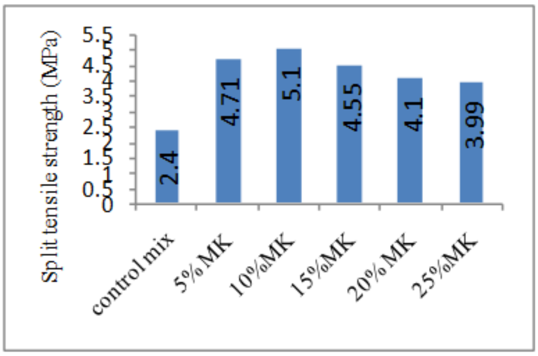

Figure 6: Comparison of Split Tensile Strength for Replacement by Metakaolin

Table 10: Comparison of Split Tensile Strength Achieved for Different Materials

	28 Days Split Tensile Strength (MPA)			
Replacement %Age by Weight of Cement	**Control Mix**	**Fly Ash**	**Micro silica**	**Metakaolin**
0%	2.4	--	--	--
5%	--	3.85	3.19	4.71
10%	--	3.56	4.05	5.1
15%	--	3.75	3	4.55
20%	--	3.45	2.4	4.1
25%	--	3.25	2.33	3.99

Table above shows split tensile strength of concrete mixes replaced by supplementary materials .Optimum strength of 5.1 MPa is obtained for 10% replacement of weight of cement by metakaloin. Variation of tensile strength shows a similar pattern as that of compressive strength.

C. Flexural Strength

Beams of size 500mmx100mmx100mm were loaded to failure in flexural strength testing machine .flexural strength at 28 days was calculated ,comparison of the strength for various percentages of fly ash, silica fume and metakaloin is plotted in the graphs below.

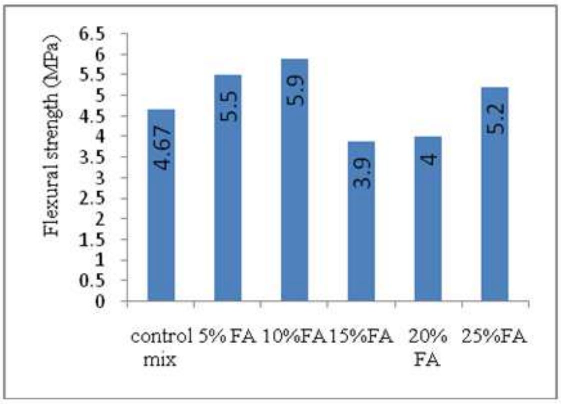

Figure 7: Comparison of Flexural Strength for Replacement by Flyash

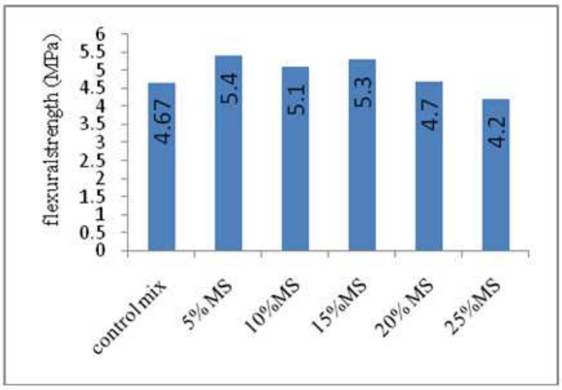

Figure 8: Comparison of Flexural Strength for Replacement by Micro silica

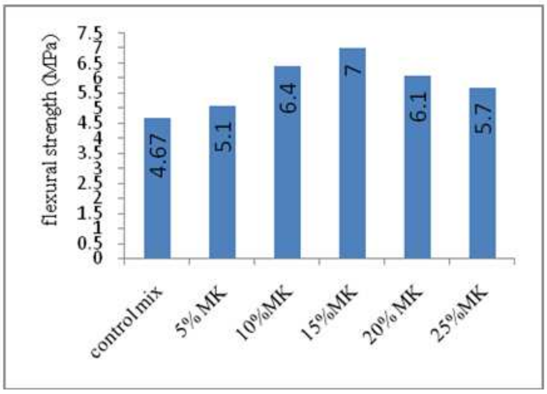

Figure 9: Comparison of Flexural Strength for Replacement by Metakaolin

Table 11: Comparison of Flexural Strength Achieved for Different Materials

	28 Days Flexural Strength (MPA)			
Replacement %Age by Weight of Cement	**Control Mix**	**Fly Ash**	**Micro silica**	**Metakaolin**
0%	4.67	--	--	--
5%	--	5.5	5.4	5.1
10%	--	5.9	5.1	6.4
15%	--	3.9	5.3	7
20%	--	4	4.7	6.1
25%	--	5.2	4.2	5.7

CONCLUSIONS

Effect of Fly Ash

- The compressive strength of concrete replaced with fly ash increases as the amount of replacement increased, upto a certain percentage (10% in the present study, the initial strength development was less compared to that of the control mix. The mix with 10 % replacement of cement with fly ash showed an increase of compressive strength by 22 %. For replacement beyond 20% the compressive strength obtained was less than the control mix.
- The enhancement of compressive strength was (22%, 30%, 20%) at 28 days of (5%,10%,15%) replacement of fly ash respectively
- The compressive strength in these mixes is attributed to both the continued hydration of Portland cement and pozzolanic reaction between fly ash and calcium hydroxide component of Portland cement
- Maximum split tensile strength of 3.85 N/mm^2 was obtained at 5% replacement level. Even after the replacement of cement by 25% the split tensile strength was greater than control mix.

Effect of Micro silica

- When cement was replaced with micro silica in different percentages, it has been observed that there is an increase in compressive strength up to 15% replacement with an increase of 25% strength as compared to control mix.
- Increase in strength for (5,10,15)% replacement levels were (8,20,25)% respectively. Beyond 15% replacement of cement by micro silica, the compressive strength showed a slight reduction, but greater than the control mix.

- Slight increase in the split tensile strength though not in a definitive manner. maximum value for split tensile strength of 4.05 N/mm^2 was obtained at 10 % replacement
- The gain in strength can be attributed to the formation of calcium silicate hydrate (C-S-H) gel which is stronger than the normal C-H gel. This silica-fume gel C-SH forms in the voids of the C-S-H produced by cement hydration, thus producing a very dense structure.
- In hardened concrete, silica-fume particles increase the packing of the solid materials by filling the spaces between the cement grains in much the same way as cement fills the spaces between the fine-aggregate particles, and fine-aggregate fills the spaces between coarse-aggregate particles in concrete

Effectof Metakaolin

- Metakaolin effectively increased the mechanical strength of concrete including compressive and tensile strength. The 28 day compressive strength of concrete has been increased by 40% for 10 % replacement of cement by metakaolin. Beyond that the strength slightly decreased
- .Unlike other two replacement materials addition of metakaolin showed remarkable increase in compressive strength. Also the strength does not decrease considerably with 20% and 25 % replacement compared to the control mix. The splitting tensile strength increased with the increase in metakaolin content at all ages.
- The increase in the splitting tensile strength was smaller compared to that obtained in the compressive strength. Split tensile strength was maximum (5.1 N/mm^2) at 10 % replacement level, beyond which the value start to decrease.
- The enhancement in compressive strength of concrete incorporating metakaolin may be attributed to the filling effect, pozzolanic reaction of metakaolin, and acceleration of cement hydration.
- When replacing cement with metakaolin the calciumhydroxide (CH) is reduced, thus leading to an increase in sulphate resistance. This is in addition to the pore refinement due to inclusion of metakaolin that restricts the ingress of sulphate ions.

Strength Achieved for Triple Blend Mix

On comparison of the compressive strength of triple blend with single material replacement specimens ,it was observed that out of the three mix Combinations(FA+MS,FA+MK,MS+MK),type three i,e MS+MK yielded maximum strength. Metakaolin gave maximum strength compared to other two replacement materials individually as well as in combination.

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