International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 07, July - 2017

Impact of Ferrochrome Ash and Gypsum Powder on Properties of Concrete

Shrinu Mohanty
Civil Engineering Dept.
College of Engineering & Technology
Bhubaneswar, India

Prof. (Dr) P K Parhi
Civil Engineering Dept.
College of Engineering & Technology
Bhubaneswar, India

***Abstract*— Ferrochrome is an alloy of iron and chromium. Ferrochrome ash (FA) is a waste material obtained from ferrochrome industry. Due to less amount of landfilling areas dumping of industrial waste materials like ferrochrome ash have become a difficult task. Instead of dumping, Ferrochrome ash have become a wonderful proposition in the preparation of concrete. Gypsum is a soft sulphate mineral composed of calcium sulphate dihydrate. Gypsum has excellent fire resistance properties and it is cheaply available in the market. It is an excellent binder. Gypsum can be effectively utilised in the production of environmental friendly concrete. This paper demonstrates the technical possibilities of incorporating Ferrochrome ash (FA) and Gypsum powder (GP) in production of concrete. In this investigation combination of FA and GP was used as a replacement of Ordinary Portland cement (OPC) for preparation of concrete. The use of industrial materials like FA and GP provided benefit in the aspects of strength, economy and environmental stability. (30% FA and 10% GP) replacement 7 days test results showed that there is a consequent improvement in strength of concrete. It was concluded that 30% FA with 10% GP replacement can be safely utilised in preparation of concrete.**

Keywords*— Ferrochrome, Ferrochrome ash, Industrial waste materials, Concrete, Gypsum, Ordinary Portland cement.

I. INTRODUCTION

In todays growing world changing from a traditional heavy consumption society to a low consuming managaeble society is very important. So, the greatest challenge which the concrete industry is facing now-a-days is the gain of sustainable and economic development. Concrete is one of the most heavily consumed material in construction industry. Due to its excellent advantages in terms of versatility, durability, wide availaibility, low cost, strength and fire resistance it is one of the most important construction material used by man. Throughout the world there is an abundant production of concrete to meet its huge demand in construction sector. With the ever increasing need for industrialisation and urbanisation in society there will be rise in demand for concrete. In the near future, there will be rapid utilization of this material. Cement is the main ingredient in concrete. It acts as a principal binding material in the concrete matrix. For daily producion of large amount of concrete in different construction sectors it is evident that a heavy production of cement is required. But production of cement leads to increase in greenhouse emissions. Increase in greenhouse emissions will lead to depletion of mineral and oil resources which in turn will lead to destruction of economical and ecological balance. So, to reduce greenhouse emissions there is a urgent need to decrease the manufacture of cement. The use of cement should be reduced and possible alternatives of cement needs to be discovered. In todays date research for the economic binder is a major concern to lessen the disadvantage recorded in production of portland cement by using industrial materials and resources availaible in the nature.

Now-a-days researches are being carried out in the use of supplementary cementitious materials as partial replacement to ordinary portland cement. Partial replacement of cement with materials like ferrochrome ash and gypsum will help to solve the problem of economic binder and would also help in the increase of the workability, strength and durability of cementing materials. The additional benefits from this includes cost reduction, energy savings, promoting ecological balance and conservation of natural resources etc.

Solid waste management due to increased amount of industrial waste materials and by-products is the major concern in todays world. Huge amount of waste products are produced all around the world. The most adopted method for taking care of waste products is their disposal in landfills. When large number of wastes are dumped it leads to the creation of huge deposits of wastes in landfilling areas. Due to less amount of landfilling areas and increase in cost of transportation, use of waste materials and by-products have become a wonderful strategy for disposal.

Ferrochrome is an alloy of chromium and iron containing 50 to 70% chromium by weight. Ferrochrome is produce by electric arc carbothermic reduction of chromite. Ferrochrome ash is an industrial by-product from ferrochromium industry. The dumping or disposal of ferrochrome ash has created an environmental concern. It is creating pollution problem in the dumping area. Now-a-days sustainable ferrochrome waste management is the subject matter leading to majoe environmental concern. Most of the world's ferrochrome is produced in South Africa, Kazakhsthan and India, which have large domestic chromite resources. Increasing amounts are coming from Russia and China. The production of steel is the largest consumer of ferrochrome, especially the production of stainless steel with chromium content of 10% to 20% is the main appluication of ferrochrome. Over 80% of world's ferrochrome is utilised in the production of stainless steel. In 2006 28Mt of stainless steel depends on chromium for its appearance and its resistance to corrosion. The avearge chrome content n stainless steel is approximately 18%. Ferrochrome from Southern Africa, known as "charge chrome" and produced from a chromium containing ore with a low carbon content, is most commonly used in stainless

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steel production. The vast majority of ferrochrome produced is charge chrome from Southern Africa.

Gypsum is a soft sulphate mineral composed of calcium sulphate dihydrate, with chemical formula $CaSO_4.2H_2O$. It is widely mined and is used as a fertiliser, and as the main constituent in many forms of plaster, blackboard, chalk and wallboard. A massive fine-grained white or lightly tinted variety of gypsum, called alabaster has been used for sculpture ny many cultures including Ancient Egypt, Mesopotamia, Ancient Rome, The Byzantine empire and the Nottingham alabasters of Medievel England. It forms as an evaporite mineral and as a hydration product of anhydrite. Gypsum is a mineral resource which has binding properties and it is widely used in construction sectors. Due to large amount of manufacturing of gypsum it is cheap and readily availaible. Gypsum has excellent fire resistance properties due to presence of "$2H_2O$" water molecules in its chemical formula "$CaSO_4.2H_2O$".

II. REVIEW OF LITERATURE

Gesoglu et al. (2015) studied the effects of using gypsum-contaminated natural sand on the compressive strength and expansion of ultra-high performance fiber reinforced cementitious composites over a period of one year. Two groups of ultra high performance fiber reinforced cementitious composites were designed with binary and ternary cementitious blends of Portland cement, silica fume, and ground granulated blast furnace slag. The microstructure of the cementitious composites were studied by SEM-EDX. They also compared some findings of ultra high performance fiber reinforced concrete with those of Portland cement mortars. From test results it was observed that ultra high performance fiber reinforced cementitious composites showed a strength gain, particularly under steam curing and an insignificant expansion even in the presence of excess sulphates, in contrast to the mortars. Ultra high performance fibre reinforced cementitious composites having additional amount of sulphates generally showed higher compressive strengths compared to the original ultra high performance fiber reinforced cementitious composites. The effect of SO_3 content on strength was more influential with heat-treated samples than with non-heated ones. They showed the strength of water-cured and steam-cured samples incorporated with sulphates was upto 4% or 8% greater than that of normal samples. SEM detected the dense microstructure of the matrix as well as the strong bond between the matrix and aggregate gave amazing compressive strength of ultra high performance fibre reinforced cementitious composites with additional sulphates. The two series of water-cured ultra high performance fiber reinforced cementitious composites having cured in water for a period of 180 days showed a slight decrease in strength beyond that period. The ultra high performance fibre reinforced cementitious composite cured at elevated temperatures showed an increase in compressive strength upto 90 days. Beyond this samples exhibited little or no strength. Ultra high performance fiber reinforced cementitious composites made with binary and ternary blends showed excellent resistance to internal sulphate attack under different curing regimes. This suggests the use of gypsum-contaminated aggregates in ultra high performance fiber reinforced cementitious composites.

Zhuang et al. (2015) investigated the geochemical characteristics of the flue gas desulphurization gypsum generated from pulverized coal combustion plant in Xinjiang, Northwest China. The physical, mechanical and insulating properties of the manufactured panels were also determined. The flue gas desulphurization gypsum/fly ash panels gave relatively lower density, lower water absorption and lower mechanical strength, but higher moisture contents and better insulating capacities with the same gypsum/fly ash proportion. The experimented flue gas desulphurization gypsum gives very low trace element concentrations and very low leaching potential for trace elements, especially those of high environmental concern. The compressive and flexural strengths of panel gets reduced with the increase of fly ash proportion in the mixtures. The insulating capacity of pure flue gas desulphurization gypsum panel is much more than that of Chinese gypsum panel as well Chinese gypsum/fly ash panels. The manufacturing of fire resistant panels is a very promising utilization for both flue gas desulphurization gypsum and fly ash with added high values, no environmental implications and low economic costs.

Zak et al. (2015) investigated on the compressive strength of earth bricks in particular day influence of additives. The test results showed that the compressive strength is highly dependant on the density of the bricks. The fibers hemp and flax have rather low impact on the compressive strength of earth bricks, but they have strong influence on the breaking behaviour. Cement and gypsum reduce the binding force of the clay minerals, lead to a highly decreased strength. Tests reported about the special attention that is paid to the water content in soil when stabilization of earth is being done with cement. Due to their low compressive strength, the bricks produced with cement are not applicable for load bearing walls. There is no significant change in compressive strength but the brittle breaking behaviour of the material gets decreased when flax fibers were introduced. In comparison to pure earth bricks, hemp fibres lead to slight reduction in compressive strength. There was no significant change in compressive strength when gypsum was mixed with gypsum.

Gencel et al. (2016) reported that usage of gypsum composite containing diatomite and polypropylene fibres decreases unit weight and thermal conductivity due to increase in porosity. The mechanical properties such as compressive and bending strength were also increased due to the incorporation of gypsum composite containing diatomite and polypropylene fibres. The gypsum composites with diatomite caused a significant decrease in unit weight. Also, with increase in diatomite content in the mixture the compressive strength of composite increases. There is an increase in thermal insulation performance of concrete.

Cho and choi (2016) reported that the slag cement concrete and ground granulated blast furnace slag-kambara reactor slag concrete showed similar 28 day compressive strengths. The ground granulated blast furnace slag-kambara reactor slag concrete showed the values of drying shrinkage and cumulate porosity as 121.08-129.08% and 190-208% respectively as compared to those of slag cement. The results showed that higher amount of ettringites lead to higher drying and shrinkage due higher porosity and absorption. The ground granulated blast furnace slag-kambara reactor slag concrete showed a very low amount of 28 days compressive strength. However, the concrete containing 50% ordinary Portland with 50% ground granulated blast furnace slag had developed 28 days compressive strengths similar to ground granulated blast furnace slag-kamabara reactor slag concrete having some additional amounts of gypsum. Results showed that the cumulative heat of hydration of ground granulated blast furnace slag-kamabara reactor slag concrete was 27.3-36.3% as compared to that of ordinary Portland cement. The cumulative porosity of ground granulated blast furnace slag-kambara reactor concrete slag concrete was 2.4-2.6 times higher than that of ordinary Portland cement. Similarly the number of capillary pores having sizes of around 10-100nm and 100-10,000nm was much greater as compared to ordinary Portland cement. XRD analysis showed that ordinary Portland cement and 50% of ordinary Portland cement with 50% of ground granulated blast furnace slag had main hydrates as $Ca(OH)_2$, C-S-H, C-A-H, $2CaO.SiO_2$ and $3CaO.SiO_2$. It was reported there is a possibility of making a cement free binder consisting of ground granulated blast furnace slag, kambara reactor slag and gypsum. Ground granulated blast furnace slag-kambara reactor slag concrete can be used as a sound absorption, sound insulation and thermal insulation due to ground granulated blast furnace slag-kambara reactor slag ability of high porosity and high absorption.

Camarini et al. (2016) reported that utilization of citric acid caused an increase in fluidity due to decrease in gypsum plaster consistency. The compressive strength and hardness decreases but the setting time increases. It was reported that during gypsum plaster hydration the maximum temperatures reached were the same. The results showed that with increase in citric acid content the compressive strength and hardness were diminished in the hardened state. The XRD pattern showed that with citric acid addition there was a complete hydration of recycled plaster. SEM showed that with lower mechanical performance there was a significant difference in crystal formation.

Zhang et al. (2016) reported that the interval between initial and final setting times became short and the initial setting times of test samples were longer. There was a decreased fluidity of the mortar. It was reported that after 28 days the strength of test samples exceeded and was same or greater than the strength of reference sample. While the earlier strength ages showed a strength lesser than the reference sample. It was observed that the mortar samples kept in water were for one year in which the ettringite amount was 13%-17% of hardened paste showed satisfactory volume stability. If the expansion stress is lower than the tensile strength then the volume stability of tested samples was good. At the hydration age of 40 days to 120 days excessive crystallization of gypsum have an undesirable effect in the volume stability harden mortar and mortar strength.

Park et al. (2016) reported that gypsum content produced fine ettringite crystals and removed large pores that were around 100µm in diameter at the best strength. As a result there is a significant reduction in pore-size refinement. There was a significant reduction of strength and generation of a large volume of detrimental pores of sizes 0.03-0.4 µm on excessive addition of gypsum. The SEM images reported that fine ettringite crystals filled the pores effectively at the gypsum dosage of the best strength leading to dense matrices. At excessive addition of coarse crystals of gypsum or ettringite produced porous matrices. The addition of gypsum in varying amounts, from 0 to 15%, as a sulphate source on the CaO-activated ground granulated blast furnace slag system in compressive. strength testing , XRD, TG/DTG, SEM and MIP was investigated. It was reported that the best final compressive strength was achieved with 10% of gypsum content. The strength worsened beyond 10% gypsum content. The amount of ettringite governed the compressive strength of CaO-activated ground granulated blast furnace slag system with gypsum. Due to the pore-size refinement effect, with a significant reduction in the large-sized pores around 100 µm, and a volume increase of significantly smaller pores in the nanometer sizes the 10% addition of gypsum improved the strength. Excessive addition of gypsum produced a more porous matrix with a lower strength due to coarser and wider crystals in the gypsum.

Acharya and Patro (2016) reported that the results were close to normal concrete at a highest replacement of 47% ordinary Portland cement (40% ferrochrome ash FA and 7% lime) in 28 days. From microscopic studies like petrography examinations the results were established showing good relationship between strength and durability properties. The relations having correlation coefficient nearer to one were well compared. In the reduction of production of ordinary Portland cement, minimization of greenhouse emissions, lowering of energy consumption, management of environmental burden and conserving natural resources utilization of ferrochrome ash in concrete making will be useful. There was a positive impact on 28 days strength and appreciable impact on long term strength properties due to replacement of ordinary Portland cement upto 47% by ferrochrome ash FA. There was a positive impact on different mix proportions for various natures of concrete works due to inclusion 40% of ferrochrome ash and 7% lime with cement. Due to positive effect of ferrochrome ash FA and lime the void content decreased. For making structural concrete and other applications concrete made with ferrochrome ash FA and lime can be efficiently used. No adverse impact was noticed due to concrete containing ferrochrome ash FA and lime.

Acharya and Patro (2016) studied the flexural behaviour of reinforced concrete beams containing 40% ferrochrome ash FA and 7% lime by replacing 47% ordinary Portland cement. The testing of beams were conducted under monolithic loading until failure. The beams crack pattern, failure pattern and capacity of beam was investigated. Test results reported that ferrochrome ash concrete beams showed better ductility, load carrying capacity and crack resistance than original concrete beams without ferrochrome ash FA and lime. The flexural behaviour of reinforced concrete beams showed nearly same results like beams containing 40% fer ferrochrome ash FA and 7% lime. The normal concrete beams showed 8.33% less load carrying capacity than ferrochrome ash FA concrete beams. The original concrete beams had 1.5 times less crack resistance capacity than ferrochrome ash FA concrete beams. The deflection in normal concrete beams is lesser than ferrochrome ash FA concrete beams which indicates that there is a increase in the ductility in ferrochrome ash FA concrete beams. The bond between concrete and reinforcement was not affected due to incorporation of ferrochrome ash FA and lime which indicates that no horizontal cracks were found. In tension side there occurred a failure in normal concrete and ferrochrome ash FA concrete beams. The result comparison showed that ferrochrome ash FA concrete beams were better than normal concrete beams indicating that there is a suitability of ferrochrome ash FA with lime in making structural concrete.

Acharya and Patro (2015) reported that due to inclusion of ferrochrome ash FA and lime there is a significant increase in early age strength in comparison to original concrete. At the age of 28 days properties of normal concrete was same as concrete containing 40% ferrochrome ash FA and 7% lime. It was reported that in concrete containing ferrochrome ash and lime increase in strength and durability was observed in later age. Observation was made that without increasing or decreasing the performance of concrete 40% ferrochrome ash FA with 7% lime can be effectively utilized in preparation of concrete. By petrography study improvement in engineering properties of concrete containing ferrochrome ash FA and lime was observed. It was reported that 40% ferrochrome ash FA with 7% lime replacement caused an increase in water demand, decrease in workability and setting time and no increase or decrease in soundness. Due to inclusion of ferrochrome ash FA and lime the early age compressive strength increases consequently. Incorporation of ferrochrome ash FA and lime causes an increase in the ultrasonic pulse velocity and decrease in water permeability. By including ferrochrome ash and lime bonding between aggregate and cement paste increases.

Acharya and Patro (2016) reported that there was enhancement of 28 days compressive strength (1.5-13.5%), flexural strength (4.5-9%), bond strength (15-29%), abrasion resistance (10-23%) and reduction of sorptivity (25-43%) due to substitution of cement with ferrochrome ash FA in various percentage with 7% lime substitution. The concrete having 40% ferrochrome ash FA and 7% lime showed same amount or even more strength than normal concrete mix at all ages. Due to incorporation of ferrochrome ash FA and lime caused decrease in workability and slight increase in fresh density. Replacement of ferrochrome ash with lime has a positive impact in compressive strength whereas, only replacement of ferrochrome ash FA with cement may cause a negative impact in concrete. There was a positive impact on abrasion resistance of concrete with incorporation of ferrochrome ash FA and lime. Concrete in which ferrochrome ash FA and lime are incorporated found less sorptivity than normal concrete mix. It was reported that ferrochrome ash FA with lime is a useful raw material for partial substitution of ordinary Portland cement upto 47%.

III. EXPERIMENTAL MATERIALS AND METHODOLOGY

A. Materials

Figure 1. Ferrochrome ash

The current selection of cement for experimental work is ordinary Portland cement (OPC). Ordinary Portland cement (OPC) conforming to 43 grade was used in the research. The physical properties of cement were found out as per IS: 8112, 1989 and the results are represented in Table 1. Natural sand collected from the river bed and passing through IS 4.75mm sieve was used in the experiment. Properties of fine aggregate (sand) were studied as per IS: 383, 1970 and represented in Table 2. The sand used in the research conformed to grading zone III. Natural coarse aggregate passing through 20 mm size sieve was used in the experiment and physical properties are represented in Table 3. Ferrochrome ash FA was brought from IMFA ltd, Cuttack, Odisha, India. The gypsum used in the research was brought from a local storage unit in Monguli, Cuttack, Odisha, India. To improve the strength results polycarboxylate based superplasticizer was used in the research.

Figure 2. Gypsum powder

Table 1. Physical properties of ordinary portland cement

S.NO.	PROPERTIES	VALUE
1	Normal consistency	32
2	Initial setting time	90
3	Final setting time	263
4	Specific gravity	3.10

B. Design Mix Proportion

A design mix proportion 1:1.57:3.01 containing 1 part cement, 1.57 part fine aggregate and 3.01 part coarse aggregate was used in the experiment. In the investigation water cement ratio of 0.4 was adopted. In different mixes Ferrochrome ash FA in the proportion of 40% and gypsum powder GP in the proportion of 40% were used as substitution for ordinary Portland cement OPC. Also combined substitutions of ferrochrome ash FA and gypsum powder GP in the proportion of (30% GP and 10% FA), (20% GP and 20% FA), (10% GP and 30% FA) were made with ordinary portland cement OPC. These mixes were designated as M1, M2, M3, M4, M5 respectively. Also different design mix proportions i.e., 1:1.84:3.54, 1:1.65:3.17, 1:1.57:3.01, 1:1.51:2.9, 1:1.44:2.76 in the form of trial mixes were conducted. Out of these, the trial mixes having ratios 1:1.57:3.01, 1:1.51:2.9, 1:1.44:2.76 gave correct results of strength to be utilized in M30 grade concrete paving a way for the selection of design mix proportion out of the three ratios. Finally, out of these three ratios the ratio of 1:1.57:3.01 was taken into consideration for design mix proportion. The trial mixes were designated as T1, T2, T3, T4, T5 respectively. In these trial mixes no substitution of ferrochrome ash FA and gypsum powder GP was made.

Table 2. Physical properties of fine aggregate

S.NO.	PROPERTIES	VALUE
1	Fineness modulus	3.03
2	Specific gravity	2.64
3	Water absorption	0.80

C. Methodology of Different Tests

Table 3. Physical properties of coarse aggregate

S.NO.	PROPERTIES	VALUE
1	Fineness modulus	7.0
2	Specific gravity	2.61
3	Water absorption	0.3

As per IS: 5816, 2009 different split tensile strength test results were determined. As per IS: 516, 1959 different compressive strength test results were determined. As per IS: 516, 1959 different flexural strength test results were determined. At the age of 7, 28 days all compressive, split tensile and flexural strength tests were conducted. For each mix trials of compressive, split tensile and flexural strength tests were conducted. Three samples were tested and the average of three samples was taken into consideration.

IV. RESULT ANALYSIS

A. Compressive Strength

Compressive strength got significantly increased on incorporation of ferrochrome ash FA and gypsum powder GP. At the age of 28 days, the percentage increase in compressive strength for mixes M3, M4, M5 as compared to original concrete mix was reported as 1.49%, 9.28%, 22.06% respectively. Also, at the age of 7 days, the percentage increase in compressive strength for mix M5 as compared to original concrete mix was reported as 2.095%. Results showed that there is a significant increase in 28 days compressive strength of concrete containing ferrochrome ash FA and gypsum powder GP. Also, there is a significant increase in 7 days strength of concrete containing combination of 10% gypsum powder GP with 30% ferrochrome ash FA. Highest strength was achieved by concrete mix M5 having 10% gypsum powder GP with 30% ferrochrome ash FA. In M3 and M4 mixes the strength decreased as compared to M5 mix containing 10% gypsum powder GP with 30% ferrochrome ash FA but the strength was more than original concrete mix. This decrease in strength of M3 and M4 concrete mixes was due the presence of more amount of gypsum powder GP as compared to M5 mix. The maximum replacement of ordinary Portland cement OPC was considered 40%. So, the maximum limit of ferrochrome ash FA and gypsum powder combined substitution was taken as 40%. For design and construction purposes 28 days age strength is considered important for concrete mixes. Compressive strength test results are represented in Fig. 3.

$f_{ck} = P/ B^2$

Where, f_{ck} - Compressive strength in MPa

P - Maximum applied load in Newton

B - Size of the cube specimen in mm

D - Diameter of the cylinder specimen in mm

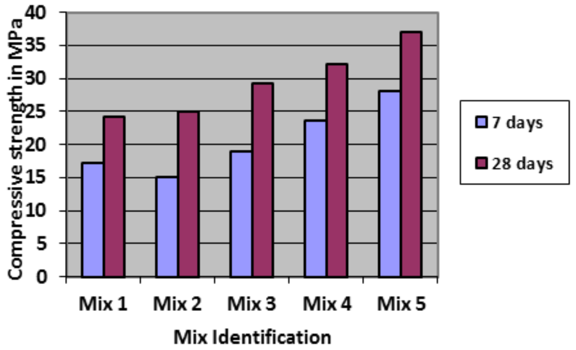

Figure 3. Impact of FA and GP on compressive strength

B. Split Tensile Strength

There was a consequent increase in split tensile strength due to incorporation of ferrochrome ash FA and gypsum powder GP. At the age of 28 days, the percentage increase in split tensile strength for all mixes M1, M2, M3, M4, M5 as compared to original concrete was found to be more. Also, at the age of 7 days, the percentage increase in split tensile strength for mix M3, M4, M5 as compared to normal concrete was more. The results showed that there is a consequent increase in 28 days split tensile strength of concrete containing ferrochrome ash FA and gypsum powder GP. Highest strength was achieved by concrete mix

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 07, July - 2017

containing 10% gypsum powder GP with 30% ferrochrome ash FA. Split tensile strength test results are represented in Fig. 4.

$f_{sp} = 2P/ \pi L d$

Where, f_{sp} - Split tensile strength in MPa
P - Maximum applied load in Newton
L - Length of the cylinder in mm
D - Diameter of the cylinder in mm

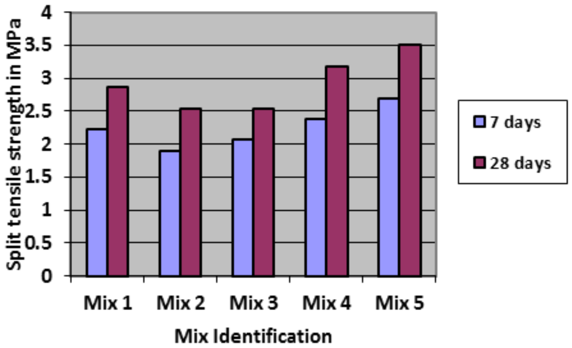

Figure 4. Impact of FA and GP on split tensile strength

C. Flexural Strength

There was tremendous increase in flexural strength due to inclusion of ferrochrome ash FA and gypsum powder GP. Both at the age of 7 days and 28 days, the percentage increase in flexural strength for all mixes M1, M2, M3, M4, M5 as compared to original concrete was found to be more. The results showed that there is a increase in both 7 days and 28 days flexural strength of concrete containing ferrochrome ash FA and gypsum powder GP. Highest strength was achieved by concrete mix containing 10% gypsum powder GP with 30% ferrochrome ash FA. Flexural strength test results are represented in Fig. 5.

$f_b = PL/ B D^2$

Where, f_b - Flexural strength in MPa
P - Maximum applied load in Newton
L - Span length in mm
B - Width of the specimen in mm
D - Depth of the specimen in mm

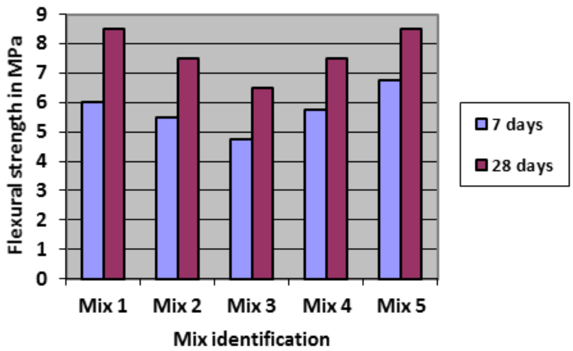

Figure 5. Impact of FA and GP on flexural strength

□□□□□□

V. CONCLUSION

The conclusions that are pointed out from this experimental investigation are listed below:-

1. Favourable consequences are noticed on 7 days and 28 days strength results due to combined substitution of 30% ferrochrome ash FA and 10% gypsum powder GP with ordinary Portland cement OPC.

2. Both 7 days and 28 days strength results have satisfactory impact on long duration strength properties.

3. Satisfactory influence is noticed in different design mix proportions having 30% ferrochrome ash FA and 10% gypsum powder GP substituting ordinary Portland cement OPC.

4. The concrete containing ferrochrome ash FA and gypsum powder GP can be suitably utilised for different structural and concrete applications.

5. Concrete containing ferrochrome ash FA and gypsum powder GP is an environment friendly material.

6. Gypsum powder GP has excellent fire resistance properties and it is a very good binder providing strength and fire proofing properties to concrete.

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