Alternatives To Cement In Concrete

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Abstract- *In the present world, concrete has become a vital part of our lives. With each passing day, the utilization of concrete is increasing at a very high rate. One of the most constituents of concrete is hydraulic cement . With the rise in use of concrete, the manufacturing and consumption of cement has increased drastically. Although cement has exceptional binding properties and is extremely suitable to be used in concrete, the manufacturing of cement leads to emission of huge amounts of CO2. Due to this, researchers have started finding alternatives to cement that are economical also as environment friendly. Fly ash, Silica Fume, Metakaolin and Ground granulated blast furnace. furnace slag are industrial by-products which give excellent binding properties to concrete and function a replacement of cement.*

These alternatives are generally termed as Supplementary cementitious materials (SCMs). The use of these materials not only helps in reducing the consumption of cement but also serves as an efficient method for their safe disposal. This paper reviews the effect of using the various alternatives which will be utilized in concrete as partial replacement of cement. The literature review of various researchers reveals that one alternative cannot provide all the advantages that cement does. Rather, a suitable combination of these products can be incorporated in concrete to provide properties similar to or better than that of Portland cement concrete.

Keywords- Civil Engineering, Construction Management, Alternatives to Cement, Construction Techniques.

I. INTRODUCTION

Concrete is a composite material formed by bonding together aggregates and fluid cement that hardens over time. The most commonly used concrete today is that the hydraulic cement Concrete. One of the main constituents of concrete is cement which is harming the environment at an alarming rate. It is estimated that about 0.9 tons of carbon dioxide is released in the environment for the production of 1 ton of cement. Carbon dioxide comes in the category of green house gas and is largely responsible for global warming. This prompts us to study the various alternatives to cement to form the concrete environment friendly.

The concept of using eco friendlymaterials in place of hazardous material in concrete is called green concrete. Green concrete makes use of varied industrial by-products like ash , silica fume, metakaolin, GGBS etc. These by-products are harmful for the environment and hence their use in concrete not only helps in safe disposal of such waste products but also helps in reducing cement production which is yet another environmental concern.

In this paper, a review of work done by various researchers on alternatives to cement is done. Finally, a comparative study of various materials used as a substitute or partial replacement of cement has been done.

II. CEMENT

Cement may be a fine grey powdery substance made by burning a mixture of clay and lime that sets hard when it's mixed with water. It is used with water and sand to make mortar or mixed with sand, aggregate and water to form concrete. The manufacturing of cement involves crushing, milling and proportioning of lime, silica, alumina, iron and gypsum. Cement is a binder material, that is, a substance that helps in binding together different materials. This property makes it an excellent constituent of concrete. The most common type of cement used in the construction industry is the Portland cement.

III. LITERATURE REVIEW

3.1 Fly Ash

Fly ash is one among the residues generated by coal combustion, and is composed of the fine particles that are driven out of the boiler with the flue gases. Fly ash is used in Portland cement concrete to improve the performance of the concrete. The Free state quicklime released during hydration of cement reacts with ash silicates to make strong and sturdy cementing compounds and helps in improving the properties of concrete
[2].

Wankhede and Fulari [3] studied the effects of fly ash on the properties of concrete and concluded that with 10 % and 20% replacement of cement with ash , the compressive strength was increased whereas for 30 % replacement, the compressive strength was decreased. It was also observed that the slump loss of concrete kept on increasing with the increase of quantity of fly ash.

Patil et al [4] investigates the compressive strengths of concrete with partial replacement of cement with ash . The cement is replaced with fly ash from 5% to 25% by an increment of 5%. The rate of compressive strength development maximum at 60 days for concrete with no replacement of cement with fly **ash.** Concrete with 5% ash has maximum rate of compressive strength development up to the age of 21 days and then the rate decreases. It is observed that 10% fly ash addition gives the maximum strength at 90 days. Thus, for concrete with partial replacement of cement with fly ash, the initial rate of strength development is less but ultimately the required maximum strength is achieved.

SigrunKjærBremseth [5] discussed the various advantages and disadvantages of using fly ash in concrete. The most important advantage of fly ash concrete is the ability to resist alkali aggregate reaction whereas the greatest disadvantage ofusing Fly ash in concrete is Air entraining and lower rate of strength gain.

Bargaheiser and Butalia [6], reviewed the advantages of using high-volume fly ash concrete to resist corrosion damage in structures. Carbon dioxide and chloride penetrating the concrete are main reasons for corrosion of concrete. Use of Fly ash in concrete helps in reducing Carbon dioxide emission, provides sustainable design and longer service life of its infrastructure, slows down the ingress of moisture, oxygen, chlorides, Carbon Dioxide and aggressive chemicals in the concrete and prevents the deleterious effect of corrosion in reinforced concrete structures.

3.2 Silica Fume

Silica fume is an amorphous polymorph of silicondioxide,silica. it's collected as a byproduct of manufacturing silicon metal or ferrosilicon alloys. One of the unique properties of silica fume is its high surface area. It is a very good pozzolanic material and hence finds its use in high performance concrete. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is often added to the concrete as admixtures or partial replacement of cement.

Ghutke and Bhandari [8] determined the optimum replacement percentages of cement with silica fume which can be suitably used under the Indian conditions. It is observed that the optimum replacement percentage varies between 10 to 15% because after 15%, the compressive strength decreases. Further investigation reveals that workability of concrete decreases with the increase in percentage of silica fume.

Roy and Sil [9] did a study on the character of Silica Fume and observedhow it affected theproperties of fresh andhardened concrete. Properties like ultimate compressive strength, Flexural strength, splitting tensile strength are determined for various mix combinations of silica fume and then compared with the conventional concrete. It is concluded that silica fume helps in achieving lower water-cement ration and better hydration of cement particles. 10% replacement of cement with silica fume gave the maximum compressive strength and also gave significant increase in tensile and flexural strength. Silica Fume can also be used in construction places where chemical attack, frost action etc are common. High early strength is achieved in silica fume concrete

Srivastava et al [10] reviewed the effects of silica fume in concrete and came to the conclusion that adding silica fume increases the compressive strength and bond strength of concrete. The tensile strength, flexural strength and modulus of elasticity of silica fume concrete are comparable to that of Portland cement concrete.

Amudhavalli and Mathew [11] performed a detailed experimental study on M35 grade concrete, partially replacing cement by silica fume by 0, 5, 10, 15 and 20%. The consistency of cement increases upon addition of silica fume to the concrete.

The increase in flexural strength was observed upto 15% replacement of cement by silica fume. The gain in split tensile strength was significant upto 10 % silica fume. The optimum compressive and flexural strength was obtained in the range of 10-15% replacement of cement by silica.

3.3 Metakaolin

Metakaolin is a dehydroxylated form of the clay mineral kaolinite. It is an amorphous non crystallized material which consists of lamellar particles. Research on Metakaolinshows that it is an excellent pozzolanic material which can improve strength, durability and other mechanical properties of concrete.

Yogesh R. Suryawanshi et al [14] investigated the effects of Metakaolin and super plasticizer on concrete of grade M-35. Cement was replaced by Metakaolin by 4,8,12,16 and 20%. The water cement ratio was taken as 0.43 for all cases and compressive strength at 3, 7 and 28 days was determined. The compressive strength increased up to cement replacement of 12% after which a decrease in compressive strength was observed. The compressive strength increased by more than 10 % on replacing cement by metakaolin. Although, the use of metakaolin reduces the workability of concrete but suitable use of super plasticizers can compensate this reduction

3.4 Ground Granulated Blast Furnace Slag

Ground-granulated blast-furnace slag also referred to as GGBS is obtained from molten iron slag which may be a by-product of iron and steel-making. The process involves quenching of iron slag from a furnace in water or steam, to supply a glassy, granular product that's then dried and ground into a fine powder. This fine powder is then called as Ground-granulated blast-furnace slag.

Awasare and Nagendra [18] analyzed the strength characteris- tics of a M20 grade concrete with 20%, 30%, 40% and 50% re- placement of cement with GGBS. Comparison of results for natural sand and crushed sand is also done. The optimum strength of concrete with both natural and crushed sand is achieved at 30% replacement of cement with GGBS. It is also inferred that flexural and tensile strengths are also improved by incorporating GGBS in the concrete.

3.5 Combination of Fly Ash and Silica Fume

Heba A. Mohamed [23] experimented on self-compacting con- crete incorporated with different percentages of fly ash, silica fume and a combination of fly ash and silica fume. Cylinder specimens were used for slump and V-funnel test. The exper- iment involved different curing conditions for different spec- imens. Concrete having 15 % fly ash and cured in water for 28 days achieved the maximum compressive strength. When fly ash and silica fume were added to concrete as a combination, 10 % fly ash and 10% silica fume were found to be the opti- mum percentages.

Nochaiya et al [24] examined the effects of adding silica fume in Portland cement concrete incorporated with fly ash. Differ- ent combinations of Portland cement, fly ash and silica fume were used to make specimens for testing. The percentages of fly ash used were 5%, 10%, 20% and 30% and percentages of silica fume used were 2.5%, 5%, and 10%. The tests for normal consistency, setting time, workability and compressive strength were carried out and it was found that on increasing the silica fume content in concrete, the water requirement for normal consistency increases, initial setting time decreases. An overall increase in compressive strength was observed in con- crete on utilization of silica fume in concrete incorporated with fly ash. The workability reduced on adding silica fume to fly ash concrete but remained higher than that of Portland cement concrete

3.6 Combination of Fly Ash and Metakaolin

Nazeer and Kumar [26] experimented on high-volume fly ash concrete blended with metakaolin. Fly ash used as partial replacement of cement in Portland Cement concrete was 50% by weight. Metakaolin was thereafter used to replace the remaining cement by 5%, 10%, 15% and 20%. The concrete mix was formed forgrade M30 with water binder ratio as 0.44 and two curing conditions i.e. boiling and normal curing were used. Test for determining workability, compressive strength, split tensile strength, modulus of elasticity and impact strength of concrete were carried out. It was observed that the impact resistance of concrete blended with fly ash and metakaolin was higher but the workability was lower than that of controlled Portland cement concrete. On adding metakaolin, compressive strength, tensile strength and modulus of elasticity reduced.

Patil et al [27] evaluated the strength and durability of a high performance self compacting concrete incorporated with a combination of fly ash and metakaolin. Cement is slightly replaced by fly ash and metakaolin. The fly ash is used in pro- portions of 5%, 15% and 25% and Metakaolin is used in pro- portions of 3%,6% and 9%. It was found that use of metakaolin and fly ash resulted in changes in the chemical composition of the pore solution phase of the hydrated material and increased the chloride resistance of concerte. Fly ash is responsible for increasing the workability of concrete. The optimum percent- ages of metakaolin and fly ash for strength and durability of concrete are 9% and 15% respectively.

3.7 Combination of Fly Ash and GGBS

Li and Zhao [29] investigated the effect of combination of fly ash and granulated blast furnace slag in high strength concrete partially replacing the cement in it. It was observed that this combination can be used to improve early compressive strength as well as long term properties of the concrete.

Pratap et al [30] observed that a concrete mix of M60 grade incorporated with fly ash and GGBS had a higher compressive strength, flexural strength and split tensile strength as com- pared to normal mix concrete. The compressive strength was found to be increased by 11.13%, flexural strength by 11.74% and split tensile strength by 23.01% at 28 days.

3.8 Combination of Silica fume and Metakaolin

Srivastava et al [32] used a combination of silica fume and metakaolin in Portland cement concrete to study its effect on 7 and 28 day compressive strength. The optimum dose of silica fume and metakaolin for maximum compressive strength was 6% and 15% respectively. It was observed that increasing me- takaolin content increased the 28 day compressive strength but decreased the 7 day compressive strength. Addition of metakaolin also reduced the slump in concrete.

Anbarasan and Venkatesan [33] carried out compressive strength test, split tensile test and sorptivity test on concrete made by silica fume and metakaolin as partial replacement of cement. The optimum percentage replacement of cement with silica fume and metakaolin is 35 % and 15 % respectively. At this percentage, the strength and durability was observed to be higher than the conventional concrete.

Shirke et al [34] studied the performance of concrete on incor- poratingmetakaolin, silica fume and a combination of them. Replacing cement by 5 % Silica fume and 15% metakaolin by weight gave the highest strength. Concrete which was ternary blended with metakaolin and silica fume showed the least mass loss on exposure to HCl solution.

IV. CONCLUSION

The present study aimed at reviewing the literature on differ- ent alternatives to cement in concrete. These include fly ash, silica fume, metakaolin and Ground granulated blast furnace slag. Cement can be partially replaced by one of these alterna- tives or by a combination of these alternatives. The literature review revealed the following conclusions –

- Fly ash increases the compressive strength, tensile strength and flexural strength of concrete. It also increases resistance to alkali aggregate reactions, slows down in- gress of moisture, oxygen, chloride, carbon dioxide and aggressive chemicals and prevents corrosion. The main disadvantages of using fly ash are lower rate of strength gain, increased air entraining and increased slump loss.
- Addition of silica fume helps in increasing the strength of concrete by 10–15 % and also gives high early strength. Other advantages of adding silica fume are lower water-cement ratio, resistance to frost action and chemical effect. However, silica fume reduces workability of concrete and increases the consistency.
- Metakaolin increases the compressive strength up to 12 %, gives higher resistance to chemical effect, reduces chloride permeability, sorptivity and pore size and enhances corro- sion resistance of concrete. The main disadvantage of us- ingmetakaolin as partial replacement of cement in con- crete is that it reduces workability of concrete.

V. FUTURE SCOPE

After reviewing the various works done by different research- ers, it can be inferred that there is a vast scope in improving the characteristics of concrete as well as reducing the content of cement used. It is clear that all the four alternatives to ce- ment presented in this paper affect the properties of concrete in a unique way. Thus, future work lies in replacing all of the cement from concrete by using a suitable combination of ce- ment alternatives to increase the strength, workability and durability of concrete. Also, new alternatives should be found which can overcome the drawbacks of the above mentioned alternatives.

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