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Various Properties of High Volume Flyash Concrete (HVFA) -A Review

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Abstract: Now a days different pozzolanic materials are used as a partial replacement of cement in concrete. Flyash is used most commonly as its production is much more than others. Green concrete has now become a significant necessity of present environment in today's scenario. Using flyash in concrete, results in less demand of cement, hence reduction in CO2emission. With increase in flyash content in concrete, CO2 emission will be less. Therefore, HVFA concrete means more than 50% cement is replaced by flyash. In this literature review, various papers were studied for different quantity of flyash replaced and compressive strength and other mechanical properties are also discussed. Addition to that effect of some additives in HVFA concrete and temperature effect on the same has been discussed. In this paper we explore previous as well as current development in HVFA concrete and gap in research of HVFA concrete. As a result, summarized knowledge would be extremely useful in planning future research in HVFA concrete made from industrial waste.

Keywords: Super plasticizer, Flyash, shrinkage, Abrasion, compressive strength, C-S-H gel

Introduction

In modern thermal power plant when coal is burnt in close container small dusty round particles produced as a byproduct of burning is called flyash. Main uses of flyash are mostly in production of cement, replacement of cement and sand in concrete and for making green concrete as less cement is used hence less generation of Co2 gas. Use of flyash in concrete is beneficial in wet concrete as improved workability and in hardened state it improves durability. As per IS 1489 (part1) 35% replacement of flyash with cement is permissible. Many research has been done for replacement of flyash with cement more than 35 % with use of some additives and by controlled curing methods. As we increase the % replacement of flyash in concrete it is not only economic but also helps in environment protection. In this literature review, different papers studied for different flyash replacement and compressive strength and other mechanical properties are also discussed.

Literature review

- G. G. Carette & V. M. Malhotra showed in their study that blended mix has given higher mechanical properties initially.At the starting mixed paste having a high w/c ratio result cement gets higher degree of hydration. Residual flyash and cement matrix results in a good bond. Pores with size greater than 0.09 µm of flyash cement mixture with water cementitous material ratio 0.30 is same as of pure cement mix after 7 days hydration. So, it may be said that use of flyash makes concrete more durable. However, some amount of lime and fly ash remains unhydrated in ling term also.

- Cengiz Duran Atis has conducted a mix design for various grades of concrete for finding abrasion resistance. Four mixes were designed namely:-
  i. M1- 70% replacement of cement with flyash and addition of super plasticizer.
  ii. M2- 70% replacement of cement with flyash (without super plastisizer)
  iii. M3- 50% replacement of cement with flyash and use of super plasticizer.
  iv. M4- 50% replacement of cement with flyash (without super plasticizer)

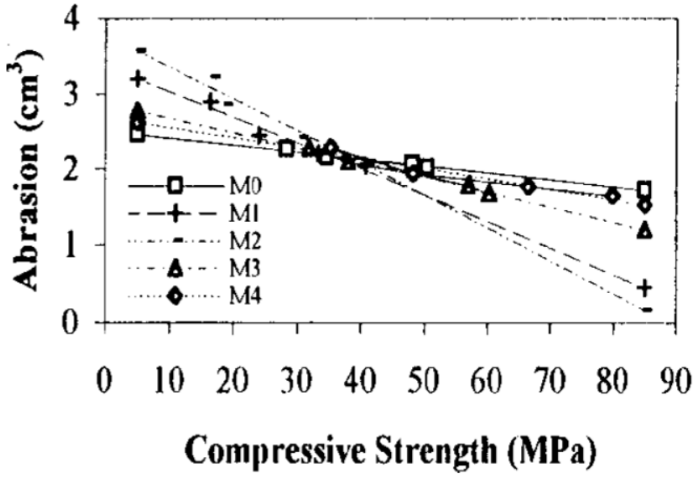

Fig. 1: Compressive strength vs **A**brasion at RH 65%

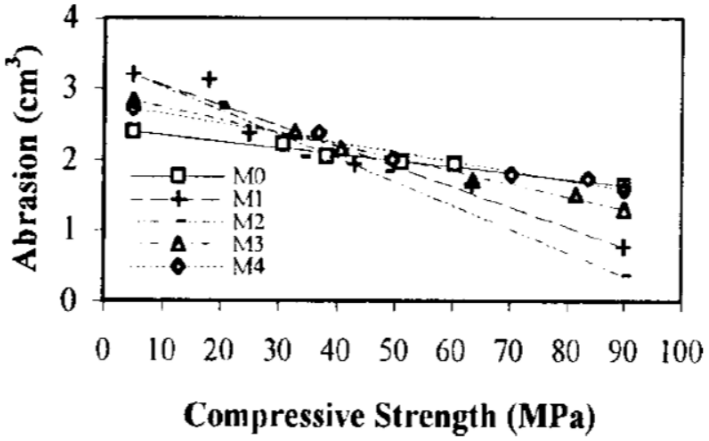

Fig. 2: Compressive strength vs **A**brasion at RH 100%

Mixes that were not added with super plastisizer showed zero slumps also called RCC. Samples were placed at 20°C temperature and with 65% and 100% RH. Results showed that abrasion resistance of M1 and M2 grade concrete were more than M3 and M4 grade concrete and also greater than normal concrete. In addition, when super plasticizers are added to flyash concrete, there is no influence on abrasion of concrete.

- Binod Kumar, G. K. Tike and P. K. Nanda has prepared three normal concrete with three different water/cement ratio (i.e 0.30, 0.34 & 0.40) with fixed cement content (i.e. 400kg/m3) and Flyash was substituted for cement in subsequent concrete mixes from 20% to 60 % range for every 10% interval. Mechanical properties of hardened concrete were measured at shorter age and at later age also

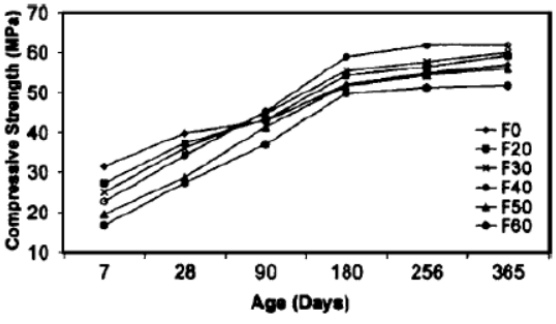

Fig. 2: Age Vs Strength (W/C-0.40)

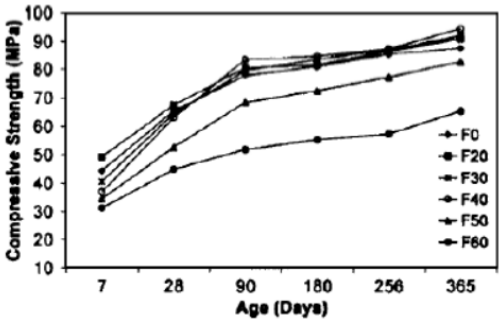

Fig.3: Age Vs Strength (W/C-0.3)

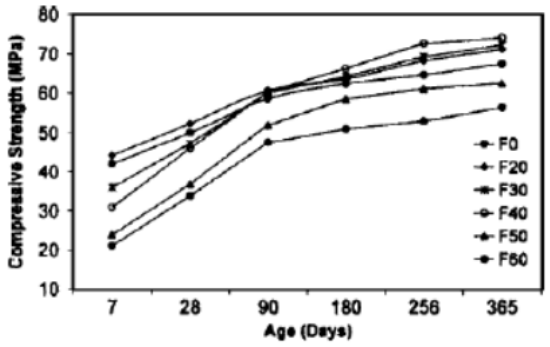

Fig. 3: Age Vs Strength (W/C-0.34)

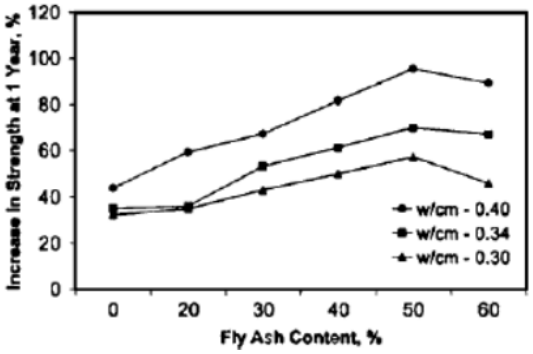

Fig.4: Increse in stength vs Flyash content

For the required compressive strength and workability,50-60% flyash replacement has given best results.40 % flyash replacement has given maximum compressive strength at 90 days.50% flyash replacement has given maximum increase in compressive strength up to 1 year. Shrinkage loss has decreased with increment in flyash content. As the % of flyash increased compressive strength and abrasion decreases.

- In all research we have studied that cement was replaced by flyash in concrete but Rafat Siddique and Jamal M. Khatib made a research by replacing sand with flyash in different proportions in concrete. Water cement ratio and workability has been kept constant. When they replaced sand with flyash, there was an improvement in all of the concrete's mechanical properties. When sand was replaced by flyash, surface area of sand particles gets reduced in concrete mix. Cementitious material was increased due to pozzolanic reaction of flyash with excess lime present in concrete as a resultant of primary reaction of hydration of cement. Due to this compressive strength of concrete with flyash got improved. More is the Abrasion resistance. Abrasion resistance of concrete can give idea of all other properties of concrete.

With the increase in flyash content with replacement of sand, mechanical properties of such concrete enhanced at various ages.28 days compressive strength results 25-41%, spilting tensile strength by 12-21%, flexural strength 14-18% and modulus of elasticity by 18-23%, Curing time also effects these properties of HVFA concrete.

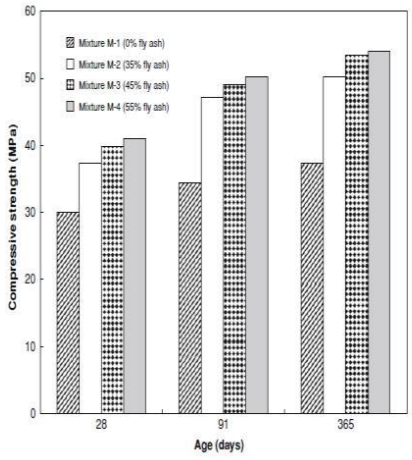

Fig. 5: Compressive strength Vs Age

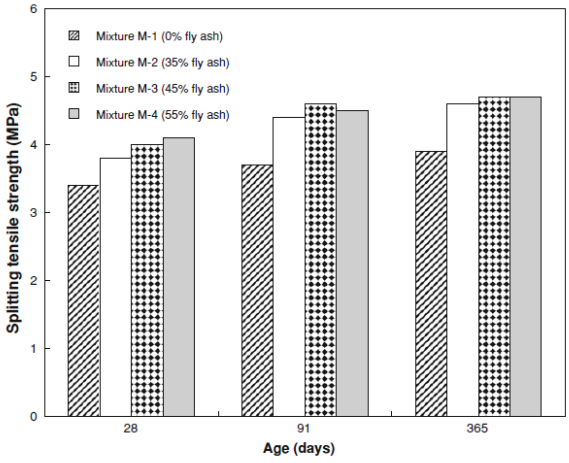

Fig. 6: Split tensile strength Vs Age

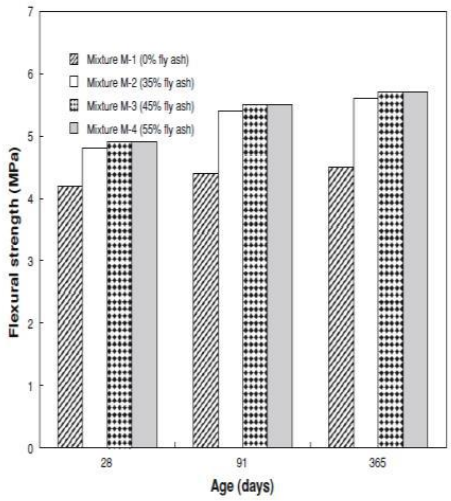

Fig. 7: Flexural stength Vs Age

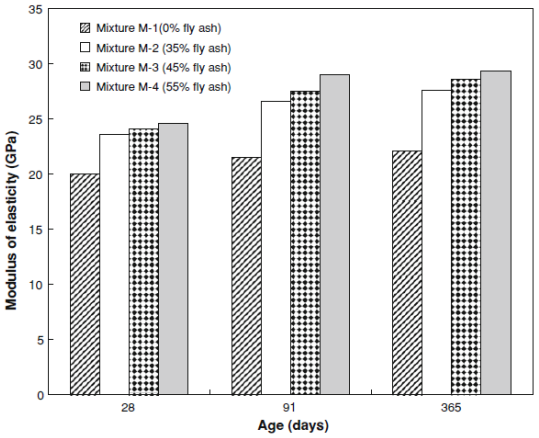

Fig. 8: Modulas of elasticity Vs Age

- T. Ch. Madhavi , L. Swamy Raju & Deepak Mathur has analyzed various properties of fresh & Hardened concrete using high volume flyash i.e. workability, Bleeding of concrete, setting time, heat of hydration, drying shrinkage, creep strains, Compressive strength, split tensile strength and flexural strength. For concrete slab with mere broom finish flyash can be used as 40 to 50% as a replacement of cement but for trowel finish only 25-50% shows good results. Fly ash contents of up to 50% Flyash content might be suitable for most concrete elements provided the early strength requirements of the project can be met with assurance of adequate moist curing The initial compressive strength decreses but at higher flyash content around 40%, w/c ratio decreses and the compressive strength increses. Concrete containing more than 40% flyash showed less strength at 28 days, but greater strength at 90 days. But concrete with flyash content less than 40%, the compressive strength at 28 days is higher. Indeed, the strength of concrete is a function of water/binder ratio,the quality of flyash and cement and the hardening time.

- Xiao-Yong Wang and Ki-Bong Park has presented a mathematical method to find development of compressive strength in HVFA concrete. This mathematical method consists of two models:

  i. Blended hydration
  ii. Strength evaluation

They have made curing age as function, how much cement and flyash reacted, how much CSH gel formed and how much fraction of phase volume were calculated. Quantity of CSH gel can give data about compressive strength. They said that in this method water/binder ratio fly ash content may change.

Test results showed less compressive strength at later age for low volume fly ash concrete compare to normal concrete. At the other side, for high volume flyash, concrete strength is less than normal concrete at later age also.

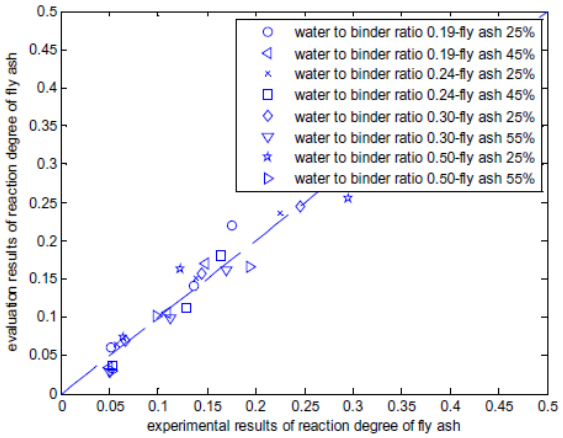

Fig.9: Evaluation vs experimental results of reaction degree of flyash

- Dr. K. V. Ramesh, M. Dharma Raju and Kasi Rekha investigated various mechanical and physical properties of HVFA concrete which was exposed to very high temperature of 800oC with interval of 200oC for 3 hrs period. flyash replaced with cement 30-50% and temp. Range from minimum 27oC and maximum 800oCwith interval of 200oC.It was found that ultimate strength of control concrete was comparable to 50 % flyash replaced concrete. Durability was also higher for flyash concrete as its weight loss was less than control concrete. Residual compressive strength, weight loss and colour change also studied. The colour of flyash concrete samples were turned into orange red colour at 600-800oC and crackes were also observed at concrete surface. Weight loss was found to be irreversible of quantity of flyash replaced but was proportionate to temperature increase. All the concretes mixes showed increase in strength upto 400oC and decreased beyond 400oC except the mix C50F50.The mix C50F50 showed an increase in residual compressive strength exposed upto 600oC at 28 days.

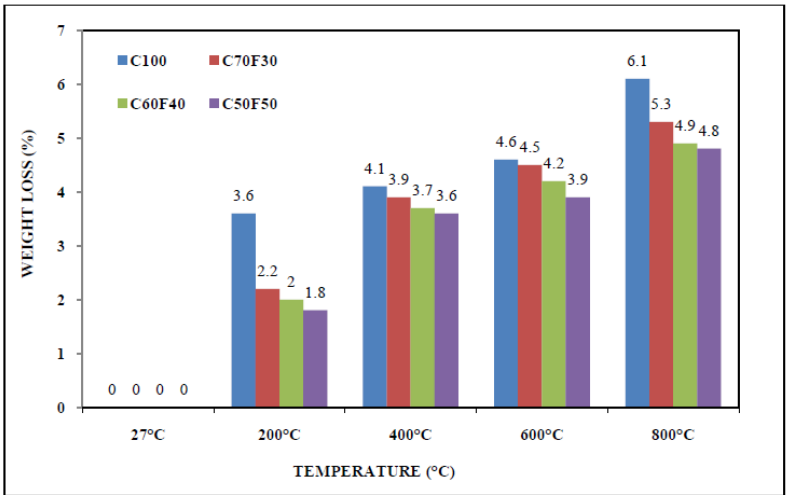

Fig.10: Percentage weight loss at different temperature

- K. Krishna Teja & B. Kameswara Rao has conducted an experimental study using fly ash from VTPS, Vijayawada with different percentages of fly ash of 50, 60, and 70%.OPC 53 grade and workability was maintained by hyper plasticizer. Two grades of concrete were cast M30 & M40.They found that early strength of two grades (i.e 7 days & 28 days) concrete with high volume flyash greater except for 70% replacement. At 28 days, the concrete strength of both grades of HVFA increased significantly upto60% replacement of flyash. At 60% fly ash replacement, the compressive strength and chloride ion

permeability of M30 and M40 are very high compared to all other alternatives including ordinary concrete.

From their study, they concluded that an optimum fly ash content of 60%replacement of cement was observed when considered the factors such as compressive strength & Permeability of Concrete.

- Bimal Kumar, Sanjeev Sinha and Hillol Chakravarty have made a high volume flyash concrete with addition of nano silica in powder form. All mechanical properties were tested at various ages of concrete. A normal concrete mix was prepared and a high volume flyash concrete mix with 55% cement replacement with flyash was prepared with addition of 2% nano silica. Results showed that compressive strength and abrasion resistance of high volume flyash with 2% nano silica were more than normal concrete. Flexural and split tensile strength also showed same trends.

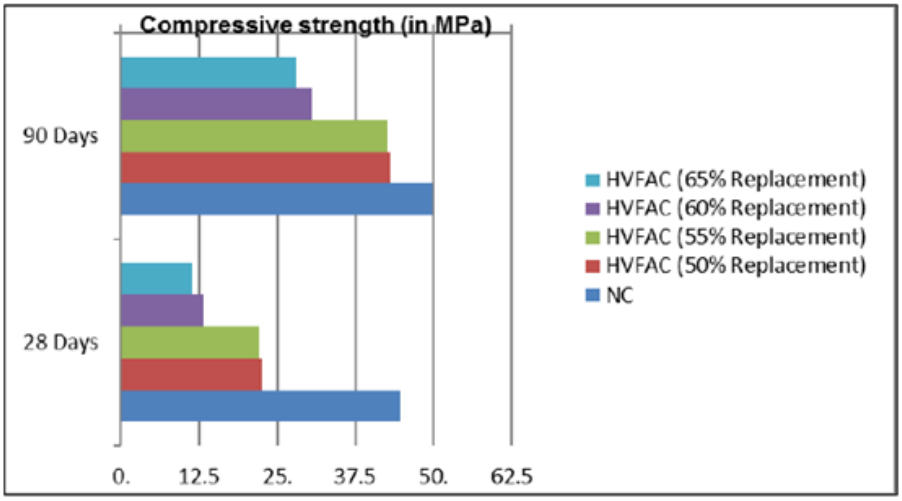

Fig.11: Compressive strength at the age of 28 days and 90 days

- Prof. Ashish S. Moon, Aditya U. Meshram, Md. Qadim Sheikh, Ravi Ranjan Kumar, Priyanka K. Waykul5, Puja N. Samarth have designed and investigated the HVFA concrete withM20,M30 and M40 grades as per IS method (IS 10262:2009). To increase workability of HVFA concrete super plasticizer was used. Mechanical properties of these mixes were investigated.

The compressive strength of high volume flyash concrete was much less than normal concrete at early days. This difference reduced at later ages.60% flyash adjusted in concrete as a substitute of cement gave good compressive strength slightly less at early ages and more at later ages. Flyash in concrete made concrete compact and nonporous than normal concrete at later ages. Flyash showed pozzolanic reaction with available excess lime in concrete which was result of hydration of cement. Extra cementitious material named as extra CSH gel was produced in secondary reaction; hence development of strength is slower in HVFA concrete. Thus high volume fly ash can termed as green concrete because it helps in sustainable development.

S. Talukder, E. Roy, M. S. Islam & S. Sakib prepared concrete of M30 grade having different flyash ratios i.e. (100: 00), (45: 55), (35: 65), (25: 75) & (15: 85). Three nos. tests were conducted on hardened concrete. Compressive strength, tensile strength & chloride penetration test. Specimen exposed for curing in plain water environment & 10% NACL environment. They nominate A as (0% flyash),B as (55% of flyash) and C as 965% of flyash).concrete Specimens C & B who cured in plain water environment showed 95% and 83% compressive strength at 28 days of concrete A. Similarly tensile strength of concrete B&C was around 94% at 28 days. In NACL environment rate of gain of strength was more than plain environment. The chloride penetration values at any depth level for HVFA concrete is observed to be lower than that of control concrete

Changyong Li and his teammate's tested a high volume flyash concrete with flyash content varies from 51.9 to 60.2% and water to binder ratio varies from 0.26 to 0.5.various properties of HVFA concrete i.e. workability, mechanical properties, resistance to chlorine ion penetration and carbonization of concrete were determined. Cubic compressive strength showed a sharp decrease at the cure age of 7 days. FAC's compressive

strength remained closely related to increasing flyash content over 28 days of cure, and tended to increase with increasing flyash over 56 days of curing with a high flyash content of 51.9 to 57.6%, Flyash concrete is exceptionally resistant to chlorine penetration and carbonation. The strength increases as the water to binder ratio decreases and reaches very high levels for the current specification.

Conclusion

In this literature review it can be concluded that when high volume flyash is replaced with cement, compressive strength at early age did not increase significantly, but at later ages it can give better results for compressive strength and abrasion resistance also. Flyash replacement is limited to maximum 60% in all research. High flyash replacement also results in least shrinkage. When these flyash replaced mixes cured at elevated temperature 50% flyash replacement gives maximum residual compressive strength. When 2% nano silica in powder form is used in flyash replaced concrete it results better compressive strength then normal one. So we can say that with using good quality high volume fly ash in concrete we can get more compressive strength then normal concrete with some additives and controlled curing condition. Further research is required in this field for use of other additives in high volume flyash concrete with greater than 60% flyash replacement, which enhance compressive strength and durability properties with minimize the shrinkage and other losses. As per IS 1489 (part1) 35% replacement of flyash with cement is permissible. It is further needed to do excessive testing of HVFA concrete having more flyash then specified in IS code to conclude the percentage of flyash in concrete. HVFA concrete cannot be used where early strength is important. Later strength should also be monitored for durability of structure considering all the negative effect of flyash on concrete with suitable methods.

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