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Effect of fly ash and plastic waste on mechanical and durability properties of concrete

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Abstract. The disposal of polythene waste and fly ash is causing serious threat to the environment. Aim of this study is to decrease environmental pollution by using polythene waste and fly ash in concrete. In this study, cement was partially replaced with 0%, 5%, 10%, 15% and 20% fly ash (by weight) and plastic waste was added in shredded form at 0.6% by weight of concrete. The specimens were prepared for the concrete mix of M25 grade and water to cementitious material ratio (w/c) was maintained as 0.45. Fresh concrete property like workability was examined during casting the specimens. Hardened properties were found out by carrying out the experimental work on cubes, cylinders and beams which were cast in laboratory and their behavior under test were observed at 7 & 28 days for compressive strength and at 28 days for density, flexural strength, dynamic modulus of elasticity, abrasion resistance, water permeability and impact resistance.

Overall results of this study show that addition of 0.6% (by weight of the concrete) plastic waste with 10% (by weight of cement) replacement of cement by fly ash result an improvement in properties of the concrete than conventional mix.

Keywords: fly ash; plastic waste; workability; density; compressive strength; flexural strength; dynamic modulus of elasticity; abrasion resistance; water permeability; impact resistance

1. Introduction

Concrete is a composite material incorporate cement, sand, aggregate, water and admixture. Concrete is the 2[nd] most largely used material in the world after water. In India, 370 million m^3 concrete is being utilized by construction industries per year and it is anticipated to broaden 30 million m^3 every year. Also, origins of all basic ingredients of concrete are nature, which are reducing with increase in consumption of concrete due to popular growth of construction industry. Therefore, it is require finding alternate material which can be utilized in the production of concrete. The revolutionary in construction industry called green concrete, which is produced by adopting the waste.

The production of plastic waste and fly ash has been increasing at an alarming rate, disposal of which has become a serious environmental problem. In this study an attempt is made to utilize

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wastes like polythene bags (collected from disposed municipal waste) and fly ash (collected from coal based thermal power station). These wastes themselves have such properties which are beneficiary when they are incorporated in concrete as ingredient. For example, polythene bags are light weight, so using them in concrete will lead to light weight concrete. Hence using them as ingredient in concrete will not only enhance the bitter properties of concrete but also help in reducing the environment pollution. Also, scarcity of nature origin ingredients of concrete will be reduced.

Some research works have been carried out to discover benefits of utilization of fly ash and plastic waste in production of concrete and thereby improving properties of concrete. Prahallada *et al*. (2013) studied the strength characteristics like compressive strength, tensile strength, flexural strength & impact strength and workability characteristics of M30 grade plastic fiber reinforced concrete in which cement was partially replaced by 0%, 5%, 10%, 15%, 20% and 25% by fly ash (by weight) and plastic waste added at a constant dosage of 0.5% by volume of concrete and water to cementitious material ratio (w/c) adopted was 0.46. Based on the experimental results, it was concluded that the waste plastic fiber reinforced concrete shows a higher compressive strength, tensile strength, flexural strength and impact strength at 10% fly ash dosage. Also, maximum workability is achieved when 10% of fly ash was utilized. In similar way Chandru *et al*. (2015) examined properties of M40 grade concrete containing plastic fibers and fly ash. Cement was partially replaced by fly ash by 5%, 10%, 15%, 20%, 25% and 30% (by weight) and plastic waste added at a constant dosage of 0%, 0.5% and 1.0% (by volume of concrete). The specimens were tested at 7, 28 and 56 days for compressive strength and at 28 days for split tensile strength & flexural Strength. Improvement in mechanical properties of concrete reported when plastic fibers and fly ash incorporated in concrete. Compressive strength was low at early age (7 days of curing) for all plastic fiber reinforced concrete than the conventional concrete. After that strength has increased at 28 and 56 days of curing when 15% of cement was replaced by fly ash (by weight) in concrete containing 0.5% and 1% plastic fibers. Split tensile strength was increased when 10% of cement was replaced by fly ash (by weight) in concrete containing 0.5% and 1% plastic fibers. Flexural strength was increased when 5% of cement was replaced by fly ash (by weight) in concrete containing 0.5% and 1%. The major focus of researchers was to evaluate the effect of fly ash and plastic waste on compressive strength, split tensile strength and flexural strength but the other properties of concrete like abrasion resistance, water permeability of concrete, dynamic modulus of elasticity were never dealt. A systematic study is done in this project to find effect of using wastes in concrete at different percentages and then comparison is done to find the permissible dosage of the waste.

2. Materials

Materials utilized in this study to produce concrete are as follows*:*

2.1 Cement

The cement used in this experimental project was 43 Grade ordinary Portland cement (OPC) conforming to IS 8112-1989 for casting the specimens of all concrete mixes. Physical properties of cement were calculated and tabulated in Table 1.

Table 1 Physical properties of cement

Sr. No.	Properties	Test results
1	Consistency	32%
2	Initial setting time Final setting time	130 minutes 213 minutes
3	Specific gravity	3.13
4	7-day compressive strength	34.95 MPa
5	28-day compressive strength	45.29 MPa

2.2 Fine aggregate

The fine aggregate used for investigation belongs to the zone II, was procured from the local fine aggregate suppliers and conform all requirements as per IS: 383-1970. The specific gravity test was performed in the laboratory and value achieved was 2.63.

2.3 Coarse aggregates

Coarse aggregate of 10 mm and 20 mm sizes were used in this study and they conform all requirements as per IS: 383-1970. It was free from dust particles, vegetation, organic matters and clay. The specific gravity test was performed in the laboratory and value achieved was 2.78.

2.4 Water

Ordinary water available in the laboratory was used in this investigation both for mixing and curing the concrete specimens throughout the investigation and it conform all requirements as per IS: 456-2000.

2.5 Plastic waste (polythene bags)

The plastic wastes used in this study were consisting waste polythene bags in shredded form. Bags did not be given any special treatment except the normal water wash, cleaning and day light drying and then cut into plastic shredding machine to achieve shredded form. Specific gravity test was performed in laboratory and value achieved was 0.33.

2.6 Fly ash

Class F fly ash collected from Shree Singaji Thermal Power Project, Khandwa, Madhya Pradesh was used during the experiment. Specific gravity test was performed in the laboratory and value achieved was 2.5.

3. Methodology

The methodology adopted to accomplish the objective of the experimental investigation and execution of work was done in step by step as follows:

3.1 Mix design

Mix design was done for M25 grade of concrete as per the guidelines given in IS: 10262-2009 and IS: 456-2000. The mixes were designed after considering many trail mixes. The design mix of 1:1.54:2.76 was adopted for casting specimens. Shredded polythene bags were added as 0.6% by weight of concrete and cement was partially replaced with 0%, 5%, 10%, 15% and 20% fly ash (by weight). The water to cementitious material ratio (w/c) was maintained at 0.45. Total 126 specimens were cast during this study.

3.2 Weighing

The quantity of a ll ingredients of the concrete i.e., cement, fly ash, fine aggregate, coarse aggregate, polythene bags and water for each batch was determined as per the mix design ratio and weighed using weighing machine available in the laboratory.

3.3 Mixing

Process of mixing of various ingredients adopted was as per IS: 516-1959 and machine mixing process was adopted for mixing using pan type mixer.

3.4 Preparation of moulds

Before casting the specimens, all cube, cylinder and beam moulds were cleaned, screwed tightly and oil was applied to all surfaces to prevent adhesion of concrete during casting.

3.5 Compaction

Placing of concrete in oiled moulds was done in three layers and each layer tamped 25 times with the tamping rod. After tamping the moulds, they were compacted using vibratory machine.

3.6 Curing

After 24 hours, all specimens were removed from the moulds and marked (to identify the casting batch) and immediately put into the curing tank for a period of 7 and 28 days. The specimens were not allowed to become dry during the curing period.

3.7 Testing

Specimens were taken out from the curing tank after 7 and 28 days to perform various tests. Three numbers of specimens in each sample were tested and the average value was calculated. Fresh concrete property like workability was examined by compacting factor test during casting of specimens. Hardened properties were found out by carrying out the experimental work on cubes, cylinders and beams which were cast in laboratory and their behavior under test were observed at 7 & 28 days for compressive strength and at 28 days for density, flexural strength, dynamic modulus of elasticity, abrasion resistance, water permeability and impact resistance.

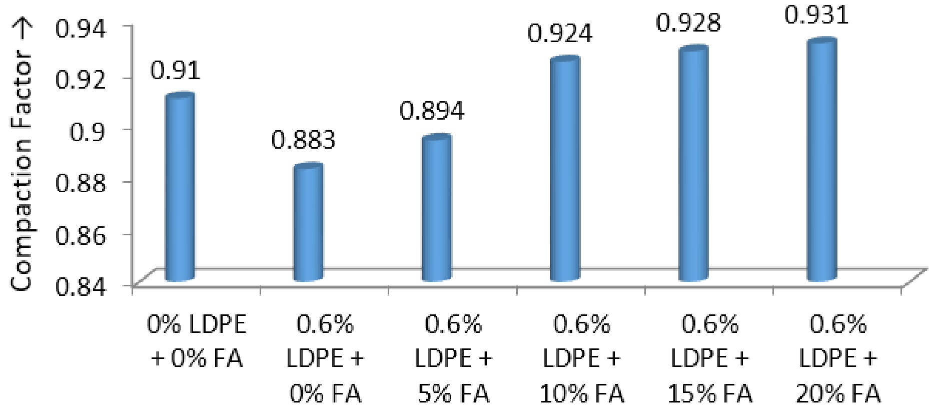

Fig. 1 Variation of compaction factor with fly ash content

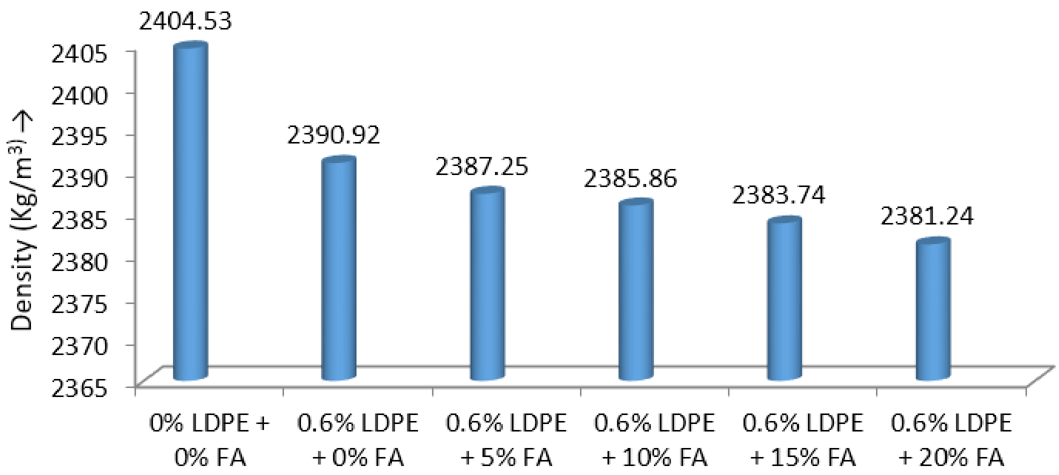

Fig. 2 Variation of density with fly ash content

4. Results and discussion

Here discussion on results of tests carried out in the laboratory to investigate the various properties such as workability, density, compressive and flexural strength, modulus of elasticity, abrasion resistance, water permeability and impact resistance is done to analyze the data obtained.

4.1 Workability

Compaction factor test was used for determining the workability of fresh concrete. Bar chart has been plotted for variation of compaction factor with percentage fly ash as shown in Fig. 1. Compaction factor value of control mix is achieved as 0.91 which reduced to 0.883 for 0.6% plastic waste addition to the control mix. On replacing 10% of cement by fly ash in plastic waste containing concrete, compaction factor value increases to 0.924. A general trend observed is increment in compaction factor with increase in fly ash content up to 10% dosage. Hence till 10% fly ash dose workability gets enhanced.

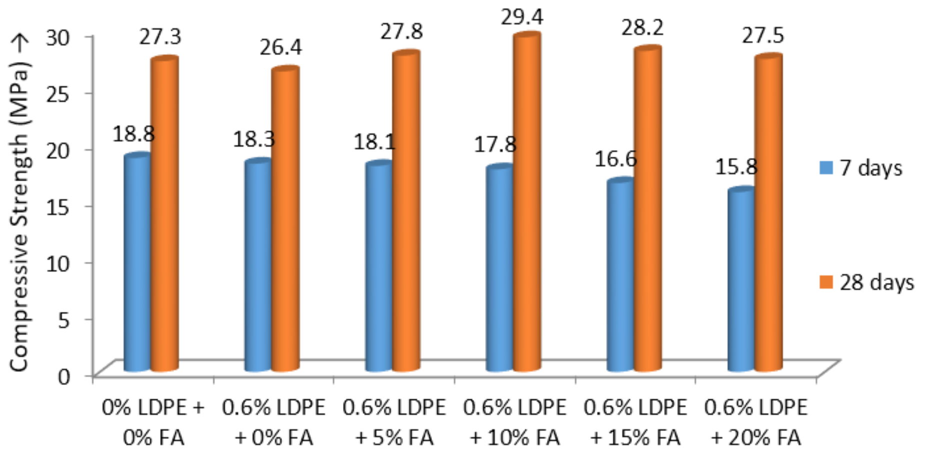

Fig. 3 Variation of compressive strength with fly ash content

Fly as particles are spherical in shape and their tendency is to coat and lubricate the aggregate particles which reduce the friction between aggregates and between concrete and supply pump. This might cause improvement in workability and pumpability of concrete. Also fly ash particles get absorbed on the surface of oppositely charged cement particles and prevent them from flocculation, releasing large amount of water, thereby reducing the water demand for a given workability and thus reduces bleeding of concrete.

4.2 Density

Fig. 2 shows variation of density with percentage fly ash addition. By observing the figure, it can be said that density decreases as the addition of fly ash increases.

Specific gravity for fly ash and polythene bags is less than that for other concrete ingredients like cement, coarse & fine aggregates, which may result in a decrease in density with increase in fly ash content.

4.3 Compressive strength

Fig. 3 shows variation of compressive strength measured at 7 and 28 days with % fly ash. It can be seen that compressive strength of the concrete increases with increase in curing age. The compressive strength decreases as the addition of fly ash increases for 7 days curing. Whereas after 28 days curing, compressive strength value increases (crosses compressive strength value for control mix) up to 10% fly ash dose and then it started decreasing.

The reason for the 28 days improvement may be due to reaction between fly ash and surplus lime, which is released during hydration of cement. This reaction results in the formation of additional C-S-H gel, which gives additional strength.

4.4 Flexural strength

Fig. 4 shows variation of flexural strength with % fly ash. It can be seen from the graph that strength increases as the addition of fly ash increases up to 10%. After 10% dose, any further

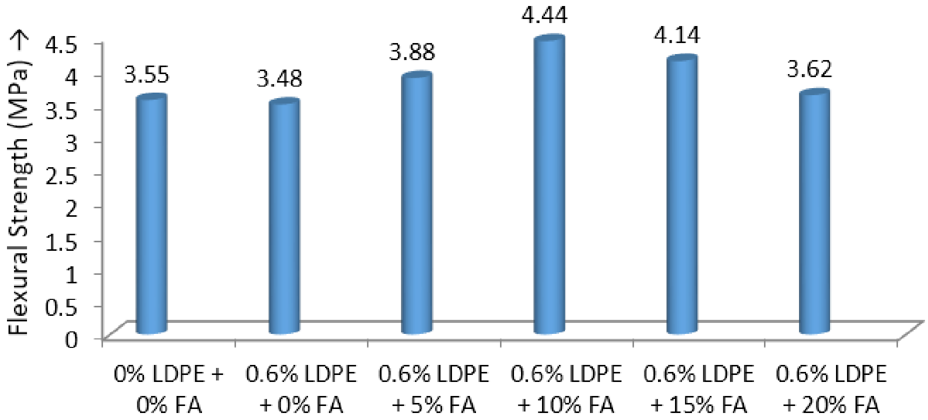

Fig. 4 Variation of flexural strength with fly ash content

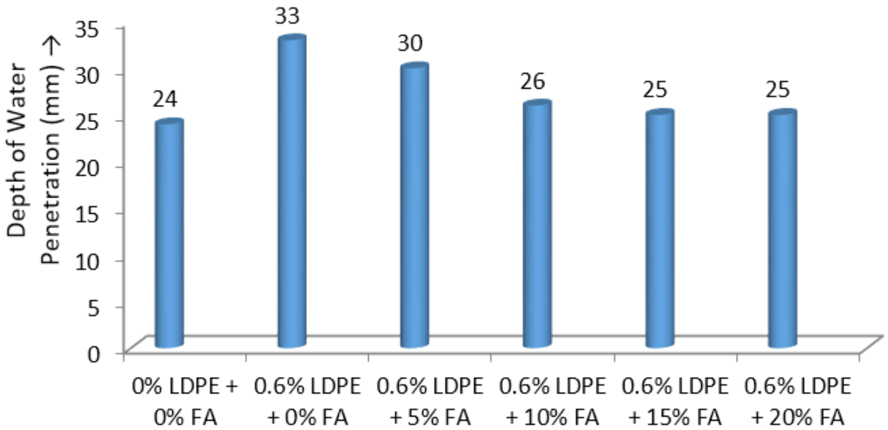

Fig. 5 Variation of depth of water penetration with fly ash content

increase in fly ash results decrease in strength value, although strength value achieved is more than that of control mix. Thus, replacement of cement by fly ash gives positive and improved results than that with cement only. Most probable cause of improvement in the strength may be due to reaction of fly ash with lime, released during hydration of cement, which produces additional binders to give additional strength.

4.5 Water permeability

Fig. 5 shows variation of water penetration depth with % fly ash. The trend recorded for the variation of water penetration depth with fly ash dose is that the depth of water penetration decreases as fly ash percentage increases. Depth of water penetration is considerably decreased till 10% and then it almost remains at same value.

The decrease in penetration of water may be due to refinement of pore structure as fly ash is more efficient void filler than OPC. Additional cementitious material results from reaction between surplus lime (liberated from hydration of cement) and fly ash, blocks capillary voids and thereby reduces permeability of concrete.

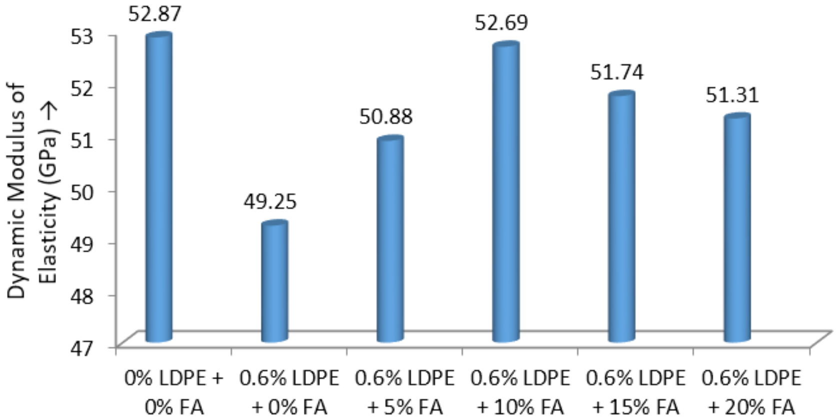

Fig. 6 Variation of dynamic modulus of elasticity with fly ash content

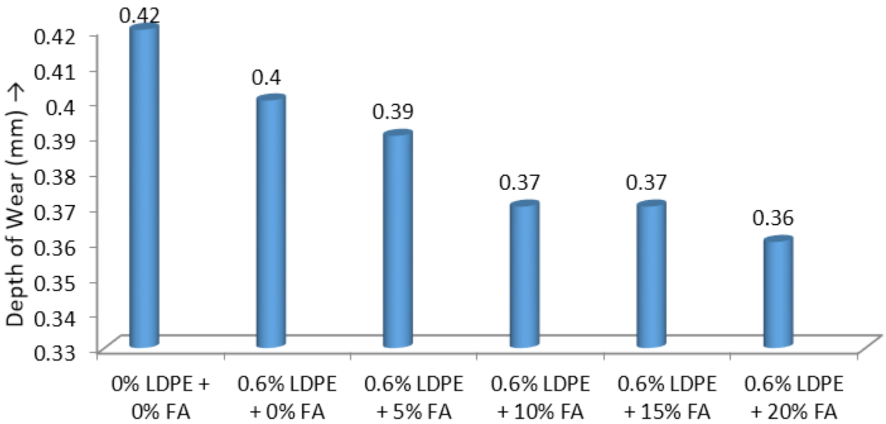

Fig. 7 Variation of depth of wear due to abrasion with fly ash content

4.6 Dynamic modulus of elasticity

Variation of dynamic modulus of elasticity with fly ash can be observed in Fig. 6 that with increment in fly ash content it increases up to 10% dose. After 10% dose decrement is observed in dynamic modulus of elasticity. Thus, 10% fly ash content gives maximum dynamic modulus of elasticity value.

Ultrasonic pulses travel with higher velocity through uniform concrete. As addition of fly ash results better packing of concrete matrix and uniformity. So, velocity of ultrasonic pulses increases, which might result increase in dynamic modulus of elasticity.

4.7 Abrasion resistance

Variation of wear depth due to abrasion with percentage fly ash content is as shown in Fig. 7. The results indicated that the abrasion resistance of concrete increased with addition of plastic waste, i.e., less wear of depth is observed when 0.6% of shredded plastic bag is added into the concrete mix than the control mix. Also by replacing cement to various percentages by fly ash,

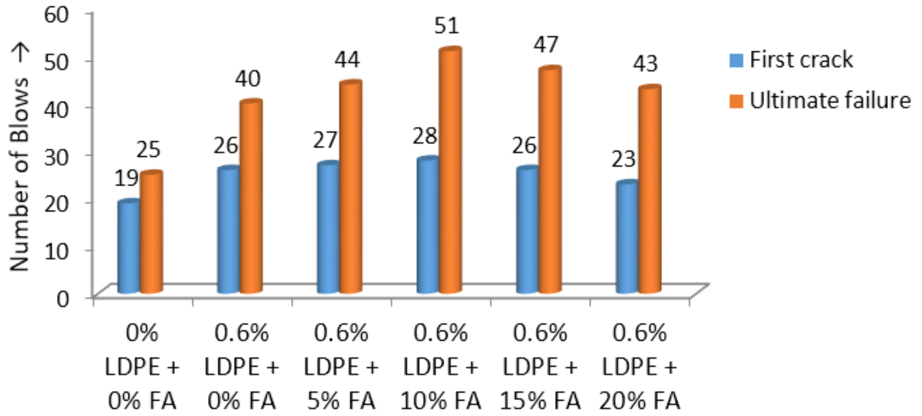

Fig. 8 Variation of number of blows required for first & ultimate cracks with fly ash content

wear depth decreased continuously. Thus, a better abrasion resistance is observed when fly ash is present in the concrete along with plastic waste.

Improved packing effect of matrix by filling up of micro pores with fly ash might be the reason of increased resistance to abrasion in concrete containing plastic waste with fly ash.

4.8 Impact resistance

The impact resistance was determined with drop weight test. The impact resistance of concrete mixes (average of three specimens for each mix) at 28 days curing was recorded in terms of numbers of blows required for producing first visible crack (N_1) and ultimate failure (N_2) of the specimen and their variation with fly ash percentage is presented in bar chart as shown in Fig. 8.

It can be observed from the graph that the number of blows required for causing the first crack and ultimate failure increased for shredded plastic bag reinforced concrete mix than control mix. Further addition of fly ash to this mix resulted into increase in number of blows for both first crack and ultimate failure up to 10% dosage of fly ash. After 10% fly ash, impact strength started decreasing, although it is more than that of control mix.

Better packing of concrete matrix due to less availability of pores and better binding of ingredients in the concrete mix may be the cause of improvement of impact strength.

5. Conclusions

The main aim of this study was to investigate the possibility of using shredded polythene waste materials and fly ash as concrete ingredients. Fresh and hardened properties like workability, density, compressive strength, flexural strength, water permeability, abrasion resistance, dynamic modulus of elasticity and impact resistance were examined in laboratory for concrete specimens containing plastic waste and fly ash. Following conclusions can be drawn after comparing the results:

• The 10% replacement of cement by fly ash improved the workability, compressive strength and flexural strength of the concrete containing 0.6% (by weight of concrete) polythene waste by 2.3%, 7.7% and 25% of conventional mix respectively.

• The density of concrete containing 0.6% (by weight of concrete) polythene waste decreased with increase in the percentage of fly ash up to 10% by weight of cement. After which any further addition of fly ash results in a small density decrease. The decrease in density at 10% fly ash content is about 0.97% of that for conventional mix.

• The dynamic modulus of elasticity decreased by 6.9% of conventional mix when 0.6% (by weight of concrete) polythene waste added. But 10% replacement of cement by fly ash in the concrete containing plastic waste increased the dynamic modulus of elasticity by about 6.9%.

• The water permeability of concrete containing 0.6% (by weight of concrete) polythene waste increased by 37% of conventional mix. When 10% of cement was replaced by fly ash in the concrete containing plastic waste, depth of penetration decreased by about 25%. Thus, improved the water permeability through by decreasing the depth of penetration.

• Replacement of 10% of cement by fly ash results decrease in depth of wear by 12% of conventional mix. The abrasion resistance of concrete containing 0.6% (by weight of concrete) polythene waste increased as the amount of fly ash increased up to 10% by weight of cement. After which the wear depth became almost constant for any further increase in fly ash.

• The number of blows required for first crack and ultimate crack for concrete with 10% fly ash content were increased by 47.4% and 104% of conventional mix respectively. Thus, impact resistance of concrete containing 0.6% (by weight of concrete) polythene waste increased with increase in the percentage of fly ash up to 10% by weight of cement.

• Based on results it can be concluded that polythene waste and fly ash can be used as ingredients in concrete. Fresh and hardened properties of concrete with 0.6% plastic waste (by weight of concrete) were improved when 10% cement was replaced by fly ash (by weight). Due to improved permeability it can be used in construction work at offshore region. This modified concrete can also be used in earthquake prone areas where the impact resistance is most required parameter over strength. Also, it becomes a good option for structures where light weight concrete required as self-weight of concrete decreases due to a decrease in density.

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