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EFFECTIVE UTILIZATION OF INDUSTRIAL WASTE (FLYASH) TO ENHANCE THE PROPERTIES OF POLYMER COMPOSITES FOR MECHANICAL COMPONENTS

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ABSTRACT

Particulate filled polymer composites, exhibit good mechanical and tribological properties when they are compounded properly. Nylon 66 is mostly opted engineering polymer due to its good mechanical properties. Flyash is very much sought –after filler for any matrix in recent years. This article reports on the investigations on nylon 66 reinforced with flyash in 5 to 25 % weight fraction increasing in steps of 5%. Flyash filled nylon composites were compounded in a twin screw extruder. The tensile, impact , flexural, compression strength and wear samples in accordance with ASTM standards were produced in 60 ton L&T injection moulding machine. The flyash filled nylon composites showed enhanced mechanical and tribological properties. SEM observations revealed good adhesion and uniform dispersion of flyash with matrix in general and in lower weight concentrations in particular.

INTRODUCTION

Polymer composites are always preferred to other varieties due to its light weight, low cost, ease in fabrication and ease in tailoring its properties according to the requirement. Polyamides have attracted attention of the researchers since it has been used in various engineering applications such as gears, bearings etc. Among all the types, nylon 6 and nylon 66 has been researched most owing to their good mechanical properties, wear resistance, corrosion resistance etc.

The effect of zinc particles and whiskers on the properties of nylon was studied and hardness and tensile strength were found to increase (Shibowanga, *et al.* 2009). Zinc metal powder and aluminium powders were reinforced in Nylon 6 and electrical conductivity, hardness and density were studied (Gabriel *et al.*, 2001; Gabriel and Jimenez-Martjn, 2001). Organclay reinforced nylon 6 exhibited high tensile strength, modulus and reduced specific wear rate (Srinath and Gnanamoorthy, 20050). Nylon 6 reinforced with mica showed increased flexural properties (Bose and Mahanwar, 2004). Short glass and carbon fibers were used as reinforcement of nylon 66 and their wear properties were studeied 6. The coefficient of friction, temperature rise and specific wear rate were found to be decreased due to better adhesion of the matrix to the fibres. Wallosanite and glass beads

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helped to increase the tensile strength and elastic modulus of Nylon 6 but weakened its impact strength and ductility (Unal and Mimaroglu, 2004) .

Many types of reinforcements have been used in polymers and nylon in particular and their properties have been studied. Particulate reinforcements have been constant attraction to researchers for various reasons. With proper interfacial adhesion, the wear properties of the composites could be enhanced (Veeresh *et al.* 2011). Various particulates such as copper compounds, iron, Zinc bronze and aluminum powders, potassium titanate whiskers (Bahadur and Gong, 1992; Xie, *et al.* 2010; Shibowanga, *et al.* 2009; Bishay, *et al.* 2011) have been used as reinforcements for various polymers, and along with the mechanical and thermal properties, wear properties have also been investigated. Apart from various conventional materials, industrial wastes and byproducts such as flyash and jatropha oil cakes have been used as reinforcements (Navin and Vashishtha, 2000; Mohan *et al.* 2011). Increase in the flyash content has improved the thermal stability of PP/FMMA blend (Navin and Vashishtha, 2000). The addition of flyash in vinylester matrix has increased the wear characteristics of the composite (Chauhan *et al.*, 2010). The mechanical properties and heat resistant property increased with incorporation of flyash in nylon 6 and it has improved more in the case of larger particle sized flyash (Bose and Mahanwar, 2004). Increased flyash concentration in RPET matrix resulted in increase of its mechanical and electrical properties but in this case the lesser particle size flyash improvised the properties more than the larger sized flyash (Sharma and Prakash, 2010). Treated flyash particles reinforced in epoxy resin exhibited better compressive strength (Kulkarni and Kishore, 2002). Increased flyash content in the hybrid reinforcement of graphite and flyash to aluminium matrix contributed to the decrease in the wear rate (Venkat Prasat, *et al.* 2011). Flyash and glass fabric reinforced epoxy resin had increased impact strength and compressive strength (Singla and Chawla, 2010). The flyash filled PEEK showed increased tensile modulus (Rahail Parvaiz, *et al.* 2010.).

The tribological properties of various polymers which are filled with variety of reinforcements ranging from fibres such as carbon and aramid, particles such as zinc and copper oxides, bronze, nanoclay, hybrid reinforcement of graphite and flyash to jatorphas oil cake have been studied since the major applications of the polymers are associated with wear of the component (Mohan *et al.* 2011; Satapathy and Patnaik, 2008).

Though researches in reinforcement of flyash with other polymers have been aplenty, very few studies have been done in flyash filled nylon and that too, the tribological studies of flyash filled nylon are very scarce. Since nylon is engineering polymer, any investigation on its mechanical and tribological properties would be significant. The investigation on nylon 66 filled with flyash is reported in this article.

Test Materials and Experimental Procedures

Materials

The matrix material nylon 66 was purchased from radici group plastics, USA and the flyash was collected from the Mettur Power Plant, Tamilnadu, India. The chemical composition of flyash is given in Table 1. Flyash was mixed with nylon in different weight ratios of 5%, 10%,15%,20% and 25%.The other materials added to the mixture are additive calcium sterate (0.3 wt %),heat stabilizer irganox PS802 (0.1%) and compatablizer amplify gr216 (1%) .

Table 1. Chemical Composition of Flyash Used

Al_2o_3	Fe_2o_3	CaO	MgO	SiO_2
27%	4.77%	Nil	5.14%	60.12%

Sample Preparation and Tests Procedures

The composite granules were prepared by using twin-screw extruder (make Berstroff) in which the temperature profiles in the barrel were maintained from 2600 C to 275^{0}C from hopper to die in 8 stages, the extrudate was cooled by passing them in water bath and were chopped into small pellets by a chopper.Tensile, Flexural , Izod impact, Compression strength and HDT samples of dimensions according to ASTM D -638, ASTM D 790 , ASTM D 256, ASTM D 695 and ASTM D 648 respectively were prepared using an injection molding machine (M/s L&T) of 60 ton capacity with temperature range of 270^{0}C to 290^{0}C from feed pit to nozzle. The injection pressure was 105 MPa and holding pressure was 90 MPa with holding time 3 seconds. Cylindrical Specimens of dimensions 8 mm diameter and 40 mm length for conducting wear tests were prepared. Tensile and flexural tests were carried in a universal testing machine of AGIS SHIMADZU make and 50 KN capacity. Compression tests were carried in universal testing machine (Make: Fuel Instruments and Engineers Pvt. Ltd., Model:UTN 40). The impact tests were carried in TINIUS OLSEN, USA impact tester IT-504. The HDT tests were carried in ATSFAAR, ITALY make instrument. The friction and wear tests were carried out under dry sliding conditions in a pin-on-disc type friction and wear monitoring test rig (TR20 LE model supplied by DUCOM) as per ASTM G 99. The counter disc used was EN31 hardened steel disc . The specimens were polished using a fine grade SiC emery paper and cleaned with acetone and dried before testing. The sliding velocity was 2 m/s, normal load was 20 N and the sliding distance was 5000m. The specific wear rate (mm3/N-m) is then expressed on 'volume loss' based on:

$$K_0 = \frac{V}{NS}$$

where volume loss(g), N is the normal load (N) and S is the sliding distance (m). The specific wear rate is defined as the volume loss of the specimen per unit sliding distance per unit applied normal load. Five tests were conducted for each filler concentration for all the tests and the average values were used for further analysis. Scanning electron microscope (Quanta 200, FEI, Netherlands) was used for studying the morphology of the composites.

RESULTS AND DISCUSSION

Effect of Flyash on the Mechanical Properties

Fig. 1 shows the tensile strength which does not show any significant difference in 5% and 10% filler loading. But it increases to a maximum at 15% filler loading and then it shows a reducing trend. Even though the flyash has a good adhesion with the matrix, 5% and 10% filler were not enough to increase the strength whereas 15% concentration helped to increase the strength. But beyond this filler content, the bond between the filler and matrix is not good enough which might be due to the agglomeration of filler.

Temperature with Filler Content

particles in this concentrations. This results in the gradual reduction of the strength. This agrees with the previous literature (Sharma and Mahanwar, 2010).

From Fig. 5, it is obvious that the elongation % decreases drastically which emphasis that the brittleness increases with the increase of filler content. Also the facts that the filler is spherical shape and of size 45 microns, might add to the justification of this behavior (Unal and Mimaroglu, 2004 and; Parvaiz *et al.* 2010).

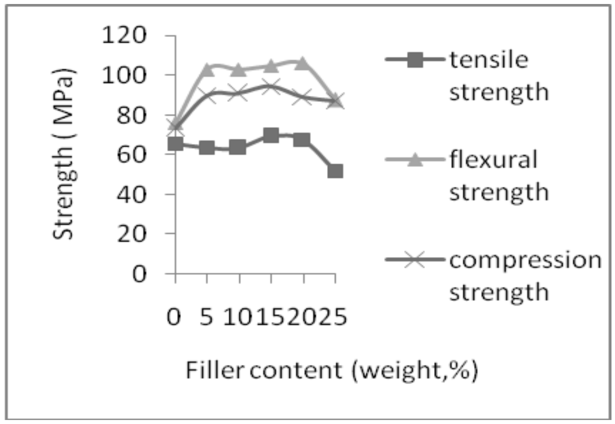

Fig. 1 Variation of tensile, flexural and compression strength with filler content

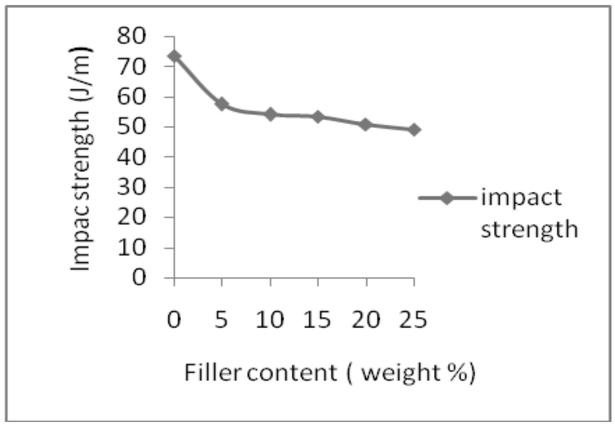

Fig. 2 Variation of impact strength with filler content

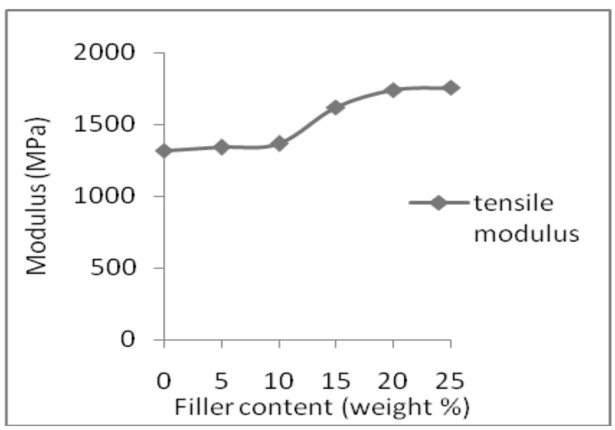

Fig. 3 Variation of tensile modulus with filler content

The tensile modulus shown in Fig. 3 shows a gradual increase with the increase in flyash content. The load carrying ability increased due to the large surface area available for the adhesion of the flyash to the matrix It establishes that the crystallinity of the

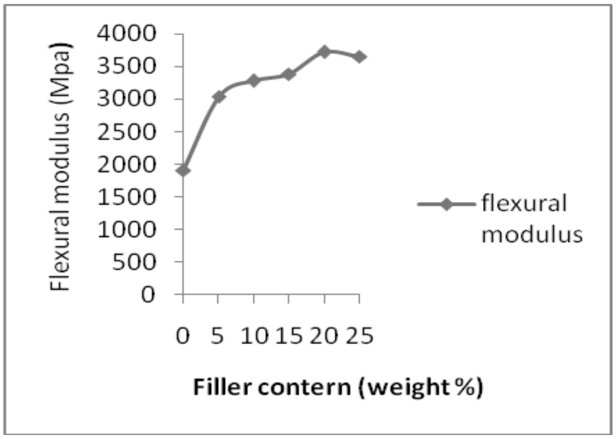

Fig. 4 Variation of flexural modulus with filler content

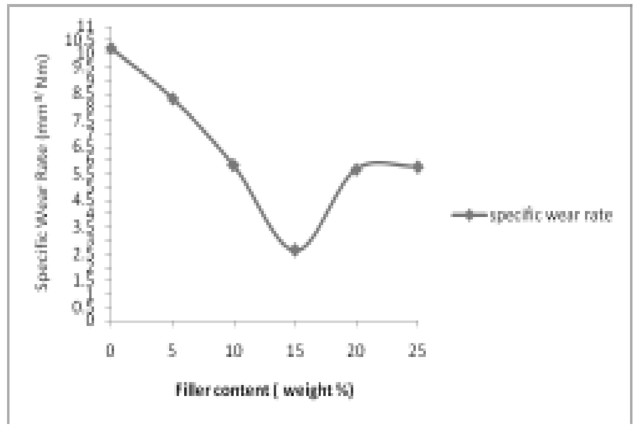

Fig. 7 Variation of specific wear rate with filler content

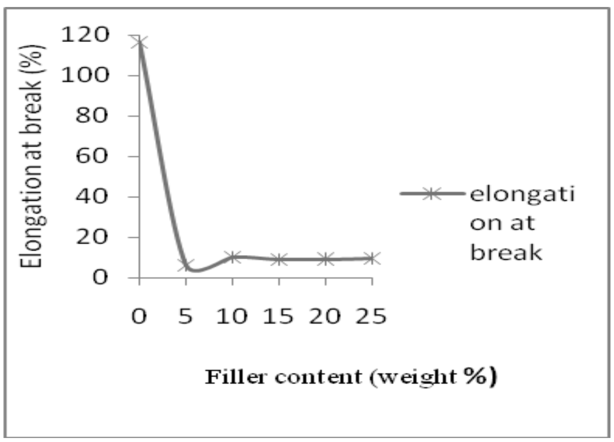

Fig. 5 Variation of elongation at break with filler content

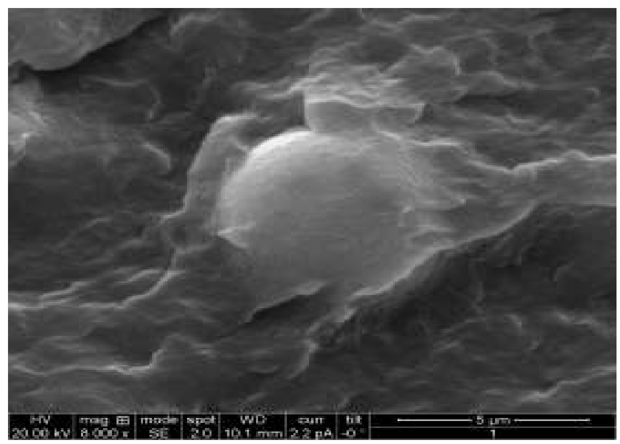

Fig. 8 SEM photograph showing the adhesion of flyash with matrix

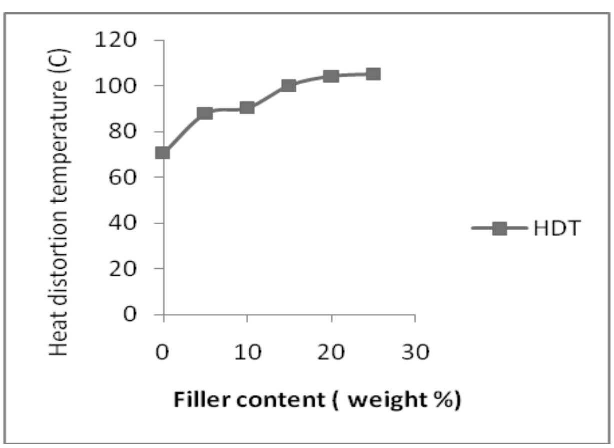

Fig. 6 Variation of heat distortion

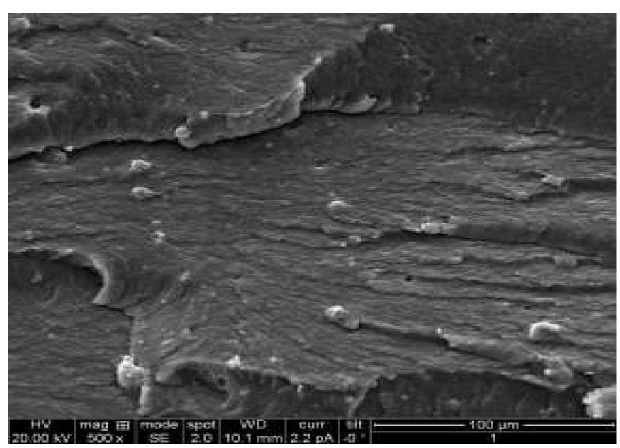

Fig. 9 SEM photograph of 5% of flyash in nylon

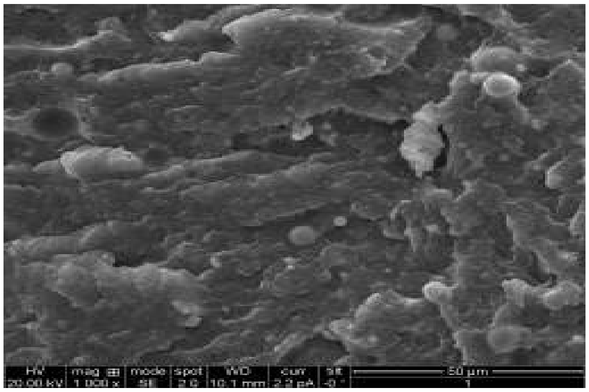

Fig. 10 SEM photograph of 10% of flyash in nylon

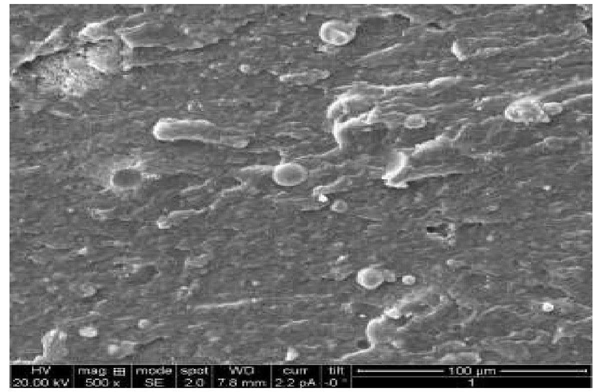

Fig. 11 SEM photograph of 15% of flyash in nylon

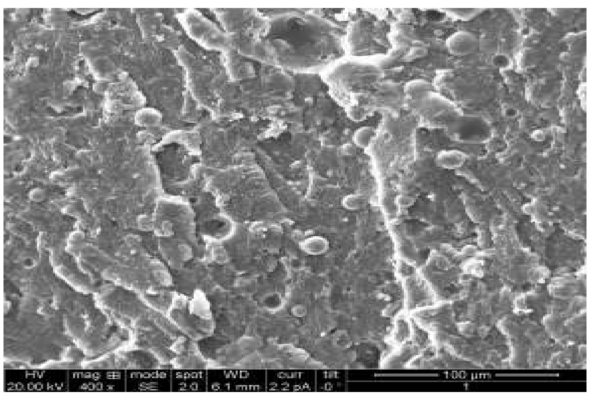

Fig. 12 SEM photograph of 20% of flyash in nylon

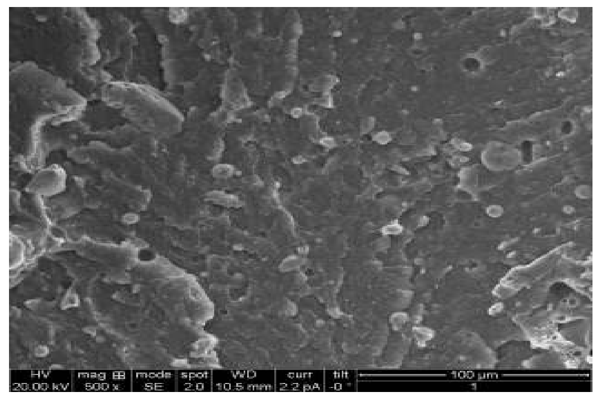

Fig. 13 SEM photograph of 25% flyash in nylon

composites increases with the increase in filler content (Srinath and Gnanamoorthy, 2005).

The variation of flexural strength and flexural modulus is presented in Fig 1 and Fig 4 respectively.It could be seen that the flexural strength increases with the addition of filler materials upto 20% weight percentage and then, it gets reduced. The increase is considerable while comparing neat nylon and composites but the increase with in the composites are marginal. This clearly indicates that the ability of flyash to impart the flexural strength to the matrix ceases after certain extent. The flexural modulus increases upto 15% and then, it decreases. This could be attributed to the fact that flyash got agglomerated after that weight percentage (Parvaiz *et al.* 2010). Also, the area available to withstand the deformation force might have got reduced due to the crack propagating stress due to agglomeration.

The compression strength is presented in Fig. 1. The compression strength increases with the increase in filler content upto 15% filler loading and then, it begins to decrease. The maximum increase in compression strength of 29% was attained at 15% filler loading . This is due to the hollowness of the flyash material (Singla and Chawla, 2010). Above 15% filler loading, the compressive strength reduces which confirms the agglomeration of the filler.

The impact strength property is presented in Fig. 2, a decreasing trend in the impact strength is found which very well agrees with the findings of the previous researches (Bose and Mahanwar, 2004; Unal and Mimaroglu, 2004; Singla and Chawla, 2010). The impact strength decreases with the increase of filler content. The strength of 5% filled composite decreases 21% compared to the strength of the unfilled nylon but thereafter, it gets reduced 5 to 7% only with every 5% increase in filler content. It confirms that flyash easily initiated the crack propagation thereby increasing the brittleness of the composites (Srinath and Gnanamoorthy, 2005) and decreasing the ductility of the composite. The heat distortion temperature exhibited in Fig. 6 increases with the increase in the filler content. About 25% increase is seen in the heat distortion temperature of neat nylon and the flyash filled composites of 5% and 10% weight fraction and then about 11% increase could be seen in the 15% , 20% and 25% filled composites. There is no significant difference between these composites but the 25% filled composites has the maximum heat distortion temperature. The heat distortion temperature keeps on increasing with the increase in flyash which establishes that the flyash has the ability to enhance the heat distortion capacity of the material due to its own nature and that it is an inorganic filler which has thermal stability in genera (Navin Chand and Vashishtha, 2000).

Effect of flyash on the wear properties

The specific wear rate of the nylon composites is presented in Fig 7. The wear rates of flyash filled composites are far less than the unfilled nylon. The wear rate sharply decreases with the increase of the flyash content upto 15% weight fraction. There after the wear rate increases with the increase with filler content but still it is less than the wear rate of the unfilled nylon. This phenomenon could be very well attributed to the combination of facts such as the interfacial adhesion of the fillers to the matrix, increase in the heat distortion temperature due to the filler content, the ability of the flyash to reduce the thermal softening of the polymer due to the interfacial heat developed during sliding. From the experimental results, it is clear that 15% flyash filled composites is superior to the other composition in perspective of wear.

Effect of Flyash on the morphological properties

The morphological and the filler distribution of the composites were analysed using SEM. The micrographs of the flyash filled nylon composites in various weight distributions from 5% to 25% are shown from Fig. 8 to 13. It could be clearly seen that the filler particles are evenly distributed in all the composites and no evident agglomeration is found which states that the composites are homogeneous. Also this is quiet clear from the increase in visible flyash particles on the surface of the matrix as the filler concentration increases. Further Fig. 8 shows the interaction between the 5% filled flyash particle and the nylon matrix which clearly shows that the interfacial bonding between the matrix and the filler particle is very strong. This tends to get reduced in higher concentration filler reinforced composites such as 20% and 25% filled composites because higher percentage of voids and particle detachment are present in the photographs. This also corroborates with the results of the mechanical properties which show ample reduction in impact and tensile properties.

CONCLUSIONS

Nylon 66 was mixed with flyash from 5% to 25% weight fraction in steps of 5% and the mechanical and tribological properties were studied. The findings are as below :

1. The flyash was dispersed in the matrix uniformly and slight agglomeration was found only in the higher weight concentration.
2. The mechanical properties were also enhanced in different proportions and considering all the properties, 15% weight fraction flyash filled nylon composite could be superior to the other compositions.
3. The wear resistance was improved drastically and was maximum at 15% weight fraction of flyash filled composites.
4. Using flyash, 15% of the cost could be reduced as the cost of the flyash is effectively nil.
5. Also by using this industrial waste effectively, industrial pollution could be controlled on a huge scale.

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