Hardness and Tensile Testing of PVC and Fly Ash Composite

Sri Phani Sushma and Amireddy Kiran Kumar

Abstract--- *This paper deals with production and testing of PVC and fly ash composite for hardness. Polyvinyl chloride (PVC) is a versatile thermoplastic material that is used in the production of hundreds of products that consumers encounter in everyday life and many more that are encountered less frequently but are nevertheless very important in construction, electronics, healthcare, and other applications. It finds widespread use in these applications because of its low cost and desirable physical and mechanical properties.*

Class F fly ash and bottom ash is the solid residue by-products produced by coal-burning electric utilities. They are usually disposed of together as a waste in utility disposal sites with a typical disposal rate of 80% fly ash and 20% bottom ash. Direct use of these materials in construction projects consuming large volumes of materials, such as highway embankment construction, not only provides a promising solution to the disposal problem, but also an economic alternative to the use of traditional materials.

Concentration of fly ash has been varied and their results were computed. This paper concentrates on preparation, characterization and testing of PVC by mixing fly ash in different proportions. Both Tensile strength and Hardness were found to increase with fly ash concentration up to a certain proportion and elongation is drastically reduced with increase in fly ash concentration. Composites with smallest size fly ash particles proved to be better in enhancing strength and relative elongation .As properties will improve on adding fly ash as filler material in PVC.

Keywords--- *PVC and Fly Ash Composite, Hardness Test, Tensile Test, Preparation Method of Composite*

I. Introduction

FLY ash has been used in roadways and interstate highways since the early 1950s. In 1974, the Federal Highway Administration encouraged the use of fly ash in concrete pavement with Notice N 5080.4, which urged states to allow partial substitution of fly ash for cement whenever feasible. In addition, in January 1983, the Environmental Protection Agency published federal comprehensive procurement guidelines for cement and concrete containing fly ash to encourage the utilization of fly ash and establish compliance deadlines. Fly ash is the finely divided residue that results from the combustion of pulverized coal and is transported from the combustion chamber by exhaust gases. Currently, over 20 million metric tons (22 million tons) of fly ash are used annually in a variety of engineering applications. Typical highway engineering applications include: Portland cement concrete (PCC), soil and road base stabilization, flowable fills, grouts, structural fill and asphalt filler.

Poly vinyl chloride is the plastic known at the hardware store as PVC. This is the PVC from which pipes are made, and PVC pipe is everywhere. The plumbing in your house is probably PVC pipe, unless it's an older house. PVC pipe is what rural high schools with small budgets use to make goal posts for their football fields. But there's more to PVC than just pipe. The "vinyl" siding used on houses is made of poly (vinyl chloride). Inside the house, PVC is used to make linoleum for the floor. In the seventies, PVC was often used to make vinyl car tops.

PVC is useful because it resists two things that hate each other: fire and water. Because of its water resistance it's used to make raincoats and shower curtains, and of course, water pipes. It has flame resistance, too, because it contains chlorine. When you try to burn PVC, chlorine atoms are released, and chlorine atoms inhibit combustion.

II. Raw Materials used in PVC and Fly-ash Composites

Raw materials used in PVC and Fly-Ash composite are Fly-Ash and PVC.

Fly ash: Fly ash is the finely divided residue that results from the combustion of pulverized coal and is transported from the combustion chamber by exhaust gases.

PVC: PVC is a paly vinyl chloride. It's similar to polyethylene, but on every other carbon in the backbone chain, one of the hydrogen atoms is replaced with a chlorine atom. It's produced by the free radical polymerization of vinyl chloride.

A. Production and Properties of Raw Materials

- *Production of Fly-Ash*

Fly ash is produced from the combustion of coal in electric utility or industrial boilers. There are four basic types of coal-fired boilers: pulverized coal (PC), stoker-fired or traveling grate, cyclone, and fluidized-bed combustion (FBC) boilers. The PC boiler is the most widely used, especially for large electric generating units. The other boilers are more common at industrial or cogeneration facilities. Fly ash is captured from the flue gases using electrostatic precipitators (ESP) or in filter fabric collectors, commonly referred to as bag houses. The physical and chemical characteristics of fly ash vary among combustion methods, coal source, and particle shape.

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- *Production of PVC*

Preparation of PVC Plastisols:

All the liquids that is used for the preparation of PVC plastisols are mixed by using a mixer device

↓

PVC powder is added

↓

It is mixed at 700-800 rpm for 10-15 min.

↓

Some part of the first prepared plastisol is get into the vacuum tube

↓

Colour pigment is added inside

↓

It is mixed for 10-15 min under vacuum

(Until a homogeneous mixture is provided)

A schematic presentation of the production of the PVC plastisol

- *Raw Materials of PVC Plastisols*

PVC plastisols are formed by PVC resin, and some additives, that is plasticizer, stabilizers, filler, etc. Usage of additives in the formulation, improves some properties of the PVC, such as flexibility and workability (Jimenez, et al. 2000)

- *Plasticizers for Plastic*

For producing flexible plastics, engineering and medical applications plasticizers have been used with polymers (Rahman 2006). Plasticizers are low molecular weight (MW) resins or liquids indeed, which form secondary bonds to polymer chains and spread them apart. Therefore, plasticizers decrease polymer-polymer chain secondary bonding and more mobility for the macromolecules, consequential in a softer and more easily deformable mass is provided (Rahman and Brazel 2004).

Plasticizers are generally chosen on the basis of the following criteria

• Compatibility of a plasticizer with a given polymer,

• Processing characteristics,

• Desired thermal, electrical and mechanical properties of the end product,

• Resistance to water, chemicals, solar radiation,

• Weathering, dirt, microorganisms, (Rahman and Brazel 2004).

- *Production of PVC and Fly-ash Composite*

Polyvinylchloride (PVC) [-(-CH2 -CHCl-)n-] is one of the three most important polymers currently used worldwide. This is because PVC is one of the cheapest polymers to make and has a large range of properties so can be used to make hundreds of products. PVC is formed by the polymerisation of vinyl chloride (Chloro-ethane) monomer units. PVC consists of polar molecules which are attracted to each other by dipole-dipole interactions due to electrostatic attractions of a chlorine atom in one molecule to a hydrogen atom in another atom. These considerable intermolecular attractions between polymer chains make PVC a fairly strong material. Uncompounded PVC is colourless and rigid and possesses poor stability towards heat and light. However, the use of additives/stabilisers enables us to change the properties of the PVC.

It is a versatile thermoplastic material that is used in the production of hundreds of products that consumers encounter in everyday life and many more that are encountered less frequently but are nevertheless very important in construction, electronics, healthcare, and other applications. It finds widespread use in these applications because of its low cost and desirable physical and mechanical properties. It is fabricated efficiently into a very wide range of both rigid and flexible products. PVC also has inherent flame resistance. Substitutes for PVC materials may be available, but often the alternative materials and processes are not as efficient or substitution costs are high.

PVC is used in an enormous variety of applications and competes with a diverse range of substitute materials. For example, PVC pipe holds a commanding share in large diameter pressure water and sanitary sewer pipe because of its low initial cost, ease of installation, long and reliable service life, and its low replacement and repair cost.

By-product material of a coal combustion process for energy generation is recognized as an environmental pollutant. Therefore a good deal of work on the utilization of fly ash has been undertaken world over. Different applications (cements, roads and backfill) of them already allow a recycling of an important part of fly ash production which, for instance, reached 450,000 tons in 1997 in France. Their use as an adsorbent material, however, is being investigated recently. Some studies have shown that these materials might be beneficial for removal of heavy metal ions from waste waters (Rio and Delebarre 2003).

Fig. 1: Injection Modelling Machine

Though a significant fraction of coal fly ash is used as a cement and concrete additive in the world, only a very small portion of the 15 million tons of fly ash generated is re-utilized in Turkey (Baba 2004). Fly ash contains a range of heavy metals of different mobilities in its structure. Since it is usually disposed of in the form of a slurry in the vicinity of the power plant, fly ash possesses significant environmental risk due to the possibility of leaching of these metals into environment. Fly ash is most commonly used as a pozzolan in PCC applications. Pozzolans are siliceous or siliceous and aluminous materials, which in a finely divided form and in the presence of water, react with calcium hydroxide at ordinary temperatures to produce cementitious compounds. The unique spherical shape and particle size distribution of fly ash make it good mineral filler in hot mix asphalt (HMA) applications and improves the fluidity of flowable fill and grout. The consistency and abundance of fly ash in many areas present unique opportunities for use in structural fills and other highway applications.

Fly ash and lime can be combined with aggregate to produce a quality stabilized base course. These road bases are referred to as pozzolanic-stabilized mixtures (PSMs). Typical fly ash contents may vary from 12 to 14% with corresponding lime contents of three to five percent. Portland cement may also be used in lieu of lime to increase early age strengths.

The chemical properties of fly ash are influenced to a great extent by those of the coal burned and the techniques used for handling and storage. There are basically four types, or ranks, of coal, each of which varies in terms of its heating value, its chemical composition, ash content, and geological origin. The four types, or ranks, of coal are anthracite, bituminous, sub-bituminous, and lignite.

Thus by adding this low cost and highly abundant fly ash to PVC as a 25 filler material we can form a new composition which can be utilised as substitute to a particular grade of plastic.

This composition can typically be fabricated on conventional injection molding equipment using the established techniques practiced in the plastics industry. Regardless of the equipment used, the general guidelines provided in the following sections may be helpful in obtaining optimum results. Several factors must be considered when fabricating the required dies with this composition. These include machine selection, material and mold temperatures, screw speed, hydraulic pressure, back pressure, injection speed, and melt cushion.

During the injection molding process, it is very important to switch from the first to second stage when the part is 90 to 95% full. If you do not switch from first to second stage pressure before the cavity is full, the high pressure of the first stage pump may cause thepart to flash and may cause damage to the mold**.** It is suggested to switch from first to second stage based on either the position of the ram or the cavity pressure. Switch-over based on the hydraulic pressure and time is suggested if ram position or cavity pressure controls are not available.

Thus after the formation of required dies using the injection molding machine, in order to verify the properties of the newly prepared composition the samples will undergo both the hardness test and tension test as well as hardness application of PVC.

- *Procedure for the production of PVC and Fly-Ash compositebillets:*

The required quantity of PVC granules are fed through a hopper into a heated barrel with a reciprocating screw, mixed, and forced into a mold cavity where it cools and hardens to the configuration of the die (circular). Now composition of 10% fly ash is mixed thoroughly with 90% PVC granules by weight and the mixture is fed into the heated barrel .Upon entrance to the barrel the thermal energy increases and the Vander Waals forces that resist relative flow of individual chains are weakened as a result of increased space between molecules at higher thermal energy states. This reduces its viscosity, which enables the polymer composite to flow with the driving force of the injection unit. The screw delivers the raw material forward, mixes and homogenizes the thermal and viscous distributions of the polymer, and reduces the required heating time by mechanically shearing the material and adding a significant amount of frictional heating to the polymer composite .The composition is heated upto 180^{0c}.The material feeds forward through a valve and collects at the front of the screw into a volume known as a shot. Shot is the volume of material which is used to fill the mold cavity, compensate for shrinkage, and provide a cushion to transfer pressure from the screw to the mold cavity. When enough material has gathered, the material is forced at high pressure and velocity into the part forming cavity. Once the screw reaches the packing pressure is applied which completes mold filling until the gate (cavity entrance) solidifies after attaining desired temperature. The billets are removed from the mold after the solidification has been completed.The same process is repeated for composition of 20%, 30% fly ash with respective weight compositions of 80%, 70% PVC granules. The material feeds forward through a valve and collects at the front of the screw into a volume known as a shot. Shot is the volume of material which is used to fill the mold cavity, compensate for shrinkage, and provide a cushion to transfer pressure from the screw to the mold cavity. When enough material has gathered, the material is forced at high pressure and velocity into the part forming cavity.

Once the screw reaches the transfer position the packing pressure is applied which completes mold filling until the gate (cavity entrance) solidifies after attaining desired temperature. The billets are removed from the mold after the solidification has been completed.

The same process is repeated for composition of 20%, 30% fly ash with respective weight compositions of 80%, and 70% PVC granules.

Fig. 2: PVC granules and PVC and Fly-Ash Composite Billets

- *Testing of PVC and Fly-ash Composite Billets*

Tensile test and Hardness test were performed on the PVC and Fly-Ash composite samples

- *Tensile Test*

Tension testing machine is used to find out the breaking strength of the PVC + Fly-Ash composite material.

Breaking strength of the body is the stress corresponding to that at failure. In brittle materials, the ultimate tensile strength is the breaking strength

Fig.3: Tensile Test Samples

Variation of Breaking Stress with Composition

Sample – 1

Width = 10mm

Thickness = 4mm

Gauge Length = 58mm

Composition (%)	Load (Kg. f)	Elongation(mm)
0	37.5	0.31
10	73.8	0.52
20	87.2	0.63
30	57.9	0.42

Sample – 2

Width =30mm

Thickness = 4mm

Gauge Length = 58mm

Composition (%)	Load (Kg. f)	Elongation
0	107	0.28
10	166	0.37
20	203	0.43
30	141	0.33

- *Hardness Test*

The property of “hardness” is difficult to define except in relation to the particular test used to determine its value. It should be observed that a hardness number or value cannot be utilized directly in design, as can a tensile strength value, since hardness numbers have no intrinsic significance.

Hardness not a fundamental property of a material but is related to the elastic and plastic properties. The hardness value obtained in a particular test serves only as a comparison between materials or treatments. The test procedure and sample preparation are usually simple, and the results may be used in estimating other mechanical properties. Hardness testing is widely used for inspection and control. Heat treatment or working usually results in a change in hardness. When the hardness resulting from treating a given material by a given process is established, it affords a rapid and simple means of inspection and control for the particular material and process

Variation of hardness (Rock Well Scale) with composition

Composition (%)	Spot-1	Spot-2	Spot-3	Average
0	35	31	37	34.3
10	68	63	58	63
20	47	48	50.5	48.3
30	39	37	32	36

III. Results and Discussion

In the Tensile test, it was found that the Breaking stress of the specimen is found to increase upto the Fly-Ash composition of 20 to 25% by weight. Beyond that percentage the Breaking stress of the specimen is decreasing. In the Hardness test, it was found that the hardness if the specimen is found to increase upto the Fly-Ash composition of 10 to 15% by weight. Beyond that percentage the Hardness is decreasing. Increase in the hardness may be caused due to the hardness of the filler material. Hence, it was found that the solubility of Fly-Ash in PVC is maximum in the range of 15 to 25% by weight. The PVC and Fly-Ash composite will possess better properties at the compositions where the Fly-Ash is well soluble in PVC. Better properties for the composite are obtained with the better mixing of the composite. Beyond this soluble range the properties of the PVC and Fly-Ash composite were found to be decreasing. The hardness and Breaking stress values may vary even with the temperature and mixing rate at which the tests are done.

IV. Conclusion

Effect of fly ash as filler material in PVC has been discussed in this project. Concentration of fly ash was varied from 0% to 30 % by weight with an increment of 10% for each sample. The composite test specimens were prepared by injection molding machine by the initial mixing of PVC and fly ash which is followed by their melting in injection molding machine inorder to mix them at high temperatures. Tensile strength and hardness were tested usingTensile testing machine and Rockwell hardness machine are conducted. As the material (PVC) is plastic in nature the hardness test on the Rockwell hardness machine has been classified under the category of plastic materials (L scale)

With varying percentage of fly ash, two samples of same fly ash composition are tested(10% fly ash 2 samples) and the aggregate of the respective two values is considered and these tests have resulted that the change in composition of the fly ash varies the properties of the composite in considerable manner. Hardness was found to increase with fly ash concentration between 0-15% and reduce beyond that. Elongation drastically reduced for fly ash concentration beyond 20%. With increasing fly ash concentration hardness value decreases. Overall, the mechanical properties of PVC-product obtained were affected positively and better PVC composites were obtained upto certain values and then decreases further.

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