Coal and Chemical Composition of Fly Ash and Its Significance for Roads

Panigrahi, R.K. Scientist
Vital, U.K. Guru Scientist
Mathur, Sudhir Scientist

e-mail: panigrahi_crri@yahoo.co.in e-mail: vittal.crri@gmail.com, e-mail: sudhirmathur.crri@nic.in

Geotechnical Engineering Division, Central Road Research Institute, New Delhi

ABSTRACT

The high temperature generated when coal burns in thermal power plants, transforms the clay minerals in coal powder into a variety of fine particles comprising of mainly aluminum silicate composition. The process of coal combustion results in fly ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all types of fly ashes include substantial amounts of silicon dioxide (both amorphous and crystalline) and calcium oxide, both being endemic ingredients in many coal bearing rock strata. An attempt has been made to come out as an expected output to establish a relationship of genesis of source of fly ash materials, process of formation of coal, carbon cycle, chemical composition of coal.

1. INTRODUCTION

Fly ash is a fused residue of clay minerals present in coal. Pozzolanas are siliceous or siliceous and aluminous material, which in a finely divided form and in the presence of water, react with calcium hydroxide at ordinary temperatures to produce cementitious compounds. Flyash is one of the substances that cause air, water and soil pollution, disrupt ecological cycles and set off environmental hazards. The combustion of powdered coal in thermal power plants produces fly ash. The high temperature of burning coal turns the clay minerals present in the coal powder into fused fine par mainly comprising aluminium silicate. Fly ash produced thus possesses both ceramic and pozzolanic properties. The problem with fly ash lies in the fact that not only does its particles numerous disposal require large quantities of land, water, and energy, its fine particles, if not managed well, by virtue of their weightlessness, can become airborne. Fly ash is one of the residues generated in the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants, and is one of two types of ash that jointly are known as coal ash; the other, bottom ash, is removed from the bottom of coal furnaces. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide ($\text{SiO}_2$) (both amorphous and crystalline) and calcium oxide ($\text{CaO}$), both being endemic ingredients in many coal bearing rock strata. Toxic constituents depend upon the specific coal bed makeup, but may include one or more of the following elements or substances in quantities from trace amounts to several percent: arsenic, beryllium, boron, cadmium, chromium, chromium VI, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, along with dioxins and PAH compounds. In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now require that it be captured prior to release. Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Since the particles solidify while suspended in the exhaust gases, fly ash mixture of glassy particles with various identifiable crystalline phases such as quartz, mullite, and various iron oxides. Fly ash also contains environmental toxins in significant amounts, including arsenic barium; beryllium; boron; cadmium; chromium; cobalt; copper; fluorine; lead; manganese; nickel; selenium; strontium; thallium; vanadium; and zinc. The chief difference between different classes is the amount of calcium, silica, alumina, and iron content in the ash. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned (i.e., anthracite, bituminous, and lignite).

2. THE HYDROLOGIC CYCLE

The hydrologic cycle refers to the movement of water...
through its various stores within the Earth system. The amount of water that cycles between the surface and the atmosphere is phenomenal. At any minute, nearly a billion tons of water is delivered to the atmosphere by evaporation and the same amount precipitated from it. The hydrologic cycle not only traces the movement of water through the Earth system, it is a path way for the movement of energy. Water is evaporated from tropical oceans where energy is abundant and is transported on the wind to high latitudes where energy is in short supply. There it condenses and gives off heat to the atmosphere. The exchange of energy from low latitudes to high latitudes helps maintain the energy balance of the Earth system. The cycle starts with evaporation from the surface, most of which comes from the tropical oceans. The water vapor later condenses into clouds in which precipitation forms. Water falling as precipitation may be intercepted by vegetation or fall directly onto the surface. Water intercepted by plants may ultimately fall to the ground and seep into it. Likewise, water falling directly on the surface may seep into the subsurface or runoff to nearby streams. Water seeping into the ground may become soil water or groundwater. Water in the soil may be taken up by plants then transpired to the air. Groundwater may seep into streams or return to the ocean along along a coast. Water found in streams may also empty into the ocean.

Fig. 1: Diagram for Hydrological Cycle

3. THE CARBON CYCLE
Carbon is the fourth most abundant element in the Universe and is the building block for all living things. The conversion of carbon dioxide into living matter and then back is the main pathway of the carbon cycle. Plants draw about one quarter of the carbon dioxide out of the atmosphere and photosynthesize it into carbohydrates. Some of the carbohydrate is consumed by plant respiration and the rest is used to build plant tissue and growth. Animals consume the carbohydrates and return carbon dioxide to the atmosphere during respiration. Carbohydrates are oxidized and returned to the atmosphere by soil microorganisms decomposing dead animal and plant remains (soil respiration). Another quarter of atmospheric carbon dioxide is absorbed by the world’s oceans through direct air-water exchange. Surface water near the poles is cool and more soluble for carbon dioxide. The cool water sinks and couples to the ocean’s thermohaline circulation which transports dense surface water toward the ocean’s interior. Marine organisms form tissue containing reduced carbon, and some also form carbonate shells from carbon extracted from the air. There is actually very little of the total carbon cycling through the Earth system at any one point in time. Most of the carbon is stored in geologic deposits - carbonate rocks, petroleum, and coal - formed from the burial and compaction of dead organic matter on sea bottoms. The carbon in these deposits is normally released by rock weathering. Carbon emissions into the atmosphere are generated by natural and human activities. Natural reactions are part of a large, complex cycle of carbon generation and absorption referred to as the carbon cycle. Carbon is absorbed through three major carbon stores, or “sinks” in nature. (a) The oceans, (b) The atmosphere and (c) The terrestrial system. The terrestrial system includes geological forms such as fossil fuel stores, which take hundreds of years to form, but also soils, plants and forests, which can store CO$_2$ on a much quicker scale. The consumption of fossil fuels and land use change are increasing the balance of carbon in the atmosphere promotes such as those involving biomass or wind turbines reduce emissions at the source e.g. biomass and wind energy reduce the use of fossil fuels as shown in fig. 2 & 3 carbon dioxide and oxygen can affect the availability of nutrients,

Fig. 2: Diagram for Carbon Cycle

Fig. 3: Cyclic Matrix for Carbon Dioxide
which in turn affect organic production and burial. A simple explanation of the various changes over time in rates of organic burial and source rock formation is difficult, with the exception of the effect of the rise of large land plants on terrestrial carbon burial. The interaction of nutrients and atmospheric carbon dioxide and oxygen with organic burial can be represented by systems-analysis diagrams. For example, if organic burial increases, carbon dioxide (the ultimate source of the carbon) decreases. Because atmospheric oxygen and carbon dioxide have not varied considerably over geological timescales, interest has focused on negative feedback pathways, which provide stabilization. The long-term carbon cycle can lead to new insights regarding the formation of source beds for oil, coal and gas and the relationship between global organic matter burial and the composition of the atmosphere.

4. ENGINEERING PROPERTIES OF FLYASH

The engineering properties of fly ash of particular interest when fly ash is used as an embankment or fill material are its moisture-density relationship, particle size distribution, shear strength, consolidation characteristics, bearing strength and permeability characteristics. The chemical composition of fly ash plays a significant role for engineering properties of fly ash. The formation of coal, source of coal material, genesis of coal, metamorphism or sedimentation or diagenetic process also play a significant role for the engineering properties of fly ash.

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<tr>
<th>Engineering Properties of Fly ash</th>
<th>Fly ash for road construction</th>
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<td><strong>Particle Size Distribution</strong></td>
<td>Fly ash is predominantly a silt-sized nonplastic material. Between 60 and 90 percent of fly ash particles are finer than a 0.075 mm sieve. The fine particle sizing of fly ash, together with the relative uniformity of the gradation in the coarse silt range, makes it imperative that the ash be handled with sufficient water to prevent dusting. Since fine-grained soils can be fairly easily eroded, enough moisture must also be present to support compaction equipment and to permit the material to be well densified, in order to prevent or minimize erodibility.</td>
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<td><strong>Shear Strength</strong></td>
<td>Fly ash derives most of its shear strength from internal friction, although some apparent cohesion has been observed in certain bituminous (pozzolanic) fly ashes. The shear strength of fly ash is affected by the density and moisture content of the test sample, with maximum shear strength exhibited at the optimum moisture content. Bituminous fly ash has been determined to have a friction angle that is usually in the range of 26° to 42°.</td>
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<td><strong>Consolidation Characteristics</strong></td>
<td>An embankment or structural backfill should possess low compressibility to minimize roadway settlements or differential settlements between structures and adjacent approaches. Consolidation has been shown to occur more rapidly in compacted fly ash than in silty clay soil because the fly ash has a higher void ratio and greater permeability than the soil.</td>
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<td><strong>Bearing Strength</strong></td>
<td>California bearing ratio (CBR) values for “low lime” fly ash from the burning of anthracite or bituminous coals have been found to range from 6.8 to 13.5 percent in the soaked condition (an optional procedure in the test method) to 10.8 to 15.4 percent in the unsoaked condition. For naturally occurring soils, CBR values normally range from 3 to 15 percent for fine-grained materials (silt and clays), from 10 to 40 percent for sand and sandy soils, and from 20 to 80 percent for gravels and gravelly soils.</td>
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<td><strong>Permeability</strong></td>
<td>The permeability of well-compact ed fly ash has been found to range from $10^{-4}$ to $10^{-6}$ cm/s, which is roughly equivalent to the normal range of permeability of a silty sand to silty clay soil.</td>
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5. CONCLUDING REMARKS
The genesis of coal, chemical composition and engineering properties of fly ash helps to establish several input parameters for design and construction of road and road embankments. The bottleneck encountered during earlier cases of fly ash used road and road embankments may be useful for geotechnical community of India by taking into consideration the relationship of genesis of source of fly ash materials, process of formation of coal, carbon cycle and chemical composition of coal.

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