Course Name: Building Materials as a Cornerstone to Sustainability

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Lecture 04

Flyash

Hello dear students. In the last class, we had had an introduction about alternate building materials and we saw how alternate building materials try to mitigate the limitations of traditional and vernacular building materials by having a proper amalgamation of use of traditional building materials along with either technology or modern technology or another modern building material or probably a waste or any other thing that we could call as composite and yet it would aim and propel us towards carbon negativity. In this context, today we will look up at fly ash as an alternate building material. In this class, we will look at production of fly ash, its characteristics, its benefits, its limitations, applications and in building how it is used. Now, what is fly ash? Fly ash is a byproduct of burning pulverized coal in power plants - it comes out as very fine powdery particles which are carried by flue gases from the combustion zone. These are separated and collected and it contains unburnt residues and inorganic materials.

This is widely employed in construction materials especially concrete. Fly ash plays a vital role in sustainable practices by repurposing it because anyways it lies as a waste. Not only as a waste but it is such a fine lightweight powdery substance that the entire area around a coal plant or a power plant would have this fly ash settled even on leaves, on water body. So, it is everywhere in the air.

Its incorporation enhances the properties of concrete and it contributes to environmental conservation because we are able to reuse this which would otherwise be a waste. And the efficiency of construction materials- making it a significant component in various engineering applications. Now, fly ash can be separated into two main types. First is known as class F and another is class C. Class F fly ash contains particles covered in a type of melted glass allowing it to reduce the risk of concrete expansion and increase resistance to sulfates and alkali aggregated reactions.

Whereas class C fly ash contains a higher percentage of calcium oxide making it more effective in strengthening structural concrete. Now, recent production of fly ash which is

a byproduct of the coal based thermal power plants annually is about 160 megatons by 2030 according to one of the studies by Envis CSIR. As per reports, India is amongst the largest producer of coal and it contributes to about 70% of the total installed capacity for power generation because of which fly ash production is very very high as compared to any other country in the world. You can see that India is amongst one of the highest producers of fly ash, which is again directly linked to the fact that India is one of the largest users of coal. Only China ranks next to it and about 112 million tons of fly ash is produced per year, per year.

110 million tons is produced per year and annually about 160 million tons is the estimate. You can also see that in India fly ash production has increased very steeply. So, the Production of fly ash has also increased drastically in India and it is expected to be about 600 million tons by 2030. 600 million tons by 2030. But if you look at fly ash utilization, a lot of fly ash is still remaining unutilized.

So, there is a large gap between fly ash production and utilization and this is where the market needs to tap in or this is where we as architect must encourage the use of fly ash so that more of it gets into the construction industry. You look at concrete block and brick manufacturing market. Now, there is a lot of market for these blocks. You can see how brick has the projected requirement of brick concrete block and projected requirement of brick requirement is very steep as compared to the year 2020 and 2023. And this is where we need to tap in and plug in the use of fly ash.

There is a requirement for concrete block, there is a requirement for brick and there is excess fly ash which needs to be used. So, the gap between its production and usage is also very high and we must try to use fly ash to plug in this gap. And this will definitely propel as we already saw that the requirement of buildings is very large in India because it's a developing country. Lot of urbanization is happening. So once we know that many buildings need to be built then it becomes very important for us to you know bring in these products in the market.

If you see the structural application segment of concrete block and brick manufacturing market is bound to again increase between 2030 and 2020. So, there is also an increase between 2020 and 2030. Either ways fly ash will have a place if we are able to propel it as an alternate building material. Let us quickly see the characteristics of fly ash. Now fly ash exhibits very distinct physical and chemical properties that make it a valuable material especially in the realm of concrete construction.

Physically it consists of fine particles with a spherical shape contributing to improved workability in concrete mixes. The colour of fly ash can vary from light to dark clay and

it is influenced by the source of coal and combustion conditions. Its density is generally lower than that of cement, making it a favourable component for lightweight concrete applications. Chemically, fly ash is characterized by high silica content, alumina, variable calcium oxide and the presence of iron. These properties along with its mineralogical composition and glass content make fly ash a versatile and advantageous supplementary material in construction practices, contributing to sustainability and enhanced concrete performance.

Let us look at the environmental benefits of fly ash. Now, fly ash utilization benefits the environment and improves cementitious binder. Using fly ash lowers the amount of clay, sand and limestone needed to make cement. Thus, it protects the natural resources in this process. Utilizing fly ash also lowers the amount of cement needed, which in turn lowers the amount of carbon dioxide released during cement making.

Using fly ash conserves agricultural land by lowering the amount of topsoil needed for land infill and brick making. The use of fly ash further strengthens the concrete's property without adding more cement to it. And therefore, to have a stronger concrete using fly ash becomes a very easy method. If you look at the composition of fly ash bricks, fly ash 60% by mass combined with cement 10% by mass combined with sand 30% by mass combined. Approximately, these are all approximate values based on the strength of each of these three materials gives a fly ash brick.

Let us look at the applications of fly ash. Now, in the commercial and industrial sectors, fly ash has very wide variety of applications and uses. Although it is primarily known for improving the durability and workability of concrete mixes, fly ash is used as filler in paints, distemper, adhesives and metal and also plastic composites. Fly ash can be used as structural fill for road. Fly ash bricks are becoming very popular.

It can also be used in ceramic tiles. It can be mixed for plaster. It can be used along with Portland cement and fly ash can be used as part of ready mix cement. Other building materials that may contain fly ash includes hot mix asphalt, grout fills, wall boards, concrete pipes and concrete bricks, fly ash based polymer composites can be substitutes for wood. So, you can see that fly ash can be used as an infill material like bricks, it can be used as an adhesive material also, in adhesive material also.

What I mean is like a grout fill and it can be mixed in asphalt. It can also be used for superficial applications. Thus, we can see that there is a wide range of application of fly ash and usage of fly ash. I am talking only with respect to the building industry. So, you can see that we can have fly ash bricks of various sizes and shapes.

We can have interlocking bricks also. It can be used in partitions as panels along with concrete. These are very popularly used in compound walls along with cement. Rubber fly ash hose is also becoming popular. Ceramic tiles and pavers, paver stones, paver blocks in pavements.

These can also be used in filler wood. So, the list of usage is very long and it is up to the imagination of a designer to understand where fly ash can be used. Let us also look at the applications of fly ash. Now, fly ash concrete it finds diverse applications in construction. In structural concrete, it is extensively utilized for buildings, for bridges and infrastructure projects due to its enhanced durability and strength, making it an ideal choice for supporting structures.

The use of fly ash concrete is common in pavements for road construction, in highways and airport runways. where it improves performance by increasing strength and reducing permeability, contributing to sustainable and resilient transportation infrastructure. Additionally, fly ash concrete is employed in the production of precast items like blocks, pipes and panels. Its workability and long term durability makes it suitable for manufacturing various precast components used in construction projects. So, in India fly ash concrete can be used it is known to be used 45 percent in cement then In reclamations, it is 17%.

Brick and tiles, 7% of fly ash is used. Road embankments are 6%. In concrete, it is only 1%. So, there is a lot of gap between production and usage of fly ash. Let us look at its benefits in fresh concrete.

Flyash brings several advantages to fresh concrete. Its spherical particles serve as concrete ball bearings, improving workability by reducing friction during pumping, enhancing pumpability and providing a smoother finish. Additionally, substituting cement with fly ash leads to decreased water demand, reducing it by around 10% at 20% fly ash content. With higher percentages, it results in a more significant reduction in usage of water. This reduction in water demand does not substantially impact drying shrinkage.

In fact, some fly ash may even lessen it. Moreover, the incorporation of fly ash in concrete reduces the heat of hydration. Mitigating potential heat related issues in large placements -all without compromising long term strength or durability. In a nutshell, benefits of fresh concrete include that their workability becomes very good when it acts as a concrete ball bearing. There is a decrease in demand for water.

When cement is substituted with fly ash, water demand is decreased. Also, the heat for

hydration gets reduced. All of this apart from the fact that fly ash is used as a waste material, the fact that it uses less water. Adds to the fact that environmental degradation is reduced and using less heat also helps us towards being environmentally conscious and being environmentally friendly. Now, let us look at its benefit to hardened concrete.

Fly ash contributes to the enhanced performance of hardened concrete in various aspects. The presence of fly ash results in improved durability by reducing free lime, increasing cementitious compounds and lowering permeability leading to concrete that is more robust, long-lasting and resistant. Additionally, the incorporation of fly ash improves resistance to alkali, silica and sulphate attacks. It mitigates alkali-silica reactions. It reacts with alkali, enhances sulphate resistance through cement replacement and reduces permeability, thereby strengthening the concrete against potential deterioration.

Moreover, the lower permeability achieved with fly ash also enhances the concrete's resistance to corrosion providing added protection against environmental factors and ensuring long-term structural integrity. Therefore, the benefit of using fly ash to harden concrete is that it increases the ultimate strength. It reduces the permeability by also having lower water content. It improves the durability. It improves the resistance to alkali, silica and sulphate attack. And it improves the resistance to corrosion.

What are the limitations of fly ash concrete? While fly ash offers numerous benefits, its use in concrete comes with certain limitations. Variability in fly ash properties, which is influenced by source and production methods, can lead to inconsistencies in concrete performance, emphasizing the importance of stringent quality control measures. In some cases, the inclusion of fly ash may extend concrete setting times. It can impact construction schedules and requires adjustment in project planning. Additionally, the availability of fly ash in specific regions can affect transportation costs.

If the source is distant, increased transportation expenses can influence the economic feasibility of using fly ash concrete, highlighting the need for careful consideration in construction projects. Let us quickly look at some case studies with application of fly ash concrete in building. Fly ash concrete plays a pivotal role in prominent building projects. In the construction of One World Trade Center, various mixes incorporated supplemental cementitious materials including fly ash, granulated ground blast furnace lag cement and silica fume. This strategic use contributed significantly to the achievement of the United States Building Council LEED Gold Rating, highlighting the environmental sustainability of fly ash.

Similarly, in the Hoover Dam bypass bridge construction, fly ash concrete played a crucial role. Its integration showcased the material's importance in critical infrastructure

projects contributing to enhanced durability and environmental considerations within the construction industry. So, in a nutshell, if we have to look at the use of fly ash in building industry, one of the most important uses of fly ash will be in concrete as a replacement for a very energy intensive material that is cement. It can be made into blocks. So we can have fly ash blocks or I will call as bricks for the sake of convenience.

It can be made into tiles. It can be used as pavers. It can be used in pipes or hose, can also be used in paints. So, these in the crux are the architectural applications of fly ash in buildings and fly ash being a 100 percent waste material by itself is harmful to the environment because it is a fine dust that can settle on anything it touches- including natural vegetation, water body, land and it can pollute all of these landform, vegetation, water bodies.

Hence, it is best to be used in building materials considering the fact that India is the largest producer of fly ash and this trend is bound to only increase with time Also there is a big gap between production of fly ash and utilization of fly ash. So, with this we will stop today's class and we will continue with yet another alternate building material in the next class. Thank you.