Course Name: Building Materials as a Cornerstone to Sustainability

Professor: Dr. Iyer Vijayalaxmi Kasinath

Department of Architecture,

School of Planning and Architecture, Vijayawada

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Lecture 04

Geopolymer Concrete

Hello everyone. In today's class we will see geopolymer concrete, another innovative and upcoming material. In this class, we will have an introduction to the material. What Portland cement does, what is geopolymer concrete, its composition, manufacturing process, properties, its advantages, uses, its limits, economic benefit, and case study. Geopolymer concrete is an innovative and eco-friendly construction material and an alternative to Portland cement concrete. Use of geopolymer reduces the demand for Portland cement, which is responsible for high CO2 emissions.

After water, concrete is the world's most abundant resource. Portland cement is traditionally used as a binding material in concrete. India manufactured approximately 502 million tons of cement. But Portland cement is not environmentally sustainable, and there are many environmental concerns involved with its manufacturing.

Cement processing accounts for about 8% of greenhouse gas emissions from carbon dioxide. Cement development depletes non-renewable resources and releases greenhouse gas emissions, which are causing climate change. So what is geopolymer concrete? Geopolymer are the materials which are characterized by chains or networks or inorganic molecules. Geopolymer cement concrete is made from utilization of waste materials produced by other industrial processes. Fly ash is the waste product generated from thermal power plant and ground granulate blast furnace slag is generated as waste in steel plant.

The use of this concrete helps to reduce waste and also reduces carbon emission by reducing Portland cement demand. The main constituents of geopolymers are silicon and aluminum, which are provided by thermally activated natural materials such as kaolinite or industrial byproducts such as fly ash or slag and an alkaline activating solution that polymerizes these materials into molecular chains and networks to create hardening binder. It is also called as an alkali activated cement or inorganic polymer cement. If we look at fly ash, fly ash is a byproduct of thermal power plant. When GGBS is a byproduct of a steel plant.

Fine aggregates and coarse aggregates as required for normal concrete. Alkaline activator solution for GPCC. It is a catalytic liquid system used as an alkaline activator solution. It is a combination of solutions of alkali silicates and hydroxides beside distilled water. The role of the alkaline activator solution is to activate the geopolymeric source materials containing silicon and aluminum, such as fly ash and ground granulated blast slag.

This is the overall composition of geopolymer concrete. Now, alumino silicate precursors are critical components of geopolymers. Aluminum ions either do not react with water or do so too slowly. The majority of these precursors are waste products generated from various processes. First, fly ash.

So, geopolymers can be produced by using low-carbon fly ash, which is obtained as a waste product from coal power plants. Metakaolin is one of the most widespread source materials containing alumino silicate in geopolymer concrete. This is produced from natural clays by calcination at a moderate temperature. Silica flume is a byproduct of the production of silicon metal or ferrosilicon alloy. The silica foam based geopolymer is appropriate for applications where higher compressive strength values are required.

Hence, silica foam-based geopolymer can be utilized as a promising alternative for the production of high-strength concrete or ultra-high-performance concrete with lower environmental impacts. Now, let us look at what is ground granulated blast slag. Ground granulated blast slag is frequently utilized as a byproduct from blast furnace during the production of metals. Next fifth is rice husk ash. Rice husk ash is a carbon neutral green material due to the presence of alumina and silica in RHA.

They can also be utilized as precursors to the production of geopolymers. Sixth is the red earth. Red mud is an offshoot of the Bayer's process used for refining bauxite to alumina. The solid components of red mud are generally composed of iron oxides, mostly hematite, alumina and toxic heavy metals. With the high alkalinity of red mud, its economical and safe disposal is a major environmental problem.

However, the use of this material in geopolymers opens a sustainable and economical way to manage these hazardous wastes. Then seventh is glass powder. Another material that can be utilized as precursor in the production of geopolymers is glass powder. Glass powder is processed from glass waste, making its use in geopolymers an effective and efficient way to manage the waste. So, geopolymers primarily comprises of three components which make it more sustainable.

First is an industrial waste, which could be fly ash, coal bottom ash, industrial slags, silica fumes, artificial puzzolona, natural puzzolonas, siliceous materials such as opal, pumice, and pumicide, and tailings. It could also contain agriculture waste such as rice husk ash, corn cob ash, palm oil fuel ash, straw ash, sugarcane bagasse ash, forest biomass bottom ash, wood ashes, alpha-alpha steam ash, cotton gin ash, municipal solid waste such as glass powder, sludge ashes, paper sludge, waste plastic, waste rubber, construction waste, municipal solid waste incinerator fly ash, municipal solid waste incinerator bottom ash. So, these materials that are otherwise considered waste can actually be used in the building material, making it a green building material. We have already seen the list of raw materials that can be used to make geopolymer concrete, comprising of slag, fly ash, and other waste as a base material. The base material of other waste could be clay, metakaolin, kaolin, ground perlite, and silica waste.

And this is the manufacturing process of geopolymer concrete. You can see clearly how fly ash, metakaolin, and ground granulated slag are used, and then I am talking only from a sustainability point of view to eventually give us the blocks. Let us now look at the properties of geopolymer concrete. Now, the compressive strength of geopolymer concrete has been found to be up to 70 megapascals newtons per millimeter square. The drying shrinkage of it is much less compared to cement concrete.

This makes it very well suited for thick and heavily restrained concrete structural members. It has a low heat of hydration as compared to cement concrete. It has considerably better fire resistance to ordinary Portland cement paste concrete. It offers better protection to reinforce steel from corrosion as compared to traditional cement concrete. This concrete is also found to possess very high acid resistance when tested under exposure to 2% and 10% sulfuric acids.

Here you can see ordinary Portland cement 1 and 2. geopolymer cement. Visual condition of these concrete samples after an 18 month exposure to sulfuric acid shows that the geopolymer concrete has better resistance to corrosion under this stress. Let us now look at the advantages over traditional concrete of geopolymer concrete over traditional concrete. First is it has global warming reducing potential because it uses a lot of waste so called waste, rice, ash, husk and so on.

There is a reduction in virgin material usage because we have a lot of filler materials. So, it has recycled industrial waste, which would otherwise get dumped, and remarkable life cycle cost savings, apart from being a low-carbon emission sustainable construction material with a longer service life. So, geopolymers utilize recycled industrial waste minimizing reliance on virgin resources and reducing the construction industry's environmental footprint. Unlike cement production, which generates significant carbon dioxide emissions, geopolymer manufacturing boasts a much lower carbon footprint, contributing to the fight against climate change. Geopolymers possess impressive mechanical properties with higher compressive and tensile strength, enhanced fire resistance and improved acid resistance compared to concrete.

Geopolymers set and harden significantly faster than concrete leading to quicker construction projects and reduced labor cost. They exhibit exceptional long-term durability, resisting weathering, degradation, and chemical attack much better than regular concrete. Let us now look at the uses of geopolymer concrete. Now the application is same as the cement concrete. So, however, this material has not yet been popularly used for various applications.

This concrete has been used for construction of pavements, retaining walls, water tanks, precast bridge decks etc. Limitations related to the acceptance of this material in the construction field are the high cost of alkaline solution, which depends on its alkali content, the mixing method prior to use, which takes 24 hours to prepare the alkaline solution, some health hazards due to the high alkalinity environment possesses, and the brittle behavior of GPC, which could also be an issue. As of now, it can be used to make blocks for cobblestone, pavements, decorative tiles and as tunnel sections which can be combined to make a large circular section. Let us look at the limitations of geopolymer concrete. Limitations related to the acceptance of geopolymer concrete in the construction field are the high cost of the alkaline solution, which depends on its alkaline contents.

The mixing method prior to use which takes 24 hours to prepare the alkaline solution. Some health hazards due to the high alkalinity environment possesses and the brittle behavior of GPC adds to it. The economic benefit of GPC is very high. Use of fly ash and slag which are a byproduct of coal industry enhances economic benefits of GPC. This makes geopolymer concrete cheaper than Portland cement in terms of materials cost.

However, geopolymer concrete seems to be cheap, and the difference between its price and Portland cement price is ranging from 10 to 30 percent depending on the transportation method. Transportation method plays an important role affecting the final price of this geopolymer concrete production which makes the cost ranging from 7 percent lower to 39 percent higher than ordinary Portland cement. Furthermore, the usage of 1 ton fly ash will earn 1 carbon credit which means a saving of approximately 20 dollars per ton of carbon dioxide. In addition to the lower price of production of GPC, its superior properties in shrinkage, creep, resistance to fire and chemical yield is excellent durability and long life term for the structure. As a result, fewer damages and less rehabilitation costs will be incurred, which is beneficial for the economic growth of the country.

We will quickly see one small case study where this material is used, geopolymer concrete. So, the Global Change Institute is an Australian organization in the University of Queensland that researches global sustainability issues including resource security, ecosystem health, population growth and climate change. The Global Change Institute is the world's first building to successfully use geopolymer concrete for structural purposes. The only prior use has been for footpaths by local authorities as a test case. The four-story high building for general public use It comprises of three suspended geopolymer concrete floors involving 33 precast panels.

They are made from slag or fly ash-based geopolymer concrete and coined earth-friendly concrete. So earth-friendly concrete contains no normal Portland cement. It allows it to have very low carbon dioxide emissions as compared to normal Portland cement-based concrete. With this example, we stop today's class. on geopolymer concrete and how it is a green material in many ways as it employs industrial waste, agricultural waste, and other earth-friendly materials too.

We will stop the class today and we will discuss yet another topic in the next class. Thank you.