Course Name: Building Materials as a Cornerstone to Sustainability

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Lecture 03

Alternate aggregate

Dear students, in our last class we had seen about aerated cement concrete, its properties and how it can be used as an alternate building material. Today we will study about alternate aggregates. What can be the alternate to the regular aggregates and what all materials can function as an alternate to this aggregate? First let us look at what are aggregates. So aggregates are inert granular materials such as sand, gravel or crushed stone which along with water and Portland cement is an essential ingredient in concrete. These aggregates account for up to 60 to 75 percent of the total volume of concrete.

Aggregates can affect the following properties of concrete. It can affect the strength, durability, structural performance, the performance as well as economy of concrete. Therefore, Aggregate is a very important component of concrete not only because it is large in volume but also because its presence can affect the qualities of the concrete. What are the functions of these aggregates? So aggregates have three main functions in concrete.

It provides a mass of particles which are suitable to resist the action of applied loads and show better durability than cement paste alone. They provide relatively cheap filler for the cementing material. And it reduces the volume changes resulting from setting and hardening process and also from the moisture changes during drying. Research has shown that aggregate in fact plays a substantial role in determining workability, strength, dimensional stability and durability of the concrete. Also aggregates can have a significant effect on the cost of the concrete mixture.

Let us look at the type of aggregates. Aggregates can be based on the sources. We can have natural aggregates. These are native deposits with no change in their natural state other than washing, crushing and grading. For example, sand, gravel, crushed stone or we can have artificial aggregates.

These are obtained either as a by-product or as a special manufacturing process such as

heating. For example, blast furnace slag or expanded perlite. Aggregates can also be classified based on their sizes. You could have fine aggregates which have a diameter of less than or equal to 5 mm. For example, sand and crushed stone.

We could also have coarse aggregate which has a diameter of more than 5 mm. For example, gravel and crushed stone. Alternate aggregates in the construction sector are mainly liable for warning of natural resources and environmental imbalances due to unplanned mining activities. Throughout the developing world, river sand and gravel is widely exploited as aggregate for construction. The massive use of concrete due to boom in various infrastructure developments has led to over extraction of river sand from the riverbed.

This has called for several harmful consequences of ecosystem and non-availability of good quality of raw materials. Thus, there is a necessity to find alternates for aggregates. We cannot afford to continue using naturally found stones as our aggregates because of mining and also because there is a dearth due to exploitation of natural resources. Hence, there is a need for alternate aggregates. Let us look at green concrete.

Now concrete is the most largely consumed construction material worldwide. The Portland cement and concrete, they are the major consumer of natural resources. In concrete, Aggregates are inert filler material which plays the vital role on its compressive strength and workability. The production of raw materials used in concrete such as aggregate and Portland cement requires a significant amount of energy input and causes various environmental problems such as emission of greenhouse gases. The green concrete is defined as the concrete produced by utilizing alternative and or recycled waste materials which are eco-friendly so that they can reduce energy consumption, environmental impact and use of natural resources.

One of the major issues associated with green concrete are what can be alternatives or waste for replacing conventional aggregate and how the alternative or waste material affects the concrete properties as compared to conventional Portland cement concrete. So, there can be various types of alternate aggregates. The alternate aggregates can be from natural material which is inorganics, rock and volcanoes. It could be from the building construction waste and quarry dust. It can be agricultural and waste materials.

It could be polymers and rubber or it could be any other material. So from the natural material we can have crushed rock sand, pumice, scoria, volcanic rock, and mangima stone. But these are all depletable over time. These are not infinite. From building construction waste and quarry dust, crushed ceramic waste, ceramic concrete, demolished hollow concrete block, crushed clay bricks, reclaimed asphalt pavement, quarry dust and

recycled concrete can be alternate aggregates and using this will make the concrete as green concrete because these are wastes which are again recycled into aggregates.

Agricultural and waste materials could be palm kernel shell, coconut shell, sunflower seed husk, and paper pulp and sewage sludge. These can also be made and used to form green concrete. Polymers and rubbers such as crushed rubbers, expanded polystyrene, plastic and high density polythene will also contribute to green concrete. Whereas other materials where we can be more innovative are glasscrete, electronic waste, sawdust using OPC and PTC cement can also contribute to green concrete. Let us look at the types of alternate aggregates.

So, we have already seen alternate aggregates based on natural materials, building construction waste and quarry dust, agriculture and sewage sludge, polymers and rubber, sawdust and bones. And here is the property comparison when we use any of these five materials. So, we can see that the best case scenario when we use alternative building material must have higher optimum strength, should not have low strength, should have higher or increasing workability, must not have lower workability, should have higher or increasing absorption or penetration, must not have reducing penetration. So, if you see the natural material is the one like rocks, they give the highest optimum strength. Whereas the lowest strength comes from quarry dust or waste, building construction waste and therefore we must be careful where we would use these.

So apart from the natural material, strength of all the other concrete is almost similar. Rocks such as rock volcano materials they have higher strengths. So appropriate admixtures or plasticizers should be applied to achieve the required compaction and strength when we use the rest of the materials. Sustainable and large scale recycling of these materials for structural or non-structural concrete or mortar could not only address resource scarcity but also may result in environmental benefit. Let us look at crushed rock sand.

Depleting resources of natural river sand and strict environmental guidelines on mining has gradually shifted the attention of the concrete industry towards a suitable fine aggregate alternative that can replace the presently used natural river sand. The crushed stone dust as suitable material for cement concrete works as alternative fine aggregate to replace the natural sand. Crushed stone dust, a solid industrial waste of the construction industry as a natural sand substitution as fine aggregate in cement concrete gives a good approach to reduce the scared good quality of fine aggregate, increase compressive strength and solve some of the solid waste problem posed by crushed stone dust. The crushed stone dust is economical also in the Indian condition. So when we look at natural material with crushed rock sand, there are two things.

One is crushed sand and another is river sand. Let us compare the source. So crushed sand is manufactured from rock stones. Whereas river sand is naturally available by the river bank and is got by transportation. Crushed sand is manufactured from available rock stone and the price will vary based on material availability.

River sand is not available so much. Due to this the price of river sand is very high. When we consider impact on environment, crushed sand has less impact on the environment as compared to sand. Excavation of river sand will reduce groundwater level and is also a depleting resource. When it comes to strength, as said above, it is manufactured from rock so the strength is high.

Whereas the strength is low compared to MSand. When we look at size of materials, no oversized particles are available since it is artificially manufactured. Whereas one needs to sort and remove the oversized particles. When we look at workability, due to the cubical shape and rough structure, little strain is there while mixing with other ingredients. Whereas due to smoothness of sand, mixing with other materials is easy compared with Msand.

When we look at moisture content, moisture content is only available when the sand is washed by water. Sand has naturally moisture content in it. Let us now look at Mangima stone. Recent studies conclude that the Mangima stone can be suitable alternative material for coarse aggregates to produce structural concrete because results showed that compressive strength of the concrete blended with Mangima aggregates attained higher strength capacity than the conventional basalt aggregates. Several varieties can be extracted but the properties of these materials are very similar except that they vary mostly on colour.

Mangima stones have become very popular with the building sectors because of its finishing. Most of its uses are for decorative tiles, roofing shingles or wall finishings with its varying natural colours. Production of desired cuts such as brick sizes have been established, thereby Mangima stone waste are also piling up in the workyards. While such waste can be useful for the concrete science, utilization of these wastes can provide a great benefit to supply the construction industry with aggregate materials while preventing the environmental impact by making more sustainable use of these wastes. The next alternative we will see is the quarry dust.

A quarry dust is a byproduct of the crushing process which is a concentrated material to use as aggregates for concreting purpose especially as fine aggregates. In quarrying activities, the rock has been crushed into various sizes. During the process, the dust

generated is called quarry dust and is formed as a waste. So it becomes as a useless material and also results in air pollution. Therefore, quarry dust should be used in construction works which will reduce the cost of construction and where the construction material would be saved and the natural resources can be used properly.

Studies conclude that the quarry dust can be used as a substitute for sand. It is identified that 40% replacement of sand by quarry dust gives good result in strength than normal concrete for M20 and M30 grade. The results possess that 40% replacement of sand by the quarry dust induced higher compressive strength and the workability of concrete decreases as replacement increases. Thus, the environmental effects and waste can be significantly reduced. Let us look at crushed clay bricks as an alternative.

Brick waste are often deposited or eliminated in dumps or sanitary landfills. It's an important alternative to reduce this waste and one of the ways is to recycle them and reuse them as a concrete component material. Due to their high absorption percentage that allows them to keep the water inside of them and then use it in the cement hydration process as internal curing of the concrete, they are found to be suitable. Studies show that it is very appropriate to use recycled crushed bricks in areas where there is less conventional aggregate when the high resistance of concrete is not a major consideration due to the advantage of reducing dead loads. It can be said that crushed brick concrete can be used in places that do not require high compressive strength.

The use of crushed brick reduces the compressive and tensile strength of concrete while it enhances the compressive strength of mortar. Let us now look at an innovative material which is agricultural and coconut shell. So coconut shell is an agricultural biodegradable waste found in most tropical countries including India. Coconut shells as a substitute for coarse aggregates in concrete is gaining importance in terms of possible reduction of waste products in the environment and finding a sustainable alternative for non-renewable natural stone aggregates. When you add it to concrete, Coconut shell concrete has better workability because of the smooth surface on one side of the shells and the size of the coconut shell used in the studies.

The strength test done on different mixes showed that coconut shell concentrate where 25% of the coarse aggregate is replaced shows properties similar to the nominal mix and 50% replaced coconut shell shows properties similar to lightweight concrete which can be used as filler materials in framed structures. There is significant self-weight reduction due to the replacement of coarse aggregates with coconut shells which can be utilized advantageously in concrete structures. Let us consider paper pulp as a waste material. We have already seen this.

Now we work vice versa. So, papercrete and fibrous cement is produced by replacing cement by waste paper. E-waste paper is processed to obtain the raw materials of papercrete and fibrous cement. The proportion is a mixture of waste paper pulp, sand, cement and water by replacing the cement with waste paper pulp in a certain percentage. Use of waste paper pulp in concrete can save the pulp and paper industry disposal costs and produce a greener concrete for construction. There is an increase in water absorption of the concrete mix.

This can be expected as the content of the paper pulp increased since more amount of paper pulp in terms of quantity will involve in the hydration process. Therefore, additional amount of water is required for cement hydration which is the common solution to this kind of a problem. Let us now look at polymers or plastic as an alternative to aggregate. So, plastic waste becomes a major problem which affects the environment as it is not easily biodegradable. It is much clearer when the percentage of plastic content as partial substitution increases the lower the strength of the concrete gets.

So when the percentage of plastic content increases the strength of the concrete gets reduced. This shows that plastic will be a good platform in producing lightweight concrete if proper research is to be conducted which on other hand will produce good compressive strength in the meantime. Plastic as fine aggregate substitution in concrete manages to produce a much better result compared to the substitution for coarse aggregates. Now let us look at use of rubber waste. Due to the fact that the waste tyre rubber as a non-biodegradable material has a relatively long lifetime.

There is great interest in replacing natural river aggregate in concrete mixes with rubber which is derived from waste tires that is rubberized concrete. This has attracted the attention of civil engineers and building industry to provide an environmentally friendly concrete with recycled tire rub. An attempt of placing the coarse aggregates with rubber aggregates will save the natural aggregates as it reduces weight of structure and also helps achieve sustainability. The workability of concrete is not affected by addition of crumb rubber. There was no major problem in binding between the crumb rubber and the cement matrix This showed that the crumb rubber proved to have good absorption and binding potential in the concrete The overall compressive strength proved to be greater than the conventional concrete consistency of the concrete is greatly reduced with increase in addition of aggregates in spite of the addition of super plasticizer.

Let us now look at adding glasscrete. So, glass is a transparent material which is produced by melting a mixture of materials such as silica, soda ash and calcium carbonate at high temperature followed by cooling during which solidification occurs without crystallization. Glass is an ideal material for recycling. In construction field, the

waste glass was reused for concrete production. Crushed glass or cullet if properly sized and processed can exhibit characteristics similar to that of gravel or sand. When used in construction applications, waste glass must be crushed and screened to produce an appropriate design gradation.

Studies show that waste glass can effectively be used as coarse aggregate replacement and the optimum replacement level of waste glass as coarse aggregates is 10%. And now let us look at electronic waste. So electronic waste or e-waste materials have serious human health concerns and require extreme care in its disposal to avoid any adverse impacts. E-waste can be incorporated in concrete to make a sustainable environment. Some of the methods for the disposal of e-waste are landfill, incineration, reuse and recycling.

Electronic waste has more resistance to wear and tear than natural aggregate. Electronic waste has wide difference of impact and crushing value while the aggregates of e-waste are stronger than that of natural aggregate. It shows that the compressive strength of e-waste specimens is lower than normal aggregate specimens. It can be consumed as lightweight aggregate in concrete. Increase in percentage of e-waste specimens' leads to reduction in the self-weight of concrete.

Workability of concrete decreases when percentage of e-waste is increased. So, it can be used only to certain extent. So, in conclusion, Cost economy, energy efficiency, durability and overall ecological profile of concrete benefit would be obtained by replacing cement with waste materials. Therefore, in the future, the use of waste materials as supplementary cementing materials should be made mandatory.

We must also go forward with alternative aggregates. Greener concrete also improves air quality, minimizes solid waste and leads to a sustainable cement and concrete industry. Alternate aggregates reduces the cost of concrete, conserves natural resources such as raw materials, reduces the amount of waste sent to landfills and incinerators, prevents pollution by reducing the need to collect new raw materials and it also saves energy. Therefore, it is necessary to replace the aggregates in concrete with waste materials thus generating a greener concrete. As far as possible you must also replace cement with an appropriate equally strong material so that the concrete becomes greener.

So with this we will conclude today's class. And next class we will look at yet another interesting topic. So in this class we have seen how alternate aggregates are just a question of our imagination and what we would like to experiment with. We have seen five types or five classifications of aggregates which can be used as an alternative and this will help you know recycle the waste into the buildings and also it will protect the

environment from mining of the aggregates. With this I will stop this class until we meet in the next class. Thank you. Thank you.