Concrete and its study as an eco-friendly material of building construction.

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Abstract— Concrete has a leading role to play in meeting the big challenges we face today. When taking the performance of a building over its whole lifecycle into account, concrete offers significant benefits over other building materials, such as its durability, its thermal mass, load carrying capacity, its recyclability, and its carbon uptake. Concrete has one of the highest CO2 emissions of all building materials, during the manufacturing of cement these emissions are produced. A way to optimize its production and application in construction while decreasing its environmental impact is essential. The solution to this environmental problem is not to substitute concrete for other materials but to reduce the environmental impact of concrete and cement. Technology can be developed, which can reduce the CO2 emission related to concrete production. The ingredients of concrete can be substituted with other materials that cause less impact on environment. Some special types of concrete are also developed to make concrete more ecofriendly. The effect of concrete is taking place in different stages from extraction of the raw material until the end of structure life. Sustainability in Architecture can also be done by reducing the impact of modern building materials to the environment rather than using traditional building materials. Concrete, is a strong and durable material which provides flexibility in design when used as reinforced concrete. High rise structures or heavy structures like dams, bridges cannot be substituted by another material.

Index Terms— concrete, ecofriendly building materials, sustainability, special concrete

1 Introduction

As it is known that several residual products have properties suited for concrete production, there is a large potential in investigating the possible use of these for concrete production. Well-known residual products are silica fume and fly ash. We should realize at an early stage that it is a good idea to be in front with regard to documenting the actual environmental aspects and working on improving the environment rather than being forced to deal with environmental aspects due to demands from authorities, customers and economic effects such as imposed taxes. Furthermore, some companies in concrete industry have recognized that reductions in production costs often go hand in hand with reductions in environmental impacts.

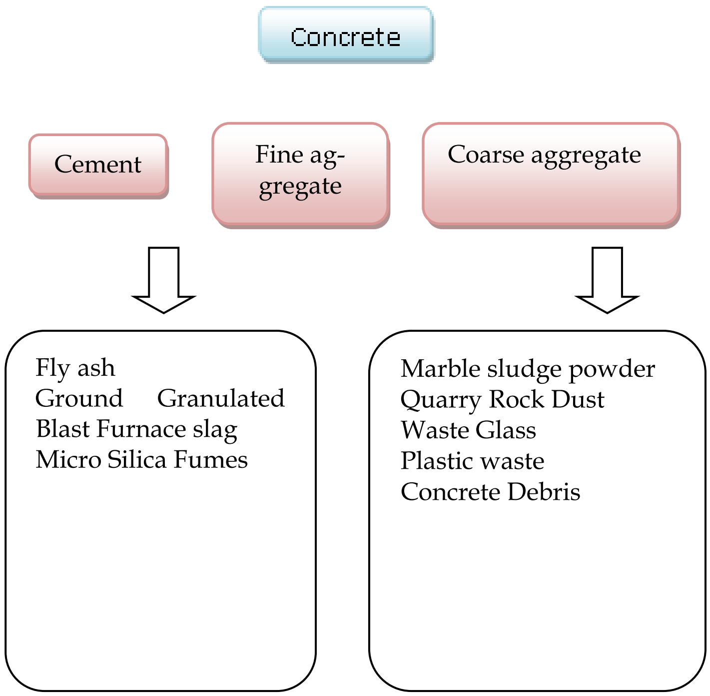
Thus, environmental aspects are not only interesting from an ideological point of view, but also from an economic aspect. Green concrete has manifold advantages over the conventional concrete. Since it uses the recycled aggregates and materials, it reduces the extra load in landfills and mitigates the wastage of aggregates. Thus, the net CO2 emissions are reduced. The reuse of materials also contributes intensively to economy. Green concrete can be considered elemental to sustainable development since it is eco-friendly itself. Green concrete is being widely used in green building practices.

2 Ecofriendly Concrete Ingredients

Frequently, concrete may be used for some special purposes for which special properties are more important than those commonly considered. Sometimes, it may be of great importance to enhance one of the ordinary properties.
These special applications often become apparent as new developments using new materials or as improvements using the basic materials. Designers and contractors often come across problems which call for special solutions involving concrete. A special concrete a concrete made with special ingredients or by a special process may be ideally suited to the need. The size of construction industry all over the world is growing at faster rate. The huge construction growth boosts demand for construction materials. Aggregates are the main constituent of concrete. Due to continuously mining the availability of aggregates has emerged problems in recent times.

To overcome this problem, there is need to find replacement to some extent. Nowadays, there is a solution to some extent and the solution is known as “Green Concrete”. Green concrete has nothing to do with color. This is a concept of eco friendly way in mass concreting. The constituent of this concrete doesn’t correspond to carbon footprint and give healthy environment to all. Green concrete is also cheap to produce because, waste products are used as partial substitute for cement, charges for the disposal are avoided, energy consumption in production is lower, and durability is greater.

Waste can be used to produce new products or can be used as admixtures so that natural resources are used more efficiently and the environment is protected from waste deposits. One way to make concrete sustainable is to utilize industry waste or by-products to replace the raw materials for making concrete, such as cement and aggregates. The industry by-products utilized to replace cement are usually called supplementary cementitious materials (SCMs). Currently, blast furnace slag, fly ash, limestone powders, and silica fume are the most commonly used SCMs. These SCMs can be obtained in large and regular amounts with a relatively consistent composition. They can be added into cement during the final grinding process of cement production to reduce amount of clinker used. They can also be added into concrete mix during concrete production to reduce the amount of cement. No matter in which way it is done, the utilization of SCMs can reduce the amount of clinker or cement. The production of the clinker or Portland cement is an energy-intensive process and consumes 4 GJ per ton of cement. Production also emits a large amount of CO2.



2.1 Substitutes for cement ingredients

- Fly ash

Fly ash is finely divided residue resulting from the combustion of powdered coal and transported by flue gases and collected by electrostatic precipitation. Fly ash is most used pozzolanic material all over the world. The volume of fly ash produced is about 75 million tons per year, the disposal of which has become a major concern. Only About 5% of the total fly ash is utilized in India, the remaining of which has to be disposed. Instead of doing so, it can be utilized in a major way. Portland cement concrete is the most popular and widely used building materials.

Due to the restriction of the manufacturing process and the raw materials, some inherent disadvantages of Portland cement are still difficult to overcome. There are two major drawbacks with respect to sustainability. About 1.5 tonnes of raw materials is needed in the production of every ton of PC, at the same time, about one ton of carbon dioxide is released into the environment during the production. Fly ash can be a cost-effective substitute for Portland cement in some markets. In addition, fly ash could be recognized as an environmentally friendly product because it is a byproduct and has low embodied energy.

It's also is available in two colors, and coloring agents can be added at the job site. In addition, fly ash also requires less water than Portland cement and it is easier to use in cold weather. Other benefits include:
Higher strength gains, depending on its use.
It can also be used as an admixture.
It can substitute for Portland cement.
It is considered as a non-shrink material.
It produces denser concrete and a smoother surface with sharper detail.
Reduces crack problems, permeability and bleeding
Reduces heat of hydration.
Fly ash is a pozzolanic substance containing aluminum and siliceous material that form cement in presence water and lime
It has greater workability
It reduces CO2 emission and heat of hydration

- Ground Granulated Blast Furnace Slag

It is an excellent cementitious material. Slag is obtained by crushing molten iron slag which is a byproduct of iron and steel making from a blast furnace in water or steam, to make a granular glassy product that is then dried and grounded into a fine powder. Similar to fly ash, even ground granulated blast furnace slag generates less heat of hydration. Ground granulated blast furnace slag is also responsible for improving durability as well as mechanical properties of concrete.

Just like fly ash, blast furnace slag is a byproduct that can be recycled and used to make an environmentally friendly alternative to concrete. This glassy granular material is produced by quenching molten iron slag from the blast furnace into water or steam.

This material can replace about 70% to 80% cement, and improves the durability of the concrete. Another advantage of blast furnace slag is that the production process emits less amount of heat for hydration.

- Micro Silica Fumes

Also known as “Silica Fumes,” micro silica is an ultrafine powder which is a by-product of ferrosilicon alloy and silicon production, from the condensation of Silicon dioxide. It can displace around 7% - 12% cement in concrete.
Micro silica is known to improve the durability of concrete by making it less permeable, and increasing its compressive strength.

Concrete made with silica fumes is specifically used for structures that are exposed to harsh chemicals. Compared to traditional concrete, it is a much eco-friendlier material.

2.2 Substitutes for aggregates

- Marble sludge powder

Marble sludge powder is obtained in dry form as an industrial by-product directly from deposits of marble factories. The specific gravity depends on the nature of the rock it is processed. Marble sludge powder has a specific gravity of 2.57. The water absorption values were obtained by IS238686 (Part III-1963) test method and was found to be 2%.

Concrete is capable for sustainable development is characterized by application of industrial waste such as marble powder, quarry dust, wood ash, paper pulp, etc, to reduce consumption of natural resource and energy and pollution of the environment. Use of such waste material saves 14%-20% amount of cement. The concrete resistance to sulphate attack and alkali-aggregate reaction is greatly enhanced. Marble sludge powder can also be used as a substitute to fine aggregate

- Quarry rock dust

Quarry Rock Dust can be defined as residue, tailing or other non-valuable waste material after the extraction and processing of rocks to form fine particles, less than 4.75mm. Quarry dust is made while blasting, crushing, and screening coarse aggregate. Quarry dust has rough, sharp and angular particles, and as such causes a gain in strength due to better interlocking. Quarry rock dust concrete experiences better sulphate and acid resistance and its permeability is less, compared to that of conventional concrete. However, the water absorption of Quarry Rock Dust concrete is slightly higher than Conventional Concrete

Use of quarry dust:

Common river sand is expensive due to excessive cost of transportation from natural sources. Also large-scale depletion of these sources creates environmental problems. As environmental transportation and other constraints make the availability and use of river sand less attractive, a substitute or replacement product for concrete industry needs to be found. River sand is most commonly used fine aggregate in the production of concrete poses the problem of acute shortage in many areas.

In such a situation the Quarry rock dust can be an economic alternative to the river sand. Quarry Rock Dust can be defined as residue, tailing or other non-voluble waste material after the extraction and processing of rocks to form fine particles less than 4.75mm. Usually, Quarry Rock Dust is used in large scale in the highways as a surface finishing material and also used for manufacturing of hollow blocks and lightweight concrete prefabricated Elements. Use of Quarry rock dust as a fine aggregate in concrete draws serious attention of researchers and investigators. In the recent past good attempts have been made for the successful utilization of various industrial by products (such as fly ash, silica fume, rice husk ash, foundry waste) to save environmental pollution. In addition to this, an alternative source for the potential replacement of natural aggregates in concrete has gained good attention. As a result reasonable studies have been conducted to find the suitability of granite quarry dust in conventional concrete.

The utilization of Quarry rock dust which can be called as manufactured sand has been accepted as a building material in the industrially advanced countries of the west for the past three decades. As a result of sustained research and developmental works undertaken with respect to increasing application of this industrial waste, the level of utilization of Quarry Rock Dust in the industrialized nations like Australia, France, Germany and UK has been reached more than 60% of its total production. The use of manufactured sand in India has not been much, when compared to some advanced countries. The durability of quarry dust concrete under sulphate attack is higher compared to conventional concrete. The durability of quarry dust concrete under acid action is also better than conventional concrete. The effects of quarry dust on the elastic modulus property are good with conventional concrete containing natural sand. The fine quarry dust tends to increase the amount of super plasticizers needed for the quarry mixes in order to achieve the rheological properties. Replacement of natural sand with Quarry Rock Dust, as full replacement in concrete is possible.

However, it is advisable to carry out trial casting with Quarry Rock Dust proposed to be used, in order to arrive at the water content and mix proportion to suit the required workability levels and strength requirement. However, more research studies are being made on Quarry Rock Dust concrete necessary for the practical application of Quarry Rock Dust as Fine Aggregate.

- Waste glass

The amount of waste glass has gradually increased over the recent years due to urbanization and industrialization where most of the waste glass end up in landfill while only small fraction can be recycled because of the high cost of cleaning and colour sorting. Since glass is not biodegradable, landfill is not an environmentally friendly solution. Recent studies have shown that the waste glass can be effectively used in concrete either as aggregate (fine or coarse aggregate) or as cement replacement. Being amorphous and containing relatively large quantities of silicon and calcium, glass is in theory pozzolanic or even cementitious in nature when the particle size is less than 75 micron. Finely ground glass as oppose to coarse waste glass does not contribute to alkali-silica reaction. Besides improving the properties of concrete by pozzolanic reaction by partial replacing the cement will contribute to a greener environment for the production of one ton of Portland cement produces about one ton of carbon dioxide leading to global warming issues.

Waste glass is converted to valuable materials like decorative aggregate, sand replacement and pozzolanic additive in concrete production. After collection, discarded waste glass is sent to the processing facility for washing and crushing. Then, the waste glass is sieved into 10 and 5 mm particle size for different purposes. Waste glass of 10 mm particle size is usually used as natural aggregate replacement while 5 mm particle size waste glass is used as sand replacement in mortar. Finally, the small particle size is ground to produce glass powder which possesses natural strength minimum water absorption and the capability to encounter excessive temperature without deterioration. Ground glass powder with particle size 75-150μm can be used as a pozzolan for cement replacement in concrete.

In the field of architectural and decorative concrete recycled glass possess breathtaking performance due to the aesthetic properties of the waste glass. By using different size of glass better aesthetic concentration can be achieved.

- Plastic waste

Utilizing waste plastic is a smart move, as it is a non-biodegradable material. Plastic waste is easily recycled, and can easily replace up to 20% traditional aggregate material.

Although concrete produced using plastic waste provides strength within a specific limit, it is unarguably an eco-friendly alternative to traditional concrete. In the present study the recycled plastics were used to prepare the coarse aggregates thereby providing a sustainable option to deal with the plastic waste.

There are many recycling plants across the world, but as plastics are recycled they lose their strength with the number of recycling. So these plastics will end up as earth fill. In this circumstance instead of recycling it repeatedly, if it is utilized to prepare aggregates for concrete, it will be a boon to the construction industry. Most of the failures in concrete structures occur due to the failure of concrete by crushing of aggregates. Plastic aggregate which have low crushing values will not be crushed as easily as the stone aggregates. Following points tell how plastic waste is beneficial as a replacement of concrete:

Polymers have a number of vital properties, which exploited alone or together, make a significant and expanding contribution to constructional needs.

Durable and corrosion resistant.

Good Insulation for cold, heat and sound saving energy and reducing noise pollution.

It is economical and has a longer life.

Maintenance free (such as painting is minimized).

Hygienic and clean.

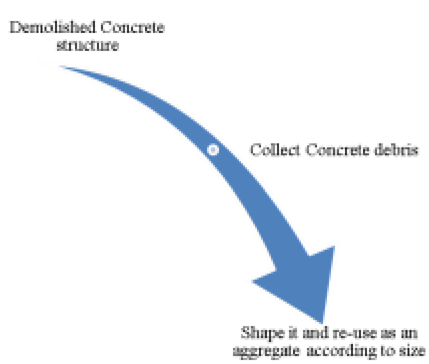
Easy to processing / installation.

Light weight

- Concrete Debris

Using concrete debris as a replacement to aggregate can make a contribution to reduce the total environmental impact of the building sector. Consequently, reclaiming aggregates from concrete debris would lead to environmental and economic benefits.

One of the things builders, developers and contractors must consider during construction, renovation or demolition is where to put all the debris. As what most people do in the preservation of the environment and for economic purposes, studies, researches and experiments are being done to discover new ways on how to find solution considering where else to put these debris and what can be done to lessen its disposal to landfills and since there is an increasing environmental problem regarding the waste disposal to landfills, it is necessary to think of possible ways on how to avoid these problems and at the same time secure safety and convenience, and that is, to recycle.



3 Special Concrete

Cconcrete may also be used for some special purpose for which special properties are more important than those commonly considered. Sometimes, it may be of great importance to enhance one of the ordinary properties. These special applications often become apparent as new developments using new materials or as improvements using the basic materials. Designers and contractors often come across problems which call for special solutions involving concrete. A special concrete a concrete made with special ingredients or by a special process may be ideally suited to the need.

- Bacterial Concrete

Concrete structures are extremely susceptible to micro-cracking which allows water, gases and other potential harmful liquids enter and degrade the concrete, reducing the performance of the structure in terms of strength and durability aspects. To defeat this disadvantage it requires expensive continuous maintenance in the form of micro crack repairs. When these micro cracks propagate further deep, not only the concrete itself will be damaged, but also leads to corrosion in the steel reinforced concrete structures. Micro cracks are therefore the major cause in reducing the durability of concrete structures. In general, high strength concrete is more prone to cracking due to greater thermal shrinkage and lower stress relaxation. On the other hand, low-strength concrete tends to crack less, due to lower thermal shrinkage and higher stress relaxation. The formation of cracks is considered an inherent feature of concrete. It must be emphasized that in reinforced concrete structures, cracks as such are not considered as damage or failure and cracking does not indicate a safety problem. The crack width, however, should not exceed a recommended crack width limit.

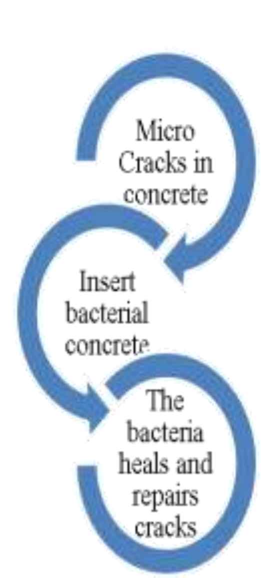
Cracks that are too wide may reduce the capacity of the concrete to protect the reinforcing steel against corrosion. Corrosion of reinforcing steel is the major reason for premature failure of concrete structures. Micro-cracks not only undesirable for aesthetic reasons but also form a continuous network of cracks they may substantially contribute to the permeability of the concrete, thereby reducing the concrete's resistance against ingress of aggressive substances. It is known that it is costly to inspect, monitor and repair cracks. Apart from cracks, the inherent porous structure of concrete could also be a point of concern. If pores are connected and form a continuous network, harmful substances may penetrate the concrete and may chemically or physically attack the concrete or the embedded steel.

Enhancing the quality and service life of concrete structures using environmental friendly solutions may sound new technology but more recently material scientists have begun to adopt a phenomena called 'self-healing' inspired from nature through biomimicry. The development of concretes which can automatically regain this loss of performance is very desirable. Along these lines, self-healing of cracked concrete is an often studied phenomenon. Experimental investigations and practical experiences have demonstrated that cracks in cementitious materials have the ability to seal themselves, commonly called 'autogenous healing'. Rapid crack-healing is necessary since it is easier for aggressive substances to ingress into concrete through cracks than through the concrete matrix. Moreover, some of the currently adopted crack repair methods are not so sustainable. For crack repair, a variety of techniques are available but traditional repair systems i.e., synthetic polymers have a number of disadvantageous aspects such as different thermal expansion coefficient than concrete and also pose environmental and health hazards.

Repairs can be particularly be time consuming and expensive because it is often very difficult to gain access to the structure to make repairs, especially if they are underground or at a great height. Several of these repairing systems are organic coatings consisting of volatile organic compounds. The air polluting effect of these compounds during manufacturing and coating has led to the development of new formulations such as inorganic coating materials made up of calcium-silicate compounds, which exhibit a composition similar to cement. Generally used epoxy treatment repair treatments are expensive and needs a skilled expert supervision and also the aesthetic appearance will be affected particularly for structures with historic importance/heritage structures. From the perspective of durability the cracks formed should be repaired conventionally using epoxy injection, latex treatment etc. or by providing extra reinforcement in the structure to ensure that the crack width stays within a certain limit.

Use of synthetic agents such as epoxies for remediation of cracks introduces a different material system of doubtful long term performance and moreover they may damage the aesthetic appearance of the structures. Self-repair mechanism could be more useful when repair is required to be carried out in the areas where it is not possible or hazardous for human beings such as nuclear power plants, waste water sewage pipes etc. In treating surfaces of structures with strategic and historic heritage importance, self-healing materials could be an ideal choice. So, if in some way a reliable method could be developed that repairs cracks and enhances performance of concrete autonomously, which could increase and ensure durability and functionality of structures results in the conception of "Bacterial Concrete" a smart sustainable biomaterial.

There are many crack repair techniques available to surmount this problem but each technique has its own advantages and disadvantages. One such alternative crack-repair mechanism is application of bio-mineralization of bacteria to seal and heal cracks in concrete. Synthetic polymers such as epoxy treatment etc., at present being used for repair of concrete, are harmful to the environment; therefore the use of a biological repair technique in concrete was focused upon. The principle of self-crack healing mechanism is that certain kinds of healing agents will be released from the concrete when cracks occur.



- Reactive Powder Concrete

Reactive Powder Concrete (RPC) is a developing composite material that will allow the concrete industry to optimize material use, generate economic benefits, and build structures that are strong, durable, and sensitive to environment. A comparison of the physical, mechanical, and durability properties of RPC and HPC (High Performance Concrete) shows that RPC possesses better strength (both compressive and flexural) and lower permeability compared to HPC.

The development of HPC results from the materialization of a new science of concrete, a new science of admixtures and the use of advanced scientific equipments to monitor concrete microstructure. HPC has achieved the maximum compressive strength in its existing form of microstructure. However, at such a level of strength, the coarse aggregate becomes the weakest link in concrete. In order to increase the compressive strength of concrete even further, the only way is to remove the coarse aggregate. This philosophy has been employed in Reactive Powder Concrete.

Reactive Powder Concrete was developed in France in the early 1990s and the world's first Reactive Powder Concrete structure, the Sherbrooke Bridge in Canada, was erected in July 1997. Reactive Powder Concrete is an ultra-high-strength and high ductility cementitious composite with advanced mechanical and physical properties. It consists of a special concrete where the microstructure is optimized by precise gradation of all particles in the mix to yield maximum density. It uses extensively the pozzolanic properties of highly refined silica fume and optimization of the Portland cement chemistry to produce the highest strength hydrates.

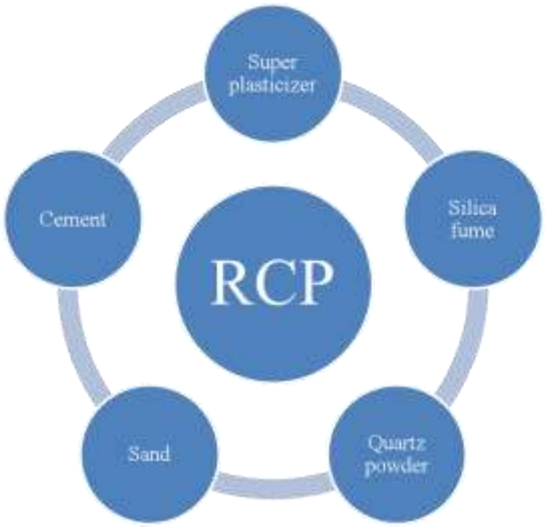
The concept of reactive powder concrete was first developed by P. Richard and M Cheyrezy and RPC was first produced in the early 1990s by researchers at Bouygues' laboratory in France. A field application of RPC was done on the Pedestrian/Bikeway Bridge in the city of Sherbrooke, Quebec, Canada. RPC was nominated for the 1999 Nova Awards from the Construction Innovation Forum. RPC has been used successfully for isolation and containment of nuclear wastes in Europe due to its excellent impermeability.

RPC is composed of very fine powders (cement, sand, quartz powder and silica fume), steel fibers (optional) and superplasticizer. The superplasticizer, used at its optimal dosage, decreases the water to cement ratio while improving the workability of the concrete. A very dense matrix is achieved by optimizing the granular packing of the dry fine powders. This compactness gives RPC ultra-high strength and durability. Reactive Powder Concretes have compressive strengths ranging from 200 MPa to 800 MPa.

Richard and Cheyrezy indicate the following principles for developing RPC:

1. Elimination of coarse aggregates for enhancement of homogeneity
2. Utilization of the pozzolanic properties of silica fume
3. Optimization of the granular mixture for the enhancement of compacted density
4. The optimal usage of superplasticizer to reduce w/c and improve workability
5. Application of pressure (before and during setting) to improve compaction

6. Post-set heat-treatment for the enhancement of the microstructure
7. Addition of small-sized steel fibers to improve ductility



RPCs have an ultra-dense microstructure, giving advantageous waterproofing and durability characteristics. These materials can therefore be used for industrial and nuclear waste storage facilities. RPC has ultra-high durability characteristics resulting from its extremely low porosity, low permeability, limited shrinkage and increased corrosion resistance. In comparison to HPC, there is no penetration of liquid and/or gas through RPC.

In a typical RPC mixture design, the least costly components of conventional concrete are basically eliminated or replaced by more expensive elements. The fine sand used in RPC becomes equivalent to the coarse aggregate of conventional concrete, the Portland cement plays the role of the fine aggregate and the silica fume that of the cement.

The mineral component optimization alone results in a substantial increase in cost over and above that of conventional concrete (5 to 10 times higher than HPC). RPC should be used in areas where substantial weight savings can be realized and where some of the remarkable characteristics of the material can be fully utilized. Owing to its high durability, RPC can even replace steel in compression members where durability issues are at stake (e.g. in marine condition). Since RPC is in its developing stage, the long-term properties are not known.

- Geo-polymer Concrete

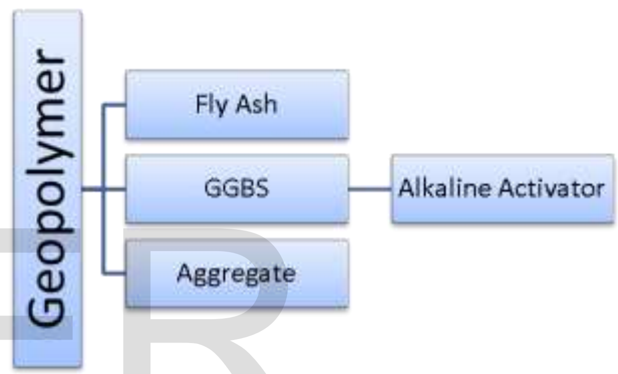
Geopolymer cement concrete is made from utilization of waste materials such as fly ash and ground granulated blast furnace slag (GGBS). Fly ash is the waste product generated from thermal power plant and ground granulate blast furnace slag is generated as waste material in steel plant.

One of the efforts to produce more environmentally friendly concrete is the development of inorganic alumino-silicate polymer, called geopolymer, synthesized from materials of geological origin or by-product materials such as fly ash that are rich in silicon and aluminum. Both fly ash and ground granulated blast furnace slag are processed by appropriate technology and used for concrete works in the form of geopolymer concrete. The use of this concrete helps to reduce the stock of wastes and also reduces carbon emission by reducing Portland cement demand.

Composition of Geopolymer Concrete

Following materials are required to produce this concrete:

1. Fly ash – A byproduct of thermal power plant
2. GGBS – A byproduct of steel plant
3. Fine aggregates and coarse aggregates as required for normal concrete.
4. Alkaline activator solution for GPCC as explained above. Catalytic liquid system is used as alkaline activator solution. It is a combination of solutions of alkali silicates and hydroxides, besides distilled water. The role of alkaline activator solution is to activate the geopolymeric source materials containing Si and Al such as fly ash and GGBS.



Compressive strength of geopolymer concrete have been found up to 70 MPa (N/mm2). The concrete gains its compressive strength rapidly and faster than ordinary Portland cement concrete. The concrete strength after 24 hours have been found to be more than 25 MPa. Compressive strength after 28 days has been found to be 60 to 70 MPa.

[James Aldred and John Day and Test results by SERC Chennai.]

Applications of Geopolymer Concrete

The application is same as cement concrete. 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.

4 CONCLUSION

Technology is changing our world and aslo is bringing new challenges and opportunities for sustainability. By studying all these methods of making concrete an ecofriendly material, we get inspired that modern construction materials can also be used in a sustainable way, which helps improve architects sustainable design and also contributes to the environment safety in the world. Technology can be developed in a sustainable way.

REFERENCES

[1] Advance Concrete Technology by Zongjin Li, 2011 Canada

[2] IJITEE, June 2014 Ronak Malpani, Sachith Kumar Jegarkal, Rashmi Shepur, Ravi Kiran H. N, Veena Kumara Adi, 'Effect of Marble Sludge Powder and Quarry Rock Dust as Partial Replacement for Fine Aggregates on Properties of Concrete' , *ISSN: 2278-3075, Volume-4, Issue-1*

[3] ResearchGate, 2017, BENGHIDA Djamil, 'Concrete as a Sustainable Construction Material', ISSN: 1662-9795, Vol. 744, pp 196-200

[4] Journal of Civil Engineering and Environmental Technology, Bharti Joshi1, Ramraj Meena, Amit kumar Shresth and Rajendra, ' A Review Paper on Green Concrete' p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 5, Issue 2; April-June, 2018, pp. 122-125

[5] ResearchGate, April 2015, 'Recycling Concrete Debris from Construction and Demolition Waste' , Tomas U. Ganiron Jr

[6] ResearchGate, April 2015, Neeraj Agarwal, Nikhil Garg, A RESEARCH ON GREEN CONCRETE , IJIRMPS | Volume 6, Issue 4, 2018

[7] FIB Conference: Sustainable Concrete: Materials and Structures IOP Ravindra K Dhir OBE Chao Qun Lye, Ciarán J Lynn and Abdurrahaman A Elgalhud, Sustainable construction materials for concrete: A question of responsible use, 2001

[8] International Journal of Advanced Engineering Research and Science (IJAERS) Patil Pramod Sambhaji, Use of Waste Plastic in Concrete Mixture as Aggregate Replacement [Vol-3, Issue-12, Dec- 2016] ISSN: 2349-6495(P) | 2456-1908(O)

[9] ResearchGate, July 2013, N. Tamanna, UTILIZATION OF WASTE GLASS IN CONCRETE