# Innovative Types of Concrete For Sustainable Development As Green Building Materials

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***Abstract***—In this present age, there are a variety of construction techniques as well as construction materials. Most of them being orthodox but are often practiced due to their strong reliability and suitability in the construction world and also due to non-availability of alternative construction practices and material. Construction materials are also detrimental to the environment causing several calamities as most of them are not naturally available and are required to be manufactured or processed. Concrete is one such construction material which has vast application but its ingredient or main constituentmaterial such as cement, aggregate, sand and admixtures can pose threat to the ecosystem. It is claimed that 5% of the world's carbon dioxide emission is attributed to cement industry. Due to the significant contribution to the environmental pollution, there is a need for finding an optimal solution along with satisfying the civil construction needs.This paper outlines the advances in the technology of concrete as a construction material by emphasizing development of innovative techniques employing different types of concrete such as foam concrete and pervious concrete. The paper also envisage the possible applications of innovative materials such as Zeolite, calcite, Titanium dioxide as a concrete ingredient and as partial replacement to cement with a view to achieve improved mechanical properties, strength and durability of concrete. It also highlights the scope of innovative concrete construction as a structural material and also as a non-structural material duly considering the positive impacts on environment, sustainability, reduction in cost and construction time, ease in construction as their weight and dimensions are reduced.

***Keywords***- *Zeolite, calcite, titanium dioxide, Foam concrete, pervious concrete*

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## I. INTRODUCTION

Cement is a key to infrastructure industry and is utilized for various purposes. Depending upon cement's immense and capricious usage in the construction industry, variety of compositions is available in market. Cements may be named after itsprimary constituents, intended purpose, the object to which they are applied or after their characteristic property. With continuous increasing demand of cement raw material, an immense necessity has arrived for the alternatives of raw materials and suitable to concrete composition. The principal objective of using alternative material is to optimize the mix to make best use of available raw materials. The use of innovative supplementary material in cement can thus be helpful.

Ordinary concrete contains approximately 12% of cement. It has to be born in mind that cement industry alone contributes to 5% of the whole global emission of carbon dioxide to meet its yearly production, at the same time,construction as well as demolition debris constitute a considerable fraction of solid waste. There is great influence of the natural aggregate production on the quality of both groundwater and running surface water. Even then, the importance of concrete in the construction field is invincible. Thus the importance of reducing carbon dioxide emission has gained instantaneousimportance and there by Sustainable Construction has gained high priority in the recent construction era. [1]

Nowadays, Concrete science is a multidisciplinary area of research in which nanotechnology potentially offers the chance to enhance the understanding with regards to concrete behavior. Thus with the help of nanotechnology the civil engineer can now study properties of concrete which can significantlyaid to lower production as well as ecological cost of construction materials.

## II. SUSTAINABLE CONSTRUCTION

Sustainable construction aims at reducing the environmental impact of a structure over its entire lifetime, while optimizing its economic viability with comfort and safety of its occupants. The principles of Sustainable Construction apply to the entire life cycle of construction startingfrom planning to disposal.

Sustainability is thus an ability to accomplish continuing economic prosperity at the same time protecting the natural systems of the planet and providing a high quality of life for its people. Green building suits these concepts through its

building practices and thus 'Green' buildings are a subset of sustainable construction.

### A. FOAM CONCRETE:-

*a)* ***Reduce resource consumption (Reduce)*** – Foam Concrete consumes a comparatively small amount of raw material relative to the amount of finished product.

*b)* ***Re-use Resources (Re-use)*** – Recent advances in construction are making use of recycled foam concrete to substitute sand in the insulation layers.

*c)* ***Use recyclable resources (Recycle)*** – In India, the total production of fly ash is nearly same as that of cement. But our utilization of fly ash is only 5% of the production. Foam concrete production consists of the recycled material fly ash (a by-product of thermal power plants)

*d)* ***Protect Nature (Nature)*** – The disposal of fly ash has become tedious and is a serious environmental problem which can be minimized with the production of Foam concrete blocks. Even though, the manufacturing of Foam concrete produces no pollution and thus protects nature, fly ash as such & fly ash based alumino silicates shall also be tested.

*e)* ***Eliminate Toxics (Toxics)*** - It does not emit toxic gases even when exposed to fire and also its manufacture process is non-toxic.

*f)* ***Apply Life-cycle Costing (Economics)*** – Proves it self to be cost effective starting from the construction stage till the operating and maintenance costs.

*g)* ***Focus on Quality (Quality)*** – Along with retaining low density due to use of foaming agent, Foam concrete fulfils the strength criteria. Lightweight concrete at its lightest density is stable and strong. [1]

### B. CALCITE IN CONCRETE

Use of calcite in concrete is sustainable approach to evaluate the effect on mechanical properties of concrete. The construction industry is the primary consumer of calcite in the form of limestone and marble dust [6]. These rocks have been used as dimension stones and in mortar for thousands of years. Limestone blocks were the main construction material used in many of the pyramids of Egypt and Latin America. Today, rough and polished limestone and marble have significant importance from material point of view and are used in prestigious architecture.
Modern construction uses calcite in the form of limestone and marble to produce cement and concrete. These materials are easily mixed, transported and placed in the form of slurry that will harden into a durable construction material.

### C. ZEOLITE IN CONCRETE

Zeolite bears natural porosity being a crystal structure with windows, cages, and super cages. The natural zeolites are limited in their pore size and are all hydrophilic. They possess or have greater affinity for water. Zeolites can also be obtained vide synthesis called as synthetic zeolites. Certain synthetic zeolites are similar when compared to an absorbent carbon as both can be considered as hydrophobic and can absorb organic vapours with molecules smaller than their "pore size".
Zeolite as a substitute for fine aggregate and cement will consequently absorb carbon dioxide. [13] Zeolite can also be manufactured in factories. It has a property to absorb the carbon dioxide as well as imparting incredible strength. Because of this nature zeolite can be a reliable substitute for cement, fine aggregate and coarse aggregate.[10]

### D. TITANIUM DIOXIDE IN CONCRETE

Concrete with added functionality such as self-cleaning characteristics and the ability to remove pollutants is desirable. Self-cleaning, air-purifying concrete is a promising technology that can be constructed with air-cleaning agents having super hydrophilic photo catalyst capabilities such as Titanium dioxide.$TiO_2$ is usually added as a percent of the cement weight. Increasing $TiO_2$ concentrations increase photo catalytic effectiveness. Partial replacement of cement with Titanium dioxide by weight within 1% to 6% has resulted in improved self-cleansing properties of pervious concrete with certain increase in compressive strength.[17]
The primary function of concrete is structural but its prevalence in our society lends it to other function thus creating the need for concrete to maintain its integrity and aesthetic quality. The concrete shall be Eco-friendly or Eco-sustainable with positive impact on the environment. Such motive can be achieved by combination of pervious concrete with photo catalyst Titanium dioxide.

## III. TYPES OF INNOVATIVE CONCRETE

### *A. FOAM CONCRETE*

Foam concreteis a mixture of cement, fine sand, water and special foam which once hardened results in a strong, lightweight concrete containing millions of evenly distributed, consistently sized air bubbles or cells. The amount of foam added to the basic cement and sand mixture determines the density of foam Concrete. Foam concrete is both fire and water resistant. It possesses high (impact and air-borne) sound and thermal insulation properties. Foam concrete is similar to conventional concrete as it uses the same ingredients. However, foam concrete differs from conventional concrete with respect to the use of aggregates as in the foam concrete aggregate is eliminated. A foam aeration agent is used to absorb humidity till the product is exposed to the atmosphere that allows the hydration process of the cement to progress in its ever-continuing strength development.

Lightweight/foam concrete can be defined as a type of concrete which includes an expanding agent that increases the volume of the mixture while the dead weight is reduced. It is lighter than the conventional concrete with a dry density of 300 kg/m$^3$to 1840 kg/m$^3$. Low density and low thermal conductivity are the main specialties of foam concrete. There are many types of lightweight concrete which can be produced either by using lightweight aggregate or by using an air entraining agent. In this paper, aluminium powder has been used as an air entraining agent of concrete. The fine powder of Aluminium to the slurry reacts with the calcium hydroxide producing hydrogen gas. This hydrogen gas in the slurry mix gives the cellular structure and makes the concrete lighter

thanthe conventional concrete that's why it is called as foam concrete or light weight concrete.[5]

***Characteristics and Properties of Foam Concrete and Products:***

1. ***Flowability****:* The flowability of foamed concrete is characterized by the fact that it is self-compacting, free flowing and pumpable in the plastic state. The fact that it is pumpable makes it to be useful in inaccessible areas.
2. ***Workability:*** Desired dimension including angles and other shapes can be obtained with an ease. It can be cut with hand saw, can also be drilled into, nailed into, grooved, routed, shaped, curved, coated, etc. and finished with paint, tile, plaster or veneer.
3. ***Thermal Insulation***: It has high thermal capacity, or ability to absorb and retain relatively large amounts of heat energy. The effects are to minimize heat loss during cold weather and maximize heat gain during warm weather.
4. ***Sound Insulation***: Because of its independent air cells, which dampen sound transmission, aerated concrete has excellent and sound insulation and absorption capacities. As a result, it is most suitable for construction of Hotels, entertaining facilities, multi-user apartment's freeway sound walls, and in buildings that require acoustic ability.
5. ***Fire resistance***: Aerated concrete has a melting point of over 1500$^{o}$C, and provides approximately twice the fire resistance of normal concrete.
6. ***Wide range of densities***: Aerated concrete can be manufacturedwith widerange of densities (300-1950 kg/m$^{3}$), with proper controlled dosage of the foam, material selection and materials composition. [4]


***Advantages of Foam concrete:-***

1. Very light in weight
2. Very low water absorption
3. Fire resistant
4. Highly thermal insulation
5. Energy efficient
6. Sound insulation
7. Offers excellent strength
8. Versatile in nature

*B. CALCITE WITH FLY ASH IN CONCRETE*

The durability of a concrete can depend on many factors. Those most often considered are cement reactivity with environment, low permeability, diffusion coefficient of species such as sulfate ions and compressive strength. The water absorption is also very important factor effecting durability such as freezing and thawing. The use of mineral additives may provide a way of improving the durability of concrete depending on the type and amount of mineral additive used. In addition, in the absence of self-compatibility the success of mortars depends on the compaction degree supplied at application site. [6]

For improving the strength and durability properties, calciteoffers a more compact structure by pore filling effect. In the case of fly ash, it also reacts with cement by binding $Ca(OH)_2$ with free silica by a pozzolanic reaction forming a non-soluble C-S-H structure. Chemical factorscomprised the effect of calcite filler in supplying ions into the phase solution, thus modifying the kinetics of hydration and the morphology of hydration products.

The use of calcite in the binding system determines the acceleration of the cement initial hydration, especially of the tri-calcium silicate. In the initial stages of the process, the increasing of the hydration degree compensates the dilution effect of the binding material by the calcite, as a consequence of the formation of a higher volume of hydrates. Therefore, pastes, mortars and concretes can develop higher initial strengths, but gets diminished after a long time, compared to ordinary Portland cement, because the binding dilution effect here plays a vital role.[7]

Fly ash can develop certain mechanical strength, due to slowpozzolanic reaction, strength that increases after long duration of time. The simultaneous presence of the calcite and fly ash in cement cumulates the effects determined by every addition separately, prevailing the effects of the addition present in a bigger proportion.It has been widely observed that use of fly ash with calcite in cement reduces the setting time and increases the mechanical properties of mortar.[8]

***Advantages of Calcite in concrete:-***

1. The use of calcite in concrete up to 10 -15% give the higher mechanical properties as compared to conventional concrete.[9]
2. The fly ash with calcite accelerates the pozzolanic reaction and permits concrete gain more strength.
3. The mortar with calcite gain strength with days of curing, although the mechanical properties increase with the addition of calcite within limits.
4. The additions of calcite or fly ash – taken separately or altogether, determine a decrease of the setting time for the blended cements in comparison with Portland cement, the effect being stronger in the case of cements with greater addition of fly ash (20-30%) [9].

*C. ZEOLITE IN CONCRETE*

Zeolites are porous alumino-silicates and therefore are natural pozzolans. They can be utilized to replace up to

40% of the cement in concrete to make lightweight concrete with specific properties.Mostly, Due to the large amount of pores in the framework structures and the high surface area, natural zeolites present higher water demand in compression with cement and consequently reduce the workability of concrete. Therefore some investigations emphasizes on the application of natural zeolites with super plasticizers. However some of the natural zeolites show insignificant effect on workability of concrete. Type of zeolites minerals and surface morphology and the crystalline nature of zeolites have diverse effects on workability of fresh state.[11] When the cement mortar incorporatedwith zeolite as supplementary cementitious materials without using the super plasticizer, the flow of the mortar was decreased almost linearly with the increase of the amount of zeolite. However workability of fresh concrete was adversely affected by applying natural zeolite. The setting time of mortar was decreased when more than 15% of cement was replaced by zeolite. [12]

The presence of large quantity of reactive $SiO_2$ and $Al_2O_3$ in zeolite chemically combines with calcium hydroxide produced by the hydration of cement to form additional C-S-H gel and hydrated aluminates, leading to the improvement of microstructure of hardened cement. Just as otherpozzolanic materials, replacement of cement composite provides lower permeability, reduces expansion due to alkali-silica-reaction, and increases resistance against sulphate attack. Thus, Zeolite shows insignificant effects on the mechanical properties, whereas it improves durability of concrete effectively.

***Characteristics of Zeolite:***

1. Zeolite can be used as a molecular sieve because it has a uniform window (or pore) size.
2. Zeolite is metastable; i.e., it is stable as long as it is at a suitable temperature and pH. Within this range, it is unaffected by wide swings in temperature, pressure, and ionizing radiation.

***Advantage of Zeolite:-***

1. It reduces the rate of emission of carbon dioxide duringcement production in the industry.
2. It absorbs the carbon dioxide from the surrounding environment and helps to prevent the air pollution.
3. It imparts more durability as well as great performance against ordinary Portland cement concrete.
4. It also improves the mechanical strength to the cement

*D. PERVIOUS CONCRETE USING TITANIUM DIOXIDE*

Pervious concrete is a composite material which consists of coarse aggregate, cement and water. It is different from conventional concrete as it contains no fines in the initial mixture but if necessary can be introduced during compaction. The aggregate usually consist of single size and is bonded together at its point of contact by the paste formed by the cement and water. The result is a concrete with a high percentage of interconnected voids that when functionally correct, permit the rapid percolation of water through the concrete. Pervious concrete can have void ratios ranging from 15-40% depending upon its application. Compared to conventional, pervious concrete has a lower compressive strength, higher permeability and lower unit weight.

Pervious concrete is a type of concrete with high porosity. It is used for concrete flatwork applications that allow water to pass directly through it, thereby reducing the runoff from a site and allows groundwater recharge. The high porosity is attained by a highly interconnected void content. Typically pervious concrete has water to cementitious materials ratio (w/cm) of 0.28 to 0.40 with a void content of 18 to 35%[14]. It is an important application for sustainable construction and is one of the techniques used forground water recharge. A pervious concrete ground surface allows the transfer of water and air to root systems allowing trees to flourish. Generally for a given set of materials, the strength and infiltration rate of pervious concrete are a function of concrete density. Greater the density, higher is the strength and lower the infiltration rate.[15]

Photo catalysis employs semiconductors such as $SrTiO_3$, $TiO_2$, ZnO, ZnS and CdS as a photocatalyst. Amongst which Titanium dioxide, $TiO_2$ possesses the highest photo catalytic activity and is one of the most widely used semiconductors for photo catalysis.[16]The photo catalyst, titanium dioxide ($TiO_2$), is a naturally occurring compound that can decompose gaseous pollutants with the presence of sunlight. $TiO_2$ is a white, highly stable and unreactive metal oxide, present in nature in three different polymorphs: anatase, rutile and brookite.[17]


***Advantage of Pervious concrete:-***

1. Pervious concrete is used in parking areas, areas with light traffic, residential streets, pedestrian walkways, andgreenhouses.
2. It helps in ground water recharge. It also reduces the bad impact of urbanization on trees.
3. It can be also utilized in construction of tennis courts, well linings, Noise barriers, Hydraulic structures, artificial reefs, swimming pool decks, groins and sea walls.

## IV. CONCLUSION

The recent trends in technologies are leading to tremendous increase in pollution. Hence it is prime concernto discover new methods to reduce the pollution otherwise consequences will be devastating.Sustainable utilization of innovative construction materials such as Zeolite, Calcite & Titanium dioxide and new techniques namelyfoam concrete and pervious concrete is the need of the day.

- Foam concrete is a light weight concrete with no coarse aggregate possessing good insulation of heat and sound and thus can be utilized in place of conventional bricks or non-load bearing elements. Although it can be used as a structural concrete, its cube test results show considerable strength and can be used as an architectural concrete.
- Calcite used with fly ash in cement give better result compared to cement without additive. The compressive

strength of concrete is improved with curing. It also improves Durability and serviceability of concrete since these parameters depend upon curing, proper compaction, impervious nature etc.In case where the slump value plays important role, self-compacting concrete using calcite and fly ash can be the remedy.

- Zeolite serves a potential substitute of construction material as it can be used as a partial replacement to cement and aggregates. Zeolite made concrete is capable of absorbing carbon dioxide without any emission of it.
- From construction point of view, addition of Titanium dioxide in concreteaffects compressive strength, workability and corrosion control action of the concrete. Environmentally, Titanium dioxide being photo catalytic can impart self-cleansing property and can remove harmful $NO_x$ and $SO_x$ gases. Employing such material in pervious concrete will result in a self-cleansing, air purifying, water filtrate concrete

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