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GREEN CONCRETE & GLOBAL WARMING

There are several causes for global warming including carbon dioxide emission from burning of fossil fuels for the purpose of electricity generation. Coal accounts for 93 percent of the emissions from the electric utility industry. Coal emits around 1.7 times as much carbon per unit of energy when burnt as does natural gas and 1.25 times as much as oil. Natural gas gives off 50% of the carbon dioxide. Carbon dioxide emitted from cars is about 20%. Carbon dioxide emitted from Airplanes causes 3.6% of global warming and that the figure could rise to 15% by 2050. Building structures account for about 12% of carbon dioxide emissions.[1]

It is well known that the ecological balance is getting disturbed but we will keep our discussions restricted to the construction industry and utility of the green concrete.

Green building is all about science-physics, chemistry, and biology. It's really about ecology because ecology is about physics, chemistry, and because ecology is all about systems and integration of physics, chemistry and biology.

Building is about shelter and creating boundaries between people and the environment. Green building is about creating optimized boundaries between people and the environment.

The green building programme has identified a set of parameters that should be kept into consideration when the building is constructed and materials are chosen for it. It is vast subject to even define the material, which constitutes as environmental friendly or green material.

Worldwide, the construction industry contributes about 9% to the global GDP, and is one of the most important elements of every economy. Today's demands on buildings, roads, bridges, tunnels and dams could not be met without construction chemicals. The strength of concrete has risen dramatically as a result of the development of construction chemicals.

The global construction chemical industry is a $20 billion business. The United States and Western Europe are the two largest markets, together accounting for 56% of the total market. Japan, China and india come next and together have a market share of about 21%.

The raw materials needed for the production of construction chemicals are manufactured by the big chemical producers. Polymers are the most important group of raw materials and are found in virtually every construction chemical formulation ranging from adhesives to waterproofing treatments. The development of new construction chemicals in many cases requires interaction by the chemical producer, construction chemical manufacturer and end user. The construction chemical industry spends about 3% of its sales on R&D of new products and applications.[2]

We often hear that India is going to become world power. It sounds musical to our ears but when you see the state of our Infrastructures, it is disappointing. In this paper we will deal with one important aspect and that is the construction industry.

The production of bricks required the burning of fuels, either fossil fuels or agricultural waster. The firing of bricks is to increase the strength and durability of the brick and to decrease water absorption. Concrete requires the manufacture of cement. To produce cement, limestone and clay are heated at 1450^{o} C consuming fossil fuels, and cement is formed. The limestone is converted to calcium oxide and carbon dioxide.

$$CaCO_3 \rightarrow CaO + CO_2$$

For every 1000kg of calcium carbonate used, 440 kg of carbon dioxide is produced.

This production of carbon dioxide raises the question for the world of the desirability and economics of emulating western building practices in these countries, given the huge population requiring housing. For the production of bricks and concrete energy-intensive activities are undertaken. In addition, the energy use results in carbon dioxide production. In the case of cement production, the demand for cement worldwide is 800 million tonnes per year. Assuming 500 million tonnes of limestone is used for this purpose each year then more than 220 million tonnes of carbon dioxide is emitted to the atmosphere from cement works alone each year. This is the equivalent of 44 kg of carbon dioxide for every inhabitant of the Earth each year.

Cement

Let us concentrate on some of the major factors contributing to this state of affairs related to construction industry. We believe that every responsible citizen would continue in adopting environmental objectives. The following table will show the energy demand and emissions generated emitted in production of 1kg of cement.

Energy	
Coal	1.9 MJ
Coke	0.51 MJ
Diesel	0.03 MJ
Car tyres	0.42 MJ
Bone meal	0.01 MJ
Electricity	0.48 MJ
Emissions to air	
CO_2	0.71 kg
CO	2.7mg
NO_x	0.7g
SO_X	0.09g
CH_4	2.6g
HC	1.3mg

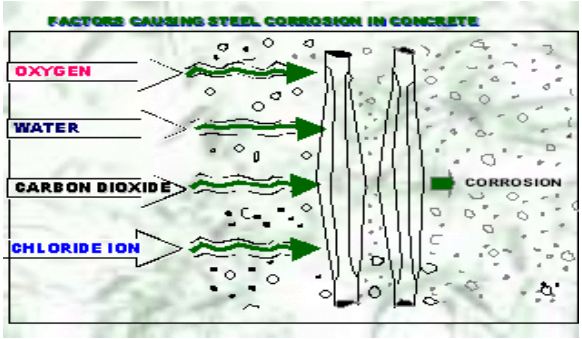
Corrosion

The corrosion of steel reinforcement is by far the single most common cause of structural damage.

The key environmental factors that reduce the passivation of steel are carbonation and chloride. Other factors which may influence either the initiation or rate of reinforcement corrosion include cracks in concrete, temperature, moisture, oxygen and in adequate concrete quality or cover.

There are two major situations in which corrosion of reinforcing steel can occur

- Carbonation
- Chloride contamination



Carbonation

Carbonation is the process of CO_2. Carbon dioxide enters in the concrete as carbonic acid in the presence of moisture and reacts with calcium hydroxide (reaction formula: $Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$)

Chloride Ions

Chloride ions can enter concrete in two ways

- They may be added during mixing either deliberately as an admixture or as a contaminant in the original constituents
- They may enter the set concrete from environment pollutants dissolved in rain water/ humidity

Both Carbonation and Chloride ions damage the protective, highly alkaline passive shield around reinforcement. This leads to the corrosion of reinforcement / malignancy of reinforcement as we call, which makes the building less durable and vulnerable to natural calamities which leads to human tragedy and loss of property.

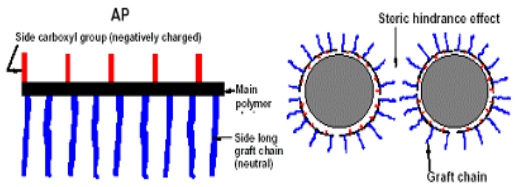
Toxicity of Admixture

While using admixture it is very important to be careful and make judicious decision so that the ingredient of cement does not react with admixture and produce undesirable side products.

Plasticizers tend to liberate cancer causing toxic product like formaldehyde.

Tons and tons of admixtures particularly plasticizers and superplasticizers are used in construction. The study shows that approximately 15-25% of sulphonated naphthalene polymers (SNP), lignosulphonate and polycarboxylates and 30-60% of sulphonated melamine polymers (SMP) were leached. Some additional test showed that this is the only part of leached organic substance that comes from superplasticizers and rest of them come from coating and adhesives.

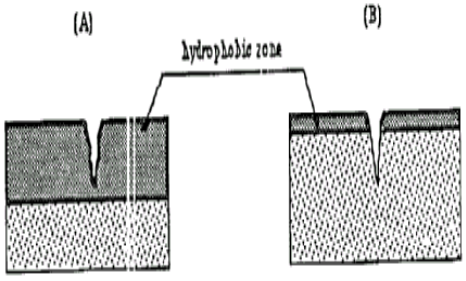
Togero[4] shows in his studies that some small fraction of formaldehyde in both SNF and SMF is liberated, which is not only hazardous but also **carcinogenic**.



Schematic picture of Acrylic Polymer (AP) and the related steric hindrance effect on the dispersion of cement particles.

Impregnants

Water vapour permeability is an essential requirement for building materials. A satisfactory water repellent leaves the treated substrate permeable to water vapour while restricting the passage of liquid through the capillaries. A natural external finish of masonry buildings may be required for aesthetic purposes**.** Treatment by impregnation does not change the finish appearance and no yellowing is normally developed during use.



Effectiveness of impregnation influenced by penetration depth: (A) impregnation effective and (B) impregnation ineffective

Permanent bonding between concrete capillaries and impregnants results in long-term durability.

Solvent based impregnants

Impregnants dissolved in a suitable solvent can be used to create a waterproof hydrophobic surface which does not allow the ingress of water. However solvent being toxic and hazardous has been banned in most of the Western countries. Moreover solvents are very expensive.

Water based

Water based impregnants form a zone within the pore of structure after penetration, resulting in a molecular size three to four times the dissolved size, and some impregnants is bound chemically bound to the silicates in the cement matrix.

Coatings

Coatings have not been successful because they tend to block pores and capillaries with the trapped water underneath it. This trapped water hits the weaker part of the surface and create ingress points in the form of cracks, blisters, honeycombs etc.,

The effect of some of the coatings is injurious like

Asbestos

We are sure that everybody knows that any type of asbestos causes cancer and it is not confined to a specific blue variety.

Asbestos as we all know is the name given to group of minerals that occur naturally as masses of strong, flexible fibers that can be separated into thin threads and woven. These fibers are not affected by heat or chemicals and do not conduct electricity. For these reasons, asbestos has been widely used in many industries.

Membranes

It has become a fashion to use membranes, the word is a misnomer since the elastomeric coating should have the following properties which these membranes do not have.

Tensile strength, Elongation, Crack bridging, Abrasion resistance, Temperature flexibility, Weatherability, Bonding, Flashing attachment, Materials compatibility, Wind uplift resistance.

The conventional membranes or thick toppings are normally bitumen, asphalt, polyurethane, and epoxy based. Besides several disadvantages like blister formation, debonding and other factors which allow water to enter.

Bitumen

The main constituents in bitumen are polyaromatic compounds which undergo photochemical oxidation particularly at high temperature (since they are black, the temperature is much higher). These photo-oxidation generates gases and strong carcinogenic compounds like Benzo[a]pyrene.

Elastomeric Coatings

Elastomeric coatings should not be misunderstood as the above mentioned membrane since these are normally non-cementitious and are produced by using special polymerization techniques and unlike other membranes they are flexible, breathable with high elongation and weatherability and crack bridging membranes rather than coating which have several problems.

Elastomeric Coatings are the latest type of coating which came into roof protection systems and tanking systems in basements.

To understand this concept we must address ourselves to basic questions to why latest membranes in this field are different than the conventional coating membranes.

Let us understand the term elastomers. Elastomers are a class of materials which differ quite obviously from all other solid materials in that they can be stretched, easily and almost completely reversibly, to high extensions and before reaching its ultimate breaking elongation - it can be released and will rapidly recover to almost exactly the original length it had before

stretching. The material is said to be elastic.

Most synthetic elastomers are not as elastic as natural rubber, but all can be stretched (or otherwise deformed) in a reversible manner to an extent, which easily distinguishes them from all other solid materials.

Elastomers are a special case of the wider group of materials known as polymers. Polymers are not made up of discrete compact molecules like most materials, but are made of long, flexible, chain-like or string-like, molecules. At this scale the inside of a piece of rubber can be thought of as resembling a pile of cooked spaghetti. In spaghetti, however, the chains, though intertwined, are all separate. But in most practical elastomers each chain will be joined together occasionally along its length to one or more nearby chains with just a very few chemical bridges, known as crosslinks. So the whole structure forms a coherent network which stops the chains from sliding past one another indefinitely - although leaving the long sections of chain between crosslinks free to move. The process by which crosslinks are added is known as vulcanization.

Polymers on the other hand are giant molecules of different chemicals. A polymer or a macromolecule is made up of many (poly) molecules ('mers') or monomers linked together like wagons in a train, for example poly(vinyl chloride), poly(ethylene), etc. The polymerization of vinyl chloride (VC), which represents some 500 to 2000 molecules of VC linked together to make a giant molecule of commercial PVC. Monomers may have the same or different chemical compositions.

Water in the form of vapour, liquid presents below-grade construction with many unique problems. Water causes damage by vapour transmission through porous surfaces, by direct leakage in a liquid state. Water presence in below grade makes interior spaces uninhabitable not only by leakage but also by damage to structural components as exhibited by reinforcing steel corrosion, concrete spalling, settlement cracks, and structural cracking.

Therefore all elastomeric membranes are not alike and different parameters like nature of monomer cross-linking agent, polymerization technique, initiators, accelerators and fillers can have an influence on the physical and chemical stability of the final elastomeric membrane.

Grouting

Grouting is the injection of a fluidized material into the soil to enhance its strength, density, or to reduce its permeability. Grouting can be more feasible than the cut and cover method, for example, excavating a trench to put in a tunnel lining and filling in the gap with soil. In the city, traffic may have to be rerouted around the cut and cover project site.

In planning a grouting programme for particular conditions, we need knowledge of various types of grouts and their properties. The basic types of grouts now in use and their properties are discussed below. Types of admixtures and fillers used and their effects on the grout are also discussed below. The most common types of grout are Portland cement, clay, chemical, and asphaltic grouts. No one grout is suitable for every situation.

Now-a-days excellent chemical grouting products have been developed, which can strengthen the voids whether in basements or otherwise. For example there are 2-component system where the damage is not only treated on the surface of the structure but that the complete centre of damage and the whole section of the building structure are completely treated.

These kinds of products do not effect the environment nor pollute the ground water.

Thermal Insulation

This has been a very misunderstood subject and there has been an understanding that Brick bat coba, surkhi or thermal insulation are preferred as Insulation products while thermal insulation does provide insulation but is not very durable. Surkhi which is now-a-days used as burnt bricks but

definitely does not provide any thermal insulation on the concrete.

Heat naturally flows from warm areas to cooler areas, regardless of direction. This flow of heat can never be stopped completely, but the rate at which it flows can be reduced by using materials which have a high resistance to heat flow.

The general guideline for thermal insulation is to understand that thermal resistance of insulating material is directly proportional to the type of material and its thickness measured in terms of thermal conductivity.

Thermal insulation for buildings has been known since long and is one of the serious requirements more because of the climatic conditions in India. Moreover we in India need any new system, which can contribute in saving energy.

Since last few years, lightweight micaceous minerals like Vermiculite have been used. The problem with this product is that it is very porous in nature and absorbs water and therefore has to be waterproofed. Moreover it is soft, and laying of tiles over it is often required.

The choice of the insulating material depends on the cost, area to be covered and the cost of heating or cooling. There are large numbers of insulation materials available in the market.

Recently ceramic microspheres and some natural clay along with redispersable spray dried polymers have played a key role. For example lightweight waterproofing concrete not only replaces brick bat coba and reduced the weight on the surface of the roof, gives a very good insulation.

It is important that the key persons in the field of real estate and construction industry should appreciate the advantages of green building and its benefits, but unfortunately they mix the cost benefit of these green buildings.

In one of the reports conducted by the World Business Council for Sustainable Development (WBCSD) reports. Respondents to a 1400 person global survey estimated the additional cost of building green at 17% above conventional construction, more than triple the true cost difference of about 5%. At the same time, survey respondents put greenhouse gas emissions by buildings at 19% of world total, while the actual number of 40% is double this. [3]

Existing technologies combined with common sense design can increase energy efficiency by 35 percent and reduce heating costs by 80 percent for the average building in industrialized markets.

Life cycle analysis shows that 80% to 85% of the total energy consumption and CO2 emissions of a building comes from occupancy through heating, cooling, ventilation, and hot water use. Buildings already represent approximately 40% of primary energy use globally and energy consumption in buildings is projected to rise substantially in the world's most populous and fast growing countries such as China and India.

It would also be interesting to note that we can perhaps use environmental friendly green material, some them are

- By-product: Unused or waste material from one manufacturing or energy producing process that can be used in another manufacturing or energy-producing process

- Diversion: Avoidance of landfill disposal of a material or product through reuse or recycling

- Embodied Energy: All of the energy required in the raw material extraction, manufacturing, distribution, and transport of a material product up to its point of use

- Global Warming potential: Possible Climate warming effect caused by the manufacture and/or use of a material or product compared to that of carbon dioxide which has a GWP of 1.0

- Indoor Air quality: Condition of air inside buildings with respect to harmful concentrations of contaminants, volatile organic compounds and particulates

- Life Cycle: All stages of production, including raw materials extraction, manufacturing, distribution, use, maintenance, reuse or recycling, disposal, and all transportation

- Off-Gassing: Releasing of gases or vapours into the air

- Rapidly renewable: Materials that are replenished relatively quickly, usually in less than 10 years

- Recyclable: Having the potential for being recycled by possessing such traits as highly recoverable, easily separated from other materials, not contaminated by toxic coating etc.,

- Recycled content: Portion of material or product that is made from recovered material

- Reused or salvaged materials: Materials or products from building deconstruction or demolition that are reused 'as –is' with little or no processing or modification

- Solid waste: Material or product, typically long lasting and not biodegradable, disposed of in landfills or incinerators

- Source separation: Separation of waste materials by material type at the point of use to facilitate recycling

- Third party certified: Materials or products that are monitored by independent organizations for compliance with recognized environmental standards

Quite often, it is extremely difficult to accurately assess the environmental performance of a building material or product over its entire life cycle. In many cases, the GBP relies on third party certification organization to accomplish this task

Green Terrace /Green roofs

We have been emphasizing on green concrete. We would once again say that ecological engineering is an emerging field, it permits us to develop design of sustainable ecosystem with integrate human society.

We can avoid sound pollution by using lightweight minerals. Many home owners and the designers prefer to add bright lights because it gives a better feeling of architecture, it lights up garden and tress but we forget that the by-product of all these is light pollution.

What is light pollution? When the light is shining into your neighbours house it creates a sky glow effect, it can cause glare and so many other problems. Light pollution is also harmful to wild life and equally to human beings.

Infact several European countries and the US have very aggressively pursued the project of green roofs or terrace gardens. This would help mitigate the urban heat insland effect, reduce storm water runoff, improve building insulation and increase green space and biodiversity in urban centers.

Progress in horticultural engineering, including improvements in drought-resistant plants, and advances in waterproofing systems aided the gradual development of a viable green roof industry. Germany has been on the forefront in this field and has subsidized green roof costs.

Green roofs are the result of a complete underlying roof build-up system, providing continuous, uninterrupted layers of protection and drainage. Recent advances in technology have made them lighter, more durable and better able to withstand the extreme conditions of the rooftop.

Waterproofing

If waterproofing is not done and is not effective it can encourage the growth of algae, fungus, mosses which are the natural sources of bacteria and inhouse pollution, radon gases which causes disease like asthma and diabetes mainly in children.

Conclusion

The benefits of green buildings are many: greater energy efficiency, reduced water consumption, longer useful life, better health conditions for occupants, and much more. All of these factors can improve the value of a building over the long term and reduce operational costs. However the mistaken perception exists that green building "costs too much" without a commensurate return on investment.

Therefore we conclude that waterproofing is a critical step but should be based on environmental friendly, non-toxic and energy saving techniques.

Reference:

1 US Emission Inventory 2004 Executive summary p.10
2 SRI Consulting SCUP Report
3 World Business Council for Sustainable Development (WBCSD)
4 Togero, 2004