Self-Sealing Crystalline Coating and Self-Cleaning Nanocoating for the Concrete Substrate for a Sustainable Development

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***Abstract* – The cracks in concretes are inevitable in spite of our best efforts in quality control as a result the ingress of deleterious substances take place though these cracks and corrode the reinforcement which leads to damage and deterioration of the concrete and there by decreasing the service life of the structures. This is more severe in any water retaining structures. To prevent this, self-sealing crystalline coating is very much suitable which is a permanent solution for crack repair there by decreasing the repair and maintenance cost of the structures. Though the integral crystalline has been developed since last three decades but its application is not wide spread. With the advent of nanotechnology recent development of self-cleaning nanocoating not only helps in cleaning the surface but also eco-friendly. Having much of additional features, these two green coatings are going to play a vital role for durability and sustainability of concrete structures.**

Keywords–Integral Crystalline, Green coating Nanocoating, Self-cleaning, Self-sealing

1. INTRODUCTION

Coatings have been formulated for various applications such as industrial, protection and decorative for a long time. But the products that contain dyes, ozone depleting chemicals, heavy metals, formal deride or carcinogens (toxic), solvent based finishes, particle board, adhesives and other products that release volatile chemicals into air have severe adverse effect on health and environment. Hence, for a sustainable development researchers are in the process of development of such products and techniques by which it will be beneficial to human beings as well as to have a cleaner and greener environment. At the same time compliance with the standards and legislation of Environmental Protection Agency (EPA) GS-11, Leadership in Energy and Environmental Design (LEED), South West Air Quality Management District (SCAQMD) is very much important. One such legislation known as REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) has been enacted recently for the development and regulation of cleaner technologies and process in Europe and other parts of the globe. But compliance and adherence to the regulations of REACH will ensure a green technology for a sustainable development but will take a long time for the developing countries for adherence. So green coating is the need of the hour for sustainability in the coating industry.

Green coating is not a product but a system as a whole for selecting appropriate raw materials, paint or coat, surface preparation, application, cleaning & suitable disposal including life cycle cost to perform certain parameters in terms of VOCs(volatile organic compounds), energy efficiency, performance & durability, recycling & others properties in accordance with the various standards of environmental protection agency[1].

The coating should be biobased polymers or biobased solvents such as methyl soyate (made from soyaben), mineral spirit, ethyl locate (made from corn esters) & ethylene glycol (EG), which contributes minimum or zero VOCs. Use of low toxic, solvent-free adhesive & sealants will help in reducing VOCs. Efforts should to develop & use more and more zero VOCs paint or coating. Using the products which are biodegradable, non toxic, and water based and cold water compatible will make ecofriendly.

Energy efficient coating is another method of green coating which helps in refracting suns infrared and UV radiation from the substrate by the heat blocking pigments in the paint or coat. This helps in reducing heat transfer and making cooler by which demand of cooling system get reduced as a result energy is being saved and also decreases global warming.

II. SELF-SEALING CRYSTALLINE COATING

Crystalline is a cementitious brush applied, waterproofing treatment for concrete. When it is mixed with water & applied to concrete, it penetrates into the concrete mass and protecting against the passage of water. Environmental factors such as ambient temperature, density of concrete, moisture present & weather conditions all can affect the timing of sealing process. Under dry conditions, it lies in dormant state. However it becomes reactive whenever it is re-exposed to moisture. It contains active waterproofing chemicals which react with moisture and unhydrated cement in the concrete. They penetrate even against strong hydrostatic pressure and becoming an integral part of the concrete for which they are also called integral crystalline system. The waterproofing chemicals remain active for the life of the structure, permanently sealing it from water penetration. It is also ideal as a curative treatment for dampness in concrete walls. It can be applied from both external and internal sides (positive & negative sides).It can also be used as admixture in new construction thus avoiding external waterproofing membrane. They are also used in joints in water retaining structures.The mechanism of crystallization process as follows:

- These needle-shaped crystal micro-fibres disperse or suspend well in a wet stage and then start inter-locking with each others forming complex 3-D network reinforcement during the curing / drying process as shown in Fig.1.
- The proprietary waterproofing active chemical plays very important role and it is a very simple reaction with the natural chemical byproducts of cement hydration, such as calcium hydroxide, various mineral oxides, hydrated & unhydrated cement particles of the concrete in wet condition. The result of chemical reaction is the formation of billions of needles like non-soluble crystals (Fig. 2) which block the pores of the capillaries, voids & micro-cracks in concrete [2]. After blocking the pores and capillary tracts of the concrete they become discontinuous which stops the permeability from all directions of the treated concrete.
- Pre-saturation & subsequent re-wetting of the surface cause diffusion of the organic chemicals & formation of crystals by reaction at greater depth. It may take from seven days to one month to reach its maximum waterproofing capability, depending on the thickness of the concrete.

Figure 1. Inter-locking of crystals forming a complex 3-D network reinforcement

Figure 2. Growth of crystals

A) Method of Application of Crystalline coating

1) Surface preparations

- Dirt, laitance, loose particles, paints, etc. should be removed by means of mechanical grinding, sand blasting, and pressure water cleaning or suitable mechanical means.
- All protrusions should be removed, honeycombed & damaged areas should be chiseled out, and the cracks should be repaired to get back to a sound concrete.

- It is extremely important to ensure that the surface should be sound, thoroughly surface prepared and vacuum cleaned to a finish of a sand paper to allow crystalline to penetrate effectively. This is achieved by mechanical surface scarification, shot blasting, etc.
- If any active water leakages are there then they should be stopped using any instant leak plug a PU (Polyurethane) based product or with a PU injection system for severe infiltration.
- The surface should be rinsed thoroughly with water several times to reach a "saturated surface dry" (SSD) condition, where the surface should be damp without any standing water.

2) Mixing

- Crystalline powder should be mixed to water in ratio of 5 parts powder: 2 parts water for waterproofing purpose and 5 parts powder: 1 part water as putty for repair purpose.
- Always powder should be mixed to water and stirred well to obtain a lump free mixture. Only that much quantities should be mixed which can be used within 30 minutes. Always Crystalline should be mixed mechanically with clean water to have a thick consistency. Separate containers of same volume should be used to measure powder and water.

3) Application

- Crystalline should be seeded or broadcasted with a pre-determined amount of powder equally using a sieve or similar device, until an uniform coverage and a consistent finish is achieved across the surface before the final trowelling is being made.
- While applying crystalline slurry, an aggressive circular motion of the brush should be ensured. A second coat should be applied after 3 to 6 hours.
- After the final set of concrete, only the water should be sprinkled for initial curing. The ponding of water should be done for regular curing after 48 hours. If application is being done in direct sunlight, it is extremely important to cover the surface after final trowelling with a rigid sheet of polythene which should not come in contact with the applied surface. This can be done by placing the sheet on bricks to ensure a gap in between the concrete surface and the sheet, which allows air circulation.

B) General Properties

Application advantage – It does not require any protective plaster and applicable over SSD & wet surface.

Waterproofing – It stops water movement through concrete and becomes integral part of the structure.

Corrosion - It protects reinforcing steel against corrosion.

Sealing – It waterproofs minor cracks and seals shrinkage cracks up to 0.4 mm width.

Permeability – It resists permeation of water from positive and negative side of the concrete.

Chemical activation – The waterproofing capability of such coating increases with the time as it remains permanently active.

Abrasion – It does not get affected by surface wear or abrasion, once the penetration is completed.

Toxicity – It is non toxic thus good for use in drinking water containments.

Hydrostatic pressure – The treated concrete withstands hydrostatic water pressure up to 40-50 metre head.

Ease of application – It can be easily applied, only to be mixed with water at site.

Protection – It protects concrete against contaminated water and corrosion.

Breathability - It allows concrete to breath but it is not a vapour barrier.

Saving – It is economical to apply than other waterproofing treatments. At the same time expensive surface preparation, costly priming and leveling of the surface prior to application of crystalline are not required.

Monolithic – It forms a monolithic layer with the concrete which cannot be punctured, teared and removed from the surface.

Some of the other properties and their standard values are given in Table 1.

TABLE 1
PROPERTIES OF CRYSTALLINE COATING

Properties	*Results*
Appearance	Grey powder
Bulk Density	1.25 g/cc
Water permeability	Nil
Water pressure head	40 – 50 m
PH (mixed with water 1:1)	11 +/- 1
Particle size	40 – 150 micron
Penetration rate	2 mm / week

C) Areas of Application

The water retaining structures such as water tanks, reservoirs, swimming pools, water treatment works, dams, canals, concrete pipes and harbours are some of the structures where crystalline coating is most suitable. Even water excluding structures such as foundations, basements, tunnels, subways, inspection pits, lifts shafts, retaining walls, sea defence walls, construction joints, bridge decks, jetties and parking places are other areas of application.

III. SELF-CLEANING NANO COATING

With the advent of nanotechnology it is possible to have nanocoatings. These coatings are composed of nanoparticles (Fig.3) which are encapsulated or dispersed in a liquid medium. Because of these nanoparticles they are widely dispersed in the medium for achieving a very high surface area to the volume ratio and enhancing their properties manifold [3]. They have many distinctive characteristics such as:

- Corrosion resistance
- Antimicrobial properties
- Improved properties, such as hardness, wear, good adhesion, and extreme flexibility
- Solar energy conversion
- Anti-graffiti Protection
- Photovoltaic application
- Biocompatible and bioactive

But the most important is self-cleaning characteristics of this nanocoating. The specific binder of titania-based in the coating helps for photoactive actions for abating the noxious substances produced by human activities (industry, transport and residential heating systems) and making the surface self-cleaning by which maintenance cost is reduced drastically and at the same time it purifies the environment.

These coatings are manufactured with the minimum energy input comparing with other types of coatings and derived from recyclable and renewable sources. It produces less waste during application. As a standard the recycling of coat or paint should contain minimum 20% recycled content and recycle of containers also solve the problem of disposal, emission from residues. All these are possible with the nanocoatings. In India this coating had been widely used in the structures of New Delhi Commonwealth Games - 2010.

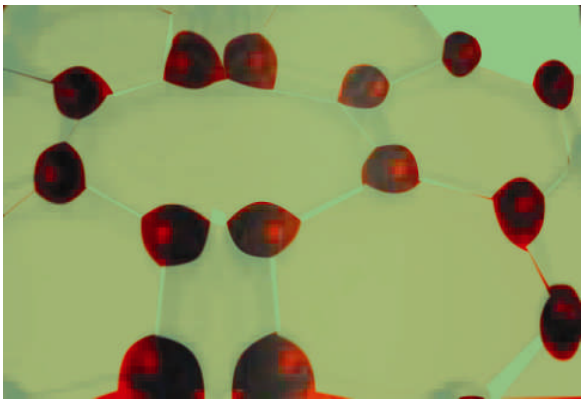

Figure 3. Dispersed Nanoparticles in the coating

IV. CONCLUSIONS

The coating industry has seen many changes in terms of environmentally friendly products with the time. Since the last few years the focus was more on VOC of the coating and its regulations. But now-a-days the focus has shifted to green coating. Integral crystalline has become an important system of waterproofing because of its self-sealing property. Nanotechnology has helped coating industry to produce nanocoatings for self-cleaning along with many other features. It not only cleans the surface but also helps in getting a cleaner and greener environment by improving the air quality and making it a choice for a new generation coating.

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