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# Detailed studies of cow dung ash modified concrete exposed in fresh water

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ABSTRACT

Concrete structures in proximity of water environment whether exposed directly or indirectly undergo physical and chemical changes. The water can be seeping into the porous concrete and this triggers the need to modify the exposed concrete with suitable add-ons. Cow dung ash is having pozzolanic qualities which can produce quality concrete structures. This study is focused on M30 grade concrete mix namely normal concrete and concrete modified with CDA. Concrete modified with CDA was prepared by 15% partial replacement of OPC with CDA. After 28 days of curing, specimens were exposed in fresh water for 56, 90, 180 and 365 days. Result showed that pH, compressive and split tensile strength and better durability was significant. X-ray diffraction studies were done to find out the crystalline structures whereas Field Emission Scanning Electron Microscope studies were performed to analyze the structural morphology of concrete specimens. Both studies showed the presence of more calcium silicate hydrate and more cementitious products in concrete modified with CDA. Lesser bacterial density was observed on concrete modified with CDA compared to NC.

## 1. Introduction

Concrete is the second world's most commonly used construction material Some concrete structures are found in water in the form of tanks, pillars, dams, foundations, pipes, poles, etc [1]. The fresh water exposed concrete structures are constantly facing the degradation problems which may be due to the freeze-thaw deterioration. As results it produces pressures in the capillaries and pores in the concrete which cause the significant expansion, cracking and scaling of the concrete structures. The chemical attack of the fresh water with cement hydration products, alkali-aggregates reactions, crystallization, frost action, corrosion, erosion etc is another problem with concrete [2,3]. These are the reason for decrease in strength and increase in permeability in concrete structures which is making concrete more susceptible for further attack and destruction [4]. The concrete industries are not only utilizing huge quantities of raw materials such as coarse aggregates, sand and water but also consume billions of tons of OPC. These activities are not environment friendly from energy consumption point of view and release green-house gases (GHG) leading to global warming. Conservation of energy is an important step to overcome the energy crisis and environmental degradation. The cost of energy in most cement production units accounts for more than 25% of the total production cost [5]. The manufacture of new materials and elements as construction resources support the energy efficient structural materials [6]. Development of new recycling green building material by reuse of daily waste improves the characters of green building [7]. Also recycled materials present good environmental behavior [8]. Now-a-days an increased amount of waste is being generated that leads to disposal crisis. The waste accumulation is mostly found in densely populated area and most of these materials are left as stockpiles, dumping garbage or illegal scrap materials in selected areas. The replacement of waste materials with cement, sand and coarse aggregates are limited to construction industry [9]. Cow dung ash (CDA) has pozzolanic qualities and thus considered as pozzolana for concrete production. In India, single cow produces dung per day approximately 30 kg and 12 tones in a year. So, there are sufficient raw material is available to produce the cow dung ash at the industrial scale. The availability of cow dung is dispersed all over the India especially in the rural area. In an industrial scale (small and medium industry), approximately 3.5 t of raw cow dung is needed to produce 1 t of cow dung ash. This study has been planned to modify the concrete structures for the partial replacement of cement by cow dung ash (CDA) to determine the effects of fresh water on the strength, durability and microstructural properties in concrete structures. Concrete structures in fresh water are also affected by microbes, which colonize on the concrete surface, its pores, capillaries, micro-cracks and damage it. The attachment of bacteria in concrete of structures of bridges, tanks, pipelines and cooling towers has not received much attention. Literature says that dung may improve workability and durability or may act as additional binder [10]. Pam Billy Fom et al. studied the compressive strength of cement cow dung

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stabilized bricks and investigated the lateritic soil blocks treated with cow-dung and found it has higher compressive strength than ordinary lateritic blocks [11]. Yalley and Manu investigated into the strength and the durability properties of earth brick stabilized with cow dung [12]. Cow dung is considered as natural antiseptic and inhibitor for microorganism and when mixed in concrete structures acting as insect repellent and prevents penetration of ultraviolet radiation.

In the recent years, many researchers have approached to modify the concrete structure with cow dung as it improves the strength and quality of concrete structures. Concrete corrosion and its resistance to fresh water were studied with slag concrete with 20–30% substitution has the best corrosion results [13]. Traditionally in India cow dung is used as waterproofing which consists of one-part of cow dung and five parts earths by weight, made into a fine paste with water and used to fill up the surface cracks [14]. Sirri et al was studied the chemical properties and pozzolanic effects of partial replacement of cement with Cattle Waste Ash (CWA) [15]. He found that 56-day compressive strengths of 5%, 10% and 15% CWA replacement had provided the best results. Farmer says that students from Prasetiya Mulya Business School in Indonesia develop cow dung building bricks by using 75% of cow manure and found not only 20% lighter, but they have a compressive strength 20% stronger than clay bricks [16]. Juimo Tchamdjou et al. also explained the importance of light weight concrete which has many advantages such as higher strength to weight ratio, better tensile strain capacity, lower coefficient of thermal expansion, and superior heat and sound insulation characteristic etc [17]. Some activities on the antibacterial corrosion of concrete have been also reported in the literatures. The micro-cracks in concrete are not having significant in strength loss of concrete but presence of moisture may pose a threat to microbial growth in concrete. In India, a few groups are working on the antibacterial corrosion studies on concrete modification by different admixtures like fly ash and superplasticizer for prevention of biofouling [18]. Previous studies confirmed that among the five-different concrete mix of M30 grade such as 2.5%, 5.0%, 7.5%, 10.0%, 12.5% and 15.0% CDA replacement by OPC [19], 15% replacement of CDA significantly gained good strength, low permeability, less pH reduction and microbial growth. So, this work was planned for one-year comparative study of NC with concrete modified with CDA with 15% replacement of OPC to find out its mechanical, durability, microstructural and antimicrobial activities in fresh water environment.

## 2. Materials and methods

### 2.1. Preparation of specimens

Two types of concrete mix namely normal concrete (NC) and concrete modified with CDA by 15% replacement of Ordinary Portland Cement (OPC) by CDA were prepared as per IS 8112:1989. The cow dung was collected, dried in sunlight, burnt to obtain the ash and sieved through 425μ mesh [20]. The water was constant and superplasticizer percentage was attuned based on the requirements. The ingredients of the mixtures for NC and concrete modified CDA specimens for all mix are shown in Table 1. The cube of 150 × 150 mm, cylinder of 150 × 300 mm and 100 × 200 mm was casted for compressive strength, split tensile strength as perthe procedure laid in IS 516 (IS 516-1959, IS 9103:1999 [21,22] and rapid chloride permeability test (RCPT) (ASTM C1202) [23]. The compaction of concrete mixture was done by internal vibration method to avoid the expelling the entrapped air from the concrete mixture during casting [24] All the specimens were withdrawn from the water after 7, 28, 56, 90, 180 and 365 days for further analysis.

### 2.2. Exposure studies in fresh water

All specimens of cube and cylindrical concrete were demolded after 24 h of casting and kept for 28 days in a laboratory curing tank filled with water at a temperature of 28 ± °C [25,26] (Fig. S-1). After removing from the curing tank, the specimens were immediately exposed to fresh water in concrete tank. The fresh water was recycled every 15 days once for one-year study. The specimens were withdrawn after 56, 90, 180 and 365days. The post exposure analysis of the specimens was pH measurements (surface and internal), mechanical properties (compressive and split tensile strength), durability studies (RCPT), microstructural properties (X-ray diffraction studies {XRD} and Field Emission Scanning Electron Microscope {FESEM}) and antibacterial activities by Total viable count (TVC) were evaluated.

## 3. Post exposure analysis

### 3.1. pH measurement study

The surface (WTW Sen Tix −3110) and internal (Hanna, HI-2211) pH of NC and concrete modified with CDA were performed for 28 days cured specimens and 56, 90, 180 and 365 days specimens were exposed in fresh water.

### 3.2. Mechanical properties

Compressive strength (IS 516) and split tensile strength (IS 5816) test results of fresh water exposed, 56, 90, 180 and 365 days were compared with 7 and 28 days cured concrete specimens. Both the test were performed by using automatic compression testing machine of 3000 kN capacity with different working force.

### 3.3. Durability studies

Rapid chloride permeability test (RCPT) was conducted to find out the chloride resistance in both NC and concrete modified with CDA. The cylindrical specimens of 200 × 100 mm of 28 days cured and 56, 90, 180 and 365 days fresh water exposed were used to determine the electrical conductance as per ASTM C 1202–97 [27]. The 50 mm thick slices and 100 mm diameter specimens was fixed between two

**Table 1**
Mix details of normal and CDA modified concrete.

| Mix Proportion | Grade of Concrete: M30 - Water/Cement Ratio: 0.44 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Free water | Cement | CDA | Total Binder | Fine Agg. (River sand) | Coarse Agg. | | | Super plasticizer (Weight %) |
| Normal Concrete | 0.44 | 1 | – | 1 | 2.18 | 3.12 | | | 0.01 (1% of Cement) |
| CDA Modified Concrete (15% by weight of total binder) | 0.44 | 0.85 | 0.15 | 1 | 2.18 | 3.12 | | | 0.015 (1.5% of Binder) |
| **Details of Mix per m$^3$ of Concrete** | Free Water (Kg) | Cement (Kg) | CDA | Total Binder (Kg) | Fine Agg. (River sand) | Coarse Agg. (Kg) | | | Admixture (Kg) |
| | | | | | | Total C. A | 20 mm (50%) | 12 mm (50%) | |
| Normal Concrete | 160.6 | 365 | – | 365 | 794.97 | 1139.54 | 569.77 | 569.77 | 3.65 |
| CDA Modified Concrete | 160.6 | 310.25 | 54.75 | 365 | 794.97 | 1139.53 | 569.77 | 569.77 | 5.48 |