Construction and Building Materials 175 (2018) 434–438

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Influence of organic agents to compressive strength of cement mortar

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HIGHLIGHTS

- Enlisting the organic impurities that may added unintentionally in mortar.
- Analysis of such impurities by preparing specimens in Laboratory.
- Evaluating compressive strength from 7 to 180 days of contaminated mortars.
- Compressive strength reduced significantly after 180 days.

ARTICLE INFO

Article history:
Received 31 October 2017
Received in revised form 10 February 2018
Accepted 22 April 2018

Keywords:
Cement mortar
Organic materials
Compressive strength

ABSTRACT

Concrete is considered as a primary unit of infrastructure and its performance have significant impacts on sustainability because lot of energy along with various resources are being consumed during its production. Several cementitious and useful organic materials are therefore added intentionally in concrete to enhance its mechanical properties and performance. But few organic materials also get mixed due to polluted construction site and may have severe impacts on performance of concrete structures. Detailed analysis of concrete under such aggressive environment must be assessed. In this research, three types of organic materials (vinegar, gram pulse and frog contaminated water) were selected that usually get mixed unintentionally during placing of concrete in developing countries. Mechanical performance was evaluated by conducting the compressive strength test after 7, 28, 90 and 180 days of curing. It was concluded that all types of organic materials used in mortar adversely affected its compressive strength, especially after a duration of 180 days. Results clearly indicated that mortar was adversely affected by inclusion of such organic materials. But it was ignored up till now and this work will provide awareness to the technologist for sustainable development.

1. Introduction

Conservation, rehabilitation and strengthening of construction industry may be termed as sustainable development. Resources, materials and environment are the three broader parameters which classify the sustainability and cleaner production. Impact of materials/construction products on environment and vice versa must be assessed experimentally or analytically or by any policy by decision makers and should be encountered for sustainable development [1,2]. In authors point of view, sustainability in construction industry may be achieved; first, by conserving or strengthening of concrete structures under severe environmental conditions [3–5] Second, is the incorporation of recycled material for the production of concrete [6–9]. Third, is the incorporation of new technology to predict the strength of any material without crushing or wasting of resources and energy [10] and fourth is the durability of the existing structures and proposing more durable structures to obtain the sustainable development [2].

Rapid industrialization, urbanization, deforestation, increase in number of vehicles are the factors which may increase the air pollution, soil pollution, landslides, floods, sea level rise, acid rains, windstorms and droughts which ultimately is responsible for the exposure of aggressive environment to already existing structures [11]. Several deteriorating mechanisms for cementitious materials are well defined in the literature and may cause failure of concrete under aggressive environment such as chemical attacks, alkali silica reaction, freezing and thawing effects, etc. [12]. These mechanisms results in change in the internal microstructure and minerals of hydrated cement paste, which ultimately results in a degradation in the mechanical properties and their durability

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https://doi.org/10.1016/j.conbuildmat.2018.04.177
0950-0618/

[12]. Several supplementary cementitious materials, polymers, and admixtures have been added in ordinary concrete in various researches to improve its resistance against such aggressive environmental conditions [2,4,5,13].

Large number of architectural monuments still exist due to the strong life of a lime mortar which has been used as binding material since very ancient time (c.12000 B.C.). Its early examples have been found in Palestine, Turkey, Greece and Roman Empire etc. But, later, it was widely used in almost all parts of the world. Several organic materials were added in the lime mortar to enhance its durability [14]. Although lime mortar was also used during the 21st century but it was mostly replaced by the cement mortar which have several advantages over it. Cement mortar is used to build industrial buildings, structures near agricultural fields, monuments etc., and may be exposed to several aggressive environmental conditions that may lead to early deterioration which leads to the reduction in their intended service life [12].

In most of the cases a cement mortar or concrete is exposed to such aggressive environment after a wet curing period of 28 days. But some impurities get mixed or incorporated during the early ages. Several such examples were observed when concrete is cast near agricultural lands [15], and no special attention was provided during its placement, especially in developing countries where flora and fauna are assumed to be the mixed impurities in concrete. Construction of lining or channels in agricultural fields may lead to mixing of impurities in the form of vitamins, proteins and acids from various flora in the fresh concrete. It is also common in Pakistan that animals; frogs or worms etc. may move to newly placed concreting site near agriculture lands and may become part of the concrete during its hardening. Contamination of such uncontrolled additions in the form of protein or biological micro-organism in a fresh mixture must be explored in detail to take a timely action to maintain or increase the intended service life and ultimately to achieve the goal of sustainable development.

Exposure of concrete structures in regions of acid contaminations results into the loss of billions of dollars, annually, in all over the world. To strengthen the structures in such regions a big capital is also consumed, which is again the socioeconomic loss associated with infrastructure deterioration. In 1993, 17 states of USA were damaged by acid rains and resulted in the loss of US$5 billion, annually. Another source of acid attack is through acid sulphate soils, which are in abundance at the coastal regions of Australia. For conservation and strengthening of infrastructure in such coastal regions requires a lot of resources and AU$189 million per year was consumed by just the state of Queensland. Similar affects have been seen in UK where over US$28.8 billion was loss in building sector due to acid rains. China, which is known as a big manufacturer in the world, also faces annual economic losses of $13.3 billion by the acid rain [16]. Although several developing countries are also facing this problem but unable to present appropriate data due to lack in technology and knowledge on such issues. Acids usually attacks on the cementitious materials resulting in severe effects on its properties ultimately influencing its behavior, leading to dissolvement of hydrated products along with the softening of the paste and scaling of the specimen depending on the concentration of the acid that is known by its pH value. Several studies are available in which detailed analysis of acid attacks have been discussed [17–20]. But the effect of acids along with the addition of vitamins and proteins is still missing, therefore this study was conducted which may contribute in the required area.

Biological micro-organisms in aerobic and anaerobic conditions are another parameter that influences the properties of the cementitious materials depending upon three main factors which are the type of protein, its concentration and environment. These factors are the main cause for affecting the growth of micro-organisms. Protein has a very versatile nature therefore the structures which can be created by using it ranges from as hard as a bone to as soft as the skin of a human being [21]. The most important feature of a protein structure is the self-organization or the self-assembling [22]. Remedial measures for bio-generic degradation has also been presented in one comprehensive study [23]. The influence on the properties of concrete by changing the concentration of organic materials (protein, biological materials etc.) was the prime concern of this research paper.

In this experimental work, several organic materials were added in concrete which mostly becomes its part unintentionally during the mixing or the placing process. Mostly such organic materials are the combinations of proteins, acids and vitamins. Their examples are vinegar and water with different concentrations of mussels and seeds etc. Such materials were added in ordinary Portland cement mortar during mixing and compressive strength of the prepared mixtures were evaluated after 7, 28, 90 and 180 days.

1.1. Research significance

With rapid climatic changes within the last century, aggressive environmental factors are gaining prime importance in terms of tangible elements. Although much data is available for obtaining sustainable materials by utilizing waste matters but limited research attention is provided to the aggressive environmental effects arising in form of acid rains, biological micro-organism or proteins on infrastructure. These harsh factors severely affects the integrity of infrastructure which results in loss of capital for their stabilization. This work was started with the aim of assessing such aggressive environment on properties of cement from fresh stage to the age of 180 days.

2. Experimental methodology

2.1. Materials

Ordinary Portland cement of ASTM Type-I was used for casting mortar. The fineness of cement was measured by using Blaine apparatus by following ASTM guidelines [24] and sand used was locally available with fineness modulus of 2.238 which was measured using guidelines [25]. Other physical properties of the cement and sand are mentioned in Table 1. Several organic materials, used in this study, were rich in protein, which were added intentionally in plastic or fresh concrete. The first organic material was the vinegar which has a varying composition of acetic acid along with other chemicals. Several citrus fruits are supposed to get dropped in the concrete when laid near agricultural lands due to strong winds and becomes its part during hardening. As in developing countries, there is no practice of blocking the constructional site by wind braking sheets or any other alternative means. To evaluate such behavior, a vinegar mixed water was used for preparation of a mortar.

Same parameters were used for the second organic material as discussed previously. It was also observed that after casting of concrete, several animals such as worms, especially frogs from nearby agricultural areas move on the surface and during its plastic to hardening stage they get trapped on the concrete bed. The parts merged with the concrete are hard to be replaced and their effects on its durability must be assessed. So to incorporate such issues, parts of the frogs were submerged in water for one month and that water was used for the casting of a cement mortar.

The third organic material was the powder form of gram pulse and the reliability with the real condition is the movement of seeds by the wind. The Blaine fineness of gram pulse was 1950 cm^2/g. Other physical properties of the gram pulse are mentioned in Table 1.

2.2. Mixture proportion

Five mortar mixtures were cast for this study. The mix proportion of cement and sand was 1:3 and water to cement ratio was kept 0.45. Clean drinkable water was added in dry cement and sand mixture. The specimen was prepared according to ASTM guidelines [26] and referred as the control specimen which is termed as CM in this work. The second mixture was cast by adding 1% of vinegar (by weight of cement amount). Vinegar was added in a water and that contaminated or treated water was used for casting of mortar keeping all other parameters similar as CM and specimen is termed as VM. The third mixture was prepared by mixing contaminated water by keeping frog pieces for one month and referred as FM. In last two