First International Conference on
Bio-based Building Materials

June 22nd - 24th 2015
Clermont-Ferrand, France

APPLICATION OF SOIL BACTERIA TO IMPROVE COMPRESSIVE STRENGTH OF PORTLAND CEMENT

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Abstract:
In order to control the demand for the use of Portland cement as well as to increase the durability of structure, although commercial admixtures are available that imparts additional cost for the construction projects. To enhance the mechanical property of Portland cement, a greener alternative solution needs to be investigated. Bacteria deposits calcium carbonate by the phenomenon called bio-cementation or microbiologically induced calcite precipitation (MICP). The present study aimed to analyse the improvement in compressive strength of ordinary Portland cement (OPC 53 grade) by addition of soil bacterial solution. In all casting for nine cubes each for controlled and bio-OPC were carried out. Experimentally, three cubes from each set were studied for compressive strength at the age of 7, 14 and 28 days. The effect of peptone and lentil seed as the protein source to soil bacteria was also analysed. At the age of 28 days, as compared to the controlled OPC 53 grade cubes, on an average 15.26 and 15.73 % improvement in compressive strength was estimated for peptone and lentil based bio-OPC respectively. Scanning electron microscopy (SEM) study was carried out and revealed the precipitation of calcite in the microbial amended cement specimen. The growth of calcite crystals within the pores of the cement matrix was observed. As compared to peptone solution, the lentil seeds are cost effective protein source to the soil bacteria and also impart in gaining more strength. The approach of bio-cementation is found to be commercially viable and environment friendly technique.

Keywords: Soil bacteria, Bio-cementation, Microbial cement, Compressive strength, bio-OPC.

1 INTRODUCTION

Portland cement is one of the most demanding products in the construction industry. In order to increase the durability of cement as well as to reduce the adverse environmental impacts researchers across the globe intervened various eco-friendly alternatives [1,10]. In order to cater the demand for the durability of the structures may not be achieved using todays ordinary Portland cement (OPC) [2,11]. The application of microbiology to the field of construction was researched to enhance the performance of conventional technology [5]. The bacterial treatment in the cementitious material enhances the durabilty of cementetious products [3,4]. This application called bio-remediation, makes the structure eco-friendly. Microorganisms and microbially mediated mineralization processes are active in almost every environment on earth and possibly in extraterrestrial systems as well. In natural environments, chemical $CaCO_3$ precipitation is accompanied by biological processes, both of which often occur simultaneously or sequentially. Microbes from soils and aqueous media were frequently reported to induce the precipitation of calcium carbonate mineral phases in both natural and laboratory settings [6]. Microbial mineral precipitation technologies have already been used for sand consolidation and strength improvement of bricks [7]. Inherent cement based biomaterials were developed to remediate the cracks and fissures in concrete structures [6]. Previous studies showed that the addition of specific microorganisms to cement–sand mortar or concrete deposit inorganic substances inside the pores of the matrices, which can be used as a filling material to remediate cracks within the structures. The biologically induced cement based materials also exhibited better durability and crack repairing performance compared to normal cement based materials. This technique can be used to improve the compressive strength of cement mortar [8,9]. The present paper aimed to study the effect of soil bacteria with variation in protein source to improve the compressive strength of Portland cement.

2 RESEARCH SIGNIFICANCE

The significance of this research is the use of soil bacteria to improve the compressive strength of ordinary Portland cement (53 grade). The investigation

has identified the effect of type and amount of biomass (soil bacteria) with the variation in protein source using peptone and lentil seeds on the compressive strength of ordinary Portland cement (53 grade) cubes. Furthermore, comparison of the values of compressive strength of cement cubes with use of peptone and lentil seeds as a protein source to soil bacteria for cultivation has been made to evaluate the performance of bio-OPC as compared to conventional OPC 53 grade. The development of the microbiologically-induced calcite as a tool for amendment in strength of cement will provide the basis for an alternative and high quality that is cost effective and environmentally safe.

3 MATERIALS AND METHODS

3.1 Materials

Following materials were used for casting of cement cubes:

- Cement- Ordinary Portland cement of 53 grade conforming IS 12269 (1987).
- Water-Locally available tap water confirming to IS 456 (2000) is used.
- Soil samples-Calcium carbonate precipitating bacteria were isolated from Rhizopheric soil**.**
- Protein source- Peptone and Lentil seeds used in powdered form.

3.2 Methods

Culture Media

Calcium carbonate precipitating bacteria were isolated from Rhizopheric soil. Microbial solution was prepared in liquid medium (Urea-$CaCl_2$), using the nutrient agar composition containing: 200gm/1000ml Soil, 5gm/1000 ml Peptone, 3gm/1000ml yeast, 2.8gm Urea/1000ml, 1.4gm $CaCl_2$/1000ml, 1gm/1000ml Glucose in 1000 ml Erlenmeyer flask. The solution was incubated for 24 hours and growth conditions were maintained at 37°C. As an alternate protein source to soil bacteria another microbial solution were prepared using lentil seed powder of concentration 20gm/1000ml instead of peptone, following same experimental procedure for bacterial cultivation. Comparative analyses of peptone and lentil seeds on compressive strength of cement cube specimen were done.

Preparation of cement specimen

In preparation of Bacterial-Cement using peptone and lentil seed as protein source, OPC 53 grade cement and microbial solution were mixed properly with water to cement ratio of 0.35 according. Casting of standard cubes 70.7mm X 70.7mm X 70.7mm were done and compacted in vibration machine. All the specimens were cured in water. For the comparison of compressive strength of bio-OPC cement based cubes specimens, the control cement cubes specimens casting was done by mixing the OPC 53 grade cement and water with water to cement ratio of 0.35. The compressive strength IS: 516 (1959) of Microbial-cement cubes and OPC 53 cement cubes at 7 days, 14 days and 28 days was determined and scanning electron microscopy (SEM) analysis was made on sections cut out of 28 days bio-OPC cement cube specimens. Micrographs were obtained with a Scanning Electron Microscope.

4 RESULTS

4.1 Compressive strength of cement specimen

The average increase in 28 days compressive strength (Table 4.1) of bio-OPC cement specimen using peptone and lentil seeds as protein source was found to be 15.73 and 15.26 % more, as compared to control cement specimen having water to cement ratio 0.35.

4.2 Scanning Electron Microscopy

In order to determine the microbial precipitation of calcite in the pores within the bio-OPC cement cube specimens scanning electron microscopy was carried out. Figure 1 shows a scanning electron micrograph of the matrix of bio-OPC using peptone and figure 2 shows scanning electron micrograph of bio-OPC using lentil seed as protein source. The sample taken from the area close to the surface showed calcite crystals precipitated over the cement specimen that resulted in increase of compressive strength of bio-OPC cement cube.

5 DISCUSSION

5.1 Compressive strength of cement specimens

Table 1 indicates the compressive strength at 7, 14 and 28 days for microbial cement using two different protein sources. Around 15 % increase in the compressive strength of bio-OPC 53 grade cement cube specimen was observed as compared to controlled specimen having water to cement ratio of 0.35.

5.2 Protein Source

For the two protein sources used for bacterial growth, it was observed that the increase in compressive strength of both the experimental (bio-OPC) samples was nearly equal. Application of lentil seeds is advocated as a source of protein for the microbial growth due to its cost effectiveness over commercially available peptone.

Tab.1: Compressive strength test of OPC 53 grade cement specimen with variation in protein source.

		Control				Bio-OPC (Peptone)				Bio-OPC (lentil seed)			
Particulars	**Days**	**C1**	**C2**	**C3**	**Avg.**	**A1**	**A2**	**A3**	**Avg.**	**L1**	**L2**	**L3**	**Avg.**
Load (KN)	7	234	245	250	243	260	280	270	270	280	275	280	278.33
	14	250	245	235	243.33	265	285	290	280	280	270	290	280
	28	250	260	240	250	310	280	295	295	300	310	280	296.67
Compressive Strength (MPa)	7	47.08	49.29	50.29	48.88	52.13	56.35	54.32	54.26	56.33	55.33	56.33	55.97
	14	50.29	49.29	47.28	48.95	53.13	57.34	58.34	56.27	56.33	54.32	58.34	56.33
	28	50.29	52.32	48.28	50.29	62.37	56.33	59.35	59.35	60.35	62.37	56.33	59.68

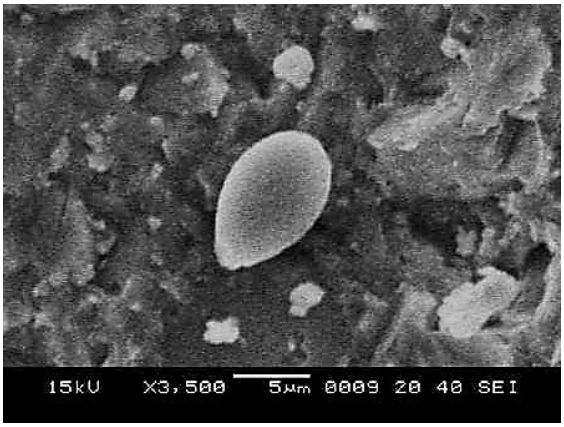

Fig.1 SEM of bio-OPC using peptone.

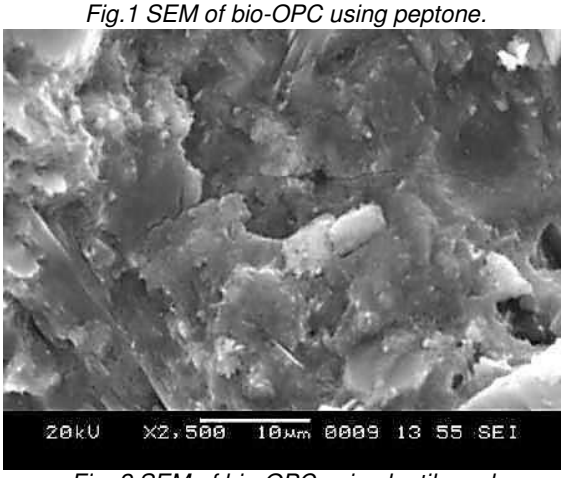

Fig. 2 SEM of bio-OPC using lentil seed.

6 CONCLUSION

In order to control the demand for the use of Portland cement as well as to increase the durability of structure, an alternative cost effective bacterial solution can be used as compared to commercial admixtures that impart additional cost for the construction projects. Based on the results of present study the improvement in the compressive strength of ordinary Portland cement using soil bacterial solution was observed. In addition, for the two protein sources used for the bacterial solution the application of lentil seeds for the microbial growth was advocated due to its cost effectiveness over commercially available peptone.

Scanning electron microscopy (SEM) study revealed the precipitation of calcite in the microbial amended (bio-OPC) cement specimen within the pores of the cement matrix due to bacterial activity.

The approach of bio-cementation was found to be commercially viable and environmental friendly technique in field of construction.

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