Implementing Innovative Ideas in Structural Engineering and Project Management
Edited by Saha, S., Zhang, Y., Yazdani, S., and Singh, A.

ISBN: 978-0-9960437-1-7

STRENGTH PROPERTIES OF BACTERIAL CONCRETE CONTAINING FLY ASH

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The Paper describes the comprehensive experimental work carried out on M40 grade bacterial concrete containing fly ash. Two types of common soil bacteria namely, Bacillus Pasteruii and Bacillus Odysseyi with a concentration of 10^5 cells/ml have been used. The optimum cell concentration of bacteria was arrived at by studying its influence on compressive strength of cement mortar matrix. Fly ash of 10 % by weight of cement was used to partially replace OPC in the concrete mixture. The performance of M40 bacterial concrete containing fly ash was assessed by testing the standard specimen for compressive strength, flexural strength and split tensile strength at different ages of curing. Results of investigation indicate significant improvement in 28 days compressive strength in the range of 12% to 27%. Twenty eight days flexural strength and split tensile strength have also shown appreciable increase in the range of 4% to 14% and 11% to 24% respectively. In general, the results of investigation are encouraging and set in positive direction for use of Bacterial concrete in the construction sector during 21st century.

Keywords: Bacillius Pasteruii, Bacillus Odysseyi, Partial replacement, Compressive strength, Flexural strength, Split tensile strength.

1 INTRODUCTION

Rapid urbanization to meet the demand of ever rising population resulted in need for development of infrastructure. This obviously led to huge requirement of building material which includes concrete, the dominant material of construction industry. Concrete being known for its specialty of being cast in any desirable shape, however, has low tensile strength, limited ductility and little resistance to cracking. While compressive strength of concrete is substantial, its durability under hostile environmental condition always needs attention. It is known that for durable concrete structure, the need is to make it crack free and impermeable so that ingress of moisture and undesirable gases from the surrounding environment do not make it unserviceable. While several methods have been attempted to address the issue of durability, the use of certain species of bacteria having self healing capability in combination with fly ash appears to be yet another effective solution to improve both strength and durability of concrete structures. Use of bacteria like Bacillus Pasteruii and Bacillus Odysseyi is a novel technique of remediating cracks and fissures in concrete by utilizing microbiologically induced calcite or calcium carbonate precipitation. Obviously, this scientific approach of bio mineralization addresses the problem of crack filling on a continuous basis as these bacteria survive and grow within the concrete structure

(Ramachandran *at al.*, 2001). Fly ash, being very fine material (finer than cement) has an ability to fill the voids between cement particles and densify the concrete. Besides this, the pozolonic material like fly ash reacts with free lime resulting in additional cementitious material thus aiding gain in more strength.

The present investigation aims at utilizing Bacillus Pasteruii and Bacillus Odysseyi in combination with fly ash to develop crack free concrete with desired properties.

2 MATERIALS AND PROPERTIES

2.1 Conventional Materials

Ordinary Portland Cement (OPC) of 53 grades, locally available river sand, and coarse aggregate of size 20mm down were used in manufacturing the required grade of concrete. Necessary test were conducted to satisfy the requirements of OPC, fine aggregate and coarse aggregate confirming to IS 12269 (1999), and IS 383 (1997) respectively.

2.2 Fly Ash and Bacteria

Fly ash is considered to be an effective mineral admixture for concrete, providing increased cohesion and improved density. The class C type of fly ash obtained from National Thermal Power Corporation, Ramagundam (Telangana) is used in the investigation studies. The properties of fly ash were verified to ensure its effective utilisation commensurate with the purpose of the present research work. As regards to bacteria,the pure culture of Bacillus Pasteruii of strain No. MTCC 1761 and Bacillius Odysseyi of strain No. 34HS were obtained from National Collection of Industrial Microorganisms, Pune. They were further cultured in Microbiology laboratory of the University for use in the concrete mixtures.

3 OPTIMUM CELL CONCENTRATION

In order to ascertain optimum cell concentration of bacteria, standard cement mortar mixtures were prepared using different cell concentration of 10^5,10^6, and 10^7 of alkaliphilic microorganism (Bacillus Pasteruii and Bacillus Odysseyi). The mortar cubes were tested for 28 days compressive strength as per the procedure described in relevant IS code. From 28 days compressive strength test results, the optimum cell concentration value was identified for maximum compressive strength (Ghosh *et al.*, 2005). Accordingly, for further investigations the optimum value of 10^5 cell/ml concentration was used.

4 MIX DESIGN

The mix proportions of M40 grade concrete were arrived at by following the mix design procedure given in IS 10262 (2009). The mix proportion**s** used in the present investigation are 1: 1.76: 2.71: 0.45. Further, materials required for one cubic meter of concrete was computed to facilitate the estimation of quantities of ingredients required for each concrete mix case. For concrete mixtures containing certain amount of fly ash, the equal amount of cement is reduced in the mixture.

5 MOULDING AND CURING OF SPECIMENS

Various constituents of concrete mixtures were weigh batched accurately. Wherever fly ash was used in a concrete mixture, the same was also taken by weight and added to dry mix. After thorough dry mixing, required quantity of water was added to the dry mixture. In the case, where a particular type of Bacteria was used in concrete mixture, the same was added in terms of designed cell concentrations during wet mixing of concrete. The ingredients of concrete were thoroughly mixed to obtain a homogeneous mixture. The cube, cylinder and prism moulds were filled in three layers and each layer was poked thoroughly with tamping rod and finally compacted on vibratory table. Temperature and humidity conditions at the time of mixing concrete and moulding the specimens were recorded. Demoulding was done after 24 hours and the labeled specimens were moved to the curing tank. Water curing was done for 7, 14, 28 and 56 days at the standards temperature and humidity as per the requirement for each property of the concrete mixtures. Procedures and guidelines specified in relevant IS codes were followed for concrete mixing and placing, and for curing the specimens.

6 TESTING OF SPECIMENS

All the specimens were subjected to mechanical strength tests namely, compressive strength, flexural strength and split tensile strength as per the procedures documented in relevant Indian standard codes of practice. For compressive strength test, an Universal Testing Machine (UTM) of 1000 KN capacity was used. To ensure uniform load transfer, two packing steel plates were placed at top and bottom of the cube specimens. The load was applied at the rate of 140 kg/sq.cm/min for cube as per IS 516(1999). The loading was continued till the failure of the specimen was noted and the corresponding compressive strength was calculated. In case of prism specimens, two points loading was applied at the rate of 180 kg/min as per IS 516(1999). The failure pattern of prism specimen was carefully observed and noted. The failure load for the specimens was noted and flexural strength was calculated as per the guidelines given in the relevant Indian standard code. As regards to split tension test is concerned, the specimens were placed on the bottom platen of the UTM with two wooden strips at top and bottom for ensuring line loading on the specimen. The loading is applied at the desired speed and failure load is recorded as per IS 5816(1999). The value of split tensile strength is computed using the test data. The 28 days test results for all the above mentioned mechanical properties of M40 grade concrete mixtures of various types are tabulated in Table 1. Further, the test results are depicted graphically for its better understanding. While, Figure 1 graphically demonstrate the development of compressive strength of concrete for all the cases of concrete mixtures under investigation, Relative mechanical strengths of various concrete mixtures are depicted in Figures 2, and Figure 3 (a&b).

7 DISCUSSIONS

7.1 Compressive Strength

As can be seen in Figure1, the development profile of compressive strength is more or less same for all types of concrete mixtures. However, the bacterial concrete containing fly ash indicated superior performance at all ages of curing. Further, Figure 1 also depicts that concrete containing Bacillus Pasteruii type bacteria exhibit relatively higher

compressive strength at all ages of curing compared to concrete containing Bacillus Odysseyi type bacteria.

Relative compressive strength presented in Figure 2 and 28 days compressive strength tabulated in Table 1 also reveal that bacterial concrete containing fly ash has 19% to 27% higher compressive strength than conventional concrete. Even the bacterial concrete containing no fly ash registered significant rise of 12% to 16% in compressive strength at 28 days age of curing with relatively better compressive strength for concrete mixture containing Bacillus Pasteruii type bacteria. Seven days relative compressive strength of all the concrete mixture under investigation also indicated similar trend.

The superior performance of bacterial concrete containing fly ash may be attributed mainly due to filling of the pores inside the concrete mass with microbiologically induced calcium carbonate precipitation (Ramakrishnan *et al.*,1998). Further, the gain in strength is also due to the presence of fine particles of fly ash in concrete helping it in densifying, together with fly ash reacting with free lime resulting in additional cementitious material.

7.2 Other Mechanical Properties

The investigation results further reveal improved performance of bacterial concrete in terms of other mechanical properties such as flexural strength and split tensile strength. Table 1, and Figure 3 (a&b) clearly indicate that when compared with conventional concrete, 12% to 14% higher flexural strength and 20% to 24% higher split tensile strength was attained by bacterial concrete containing fly ash. Further, bacterial concrete containing no fly ash also exhibited 4% to 9% and 11% to 13% higher flexural strength and split tensile strength respectively when compared with conventional concrete. The results also reveal that mechanical properties of concrete containing Bacillius Pasteruii type bacteria are superior when compared with the corresponding mechanical properties of concrete containing Bacillius Odysseyi type of bacteria.

Table 1. Mechanical properties of various types of M40 grade concretes at 28 days age of curing.

Type of Concrete	**Bacterial Concentration (Cells/ml)**	**Compressive Strength (MPa)**	**Flexural Strength (MPa)**	**Split Tensile Strength (MPa)**
Conventional concrete (CO)	–	52.0	4.3	4.5
Concrete with Bacillus Pasteruii (COBP)	10^5	60.3	4.7	5.1
Concrete with Bacillus Odysseyi (COBO)	10^5	58.2	4.5	5.0
Concrete with Bacillus Pasteruii using fly ash (COBPF)	10^5	66.0	4.9	5.6
Concrete with Bacillus Odysseyi using fly ash (COBOF)	10^5	62.0	4.8	5.4

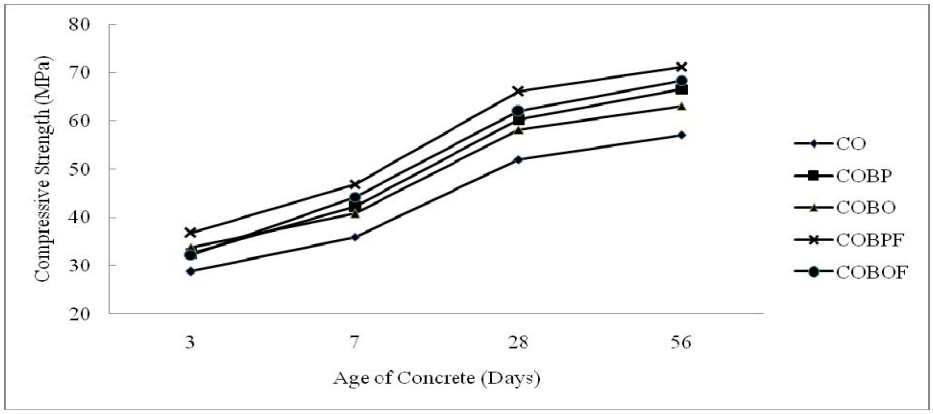

Figure 1. Development of compressive strength of M-40 grade concrete mixtures.

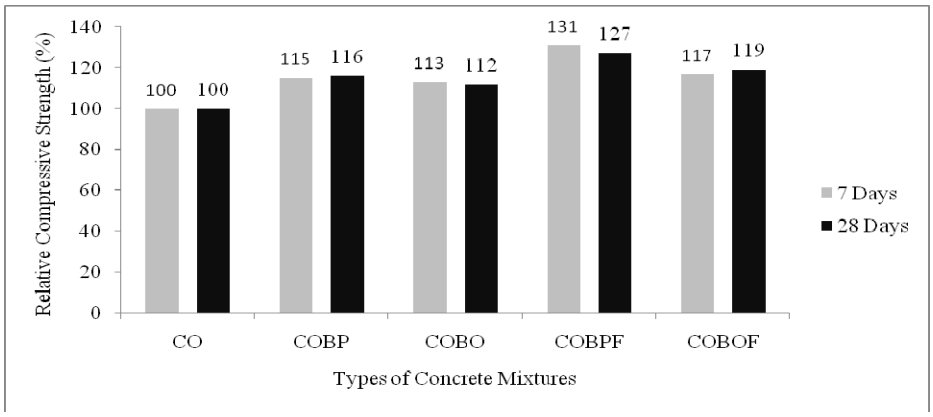

Figure 2. Relative compressive strength of M40 grade concrete mixtures.

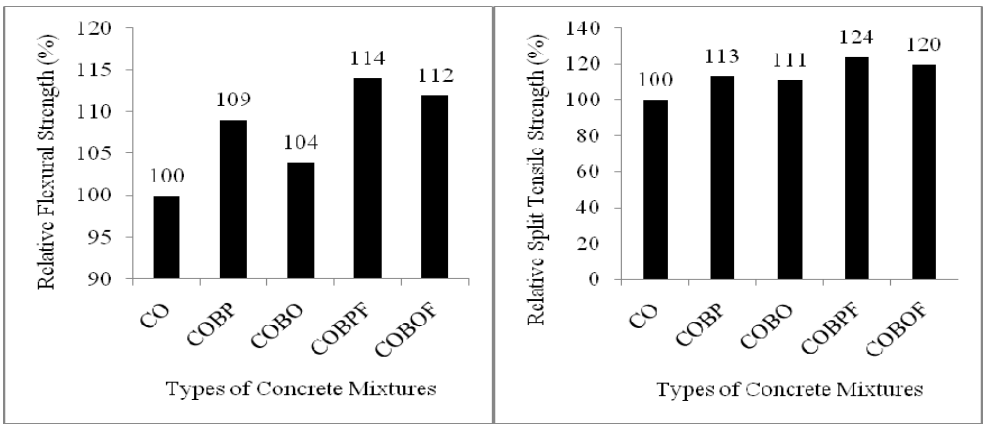

Figure 3. Twenty eight days relative mechanical strengths of M40 grade concrete mixtures.

The reasons for improved performance of bacterial concrete in terms of mechanical properties may be attributed to the mechanism of calcium carbonate precipitation and formation of additional cementations material as explained above (Ramakrishnan *et al.*, 1998). Further, mechanical properties such as flexural strength and split tensile strength being function of compressive strength of concrete, the mechanism hold good for all aspects of performance of concrete.

8 CONCULSIONS

Based on the present experimental investigations, the following conclusions are drawn:

- Bacterial concrete containing fly ash achieved 19% to 27% higher compressive strength than conventional concrete. Further, flexural strength and split tensile strength of bacterial concrete containing fly ash is 12% to 14% and 20 to 24% higher than conventional concrete.
- Amongst two types of bacteria used, presence of Bacillus Pasteruii type bacteria in concrete mixture proved to be advantageous yielding relatively higher strength compared to presence of Bacillus Odysseyi type bacteria in concrete mixture.
- Bacterial concrete without fly ash achieved 12% to 16% higher Compressive strength, 4%to 9% more Flexural strength and 11% to 13% higher Split tensile strength when compared with corresponding properties of conventional concrete.
- Profile of development of compressive strength remain more or less same for all five mix cases considered with higher values for Bacterial concrete containing fly ash.
- The results of present investigation favour the use of bacteria and fly ash combination in a concrete mixture as an effective solution for producing strong and durable concrete.

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