POTENTIAL OF SOIL BACTERIA FROM THE COMARCA LAGUNERA, NORTH-EAST MEXICO FOR BIOCONCRETE DEVELOPMENT

R. Narayanasamy¹, A. Alvarado², J. Sanchez Medrano¹, J. Betancourt Hernandez¹ and N. Balagurusamy²

¹ Facultad de Ingeniería, Ciencias y Arquitectura, Universidad Juárez del Estado de Durango, Av. Universidad S/N Fracc. Filadelfia, C.P. 35010, Apdo. Postal 36 –B, Gómez Palacio, Durango, México. e-mail: naraya@ujed.mx; jesus_ocl@hotmail.com; jbetancourth@ujed.mx
² Laboratorio de Biorremediación, Escuela de Ciencias Biológicas, Universidad Autónoma de Coahuila, Carretera Torreón- Matamoros km 7.5, C.P.27000, Torreón, Coahuila, México. e-mail: ale.alv89@gmail.com; bnagamani@uadec.edu.mx

Keywords: concrete, cement mortar, bacteria, self-healing, compressive strength

ABSTRACT

Sustainability or environment friendly green technology is based on the use of agents of biological origin that can mimic nature in their process applications. The production and use of conventional Portland cement is significant contributor to emission of greenhouse gases and the resultant global warming. Microbial induced carbonate precipitation (MICP) is an emerging technology to minimize the environmental problems, to improve the concrete qualities, and more importantly as a self-healing agent.

This study was aimed at isolation, selection and evaluation of urease producing bacterial strains from the soils of Comarca Lagunera of North-East Mexico. Carbonate precipitation is achieved by urease enzyme, which catalyzes the hydrolysis of urea to CO₂ and ammonia, resulting in an increase of the pH and carbonate precipitation.

Out of twenty four bacterial strains isolated, six were selected based on their urease activity and were denoted as ACRN1 to ACRN6. All strains recorded their maximum growth after 24 h and death phase after three days. ACRN4 showed the highest biomass production at 35°C, while ACRN6 recorded the least growth rate. Initially the ACRN4, ACRN5 and ACRN6 were evaluated for their potential in increasing the compressive strength of cement mortar by varying the cell concentrations and were observed that addition of bacteria at 10⁵ cells significantly increased the compressive strength around 35%.

However, concrete specimens were prepared with ACRN4 at same concentration, in the presence and absence of water reducing additives showed an increase of 4% and a decrease of 6.64% in their compressive strength on 14th day, and a decrease of 6% and 7.6% on 28th day, with and without additive respectively. Scanning electron microscopic and X-ray diffraction studies are in progress to understand the phenomenon observed.
1. INTRODUCTION

Recent interest in the term "sustainability" involves use of environment friendly green technology, which involves the use of an agent of biological origin. Existing biological principles and advances in knowledge on microbial induced carbonate precipitation (MICP) offer opportunities to use natural stable systems to meet these challenges. Recent studies reveal that the addition of bacteria like *Bacillus pasteurii*, *Bacillus sphaericus*, *Shewanella* sp., *Bacillus pseudofirmus*, *B. Cohnii* and *Bacillus Subtilis* promoted self healing of the cracks in concrete since they are capable of carbonate precipitation [1]. This study was focused to evaluate the behavior of bacterial strains on the bio concrete.

2. MATERIALS & METHODS

Ordinary Portland cement, gravel and sand available in the local market were used for this study. Distilled water was used for the isolation of bacterial strains. Locally available potable water (tap water) was used for the preparation of mortar cubes and concrete cylinders. Out of 24 bacterial strains from the soils of *Comarca Laguna* of North-East Mexico which has the ability to produce Urease were isolated, evaluated and the best six (ACRN1 to ACRN6) were selected based on their urease activity for the mortar and concrete preparation. Bacterial strains were multiplied in the urea medium and harvested after 48 hrs. were used to prepare mortar cubes and concrete cylinders.

2.1 Cement Mortar Cubes preparation and Compressive Strength Testing

a) Three cubes of dimensions 50 x 50 x 50 mm for each bacterial strain and three cubes without bacteria (Control) were cast. Bacterial strains ACRN 4, ACRN 5 and ACRN 6 were added at a cell concentration of $10^8$ per ml of water to prepare the cement mortar. The compressive strength was determined after 28 days of curing.

b) Mortar cubes were prepared by adding bacteria ACRN 4 (higher compressive strength compared to other strains) at different cell concentrations ($10^4$, $10^5$, $10^6$, $10^7$ and $10^8$ per ml of water) to the water used for preparing the cement mortar. The tap water was used for the dilutions of the bacteria cells and was used directly for the preparation of mortar samples. After 24 hrs. of casting, all the specimens with or without cells were demolded and were cured under water in the moist curing cabinet. The compressive strength was determined after 7, 14, 21 and 28 days.

2.2 Concrete cylinder preparation and Compressive Strength Testing

Cement, coarse aggregate and fine aggregate were mixed properly to obtain a concrete of strength, $f_{c'}$ 200 kg/cm². A total of 60 concrete cylinders of dimensions 150 mm diameter with 300 mm height were prepared by adding bacteria ACRN 4 at its optimum concentration (identified from the mortar cube samples) of $10^5$ per ml of water to the water used for preparing the concrete. After 24 hrs. of casting, all the specimens with or without bacteria were demolded and were cured under water in the moist curing cabinet. The compressive strength of the cylinders was determined after 3, 7, 14 and 28 days.
2.3 SEM analysis of Concrete Cylinder specimens

The broken concrete cylinder samples (with / without bacteria) collected after compressive strength testing were thinned down to small pieces and were coated with carbon prior to SEM examination. The prepared samples were examined in ESEM (Fei –Quanta 600 ESEM™) with Tungsten Filament (W) with high vacuum mode to take the microphotographs.

3. RESULTS & DISCUSSION

Compared to control, the mortar cubes prepared with bacterial strain ACRN 4 with 10^8 cells per ml of water showed higher compressive strength of 21.92 % after 28 days (Table 1). From the compressive strength results of the mortar cubes prepared with 10^8, 10^7, 10^6, 10^5 and 10^4 cells per ml of mixing water, it was found that the optimum cell concentration of the bacterial strain ACRN 4 was 10^5 cells per ml (Figure 1) with an increase of 18.83% compared to the control after 28 days, which is almost similar to the results reported earlier [2].

Table 1: Effect of added bacteria strains on Compressive strength of Mortar cubes

<table>
<thead>
<tr>
<th>Treatments</th>
<th>28 day Compressive Strength of Mortar (Kg/cm²)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Specimen #1</td>
<td>Specimen # 2</td>
<td>Specimen #3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increase (%)</td>
<td></td>
<td>Increase (%)</td>
<td></td>
<td>Increase (%)</td>
</tr>
<tr>
<td>Control(without bacteria)</td>
<td>187</td>
<td>-</td>
<td>184</td>
<td>-</td>
<td>185</td>
</tr>
<tr>
<td>With ACRN 6</td>
<td>219</td>
<td>17.11</td>
<td>169</td>
<td>-8.15</td>
<td>180</td>
</tr>
<tr>
<td>With ACRN 5</td>
<td>201</td>
<td>7.48</td>
<td>191</td>
<td>3.8</td>
<td>196</td>
</tr>
<tr>
<td>With ACRN 4</td>
<td>228</td>
<td>21.92</td>
<td>201</td>
<td>9.24</td>
<td>203</td>
</tr>
</tbody>
</table>

Figure 1: Compressive strength of Cement mortar cubes in relation to different cell concentrations of bacterial strain ACRN 4.

The addition of ACRN 4 strain at a concentration of 10^5 cells per ml of water in concrete cylinders resulted in higher compressive strength (4.11% increase) after 14 days of curing compared with the control specimens. The cylinders prepared with bacteria added with admixture showed lower compressive strength (7.60 % decrease) after 28 days of curing period. But the cylinders prepared with admixture only showed higher compressive strength (8.57% increase) after 28 days of curing...
period (Figure 2). The prepared broken samples of concrete cylinders, control one and with bacteria and admixture were examined (Figure 3). Figure 3(b) revealed the formation of calcite crystals with well-formed rhombohedral shape as reported [3]. SEM image (Figure 3(c)) showed the presence of microorganisms on the surface of the concrete cylinder sample prepared with bacteria and admixture.

4. CONCLUSION

Ureolytic bacteria that can form calcites are isolated from the soils of Laguna region. Cell density (ACRN 4) of $10^5$ per ml of water was found to be optimum concentration, which increased the compressive strength of concrete cylinders. SEM studies confirmed the formation of calcite crystals and the presence of bacteria on the surface of the broken samples of concrete cylinder.

ACKNOWLEDGEMENTS

Authors gratefully acknowledge the help of M.C. Juan Fernando de la Rosa, CIDT, Peñoles, Torreon in SEM analysis.
REFERENCES

