Finite Element Modeling of Concrete Based on Quantitative Computed Tomography (QCT)

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Finite Element Modeling of Concrete Based on Quantitative Computed Tomography (QCT)

As shown in Figure 5, X-ray attenuates when passing through an object. Attenuation is following by Beer’s law: 

\[ I(x) = I_0 e^{-\mu x} \]

**INTRODUCTION**

Models have been used before to predict the mechanical and transport behavior of concrete. In most of these studies, aggregates were considered either circular or sphere, and the impact of the aggregates geometry and in-homogeneities in concrete structure is ignored.

**OBJECTIVES**

The objective of this study is to develop a novel three-dimensional aggregate method for accurate prediction of the mechanical behavior of concrete using quantitative computed tomography (QCT)-based finite element analysis. Concrete cylinders were cast and cured for 28 days. The QCT scans were carried out on the samples using a clinical CT scanner. An image processing method was applied to detect aggregates, paste content, and the air voids. The distribution of each phase calculated in each image slice and in the bulk material. The processed QCT images were directly converted into voxel-based 3D FE models for linear and nonlinear analyses. The FE models were generated by conversion of each voxel into an 8-node brick element. Air void content of the cylinders (2D and 3D) was determined. In addition, the aggregates content was estimated using the image analysis. In both cases, the results obtained by the image analysis and the actual measurement and ASTM method are in very good agreement.

**SAMPLE PREPARATION**

<table>
<thead>
<tr>
<th>Materials</th>
<th>Specific Gravity (Lbs/ft³)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>2.65</td>
<td>100%</td>
</tr>
<tr>
<td>Water</td>
<td>1.0</td>
<td>58%</td>
</tr>
<tr>
<td>Fine Aggregate</td>
<td>2.46</td>
<td>22%</td>
</tr>
<tr>
<td>Coarse Aggregate</td>
<td>2.48</td>
<td>10%</td>
</tr>
</tbody>
</table>

**RESULTS AND CONCLUSIONS**

All processed images assembled slice by slice to make a three-dimensional model. Using this sectioned view, aggregate and void distribution inside concrete could be investigated in order to find if there are any defects or segregation. One of the QCT applications is shown in Figure 17. It illustrates a 3-D model indicating aggregates in light gray, cement matrix in dark gray, and air voids in red color inside it.

**FINITE ELEMENT MODELING**

QCT-based finite element models of concrete specimens have been created by voxel-based method. In this method, the geometry is obtained directly from the images without using any surfaces or solid bodies and the finite element mesh is developed by assigning hexahedral elements that encloses a predefined cubic volume of image voxels. Element sizes on the order of 0.25 mm x 0.25 mm x 1 mm have been used for the voxel-based method.