Concrete Stiffness Matrix of Cracked Membrane Elements

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Abstract

The power of the modern computer and the development of the finite element method have made it possible to perform rational analysis of the behavior of cracked reinforced structures. The large wall-type reinforced concrete structures can be visualized as assemblies of membrane elements. Their behaviors can be predicted if the behaviors of the membrane elements are known. Cracking in reinforced concrete transforms it from a linear, isotropic material into a non-linear, orthotropic material. Being more complex, the biaxial properties of cracked reinforced concrete are not yet clearly understood. Currently, there are two types of models for the post-cracking concrete stiffness matrix, namely the **rotating-crack model** and the **fixed-crack model**. In both these models, Poisson ratios are assumed to be zero, which is not realistic. A new general model with a consistent set of five mechanical properties ($\bar{E}_2$, $\bar{E}_1$, $\bar{G}_{21}$, ν_{12}, ν_{21}) is proposed. These five mechanical properties are established by extensive experimental and theoretical research, carried out at the structural laboratory of University of Houston. To date, seven specimens with different variables (steel ratio, steel bar angels) have been tested. Based on the results of tests and analysis, the "apparent Poisson ratios" _ ν_{21} and ν_{12} are about 0.1 and 2.5 respectively.

1. Introduction

In the past twenty years, a new rational approach was developed to study large reinforced concrete structures, e.g. shear walls, box bridges, nuclear containment vessels, concrete offshore structure, etc. The behavior of the whole structure can be predicted by understanding the collective behavior of its parts. This approach developed into two steps. The first step is to study experimentally the behavior of the individual membrane elements subjected to shear and normal stresses, and to acquire the capability to predict the shear stress vs. shear strain relationships of the elements. In the second step, the load-deformation relationships of the elements are assembled to construct the load-deformation response of the whole structure.

The research in the past ten years at the University of Houston resulted in the establishment of the softened truss models. In this research, the soften truss models are being generalized to include the two Poisson ratios ν_{21} and ν_{12}.

2. Specimens and Experimental Procedure

The dimension of each panel is 55 in. square and 7 in. thick. Each panel is reinforced with two layers of steel bars near the surface of panel, allowing for the required cover thickness. The diameters of the steel bars are ○ in., �., and 1 in. The strength of concrete is designed to be 45

MPa and 100 MPa respectively. The UH �universal panel tester� consists of a giant steel frame that houses 40 in-plane jacks of 100-ton capacity each and 20 out-of-plane jacks of 60-tons each. A proportional loading is approximated by small step-wise increases so that Poisson ratios can be measured at each step.

3. Experimental Results

According to test results of seven specimens, the "apparent Poisson ratios" ν_{21} and ν_{12} are about 0.1 and 2.5 respectively, irrespective of steel ratio and the steel bar angles. More specimens are scheduled to be tested which will have high strength concrete of 100 MPa.

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5. References

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