NECESSARY AND SUFFICIENT CONDITIONS FOR PROPERTIES OF FRAMED SHEAR WALLS AFTER CRACKING

by

Y. Sonobe[I], M. Yokoyama[II], and H. Imai[III]

SUMMARY

The properties of framed shear walls under shear stress after cracking are being studied using two analysis methods having flows in opposite directions. One is the conventional theoretical analysis method, whereas the other is a newly proposed analysis method based on indirectly measured values where deformations and stresses are analyzed based on data directly measured by experiments. Since the results of analyses by the two correspond well with each other, it is judged they express the necessary and sufficient conditions regarding mechanical properties of framed shear wall test pieces.

§1. INTRODUCTION

Shear walls play important roles in earthquake-resistant design of reinforced concrete structures, but since much remains unknown regarding the mechanical properties of shear walls after cracking, designing is done based on comparatively rough judgments, and clarification of the properties of shear walls in the plastic range is being called for. Recently, the properties of framed shear walls after formation of shear cracks in wall panels have been studied using the anisotropic elastic plate theory or the anisotropic finite element method.

However, in theoretical analysis, since many assumptions are provided prior to analysis, simply that theoretical analysis results and experimental results agree well does not prove the reasonability of the theoretical analysis assumptions or the reliability of analytical results. Using another expression, theoretical analysis assumptions possess sufficient conditions against facts (which when quantified are measured values), but not always the necessary conditions.

In this paper, a new analysis method (Indirectly Measured Values Analysis Method) is proposed and stress analyses of framed shear walls are made based on measured values only. The flow of analysis in this method is in the reverse direction of the flow of the conventional theoretical analysis method, and it may be judged that the two possess necessary and sufficient conditions for mechanical properties of framed shear walls if their analysis results agree well.

I. Professor, Institute of Structural Engineering, University of Tsukuba, Ibaraki, Japan
II. Director, Technical Research Laboratory, Mitsui Construction Co., Ltd., Tokyo, Japan
III. Lecturer, Institute of Structural Engineering, University of Tsukuba, Ibaraki, Japan

§2 OBJECT TEST PIECE IN ANALYSIS

The test piece to be the object of analysis was a one-storied framed reinforced concrete shear wall approximately one half of actual size as shown in Fig. 1, the peripheral frame being of composite steel and reinforced concrete. Alternating positive and negative shear loading was done applying equal compressive and tensile forces to the two ends of the top beam, and deformations in diagonal directions and axial strains, curvatures and shear strains of many cross sections of structural steel of the frame were measured. Parallel shear cracks at an angle of 45 deg. as shown in Fig. 2 were formed on repetitive loading, and at the final stage failure occurred in the form of compressive shear of wall concrete.

§3. RELATION BETWEEN THEORETICAL ANALYSIS VALUE AND INDIRECTLY MEASURED VALUE

The stages for theoretical analysis of the properties of a structure by the direct stiffness method are divided into the three of material, member and structure as shown in Table 1, and analysis is done by a process progressing from top to bottom in Fig. 3. It is essentially the same in theoretical analysis beyond the elastic range, and incremental displacement and incremental stress for incremental external force are obtained suitably varying stiffness. Here, the conventional analysis method assuming stiffness at the beginning as described above will be called the "Theoretical Analysis Method."

As previously mentioned, a method for theoretical analysis of a structure in both elastic and plastic ranges has been established at the present stage, but with concrete structures a problem remains in that it is difficult to predict stiffness close to reality before analysis due to cracks and slipping.

If static loading tests are performed it will be possible to directly measure the external forces at nodal points and strains of materials given in Table 1. Hereafter, these will be called "directly measured values." In contrast, the "indirectly measured values" to be proposed below mean nodal displacements and strains and stresses of members analyzed based on the method of least squares theory of error best matching "directly measured values." Therefore, these possess the necessary conditions against facts.

§4. ANALYSIS METHOD FOR INDIRECTLY MEASURED VALUES

Method of Determining Nodal Displacements

An analysis model composed only of members for which there are directly measured values is assumed as shown in Fig. 4, and indirectly measured nodal displacements are obtained based on directly measured strains. Since the strain measured is considered as average for the member, it is necessary to select the location of the nodes in a manner that each measuring point will be at the middle of the member.

Since there are measurement errors in directly measured values, or since the strain at the middle of the member is considered as the average