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Strut-and-tie model for the load-deformation analysis of flexural members subjected to transverse loading

Sung-Gul Hong[1)], Soo-Gon Lee[2)], *Seongwon Hong[3)], and Thomas Kang[4)]

[1), 4)] *Department of Architecture and Architectural Engineering, Seoul National University, Seoul 151-744, Korea*
[2)] *Samsung Construction Co., Seoul, 137-956, Korea*
[3)] *Engineering Research Institute, Seoul National University, Seoul 151-744, Korea*

ABSTRACT

A deformation-based strut-and-tie model for the flexural members at post-yield state is presented in this paper. In this model, boundary deformation conditions by flexural post-yield response are chosen in terms of the flexural bar strains as the main factor affecting the shear strength. The objective of the proposed model is to estimate the shear capacities of the flexural members associated with the given flexural deformation conditions. To validate the strut-and-tie model, the calculated shear strengths depending on the flexural deformation are compared with the experimental results. The experimental data are in good agreement with the values obtained by the proposed model.

1. General

Design for the line components of structures, such as beams, subjected to transverse loading is mainly concerned with their flexural and shear capacities. From the structural analysis of an entire structure, the flexural design is first carried out so that their flexural capacities satisfy applied bending moments. The shear strength is then checked to be stronger than the shear forces associated with the flexural strength. Flexural design of the members is easily achieved by sectional analysis under the assumption of the plane section. However, despite the tremendous empirical or analytical studies (Bresler and Scordelis, 1963; Kani et al., 1979; Anderson and Ramirez, 1989; Reineck, 1991; Collins et al., 1996), there are no shear strength models which were generally consented, and the conservative shear strength obtained from empirical works is used in current design.

[1)] Professor
[2)] Structural Engineer
[3)] Post-doctoral Researcher
[4)] Associate Professor, Mail:tkang@snu.ac.kr
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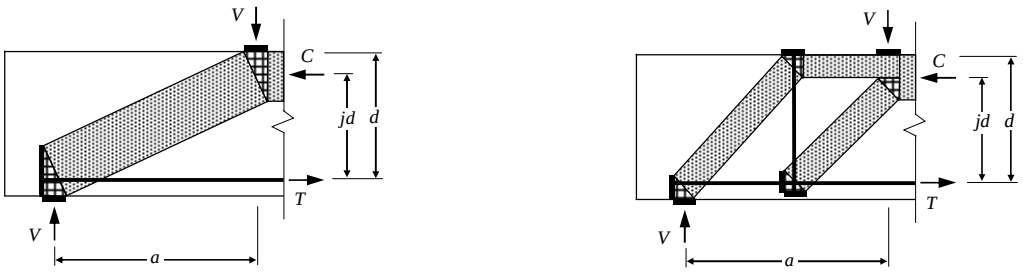
The shear strength of reinforced concrete members is known to be influenced by a number of factors, which include the concrete strength, the quantity of the shear reinforcement, the ratio of shear reinforcement to flexural reinforcement, and the ratio of shear span relative to section depth. Besides these geometrical factors, however, deformation condition of the members can be also an important factor determining the shear strength because of the softening characteristics of concrete with the increase of the strain in transverse direction and the bond loss with yield penetration.

In this paper, a deformation-based strut-and-tie model for flexural members at the post-yield state is developed. The deformation states of deep beams are classified into four states. To verify the proposed strut-and-tie model, the calculated shear strengths are compared with the experimental data. The experimental data show good agreement with the values estimated by the proposed model.

2. Deformation-based strut-and-tie model for deep beams

Figure 1 shows the load path of shear forces in deep beams. Arch action represents the shear transfer by direct diagonal strut connecting from the loading to the support, while truss action represents the shear transfer via the transverse tie. In general, the portions of arch action and truss action are known to be dependent on the ratio of shear span to section depth (*a*/*d*) and the contents of transverse reinforcement.



(a) Arch action (b) Truss action

Fig. 1- Shear transfer mechanisms of deep beam: (a) Arch action; (b) Truss action

The shear force acting on the beam can be expressed in terms of the flexural tensile force at the loading section as:

$$V = \frac{jd}{a} T \tag{1}$$

where jd is the lever arm length of beam section and a is the shear span length that is the distance between the load and support points.

If the main bars at the loading section are assumed to be yielded, Eq. (1) can be replaced with the tensile strength ($A_s f_y$):

$$V = \frac{jd}{a} A_s f_y \tag{2}$$

To present the strut-and-tie models depending on the deformation condition, the deformation states of deep beams are categorized into one of four states with the