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Autor: Oliveira, M.A.A. / Moreno, A.L.Jr.

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High Strength Concrete Beams Subjected to Reversed Loads

M.A.A OLIVEIRA
Graduated Student
Campinas University
Campinas, SP, Brazil

A.L. MORENO Jr
Assistant Professor
Campinas University
Campinas, SP, Brazil

Abstract

The transfer mechanisms of the shear force from section to another of the beam only recently are being explained and, even so, partially. This way, a definitive quantification of the contribution of the same ones in the transmission of the shear force becomes only speculation.

Tests of beams conducted by Leonhardt defined the portions of contribution of shear carrying mechanisms in a beam with web reinforcement. In these studies, it was ended that a big portion of the shear force was transmitted by the web reinforcement and a remaining minority portion can be attributed to the aggregate interlock and dowel action of the longitudinal reinforcement.

About the first subject, many shear behaviour models, seeking to determine the real contribution of the web reinforcement in the transfer of shear force has been proposed. However, a model that determines, with accuracy, this portion of contribution, was not still presented.
The shear strength of the concrete beams can be affected by factors that influence the efficiency of one of the shear carrying mechanisms. Leonhardt admits the existence of approximately 20 of these factors.

Besides numerous, the influential factors in the internal shear strength are complex and, most of the time, interrelated. Among these factors it can be included, for example, the compression strength of the concrete and the type of load (normal or reversed load).

Serious doubts still stay regarding the shear behaviour of a reinforced concrete beam subjected to reversed loads. While Alatorre and Casillas concluded that the shear behaviour of these beams would not be altered, Japanese investigations , reached to the conclusion that the portion of shearing, resisted by the web reinforcement, would be reduced in more than 50% in the beams subjected to reversed loads.

The Brazilian Code, NBR 6118, do not mention any special procedures for shear design of beams subjected to reversed load. The American Code, ACI 318, suggests that all shear force will be resisted by web reinforcement only. About the shear behaviour of high strength concrete beams subjected to reversed loads any special designs procedures are mentioned in both Codes.

The experimental investigation here described had its motivation in doubts lifted about the shear strength behaviour of high strength concrete beams subjected to alternate loads. It were experimentally analysed 12 beams with identical geometry and longitudinal reinforcement. The concrete compression strength and the type of load, normal or alternate, were the adopted variables. A first series constituted by 6 beams without web reinforcement and a second series by beams with this reinforcement. For each series, there were three ranges of concrete compression strength. Of the

beams with the same concrete compressions strength, one was subjected to normal loads and another to alternate loads.
A concentrated load, F, was applied at the midspan of the beams until the expected shear failure. In those tests that included reversed loading the concentrated load was applied in one of the faces until the wanted load increment, then the beam was discharged and the load was applied in the other face. The load increment was of 5 kN. The specimens were instrumented for deflection and steel strain measurements.

The cracking pattern of the specimens tested monotonically was similar. The fist cracks to appear in the specimens were short vertical flexure cracks in the midspan. Continued increases in the load led to the formation of inclined cracks that extended out from the vertical cracks to form flexure-shear cracks. With increasing load the existing cracks developed and new cracks were formed until they had extended through the longitudinal steel at both layers. When the loading was reversed, an additional pattern of cracks appeared in the apposite direction.

After the formation of flexure-shear cracks, the shear carrying mechanism was assumed to consist of contribution from the compressed concrete above the crack, aggregate interlock or friction forces along the crack dowel forces along the longitudinal reinforcement and, for beams with web reinforcement, consists of stirrups crossed by the inclined cracks too.

The pattern of stress evolution was the same for all the beams. The stirrup stresses were not perceptible until inclined cracking occurs. After inclined cracking, the stirrup stresses increase with applied shear. Starting from the mobilisation of the stirrups, the growth of the stresses accompanied, in an approximate way, the foreseen growth by the classical analogy.

It can be observed that in any stage of load of the beams the stresses in the web reinforcement were greater than the values predicted by the classical analogy (shear force carried by the web reinforcement only), even for the beams subjected to reversed loads. This fact checks that, although the contribution offered by the concrete of the compressed zone can be unimportant, it still exists the collaboration of another alternative mechanisms, that not the one formed by the web reinforcement, in the shear strength of high strength concrete of beams submitted to reversed load. The dowel force of the longitudinal reinforcement can be placed as a great collaborator.

It can be concluded that exists a decrease of the shear strength in high strength concrete beams submitted to reversed load in relation to the same beam submitted to normal load. This reduction was shown itself significant, but insufficient to approach the shear behaviour of these beams of the classical model – where the total shear force is carrying by the web reinforcement.

The Brazilian Code do not mention any special procedures for shear design of beams subjected to reversed load. The American Code suggests that all shear force will be resisted by web reinforcement only. About the shear behaviour of high strength concrete beams subjected to reversed loads any special designs procedures are mentioned in both Codes. The results obtained in this work showed that the procedures of ACI 318 , where all shear force would be resisted by web reinforcement only, could be very conservative