TENSILE STRENGTH OF PRESTRESSING STEELS UNDER TRANSVERSAL LOADS

A. Valiente, M. Elices and J. Toribio*

INTRODUCTION

Prestressing reinforcements in prestressed concrete structures are often subjected to transversal loads because of constructional reasons such as anchorages, supports of the tendon sheats, changes of direction of tendons, etc. It is known that this kind of loading reduces the tensile strength of the reinforcements and due to this effect, in civil engineering there is an increasing interest to characterize the transversal loads sensibility of prestressing steels, Elices (1).

The purpose of this research was to find a failure criterion for a steel prestressing wire under the simultaneous action of a longitudinal tension load and a transversal local compression load. This criterion could contribute to solve practical questions such as evaluation of tolerance to transversal loads and prediction of tensile strength losses.

EXPERIMENTAL WORK

For experimental work, a testing system has been designed in order to apply simultaneously a longitudinal tensile load and a transversal compression on a steel wire, in a similar manner to actual loading in service. Tensile load was applied by means of a tensile testing machine and for transversal loading a load frame of small dimensions was used. Compression was produced by a microcylinder attached to the frame in a way that there is not relative motion of specimen and frame and undesirable effects are avoided. Pressure source for microcylinder was a container of pressurized nitrogen and magnitude of transversal loads was controlled through the pressure regulator of nitrogen. Maximum load which may be achieved is 23 kN. Using this testing system, two commercial prestressing steels have been tested and the tensile fracture load has been measured as a function of the transversal force. Steel A is a 3.5 mm diameter wire and steel B is also a 5 mm diameter wire. Yield stress of both is over 1400 MPa. The results obtained are showed in figure 1 where the ratio of the fracture load to the ultimate load in single tension is plotted versus the lateral force. Both steels show a marked loss of tensile strength as transversal load is increased, but this loss is different in each steel. Likewise, ductility parameters, such as elongation at fracture, also decreases because of transversal compressions. From photographs illustrating the figure, it is also observed that the loss of the tensile strength begins to be significant when the fracture changes from a cup and cone type to a shear one without necking.

* Department of Materials Science. Faculty of Civil Engineering. Madrid Polytechnical University. Spain.

THEORETICAL WORK

Theoretical work has been focused to develop a failure criterion according to experimental results and physical characteristics of fractures observed in the tests. The failure model proposed assumes a planar fracture surface which is on an angle 45º away from the wire axis. This value agrees with the measurements made on broken specimens. The criterion found provides an analytical relation between the tensile load P and the transversal load Q at fracture, and is based on the upper bound theorem of limit analysis and the maximum shear failure condition. The equation derived is:

$$P + kQ = P_0 \qquad (1)$$

where P_0 is the maximum load in tension and k is a nondimensional coefficient. It is due to the unequal distribution of the transversal load on the two halves of specimen and its value ranges from 0.5 to 1 depending on supports used to apply the transversal compression. For the testing system used in this work a value about 0.5 may be expected, according to figure 2.

When data from tests are plotted referring both, tensile and transversal load, to P_0, such as equation (1) suggests, no difference is observed between steels A and B (figure 2). Points from both steels cluster along a straight line, with a good correlation coefficient (0.99) and the slopes obtained (-0.55 and -0.57) are very near to the expected value of -0.5. This also occurs if other published test data Maupetit et al. (2) are plotted in the same manner.

The agreement between theoretical and experimental results is good and indicates that steels studied behave in a ductil manner under biaxial loading, because failure criterion has been derived on the basis of this type of behaviour. Therefore, this criterion delimites the ductil behaviour for prestressing steel under tensile and transversal loads.

CONCLUSIONS

A fracture criterion for prestressing steel wires under biaxial loading has been derived and contrasted successfully with experimental results. The test system developped along with the fracture criterion can be used to evaluate the sensibility and tolerance of prestressing steels to transversal loads.

AKNOWLEDGEMENTS

This work has been sponsored by the Spanish Commission for Scientific and Technological Research under grant number 0511-84.

REFERENCES

(1) Elices, M., "Fracture of Steel for Reinforcing and Prestressing Concrete", in Fracture Mechanics of Concrete (G.C. Sih, Ed.), Martinus Nijhoff, 1985.

(2) Maupetit, P. et al., Int. J. of Fracture, Vol. 13, 1977, pp. 725-727.

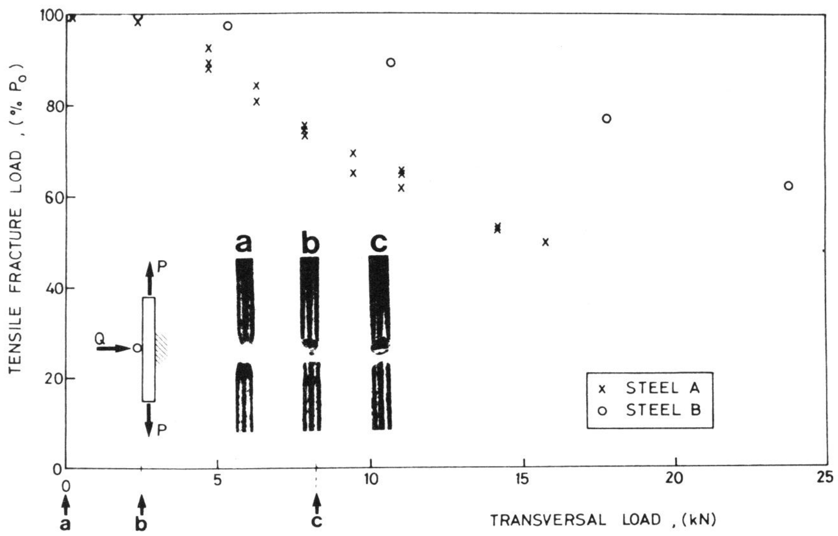

Figure 1 Results of biaxial loading fracture test.

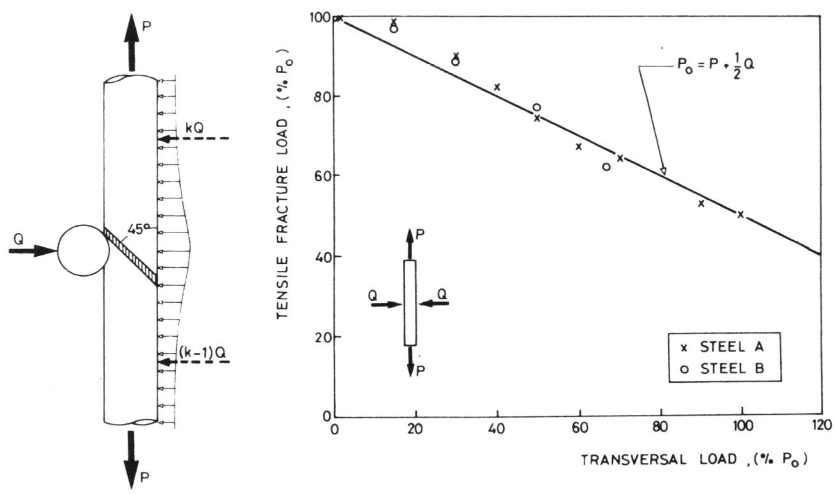

Figure 2 Failure mechanics and theoretical failure criterion contrasted with experimental data.