Code feature section

MAXIMUM YIELD STRESS IN

REINFORCED   CONCRETE FRAMES

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In the past steelmakers have tried to ensure that the yield stress of their reinforcing bars has always been above the specified minimum.

It now appears that for earthquake moment resisting frames it should always be below some known maximum stress. Such a stress could with justification be included in the Standard Specification for the reinforcing concerned.

It has been shown by electric analog studies that the bending moment and forces induced in a building by a heavy earthquake can be a number of times more than those implied by the design Loading Code. Just how many times is uncertain as it depends on the size of the earthquake, the properties of the individual building, and the ground conditions.

Earthquake energy is most economically absorbed by utilising the ductility principle. This takes advantage of the fact that the work done or energy absorbed in deforming beams and columns that have yielded can be many times that done if they had remained elastic. This can be seen by comparing the areas under the stress-strain curve of reinforcing that has yielded with that which has not.

Although repeated reversals of heavy earthquake shocks cause a progressive reduction in the stiffnessess of reinforced concrete frames, and therefore a reducing response, it is essential that all frames should survive the first few shocks. To do so, every frame must obey the following rules:-

      (A)   It must not fail in compression.
      (B)   It must not fail in shear.

Rule (A) requires that in any section of a member subject to bending and axial load, the compression resistance must be greater than the tension forces, i.e. $C > T$.

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Rule (B) requires that the shear capacity of a beam or a column at any section must be greater than the maximum shear force that could be imposed on the member by an earthquake, i.e.

$$(V_c + V_u') > (V_g + \frac{M_1 + M_2}{L})$$

Where V_c and V_u' are the ultimate shear forces carried by the concrete and the stirrups respectively, V_g is the maximum gravity or transverse shear applied, and $M_1 + M_2$ is the largest sum of opposite-sign ultimate moment capacities at the ends of the member. For columns V_g is zero and M_2 may be the sum of the ultimate moment capacities of the beams framing into the top of the column, in the plane considered. These may all be calculated by the formulae in Chapters 16, 17 and 19 of the 1963 A.C.I. Building Code.

The formulae for shear and bending show that the ultimate resisting capacity of a section is more or less proportional to the yield point of its reinforcing.

For complete safety, the resistance to shear or bending must be calculated on the lowest yield stress, while the applied shear or bending forces must be calculated on the maximum yield stress.

Similarly, to allow for deficiencies in the concrete or the formulae, resistance must be decreased by $\emptyset$, the undercapacity factor. Applied forces must be increased by whatever over-capacity may exist.

It is therefore essential to know the maximum as well as the minimum yield stresses of the reinforcement to be actually used. For economy, these must be as close to each other as practicable.

Economy may also be achieved by accepting a degree of risk. The likelihood of low yield stirrups being combined with high yield main bars can be calculated if the histograms of tests of the steel being used are available. What degree of risk to accept is difficult to decide on, but it would have to be appropriate to the possible loss due to failure.

A further margin of strength can be found in the concrete strength, which in all probability has advanced from its 28 day strength by a percentage governed by curing conditions and the composition of the cement.

Designers can stipulate in their Specification that the minimum yield stress of the reinforcement must be, say 40 ksi, and the maximum 50 ksi. This requirement can be satisfied by the supplier providing the appropriate test certificates. However, it is possible that some "foreign" bars may be inadvertently used. It is therefore better if the specified limits were taken close to the actual limits of the steel produced.

Fig. 1. gives average yield points and the limits within which 95% of tests lie for reinforcing to N.Z.S.S. 1693 and N.Z.S.S. 1879, for steel as produced by Pacific Steel Ltd., Otahuhu. The information is from a private communication from the Company and is indicative only.

It should be noted that No.12 bars are not as yet defined by N.Z.S.S. 1879. Another line should be added to Table 3 of that Standard.

Amendment No. 1, dated December 1968, to N.Z.S.S. 1693, raised the minimum yield stress for steel to that Standard from 33 ksi to 40 ksi.
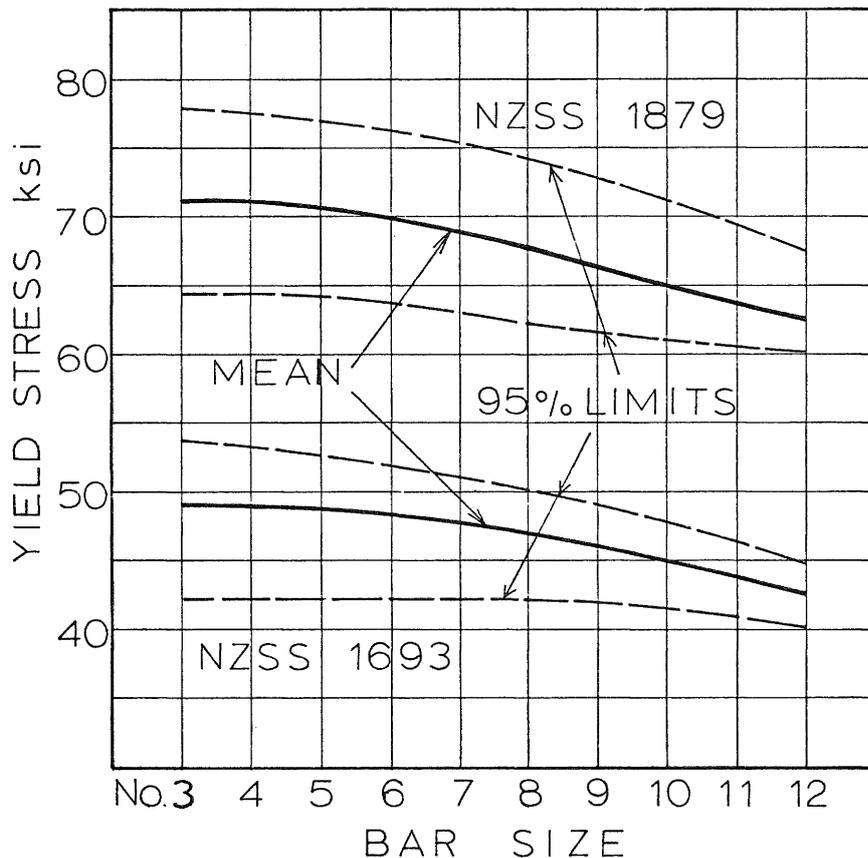
Fig. 1