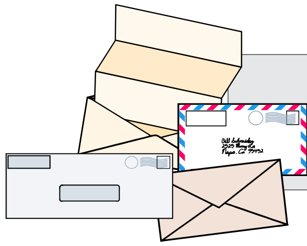

Letters to the Editor

High ductility ribbed bars

I have read with considerable interest the paper titled "RC beams with high ductility ribbed bars - Behaviour under monotonic loading" by Dr T. S.Thandavamoorthy, on pp. 282- 285, published in the April 2001 issue of *The Indian Concrete Journal*. I shall be grateful if the learned author would kindly respond to the following clarifications in connection with this paper.

(*i*) The author has advocated the use of high ductility ribbed bars in reinforced concrete (RC) construction. He has also demonstrated the higher ductility and superior rotation characteristics of beams reinforced with these bars. This characteristic will be undoubtedly useful in the case of statically indeterminate structures where the members should have sufficient rotation capacity so that moment redistribution can take place. The higher yield strength of these bars implies that higher strains will be set up in these bars at working and ultimate loads. The concrete crack widths in the tension zone are a function of the strain in the rebars and it is likely that use of such high strength rebars cause excessive crack widths.

It would be interesting to know as to what were the author's observations regarding the crack widths in the beams investigated. The adoption of these bars in practice is contingent upon the serviceability behaviour of members incorporating them and it would have been more instructive if the crack width data at various load levels were included in the paper so as to conclusively decide the issue.

(*ii*) The excessive mid-span deflection at ultimate loads reported for the test specimens can be a serious liability. The maximum permissible deflection as per IS 456 : 2000 is span/250, which works out to be 12 mm for the beams with a span of 3000 mm used in the tests. A perusal of *Fig* 6 in the paper showing the load deflection curve for SB 1-2 reveals that at the code prescribed limiting deflection, the beam was able to reach approximately half its potential load carrying capacity and the ultimate load was reached at deflections well beyond the permissible values. Therefore, the serviceability behaviour of beams reinforced with high ductility ribbed bars is unsatisfactory. Hence, although the post-peak behaviour of these beams may be desirable, it is imperative that the undesirable serviceability limit state behaviour be kept in mind before these may be employed in practice.

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The author replies :

It is gratifying to note that the paper has evoked interest and that a discussion has arisen on it. I profusely thank the discusser for raising interesting points on it.

(*i*) There is no doubt that crack width is a function of strain in steel. Therefore in the experiment the crack width was measured at the level of tension steel. For various beams the measured crack width varied from 0.06 mm to 0.23 mm at the service load. IS 456 : 1978 prescribes a maximum value of 0.3 mm as crack width of concrete structures under design load. Accordingly, the measured crack width was less than the permissible limit. The revised code, IS 456 : 2000, exclusively provides a formula to calculate the surface crack width based on the strain in steel. Therefore, the crack width for any type of reinforcing steel can be checked according to this formula. Notwithstanding this, clause 43 of IS 456 : 2000 for limit state of serviceability for cracking stipulates that, in general, compliance with the spacing requirements of reinforcement, given in clause 26.32 of the said code, should be sufficient to control flexural cracking. As per the formula given in IS 456 : 2000, in addition to average strain in steel, the crack width also depends on the cover to the longitudinal bar, overall depth of the member, depth of neutral axis, etc. Therefore, strain in steel alone is not the sole criterion to decide the crack width.

Moreover, checking for service ability criteria is under the designer's control and design of concrete members with any type of steel can be done appropriately after the section was designed for ultimate strength. In this process, the savings that could be achieved in the design of concrete members with the use of higher yield strength bars need not be lost sight of.

(*ii*) The permissible deflection stipulated in IS 456 : 2000 and pointed out by the discusser is due to all loads including the effects of temperature, creep and shrinkage. In the paper only deflection due to short term applied load has been presented. The short term deflection can be calculated as per the details given in Annexure C of the said code. Moreover, the limit state of serviceability for deflection is checked at service load rather than at ultimate load as made out in the discussion. The mid-span deflection measured in the experiment at service load varied from 3.66 mm to 6.04 mm for various tested beams. These values are well within the permissible limits. Therefore, the behaviour of beams reinforced with high ductility bars under serviceability condition is quite satisfactory. Also, under clause 42.1.1 the code stipulates that, in all normal cases, the deflection of a flexural member will not be excessive if the ratio of its span to its effective depth is not greater than appropriate ratios given in clause 23.2.1. Check for deflection at service load is under the control of the designer and if the section is found to be not satisfactory it can be revised as is normally done in the case of concrete members reinforced with conventional steel bars. Therefore, the situation is not at all alarming as is made out in the discussion.

It is totally uneconomical and may be impossible to design RC structures to resist the full loads generated by the above phenomena to the satisfaction of the serviceability criteria. That is why the ductility of the structure is given more importance. The structure designed for blast- and seismic-resistance are allowed to rotate excessively beyond the value prescribed for serviceability to absorb the energy imparted by the above phenomena and the design criteria in this respect is that it should not fracture while undergoing excessive deflection. The current design philosophy is that we should be able to save precious human lives without the structure being broken to pieces. For such type of situation the new type of high ductility bars are best suited which have enormous inherent ductility compared to that of the conventional HYSD bars. It is common knowledge that, under normal circumstances, RC members are designed to be more ductile so that they give enough warning before collapse.

Normally even with conventional steel reinforcement if the serviceability limits are not satisfied, the section is redesigned. Therefore, it may not be proper to doubt a bar with better advantages and also state that the serviceability behaviour of beams reinforced with high ductility ribbed bars is unsatisfactory without a complete understanding of the limit state of collapse and serviceability of RC members and structures especially when experimental investigation proved their satisfactory behaviour. These high ductility rebars are already available in the market and are being used in the construction of RC structures.

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