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The Compatibility of Concrete Strength with High Strength Reinforcing Steel

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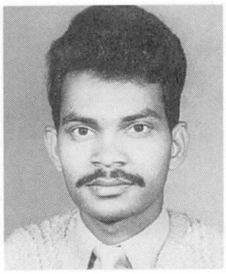

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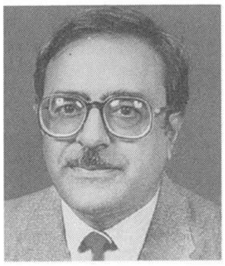

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Summary

It has been observed that the use of HYSD bars with low strength concrete develop more number of cracks in the structure in comparison with plain round bars and same concrete strength. The paper describes one cause of distress due to inadequate compatibility of reinforcing steel with concrete strength, at ultimate load and foresee how the cracks formed in a structure because of above cause. The cracks, thus formed provide the paths to ingress the aggressive ions in the concrete which may rust the embedded steel.

1. Introduction

Only the mass produced mild steel was initially used as a reinforcement. Later it was thought that the cost of reinforcement can't be reduced by the use of steel having a lower cost per unit weight. For this reason research and development has been carried out on mass scale to produce the steel of high yield strength. Now a days numerous steel grades are available to suit the construction requirements. Peoples started the use of High Yield Strength Deformed (HYSD) bars with low strength concrete without taking care of the compatibility of reinforcing steel with concrete. Such type of combination develops numerous cracks in a structure which ultimately affects the safety, serviceability and durability requirements.

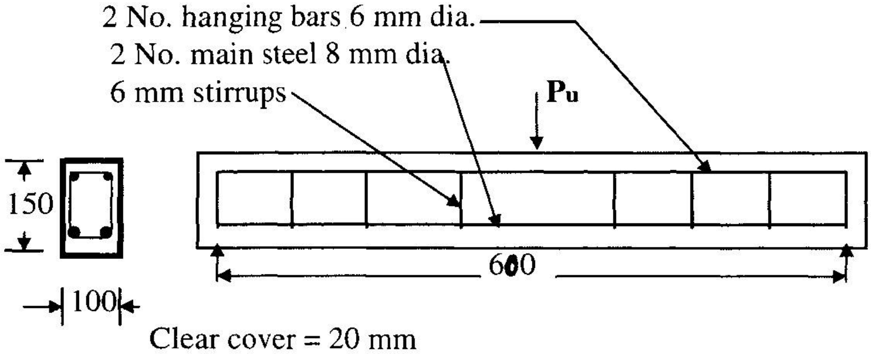
2. Effect of high yield strength deformed steel on steel concrete bond

The properties of R.C.C. structure depends upon the bond between steel and concrete. When a reinforcing bar is embedded in concrete, the concrete adheres to its surface and resist any force that tries to cause slippage of bar relative to its surrounding concrete. This is achieved by the development of the shear stress at the interface of bar and concrete. The bond transfer stresses from one material to other. At ultimate load, slipping of bar relative to concrete should not cause ultimate failure as long as the bar is not pulled out at the ends. Bond stress developed at the interface of steel and concrete are due to pure adhesion, frictional resistance, and mechanical resistance. The bond resistance of plain bar is due to adhesion and friction between concrete and steel. However even at low tensile stress, adhesion between concrete and steel will break, causing slippage of steel. After the occurrence of the slip, further bond is developed by friction between concrete and steel. Shrinkage of concrete grips reinforcement and increases the bond between the concrete and the steel. Failure of bond occurs when adhesion and frictional resistance are overcome and the bar is pulled leaving a round hole in the concrete. To prevent this, end enchorage is provided, in the form of hooks. If the end enchorage is adequate, such a beam will not collapse even if the bond is broken over the entire length. This is because the member act as a tie arch.

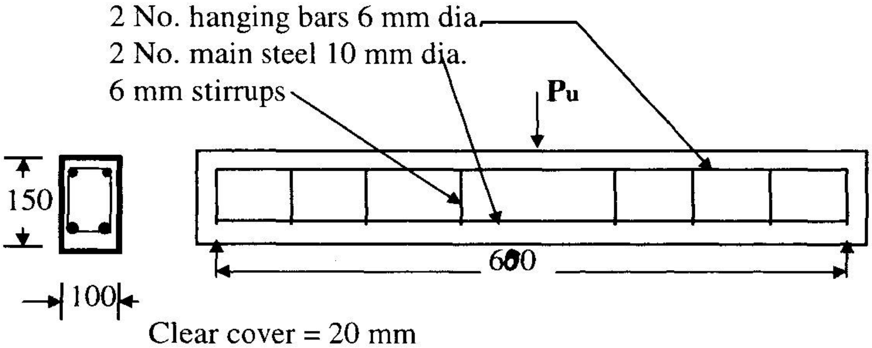
Deformed bar increases the bond capacity due to mechanical resistance in addition to adhesion and frictional resistance. Therefore the bond failure due to pulling of bar does not occur, but the surrounding concrete which is subjected to excessive circumferential tensile stress will fail by splitting.

3. Experimental planning

Rectangular beams in which plain mild steel bars and high yield strength deformed bars were employed as reinforcement were designed in accordance with the R.C.C. theory in order to carry out flexure test. End enchorage is provided, to all the main bars, in the form of hooks. Typical reinforcement details for beams are illustrated in Fig. 1. In the preparation of concrete for fabrication of beams, ordinary portland cement (OPC 53 Grade), river sand and crushed black granite of 20 mm maximum size were used as ingredients. Concrete beams reinforced as above were constructed in two series. In series 1, the proportion in which these constituent materials were mixed in making the concrete was 1:2.6:4.0 with water cement ratio 0.62 by weight while, in series 2, the proportion of these constituent materials was 1:2.0:2.9 with water cement ratio 0.53 by weight. Beside beams, control cubes to assess the compressive strength of concrete and control beams for flexural tensile strength were also prepared.



Beam B-1-1 (With HYSD bars)



Beam B-1-2 (With plain round bars)

Fig. 1 Typical Details of Test Beams for Static Loading

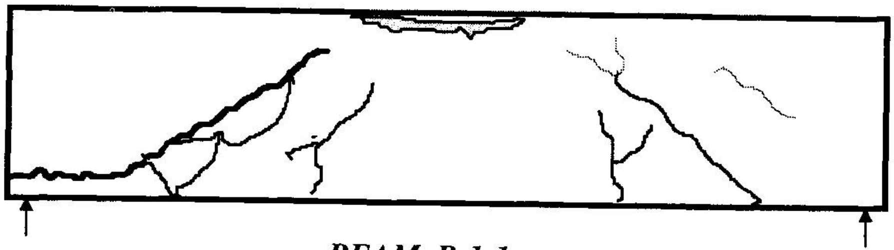
Beams were loaded as shown in Fig.1. Load was applied on beams using hydraulic jack in an increment of 1.0KN. The load corresponding to first visible crack was carefully observed and recorded. Thereafter for each load increment, cracks were marked along the depth of the beam as and when they grew under load. Load was increased monotonically up to the failure of the beam. The load at which the failure of beam occurred, was recorded. In all the beams the failure was due to crushing of concrete at top in the compression side of the beam. Fig. 2 depict a typical crack and failure pattern of beams tested under flexural load. The first crack load and the ultimate load for all the beams are given in Table 1.

Table 1 Results of flexure tests

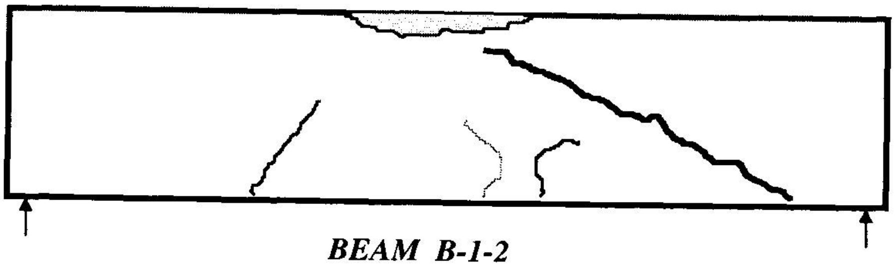
Beam No.	First Visible Cracking Load (KN)	Ultimate Load (KN)
B-1-1	15.0	41.0
B-1-2	13.0	43.0
B-2-1	18.0	47.0
B-2-2	16.0	48.0

4. Test results and discussion

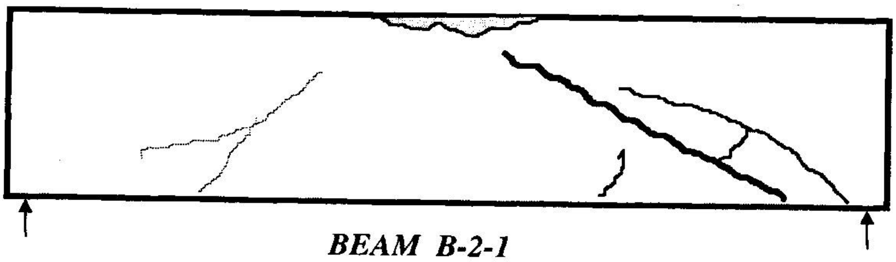
Fig. 2 shows the comparison of the formation of cracks in beams of two series reinforced with plain round mild steel bars and high yield strength deformed (HYSD) bars from the flexure test. Details of flexural load tests are given in Table 2. For beams of series 1, it is observed that the average volume of the cracks expressed as a percentage of the volume of the specimen is about 1.5% for the beams reinforced with HYSD bars, whereas the corresponding value is 0.8% for the beams with plain round mild steel bars. Therefore for the series 1, the beams with HYSD bars develop about 90.0% more crack volume as compared to beams with plain round bars. The formation of cracks in the tension zone of a beam subjected to a given loading depends to a large extent on surface texture of embedded steel rods i.e. bond between the concrete and reinforcing steel and flexural tensile strength of the concrete. After the formation of the first crack, the concrete is free from strain at the cracked surface and the strain tends to increase towards the centre between the two cracks. A little consideration shows that a further increase of the load will result in an increased strain of the concrete between the cracks so that the concrete will share the transmission of the force in accordance with the developed bond between the concrete and reinforcing steel. This will continue until the bond resistance has been overcome so that the bar slips in the concrete and the stress set up in reinforcing steel between the cracks and in a crack become equal. In some cases where the bond strength between the steel and concrete is more in comparison to modulus of rupture of the concrete, as in case with HYSD bars and low strength concrete, then the rupture elongation of the concrete may exceed the permissible value and a new crack may form between the two existing cracks before the bond resistance is overcome. These consideration leads to recognition that the concrete beams reinforced with plain mild steel bars will form very few cracks which will be fairly wide because they must accommodate the entire strain of the steel slipping in concrete. On the other hand the concrete reinforced with HYSD bars will tend to form number of cracks, between which the bond strength between concrete and steel is maintained. In case of beams with HYSD bars, the bond between the steel and concrete is more than the rupture elongation of the concrete and hence the numerous cracks formed.



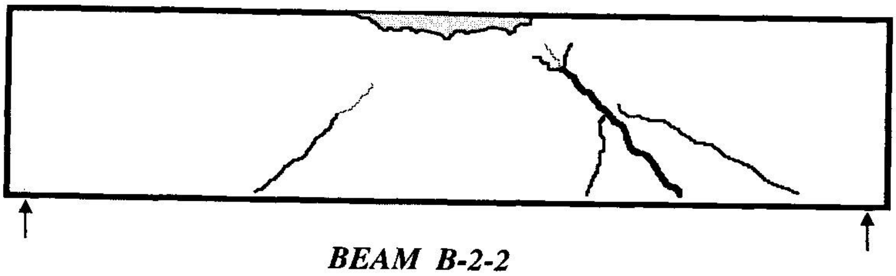
BEAM B-1-1



BEAM B-1-2



BEAM B-2-1



BEAM B-2-2

Fig. 2 Cracks and Failure Pattern of Beams Under Flexure

In beams of series 2, it is observed that the average volume of the cracks expressed as a percentage of the volume of the specimen is about 0.45 % for the beams reinforced with HYSD bars, whereas the corresponding value is 0.30% for the beams provided with plain round mild steel bars This may be because of high flexural strength of the concrete as compared to the concrete of series 1.

Table 2 Details of flexural load test

Beam No.	Concrete strength (MPa)		Steel type	Avg. No. Of Cracks	Volume of cracks (% of the specimen volume)
	Comp.	Flexural			
B-1-1	19.0	3.50	HYSD	8	1.50
B-1-2	19.0	3.50	M.S.	4	0.80
B-2-1	28.0	4.60	HYSD	5	0.45
B-1-2	28.0	4.60	M.S.	4	0.30

5. Conclusions

The results of the study show that with HYSD steel, the average volume of the cracks in beams made with concrete of 28-day strength 28.0 MPa is significantly less as compared to beams made with concrete of 28-day strength 19.0 MPa, whereas the concrete beams reinforced with plain mild steel bars form very few cracks and hence the less crack volume. Therefore it is suggested that the HYSD bars used for reinforcing the concrete should be compatible with concrete strength to minimize the cracks in the structures, hence it should not be use with low strength concrete whose tensile strength is less as compared to bond strength. For this reason the most suitable combination of steel and concrete is that in which the bond strength between concrete and steel is less than the rupture elongation of the concrete or the most suitable concrete strength for HYSD steel is that in which the cracks volume will be as small as possible for a level of stress in steel corresponding to maximum allowable load.

6. Reference

1. Price, W.H., "Factors Influencing Concrete Strength," Journal of the ACI, Vol. 47, No.6, pp. 417-432, 1951.
2. Neville, A.M., "Properties of Concrete", The English Language Book Society and Pitman Publishing, Third Edition, 1983.
3. Mindess, Sydney and Young, J. Francis, "Concrete", Prentice- Hall, Inc., Englewood Cliffs, New Jersey, 1981.
4. Beeby, A.W., "Corrosion of Reinforcing Steel in its relation to cracking," The Structural Engineer (London), V.56A, No.3, pp. 77-81, 1978.
5. Martin, H. and Schiessel, P., "The Influence of cracks on the Corrosion of Steel in Concrete," Preliminary Report RILEM, International Symposium on Durability of Concrete, Prague, V.2, 1969.
6. Sinha, S.N., " Reinforced Concrete Structures," Published by Tata Mc-Graw Hill, New Delhi, First Revised Edition,1990.