

Wire mesh as shear reinforcement in concrete

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The Paper considers an interesting combination of materials and its conclusions suggest that wire mesh shear reinforcement is an effective alternative to conventional stirrup reinforcement. Did the Authors find it difficult to fix the mesh and to ensure that it did not move while the beams were concreted? Did they consider the use of expanded metal mesh? This mesh has sufficient rigidity to require no more fixing than its equivalent conventional reinforcement, in addition to which the mesh could be used as the main reinforcement for the structural element. The mesh is readily deformed and a sheet of mesh could be bent into a trough shape and placed in the shutter. If required, extra sheets could be cut for placing in the bottom of the trough to provide extra tensile reinforcement in the beam.

31. I would suggest that precast ferro-cement trough units could be manufactured which could be subsequently used as permanent shutters for beams and columns, or as primary structural elements in themselves. The idea of using ferro-cement in such a way is not new: numerous examples of its use have been reported, including ferro-cement slabs and boats.

32. However, it must be borne in mind that the full potential of any material can be realized only once its fundamental behaviour is understood. I carried out an investigation into the behaviour of expanded metal mesh when I was a research student at the University of Sheffield. The main conclusions of the investigation confirmed that by the use of simple plastic theory the behaviour of the mesh with no infill material and subjected to gross deformation could be predicted fairly accurately. The use of the theory allows the final shape of a sheet of mesh to be determined when subjected to a generalized loading system with various boundary conditions. The mesh can easily be deformed to the required shape and mortar plastered or gunited on to the mesh to produce ferro-cement units or structures. This would be cheaper than the labour-intensive method of producing ferro-cement outlined by Nervi.⁵

33. Did the Authors consider the interaction between the mesh and the concrete infill and in particular the effect that this would have on the crack propagation and distribution?

Dr F. A. Noor, Teesside Polytechnic

The favourable effect of using closely spaced binders in reinforced concrete beams has been reported by many research workers, even as early as 1911.⁶ However, a question which remains is whether or not a steel mesh, when used as shear reinforcement, can give

Table 6. Sectional properties of T-beams

Test group	Test number	Span l , mm	Shear span/ effective depth a/d	Main steel $\frac{100A_s}{b_d}$, %	Yield stress of main steel f_y , N/mm^2	Web steel	Yield stress of web steel f_{yw} , N/mm^2	Cube strength f_{cu} , N/mm^2	Cylinder splitting strength f_{co} , N/mm^2	Effective depth d , mm	Web steel $\frac{100A_{sw}}{b_s}$, %
	T2	1981	2.92	2.13	277	R6-305 + FE 3404 mesh	248	28.8	2.78	235	0.41
	T5	1981	3.16	1.66	463	R6-305 + GP 142 mesh	314	30.5	1.97	241	0.50
Mesh	T6	1981	3.16	1.66	463	R6-305 + GP 142 mesh	314	42.7	2.73	241	0.50
	T6A	1981	3.16	1.66	463	R6-305 + GP 142 mesh	314	42.7	2.73	241	0.50
	T1	2286	3.16	2.13	277	R6-76	319	33.0	2.22	235	0.47
	T3	1981	3.16	1.66	463	R6-76	319	46.3	2.94	241	0.47
	T4	1981	3.16	1.66	463	R6-76	319	31.3	1.57	241	0.47
Stirrups	T4A	1981	3.16	1.66	463	R6-76	319	31.3	1.57	241	0.47
No web steel	T7	1981	3.16	1.66	463	0	—	22.3	1.70	241	0

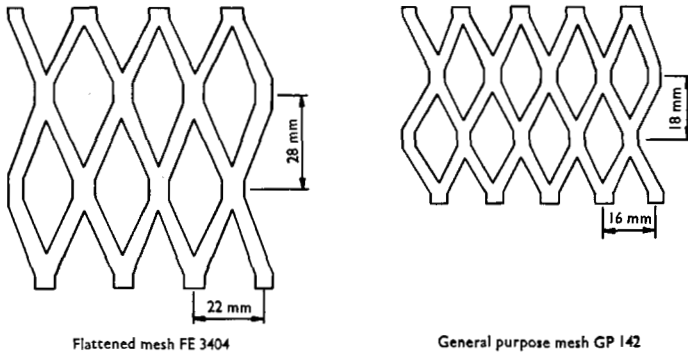


Fig. 9. Details of mesh

sufficient gain in strength and saving in steel fixer's time to justify the extra cost of its production.

35. During the course of an investigation into the use of non-conventional materials for reinforcing concrete under the supervision of Professor C. B. Wilby at the University of Bradford in 1966 I tested both asbestos cement sheets and expanded metal mesh as shear reinforcement. Fig. 9 shows the two types of mesh used. These meshes are produced by the Expanded Metal Co. Ltd, and are commonly used as guards to either heating or mechanical installations. Seven simply supported T-beams were tested under two symmetrical point loads, giving a shear span/effective depth ratio of about 3, in each beam. Three had mesh with a few stirrups for holding the mesh in place, three had only stirrups and one had no shear reinforcement at all. Details of the tests are given in Table 6 and Fig. 10. Fig. 10 also shows the correct method of fixing the mesh. In beams T3 and T5 the mesh was not bent over the main reinforcing bars and its longer side was vertical.

36. Two types of specimen were used for assessing the material strengths of the mesh. The first was a single strand cut from the mesh and the second comprised a 75×75 piece

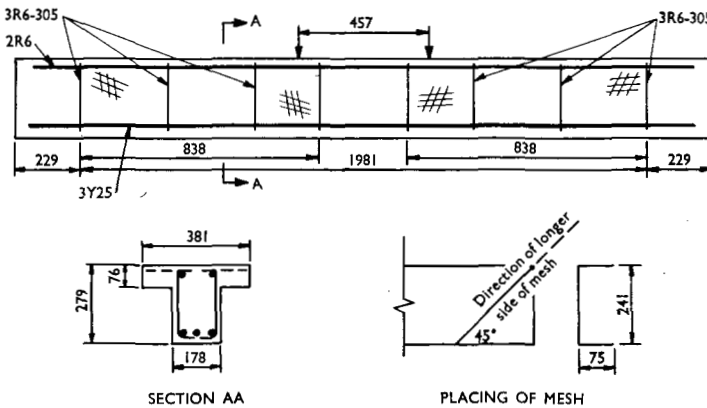


Fig. 10. Details of loading and reinforcement of beam T6

Table 7. Results of T-beam tests

Test group	Test number	Experimental shear strength V_{ue}, kN	Experimental flexural strength M_{ue}, kNm	Central deflexion Δ, mm	Principal tensile stress/cylinder splitting strength f_{sp}/f_{co}	M_{ue}/M_{uc}	V_{ue}/V_{uc}	Failure mode
Mesh	T2	159	109.4	9.04	1.13	1.03	1.32	F
	T5	122	92.7	4.77	1.29	0.72	1.02	S
	T6	170	129.4	5.15	1.19	0.96	1.23	S
	T6A	156	119.1	—	1.19	0.88	1.14	S
Stirrups	T1	131	99.7	6.95	0.98	0.93	1.10	F
	T3	187	142.2	8.70	1.14	1.04	1.35	S
	T4	127	96.4	4.65	1.78	0.75	1.05	S
	T4A	144	109.6	—	1.78	0.85	1.20	S
No web steel	T7	54	41.4	1.91	0.96	0.38	0.78	S

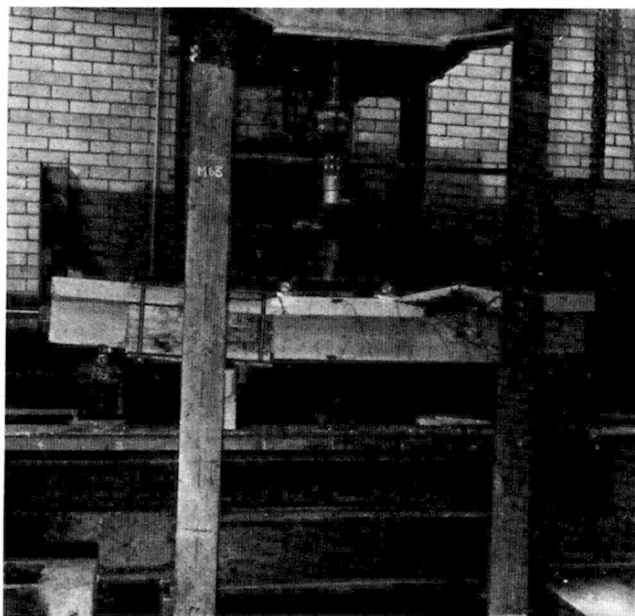


Fig. 11. External stirrups on beam T4A

of mesh with 75×100 steel plates, of similar thickness, welded at each end. As expected, the latter specimen changed its shape during the tensile test and tended to give a lower yield stress. The concrete mix was $1:1\frac{1}{2}:3\frac{1}{2}$ with 10 mm down gravel and a water-cement ratio of 0.5.

37. The beams were tested, under load control, in a 1000 kN Fowler press. The exact load at failure was obtained by switching on the load recorder to take continuous readings for the loading increments near the ultimate load. External stirrups were used to hold the failed shear spans of beams T4 and T6, and further tests were carried out on the other shear spans. The external stirrups are shown in Fig. 11 and the results of these tests are recorded (Table 6) as beams T4A and T6A.

38. The results are summarized in Table 7. Both beams T1 and T2 failed by yielding of the tensile steel, but T2 showed a greater deflexion and had widespread inclined cracks. The other beams, reinforced by mesh, failed by a main inclined crack extending from the support to one of the loading points. One other wide inclined crack, roughly parallel to the main crack, was also present. The cover to the concrete between these cracks could be removed and in beams T2, T6 and T6A the mesh was fractured. There were no stirrups extending into the flange in beam T5 and hence the flange between the loading points cracked on the near side (Fig. 12). The absence of any dowel action, due to the lack of restraint by the mesh, is apparent in Fig. 12. Fig. 13 shows the mesh of beam T6A and, in this case, the bond between the mesh and the concrete was much better. This was due to degreasing of the mesh before fabricating the steel cage.

39. The shear failures in beams reinforced by stirrups also showed two inclined cracks, the main crack extending from the support to one of the loading points. As expected, beam T7, which had no shear reinforcement, failed in diagonal tension, soon after the appearance of the initial inclined crack, and showed a much lower ultimate load

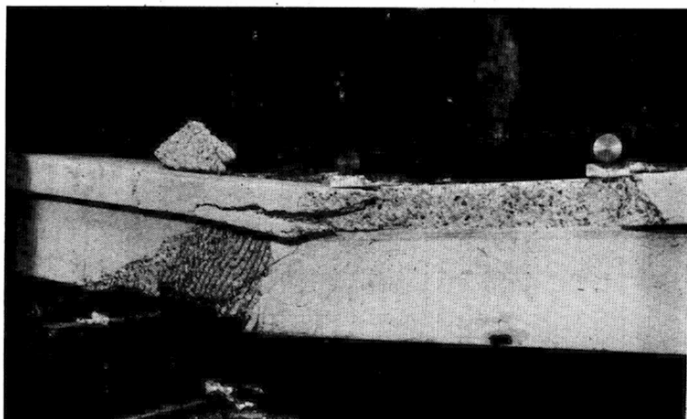


Fig. 12. Failure of bêam T5

than any other beam. When the load-deflexion curves and the crack distributions of the beams with mesh were compared with those of the beams with stirrups, no significant difference was apparent.

40. The theoretical shear and flexural strengths used in Table 7 were obtained by the methods of Laupa *et al.*⁷ and Whitney⁸ respectively.

41. It appears that properly designed and detailed mesh is likely to be more effective than a similar weight of vertical stirrups. As yet, there has been only one test result (KB'10) where the gain in strength has been more than marginal. A number of test results show the strength was about the same but in some of these tests the mesh was not always used correctly and further experimental work is required. At present there is unlikely to be any saving in cost when using the commercially available mesh. However, it may be possible to produce a high tensile product which can be cut and bent so that the longer side of the diamond is at 45° to the horizontal. Such a mesh would be useful where inclined stirrups are necessary, and when steel fixers get used to cutting and bending the new type of reinforcement there will be a saving in fabricating time. As greater quantities of mesh are produced, manufacturing cost will decrease and there may be a saving in the overall cost of providing the lateral reinforcement to both beams and columns.

Mr Ghosh and Dr Mukhopadhyay

Dr Melbourne has enquired about certain aspects regarding the preparation of the specimens. No difficulty was experienced during the fabrication and manufacture of concrete beams having wire mesh as web reinforcement. Only hexagonal chicken wire mesh was used in the investigation; expanded metal mesh was not tried. Wire mesh pieces equal to the vertical face of the beam were first cut keeping suitable provision for cover. They were then tied to the longitudinal reinforcement at top and bottom at close intervals by steel wires. The concreting was started from the outer edge of the mould and proceeded inwards. The wire mesh was not bent in the shape of a trough and no attempt has been made to use it as permanent shutter as is done in ferro-cement slabs and boats. During casting the wire mesh was secure in its position and any movement can be neglected for beams where wire mesh is used as shear reinforcement.

43. As regards the incorporation in the analysis of the interaction between the wire mesh and infilled concrete, in the theory proposed in the Paper wire mesh was considered

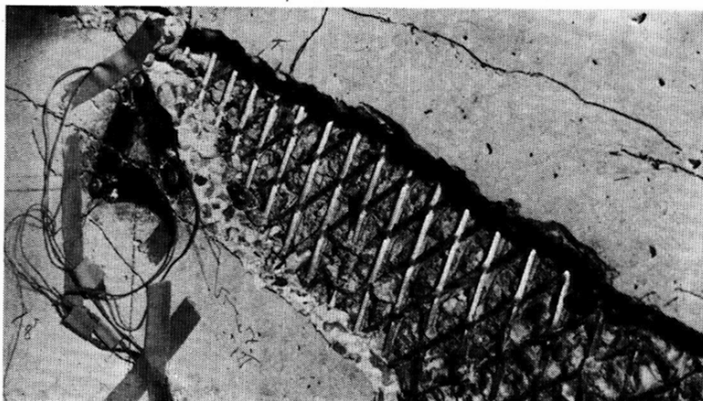


Fig. 13. Mesh in beam T6

as a substitute for stirrups or inclined rods were considered as shear reinforcement in conventional reinforced concrete analysis. As such no interaction was taken into account this conforms with the research carried out by Dr Melbourne.

44. From Dr Noor's test results in Table 7 it is not possible to make a comparative study of the wire mesh and the vertical stirrups as shear reinforcement which was one object of our investigation. From the study of comparable beams—one had wire mesh and the other had stirrups of the same weight—it was concluded in the Paper that wire mesh would be more effective beyond a certain percentage of web reinforcement.

45. Dr Noor's test results indicated that the load-deflexion curves were unaffected by the type of web reinforcement which is consistent with the observations made in this regard in the Paper. However, unlike Dr Noor, we found that crack distribution in our beams was significantly affected by the type of shear reinforcement. It may be due to a lower percentage of web steel in his beams. Wire mesh provides much more bonded area than do stirrups and so it is only to be expected that the cracks would be more in number and more closely spread.

46. We agree that further experimental results will throw more light on the topic, but feel that at present it is premature to comment on the economic aspect of the use of wire mesh as shear reinforcement in concrete.

References

5. NERVI P. L. *Ferro-cement: its characteristics and potentialities*. Translated from Italian. Cement and Concrete Association, London, 1956, Cj 60, Publication 61.060.
6. BACH C. and GRAF O. *Deutscher Ausschuss für Eisenbeton*. Berlin, 1911.
7. LAUPA A. *et al.* Simple-span T-beams under one or two symmetrical concentrated loads. *Bull. Ill. Univ. Engng Exp. Stn*, 1955, No. 428.
8. WHITNEY C. S. Plastic theory in reinforced concrete design. *Trans. Am. Soc. Civ. Engrs*, 1942, 107, 251-326.