EVALUATION OF A HINGED WIRE MESH REINFORCEMENT FOR CONCRETE PAVEMENTS

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A sample of hinged reinforcing mesh manufactured by the American Steel and Wire Division, U. S. Steel Corp., was received at the Laboratory for testing on April 10, 1962. Each transverse wire along the 15-ft mat length was hinged at the center longitudinal wire, at 1-ft intervals. A typical hinge section is shown in Fig. 1.

In 1960, hinged mesh manufactured by the Pittsburgh Steel Co. and differing from the new sample only in hinge section details, was investigated at the Laboratory and reported by R. Hooper in Research Report No. 344. On the basis of overall performance in those tests, this mesh was described as not being an acceptable alternate to standard welded mesh reinforcement. However, with regard to transverse pavement cracking, the effect of the hinge on deformation and ultimate load resistance of the center longitudinal wire was negligible. Thus, in this latter respect the hinged mesh was considered an acceptable alternate.

Testing of the new hinged mesh, therefore, was confined to tension determinations using specimens of three types. Each specimen consisted of a single transverse wire hinged or welded to a single longitudinal crosswire, with this mesh joint placed in a wood form box and cast in

WELDED

#4 GAGE
(0.225 DIA.)

#00 GAGE
(0.332 DIA.)

3/8"

TOP VIEW

B   A

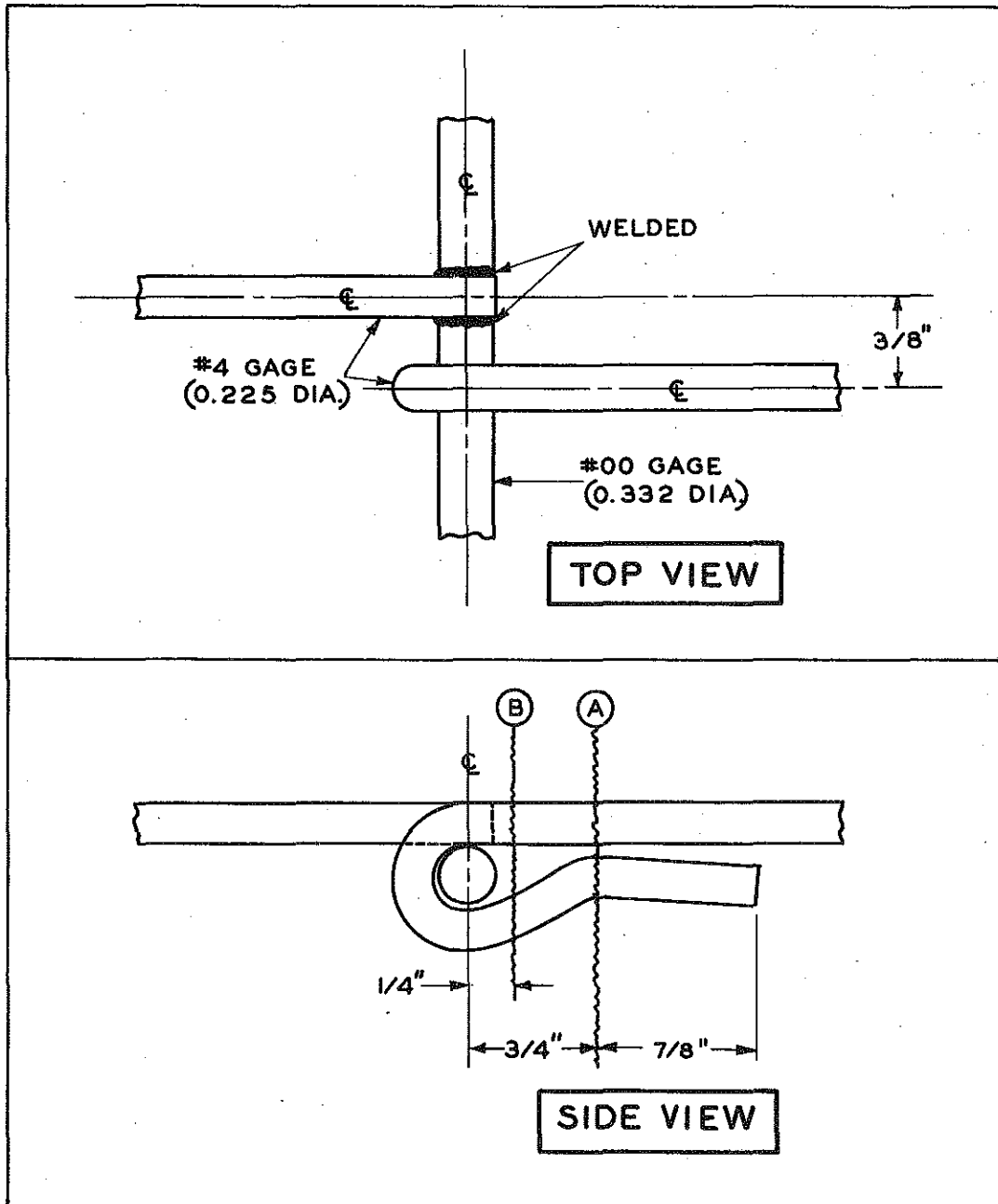1/4"

3/4"   7/8"

SIDE VIEW

Figure 1.   Typical hinge section.

concrete. These specimen blocks were then partially sawed through and precracked prior to deformation testing. The three specimen types were differentiated as follows:

Specimen No.	Joint	Precracked
1, 2, 3	standard weld	at joint
4, 5, 6	hinged	at hinge base*
7, 8	hinged	beside crosswire**

    * Plane A (Fig. 1)
  ** Plane B (Fig. 1)

Three test specimens were prepared for each of these specimen types; one hinged-mesh specimen (No. 9) was damaged in the precracking process, so only two specimens of this type were tested.

Test Procedure

Tensile loads were applied directly to the transverse wire and four 0.001-in. dial gages were attached to a yoke so that the deformations across the crack could be recorded. The dial gages were read simultaneously and recorded with the load causing that deformation. The average crack opening was then computed by averaging these four deformations algebraically.

Test Results

Tensile loads at an 0.01-in. average crack opening and ultimate tensile loads taken from Fig. 2, and types of failure for each specimen are tabulated in Table 1. Since hinged specimens precracked at Plane
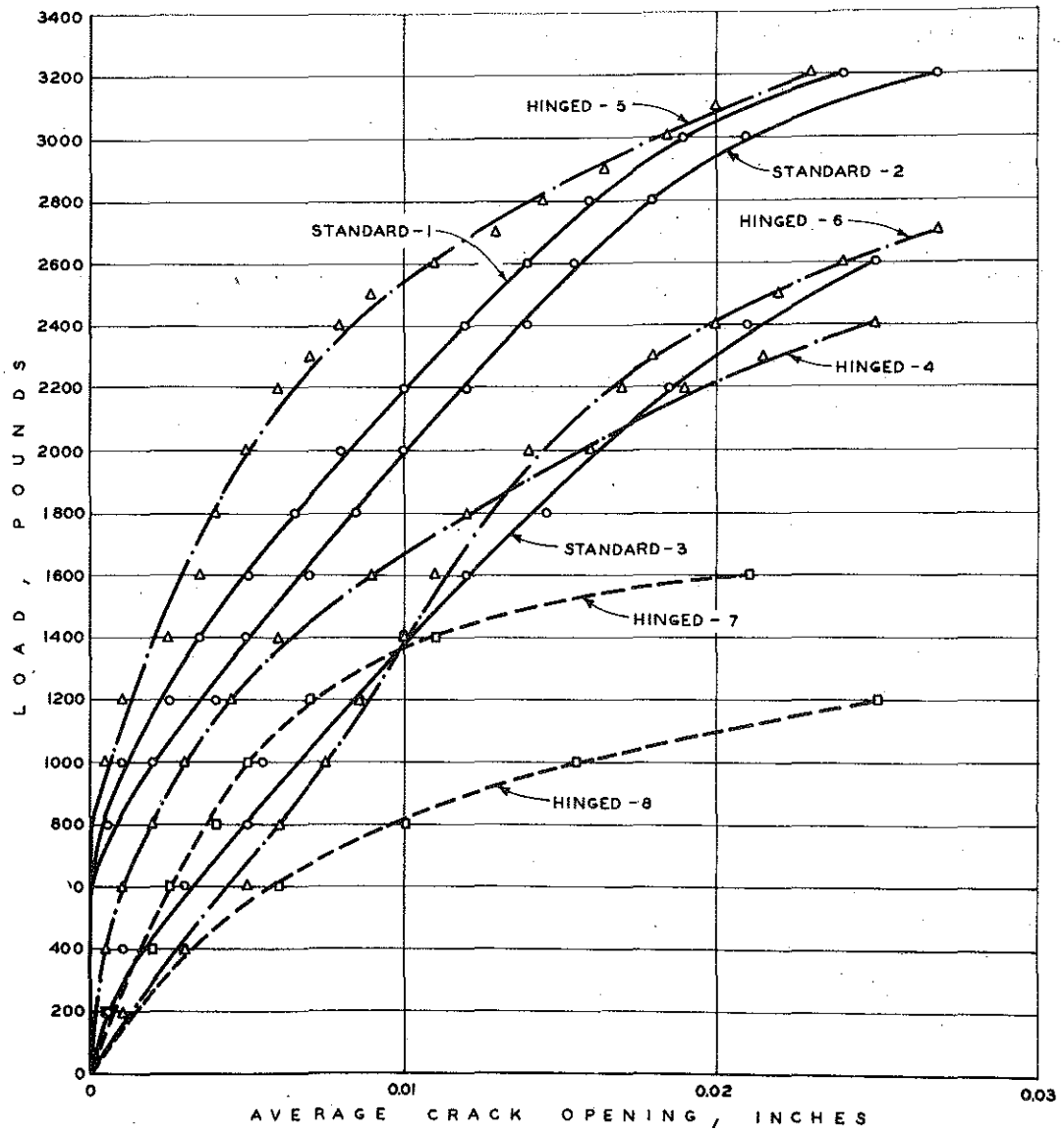
Figure 2. Load-deformation curves.

TABLE 1
TRANSVERSE WIRE TEST RESULTS

Specimen Number	Type	Tensile Load at 0.01-in. Average Crack Opening, lb	Ultimate Tensile Load, lb	Type of Failure
1	Standard	2200	3860	Failure of transverse wire near longitudinal wire.
2	Standard	2000	3830	Failure of transverse wire near longitudinal wire.
3	Standard	1380	3350	Failure of transverse wire near longitudinal wire.
Average		1860	3680	
4	Hinged	1660	3040	Failure of concrete and elongation of transverse wire.
5	Hinged	2530	3860	Failure of transverse wire outside of concrete block.
6	Hinged	1360	3420	Failure at transverse wire weld junction inside concrete block.
Average		1850	3440	
7	Hinged	1370	2130	Failure at transverse wire weld junction inside concrete block.
8	Hinged	820	1900	Failure at transverse wire weld junction inside concrete block.
Average		1095	2015	

B (Fig. 1) resulted in greater deformations across the crack and failed at lower test loads, this was considered as the critical case when comparing the hinged and standard mesh.

Methods of Analysis

Interpreting the test results according to various criteria, numerous conclusions as to the equivalence of the hinged and standard mesh reinforcement could be reached. Therefore, each criterion is stated here with the appropriate conclusion as to equivalence of the two types of reinforcement:

1. Using the subgrade friction theory, 975 lb is the maximum force exerted on each transverse wire in a pavement of two 12-ft lanes should a longitudinal crack develop at the 6-ft point or hinge line. In 1956, Subcommittee IV of ACI Committee 325* observed that:

"Based on maximum pavement load deflections of 0.02 in., (Fig. 110 of "Final Report on Road Test ONE-MD", HRB Special Report No. 4), horizontal crack widening of 0.01 in., due to reinforcement tension, would seem to be a permissible limit."

Although the ACI speaks of a transverse crack widening of 0.01 in., it would also seem necessary to limit any longitudinal crack widening to 0.01 in.

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* "Design Considerations for Distributed Reinforcement for Crack Control," Journal of the ACI, Vol. 28, No. 4 (Oct. 1956), p. 346.

The results of the load-deformation tests for a maximum average crack opening of 0.025 in. are plotted in Fig. 2. Average tensile loads required to cause an average crack opening of 0.01 in. as interpolated from Fig. 2 and given in Table 1 were 1095 and 1860 lb, for the hinged and standard mesh, respectively, and thus both average tensile loads were greater than the maximum design force required (975 lb). Therefore, based on this criterion, the hinged and standard mesh would both meet the minimum design strength. However, the safety factor of the hinged mesh would be 1.1 as compared to 1.9 for the standard mesh reinforcement.

2. Again, using the subgrade friction theory, 2925 lb would be the maximum force exerted on each transverse wire in a pavement of three 12-ft lanes should a longitudinal crack occur at the 6-ft point of the center lane. Therefore, as interpolated from Fig. 2 and given in Table 1, the average tensile loads required to cause an average crack opening of 0.01 in. were 1095 and 1860 lb for the hinged and standard mesh, respectively, and thus both average tensile loads were less than the maximum design force required of 2925 lb. Based on this criterion, neither the hinged nor standard mesh reinforcement would meet the minimum design requirements.

3. In this case, the average tensile load developed is compared with the maximum design force required of each transverse wire. The average

ultimate tensile loads developed by the hinged and standard mesh specimens, as shown in Table 1, were 2015 and 3680 lb, respectively. Since the maximum design force required is 975 lb, the hinged and standard mesh would both meet design standards. However, the factor of safety of the hinged mesh would be 2.1 as compared to 3.3 for the standard mesh reinforcement.

4. However, comparing average ultimate tensile loads developed by the specimens with the required design force for three-lane pavement, the following strength values may be stated. The average ultimate tensile loads developed by the hinged and standard mesh specimens, as shown in Table 1, were 2015 and 3680 lb respectively, while the maximum required design force for three-lane pavement is 2925 lb. Thus, the standard mesh meets the minimum design strength requirement with a safety factor of approximately 1.3, while the hinged mesh does not meet the minimum design strength requirement.

5. When hinged mesh and standard mesh reinforcement are compared on an average ultimate tensile load basis, the hinged mesh is not equivalent. As shown in Table 1, the average ultimate tensile loads of the hinged and standard mesh specimens were 2015 and 3680 lb, respectively. Based on these average figures, the hinged mesh could take approximately 55 percent of the ultimate tensile load developed by the standard mesh reinforcement.

6. The hinged mesh would also not be equivalent to the standard mesh reinforcement when compared on the basis of total elongation at failure. The average elongations at failure for the hinged and standard mesh reinforcement were 0.147 and 0.094 in., respectively.

7. In 1956, the ACI Subcommittee also stated:[*]

"In the case of two-lane pavements, transverse warping stresses due to temperature variation in the slab are relieved by the longitudinal joint, and therefore longitudinal cracking is most unlikely. The cross-sectional area of transverse steel based on design consideration is generally exceeded in practice because of other considerations such as construction handling and convenience. The spacing of transverse wires may be controlled by design consideration of cross-wire anchorage for longitudinal steel."

The hinged and standard mesh reinforcement would meet the requirements for two-lane pavements as stated by the ACI. With regard to the multiple-lane pavements, the area of transverse steel required, based on the tie bar and mesh reinforcement yield points, would be 0.065 sq in. per lin ft, while the area of transverse steel present in the hinged mesh and the standard mesh presently specified by the Department equals 0.04 sq in. per lin ft. Therefore, neither the hinged nor standard mesh reinforcement would meet the minimum design requirements for multiple-lane pavements stated in the ACI Report.

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* Op. cit., p. 348.

Conclusions

The acceptability of hinged mesh reinforcement depends on the acceptance criterion established to evaluate it. Several bases of approval can be considered:

1. For acceptability a new product or device must be expected to perform as well as or better than the old or established product. On this basis, hinged mesh reinforcement is not acceptable because this, and all previously tested hinged mats, are not as strong nor as resistant to longitudinal crack opening at the hinge as an unhinged mat of the same wire size. This is the Department's present criterion.

2. For acceptability a new product or device must meet certain minimum design requirements:

Two-lane pavement. If the design requirement is sufficient strength to control maximum crack opening of 0.01 in. for a crack at the hinge in a pavement of two 12-ft lanes, the factors of safety are 1.1 and 1.9 for the hinged and unhinged mats, respectively. These factors of safety do not take into account any reduction in area with time due to corrosion.

Three-lane pavement (Interstate expressway-type pavement constructed as two 12-ft lanes per roadway, but designed for eventual widening to three 12-ft lanes per roadway). If the design requirement is sufficient strength to control maximum crack opening of 0.01 in. for a crack at the hinge in the middle lane of a pavement of three 12-ft lanes, then the hinged

and standard mesh have factors of safety of 0.375 and 0.635, respectively. Neither type of reinforcing would be acceptable under these design conditions.