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Effect of connection bar stiffness on failure strength of connected steel grid reinforcements

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ABSTRACT: As the steel grid reinforced earth walls become higher and larger, the required reinforcement length becomes longer, and subsequeutly it is indispensable to connect reinforcements from the economical viewpoint. An effective mechanical connection between steel grid reinforcements has already been proposed by the authors. In this paper, the failure strength and failture mode of mechanical connections between steel grid reinforcements are examined, changing diameters of connection bars. The effect of connection bar stiffness on the failure strength of mechanical connections are discussed based on tension test data. As the results, the connection bar stiffness plays an important role on the failure strength and failure mode of the mechanical connections. The failure strength increases as increasing the diameter of connection bar, however, a suitable diameter of connection bar exists for the mechanical connection from the viewpoint of failure mode.

1 INTRODUCTION

The reinforced earth structures have been extensively constructed instead of the gravity retaining walls during the past two decades. Figure 1 shows the transitions of the number of construction sites and the average construction area of steel grid reinforced earth walls constructed by Geosystem Co. Ltd., of which heights are more than 10 m. This figure shows that higher and larger steel grid reinforced earth structures increase and become popular and that their average area is larger than 400 m^2. As the result, the required reinforcement length becomes longer. Longer reinforcements are not economical to transport to construction sites and not easy to manufacture. Therefore, it is indispensable to connect regular length reinforcements. The mechanical connections between steel grid reinforcements have been developed and improved so far.

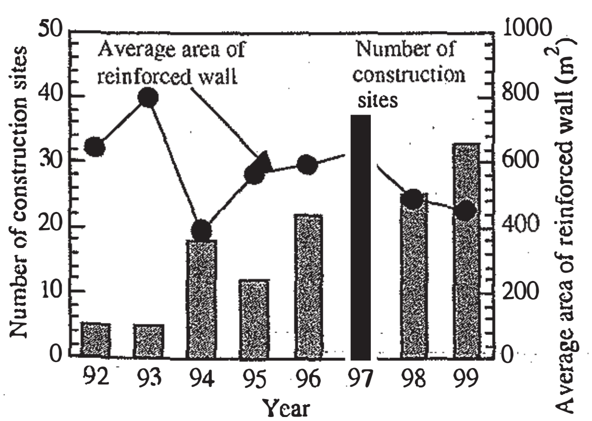
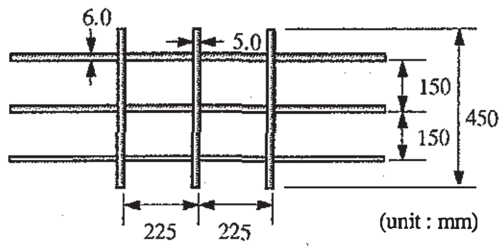


Figure 1. Transitions of number of construction sites and average construction area of the steel grid reinforced earth wall (h≥10m; provided from Geosystem Co. Ltd.).

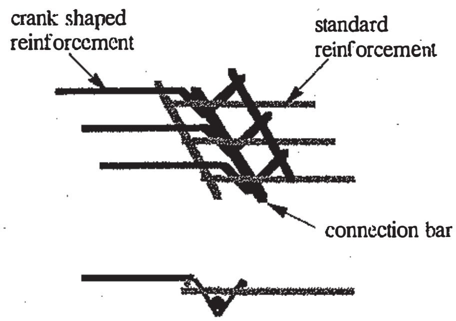
In this paper, the authors examine the failure strength and failure mode of mechanical connections between steel grid reinforcements, changing diameters of connection bar into four kinds. The tension tests in the soil are carried out to estimate the failure strength of the mechanical connections and investigate their failure mode. The authors discuss the effect of connection bar stiffness on the failure strength and failure mode of mechanical connection.

2 STEEL GRID REINFORCEMENT AND MECHANICAL CONNECTIONS

The applied steel grid reinforcement is a grid-type reinforcement, in which longitudinal and transverse members are welded each other as shown in Figure 2(a). The diameters of transverse and longitudinal members are 5.0 and 6.0 mm respectively. Many types of connections have been proposed and the mechanical connection used in this paper was the best among them from the viewpoint of failure strength (Nabeshima et al. 2000). Figure 2(b) shows the schematic diagram of the mechanical connection between steel grid reinforcements. The proposed mechanical connection consists of standard and connection reinforcements and a connection bar. The connection reinforcement is characterized by crank shaped edges. The standard reinforcement is overlapped on the connection one, and the connection bar is used to connect both the standard and connec-



(a) standard steel grid reinforcement



(b) mechanical connection

Figure 2. Schematic diagram of steel grid reinforcement and mechanical connection.

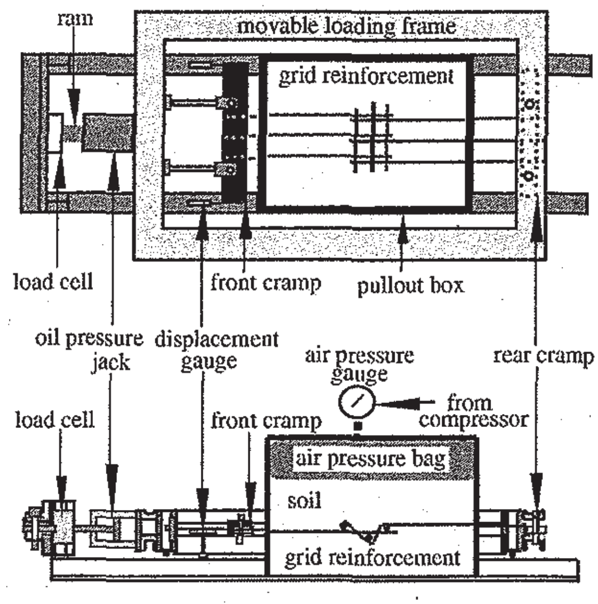


Figure 3. Schematic diagram of pullout apparatus and arrangement of mechanical connection in the pullout box.

tion reinforcements. Therefore, the connection bar seems to play an important role in the failure strength of the mechanical connection. The diameter of connection bar can be varied from 5.0 to 9.0 mm.

3 TEST PROCEDURES

The tension tests of steel grid reinforcement with mechanical connections are performed in the dry sand ground under a surcharge of 98.1 kPa. Figure 3 shows the schematic diagram of the pullout test apparatus. The apparatus and used material are the same as those in the references (Matsui et al. 1997, Nabeshima et al. 2000). The rear end of the connection reinforcement is fixed on the loading flame, to carry out the tension test in the pullout test apparatus. All mechanical connections are pulled at a constant rate of about 1.0 mm/ min. The diameter of connection bar is varied in four kinds of 5.0, 6.0, 7.5 and 9.0 mm, to examine the effect of connection bar stiffness on the failure strength of mechanical connection. Figure 3 also shows the arrangement of the mechanical connection in the pullout box before tension tests.

4 CONNECTION BAR STIFFNESS AND FAILURE STRENGTH OF MECHANICAL CONNECTIONS

Figures 4 to 11 show the variations of tensile force of mechanical connections with displacement and their failure mode after tension tests for four kinds of diameter of connection bar, respectively. In case of D=5.0mm, the curve shows very brittle behavior and the connection bar visibly slightly deformed after tension test. This means that the stiffness of the connection bar is not enough. On the other hand, in case of D=9.0mm, the curve shows ductile behavior which is quite different from the other cases. Also, although the deformation of connection bar is hardly observed, the tension failure of longitudinal member is observed after tension test. This means that the stiffness of connection bar is too big. And in cases of D=6.0 and 7.5mm, their curves show intermediate behaviors between those of 5.0 and 9.0 mm. From the above observations, the connection bar stiffness plays an important role on the failure strength and failure mode of the mechanical connections. The failure mode changes from brittle to ductile as increasing the diameter of connection bar, and the displacement at the maximum tensile force becomes larger.

Figure 12 shows the variation of failure strength with the diameter of connection bar. The failure strength of mechanical connection increases as increasing the connection bar diameter. However, the increment of the failure strength gradually decreases in cases where the diameter of connection bar is greater than that of transverse member. The displacement at the maximum tensile force is about 55 mm in case of D=9.0mm, which is the largest in all tension tests. From the viewpoint of failure mode, a suitable diameter of connection bar exists for the mechanical connection, which seems to be 7.5 mm, that is almost 1.5 times the diameter of transverse member.

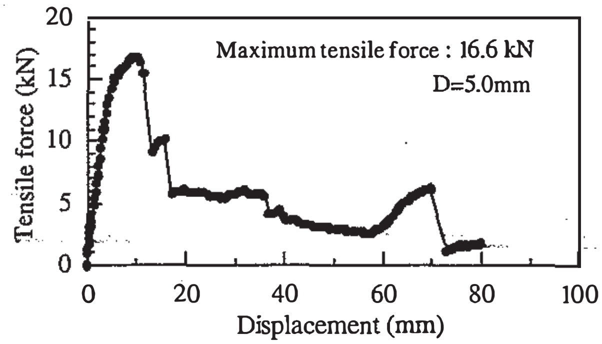


Figure 4. Variation of tensile force during tension test (diameter of connection bar : 5.0 mm).

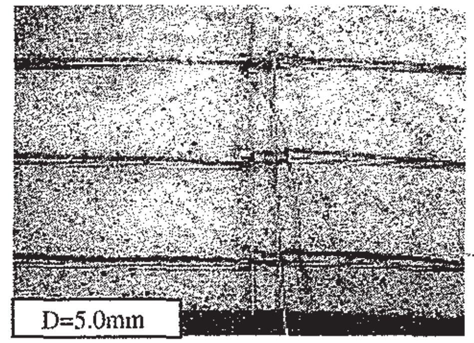


Figure 5. Failure mode of mechanical connection (diameter of connection bar : 5.0 mm).

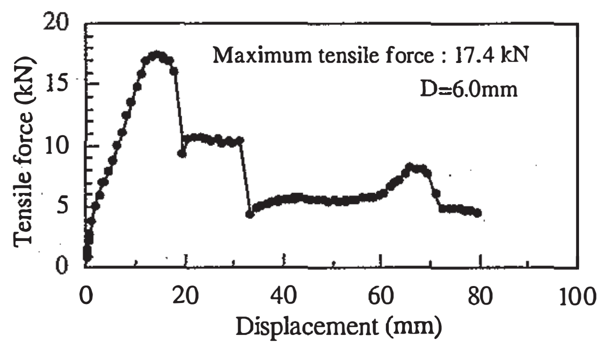


Figure 6. Variation of tensile force during tension test (diameter of connection bar : 6.0 mm).

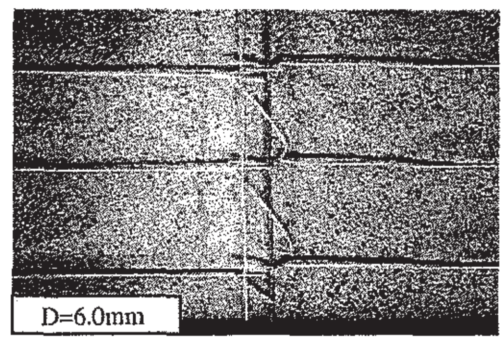


Figure 7. Failure mode of mechanical connection (diameter of connection bar : 6.0 mm).

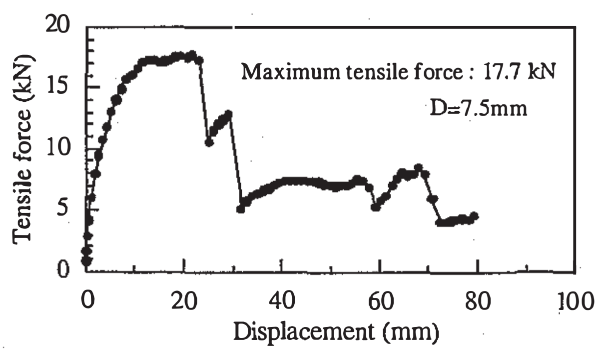


Figure 8. Variation of tensile force during tension test (diameter of connection bar : 7.5 mm).

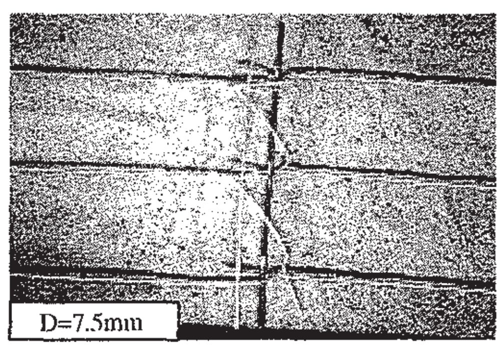


Figure 9. Failure mode of mechanical connection (diameter of connection bar : 7.5 mm).

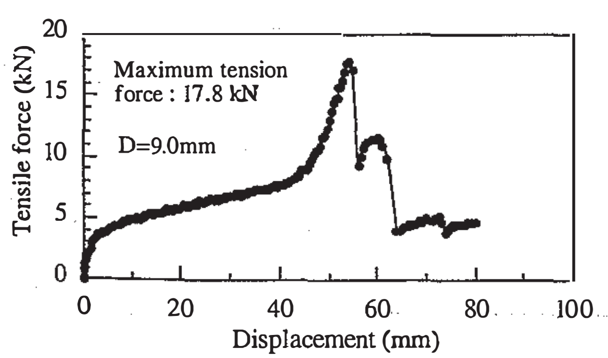


Figure 10. Variation of tensile force during tension test (diameter of connection bar : 9.0 mm).

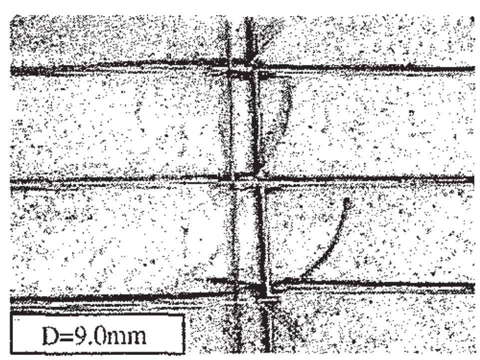


Figure 11. Failure mode of mechanical connection (diameter of connection bar : 9.0 mm).

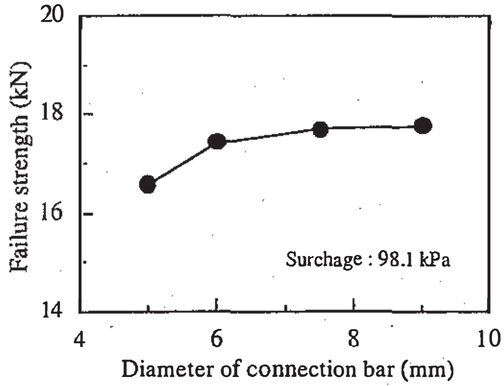


Figure 12. Variation of failure strength with diameter of connection bar.

5 CONCLUSIONS

The authors examined the failure strength and failure mode of mechanical connections between steel grid reinforcements changing diameters of the connection bar. Main conclusions in this paper are summarized as follows:

1) The connection bar stiffness plays an important role on the failure strength and failure mode of mechanical connections. The latter changes from ductile to brittle as increasing the diameter of connection bar.
2) The failure strength increases as increasing the connection bar diameter. The increment of the failure strength gradually decreases in cases where the diameter of connection bar is greater than that of transverse member.
3) A suitable diameter of connection bar exists for the mechanical connection from the viewpoint of failure mode, which is almost 1.5 times the diameter of transverse member.

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