SHEAR BEHAVIOUR OF HYBRID STEEL GIRDERS

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1. Introduction

This paper describes the strength and the collapse mode under shear of hybrid steel girders which are considered as the combination of shell elements.

When an I-sectioned girder is subjected to the bending, higher stress arises in the flange plates of the girder. A hybrid steel girder is a girder which has flange plates made with the higher strength steel and a web plate with “normal” steel. In the discussion on a hybrid steel girder, behaviour under the bending has been mainly focused. As a member of the Subcommittee on "the design method of hybrid steel girders" organized by JSSC (Japanese Society of Steel Construction)[3], one of the authors made a series of studies[1-2] on the hybrid steel girders. As described above, a hybrid steel girder is effective for the bending. Therefore, it is natural that the bending behaviour of the hybrid girders is focused.

However, to design a hybrid steel girder, its shear behaviour such as the collapse mechanism under shear must be known. Thus, in this paper, numerical analyses are made to know the strength and the collapse mechanism of hybrid steel girders under shear. The results of the collapse mechanism and strength are compared to those of the homogeneous girders which are made of the same grade steel for their flange and web plate.

2. Numerical models and numerical method

A typical numerical model is illustrated in Figure 1. As illustrated in Figure 1, the model is fixed at its left, and is subjected a downward load at its right edge. This model has its length l=5000 mm, web depth b=1200mm and flange width b_f=260 mm. The web panel with the width of a and subtended by two stiffeners is focused in this study. The stiffeners have their section of 100 x 8mm. The web thickness t_w is t_w=8mm or t_w=12mm, and the flange thickness t_f is varied from t_f=4mm to t_f =20mm to investigate the effect of the flange stiffness.

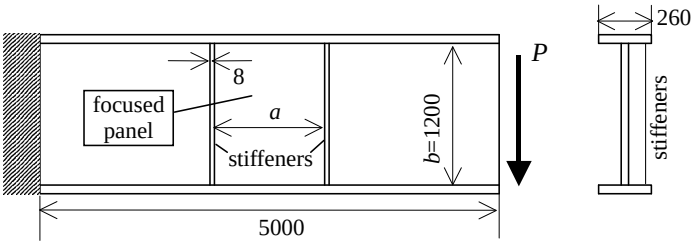

Figure 1. A typical numerical model

The aspect ratio of the focused panel, $\alpha=a/b$ is considered as one of parameters and from 0.75 to 3.0, that is, a is from 900mm to 3 600mm.

In this study, the grade SM400 steel which has the yielding stress σ_y of σ_y =245Mpa and the grade SM570steel with σ_y =460MPa are considered. For the hybrid girder, The SM570 steel is utilized for only the flange plates of the hybrid girder, and for the flanges of the homogeneous girder and the web plates, SM400 is considered.

The numerical analysis is made with the computer program package MSC Marc, and the model is discretized with 50x50mm thick shell elements.

3. Numerical results

In Figure 2, a deformation pattern of the hybrid girder with t_w=8mm, t_f=12mm and α=1.0 at the ultimate load is illustrated. The distinct shear buckling deformation is observed in the web plate in this figure. This figure also shows that each flange plate deforms with the web deformation. However, although it is not clear in this figure, no plastic hinge is formed in the flange plate in this model.

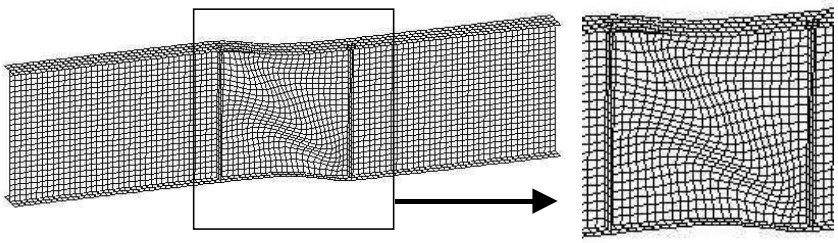

Figure 2. Shear Deformation of Hybrid Girder (α=1.0, t_w=8mm, t_f =12mm)

The maximum load P_{max} of this model is P_{max} = 1096 kN, and the corresponding homogeneous girder has its P_{max} is P_{max} =1091 kN. Thus, in this case, the hybrid girder has almost equal strength to the corresponding homogeneous girder. In the case with the aspect ratio α=3.0and with the same plate thickness, both the hybrid girder and the homogeneous girder also have no plastic hinge in their flange plates. However, in this aspect ratio, the hybrid girder has its P_{max} = 758 kN and this is larger by 8% than the homogeneous girder which has the P_{max} = 700 kN. Although the detail is not shown in this abstract, with the larger aspect ratio, hybrid girders have larger P_{max} than homogeneous girders.

In addition, on the cases with the plate thickness of t_w=12mm, t_f=12mm, or t_w=8mm, t_f=8mm, hybrid girders have no plastic hinge in the flange plates although in corresponding homogeneous plastic hinges arise in the flanges. That is, in these cases, the hybrid girder and the homogeneous girder have different collapse mode to each other.

4. Conclusion

The flange plates of a plate girder carry mainly the bending, and the shear is carried by mainly web plate. A hybrid steel girder is originally considered to carry the bending effectively. However, the results shown in this paper indicate that a hybrid girder is also effective for the shear when the girder has the larger aspect ratio. In addition, to estimate the shear strength of a girder, the collapse mode with the plastic hinges in the flange plates is often adopted. But, the collapse mode of a hybrid girder obtained in this study has, in some cases, no plastic hinge although the plastic hinges arise in the corresponding homogeneous girder. This fact suggests that a separate shear collapse mode is required for the hybrid girders other than the homogeneous girder.

5. References

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[3] Subcommittee for Design Method of Hybrid Steel Plate Girders (2002), *A Proposal for Design Method of Hybrid Steel Plate Girders using Ultimate State Design*, JSSC(Japanese Society of Steel Construction) , Tokyo