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Synthesis and Conclusions

Synthèse et conclusions

Synthese und Schlussfolgerungen

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Prepared Discussion

The numbers of papers presented at the prepared discussion are seven for theme Va,two for theme Vb and two for theme Vc. The following is a short summary of these contributions.

Theme Va. Starting with theme Va."Structural Behavior Including Hybrid Construction", P.Ferjencik reported on the structural behavior of prestressed steel beams. A wide flange beam is prestressed by means of high-strength tension wires installed just beneath the lower flange. Test results showed that elastic limit capacity of this system increases remarkably compared with that of non-prestressed regular steel beam. Due to the effect of prestressing and of plastic reserve strength,the ultimate strength of this system can attain as high as twice the computed ultimate strength of non-prestressed beam if the premature lateral and local buckling is carefully prevented.

M.Yamada and B.Tsuji carried out an elastic-plastic analysis of hybrid beam-columns subjected to repeated and reversed bending under constant axial force. It was demonstrated that in hybrid beam-columns,the expansion of hysteresis loops for each additional cycle can not be expected so much when the magnitude of the axial force is large.

Z.Cywinski carried out a plastic analysis of hybrid beams on the basis of lower bound criterion,and pointed out that for short span beams,the effect of shear stress becomes more severe than that assumed in the present ASCE-AASHO regulation.

A.Plumier investigated the fatigue strength of plate girders with rather unique details.Main series of test girders had transverse stiffeners both ends of which were welded to upper and lower flanges. A girder in which only one end of stiffener is welded to tension flange was also tested as a supplement. Both hybrid girders and homogeneous girders made entirely of C-class steel were tested. Obtained results are that the fatigue strength of these girders are inferior than that of regular girders in which stiffener is welded at compression flange only, and that there are no difference in fatigue strength between these two types of girders tested and fatigue strength of homogeneous girders is a bit superior than that of hybrid girders. J.Janss has reported this in lieu of Plumier.

Y.Maeda reported an additional study on type 2 cracks in hybrid girders which supplements his previous paper presented in Preliminary Report. He checked the effect of finishing of weld toes,and showed that fatigue strength will increase about 1 kg/mm^2 by this finishing. However this effect will be covered up by other fluctuating factors such as residual stress,quality of weldment and misalignment of loading system.

Also as a supplement of his investigation presented in the Preliminary Report, T.Yamasaki discussed on the possibility of estimating fatigue lives by means of fracture mechanics approach. He showed that fatigue lives can be predicted by using material constants obtained from a simple test,and thus the fracture mechanics approach is useful for fatigue problem also,if the size of initial crack could be estimated in advance.

The COD criterion is widely used in the field of non-linear fracture mechanics However,when the yield region is spreaded widely enough,the physical meaning of COD theory becomes not so clear compared with the concept of J_{1c} fracture criterion. Furthermore,since the J_{1c} value is rather insensitive to the scale effect,one can determine the J_{1c} value using the smaller test specimens. H.Aoki had evaluated J_{1c} values for B and C-class steels,and showed that J_{1c} value of C-class steel is about 2/3 of that of B-class steel. He also pointed out that critical J-value will decrease with the increase of multi-axiality of the stress field.

Theme Vb. First discussion on theme Vb "Design Problems" was contributed by J.Lindner. He discussed on the lateral buckling strength of beams with mono-symmetric cross sections. It is well known that a mono-symmetric cross section of which the upper flange is larger than the lower flange is more advantageous than a doubly symmetric section of equal sectional area as far as elastic bifurcation is concerned. In plastic region,however,he pointed out that the buckling strength of a beam having mono-symmetric cross section will become lower than that having doubly symmetric cross section,and the merit of high-strength steel becomes very small.

P.Dubas talked about the utilization of high-strength steels in the design of composite girder highway bridges in Switzerland refering to the Veveyse bridge and others designed by himself. High strength steel currently used in Switzerland is almost limited to B-class steel. He remarked that though the weight saving and the reduction of material cost expected from the use of high-strength steel is not substantial, some merit can be obtained by performing a good design. A merit will be brought by using high-strength steel at the end portions of each span of a continuous girder where negative moment and shear force are very high. Sectional area at this portion will decrease by this selection and thus the almost uniform cross section will be obtained throughout the span which makes the fabrication very simple. Since the shrinkage of concrete is restrained by shear connectors,tensile stress will arise in the concrete slab. This tensile stress will be reduced by the use of high-strength steel since the sectional area and thus the rigidity of the steel beam is reduced. This is another advantage. He also encouraged the development of the weathering high-strength steel which will offer a merit with respect to the maintenance.

Theme Vc. In theme Vc "Fabrication and Election Problems", a new type of steel orthotropic bridge deck was introduced by M.P.Petrangeli. The upper plane sheet and corrugated metal deck were connected by means of high strength bolts. This fabrication method was adopted by considering the fact that the welding becomes very difficult and expensive when these decks are made of high-strength steel. The structural performance of this deck was investigated by model tests. Elastic behavior,ultimate strength under static loading and fatigue strength were investigated to obtain the satisfactory results.

As a supplement to his contribution to the Preliminary Report,M.Sasado discussed on the welding procedure of high-strength steels used in the construction of Osaka-port bridge. C-class steels up to 75mm in thickness were used in this bridge. The condition of welding,welding methods and quality controll adopted in this construction to avoid the possible cracking and embrittlement at welded joints were reported.

Free Discussion

Nine topics were contributed in the form of free discussion; they are three for theme Va,five for theme Vb and one for theme Vc.

Theme Va. As the results of additional tests on composite beams with formed steel deck undertaken after the publication of their paper in the Preliminary Report, I.M.Viest and J.W.Fisher proposed some modifications of eq.(2) and eq.(4) presented in the Preliminary Report as follows;

$$Q_{rib} = \frac{0.85}{\sqrt{n}} \left(\frac{H-h}{h}\right)\left(\frac{w}{h}\right) Q_{sol.} \leq Q_{sol.} \tag{2a}$$

where n=number of shear connectors placed in a rib.

$$I_{eff.} = I_s + \sqrt{\frac{V'_h}{V_h}} \left(I_{tr} - I_s \right) \tag{4a}$$

O.Jungbluth conducted a series of load carrying tests on portal frames made of various grades of steel,and demonstrated that the simple plastic theory may be applicable even for the rigid frame made of C-class high-strength steel (σ_y=685 N/mm^2).

A.C.Wallace discussed on the structural behavior of connection details of the tied bowstring arch bridge made of high-strength steel refering to an actual example.

Theme Vb. N.Streletzky talked about the application of high-strength steels to building and bridge structures in UdSSR. High-strength steels newly developed in UdSSR are 16Г2АФ(σ_y=440 N/mm^2, C'-class) and 14X2ГМР(σ_y=590 N/mm^2,C-class). Brief comments on the allowable stress and the method of analysis were also given.

The effect of exposure on corrosion of weathering high-strength steel was discussed by W.I.J.Price. He examined the difference between the formation of the protective coating achieved in open exposure and that obtained in a sheltered environment which is the case of composite bridge where the concrete deck shelters the steel beam from direct rain and sun. He demonstrated that the sheltered corrosion rate is higher for marine and saline situations,and also pointed out that severe pitting observed in these environments will cause the adverse effect against fatigue and brittle fracture.

W.Hoyer evaluated the limit of adaptability of weathering high-strength steel for various environmental and service conditions based on a extensive research work.

The reduced modulus of a stayed cable was discussed in both the Introductory Report Vb and the Preliminary Report by Hajdin both of which are based on the formula proposed by Ernst in 1965. M.Ito derived a revised formula which is theoretically more reasonable. It was revealed,however,that Ernst's formula could give practically satisfactory results except for the case where a very long cable is subject to relatively low tensile stress.

K.Horikawa calculated the stress intensity factor which may arise in a welded joint of C-class steel(HW80) containing a possible crack which might be overlooked through the regular nondestructive inspection,and pointed out that the critical toughness of such a joint material must be larger than that calculated value.

Theme Vc. As one of the means to obtain column-to-beam rigid connections,high strength bolted T-stub flange-to-column connections are widely used. K.Sato talked about the utilization of high-strength cast steel T-stubs for this connection system. When beam ends are subjected to very large bending moment due to earthquake or wind force,these attachments can be utilized effectively.

Appendix.

The list of high-strength steels attached at the end of theme Va. of the Introductory Report should be supplemented by the following two high-strength steels. One is of United States,and this steel has been already introduced at the beginning of this session by the author. The other is of F.R.G.(West Germany) which is quite similar to A514 steel of United States,and to HW 70 steel of Japan in quality. This steel was used by J.Lindner and by A.Plumier in their research and reported in this prepared discussion. With respect to 16Г2Аф and 14Х2ГМР steels of UdSSR refered by Streletzky,detailed information is not available.

New High-strength Steels to be Added to Appendix of Introductory Report

Country	Standards	Designation	Min.Yield Stress N/mm^2	Tens. Strength N/mm^2	Class	Y
U.S.A	ASTM	A572,Gr 65	448	552	C'	0.812
F.R.G (West Germany)	DASt. Ri.011	St.E 70	686	785 ~ 932	C	0.875

$$Y = \frac{\text{Yield Stress}}{\text{Tensile strength}} = \text{Yield ratio of material(maximum)}$$