XXV Konferencja Naukowo-Techniczna, Międzyzdroje 24-27 maja 2011
awarie budowlane 2011

DAISUKE YAMAOKA, *yamaoka_dai_ssd@yahoo.co.jp*
MASAHIRO SAKANO, *peg03032@ipcku.kansai-u.ac.jp*
Kansai University, Osaka, Japan
YOSHIHIRO NATSUAKI
Japan Bridge Association, Osaka, Japan
SNUNAO NONAKA, YOSHIMASA NAKAGAWA & KASUMI NAKAMURA
Kinki Regional Development Bureau, Ministry of Land, Infrastructure and Transport, Osaka, Japan

EFFECT OF REINFORCING METHOD AGAINST FATIGUE CRACKING OF ORTHOTROPIC STEEL DECK WITH BULB RIBS

SKUTECZNOŚĆ ZASTOSOWANEJ METODY WZMACNIANIA PRZECIW PĘKANIU ZMĘCZENIOWEMU ORTOTROPOWYCH STALOWYCH PŁYT POMOSTOWYCH Z ŻEBRAMI ŁEBKOWYMI

Abstract Recently, thousands of fatigue cracks have been detected in orthotropic steel decks in Japan. Of these, fatigue cracking in welded joints between bulb ribs and transverse ribs is the most frequent type found in the Kansai area. In this study, we tried to grasp fatigue behaviour in the welded joints between the bulb rib and the transverse rib through fatigue tests of the orthotropic steel deck specimen with the same structural detail as a bridge itself. Fatigue cracks were initiated at the weld toe of the upper part of the slit and propagated through the weldment into the deck plate. We confirmed that the fatigue crack detection life of the welded joint between the bulb rib and the transverse rib was improved more than eight times by applying angle steel reinforcement.

Streszczenie W ostatnim okresie wykryto tysiące pęknięć zmęczeniowych w ortotropowych płytach pomostowych w Japonii. Spośród nich najczęściej znajdowanymi w rejonie Kansai były pęknięcia zmęczeniowe w spoinach łączących żebra łebkowe z żebrami poprzecznymi. W prezentowanym studium podjęto próbę uchwycenia zachowania zmęczeniowego spoin łączących żebra łebkowe z żebrami poprzecznymi za pomocą badań zmęczeniowych próbek stalowych pomostów ortotropowych o takich samych szczegółach konstrukcyjnych jak w mostach. Pęknięcia zmęczeniowe były inicjowane na brzegu spoiny w górnej części szczeliny i propagowały przez spoinę do płyty pomostu. Wykazano, że oczekiwany okres pojawiania się pęknięć zmęczeniowych w spoinach łączących żebra łebkowe z żebrami poprzecznymi został zwiększony ponad osiem razy dzieki zastosowaniu wzmocnienia ze stalowych kątowników.

1. Introducion

Recently, thousands of fatigue cracks have been detected in orthotropic steel decks in Japan. Of these, fatigue cracking in welded joints between bulb ribs and transverse ribs is the most frequent type found in the Kansai area (Committee of JSCE on steel structures 2007). Fatigue cracks are classified into 4 types, as shown in Figure 1 (Tabata et al. 2007). At the intersection of the bulb rib and the transverse rib, the crack that propagates from the weldment of the lower part of the slit into the transverse rib web is d-type, and the other that propagates from the weldment of the upper part of slit into the deck plate is a-type. These cracks may propagate into the deck plate and have a bad influence on traffic.

It is important, therefore to grasp such fatigue cracking behaviour. An effective method against the fatigue cracks is needed. In this study, we tried to grasp fatigue cracking behaviour in the welded joints between the bulb rib and the transverse rib by means of fatigue tests of the orthotropic steel deck specimen which is the same size and has the same structural detail as the actual bridge. Also, we verified the effect of the proposed reinforcing method using angle steels.

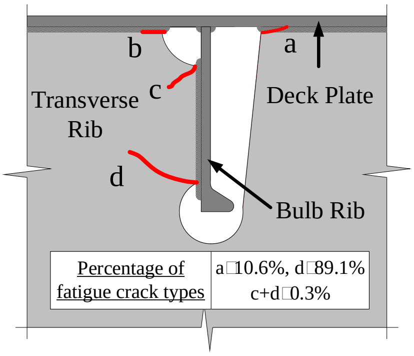


Figure 1. Fatigue cracks in welded joint between bulb rib and transverse rib in the Hanshin Expressway

2. Experimental method

2.1 Specimen

Figure 2 shows configurations and dimensions of the specimen. In this study, the object is A bridge consisting of orthotropic steel deck, bulb ribs and transverse ribs. We produced a specimen which has the same structural detail as the bridge. It has 8 bulb ribs and a transverse rib, and is 1m long, 4m wide and 1m high.

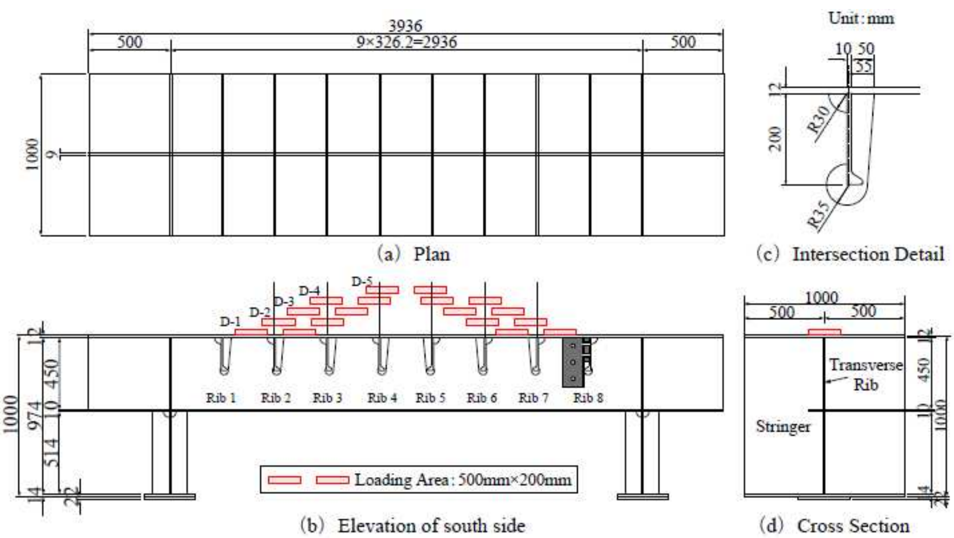
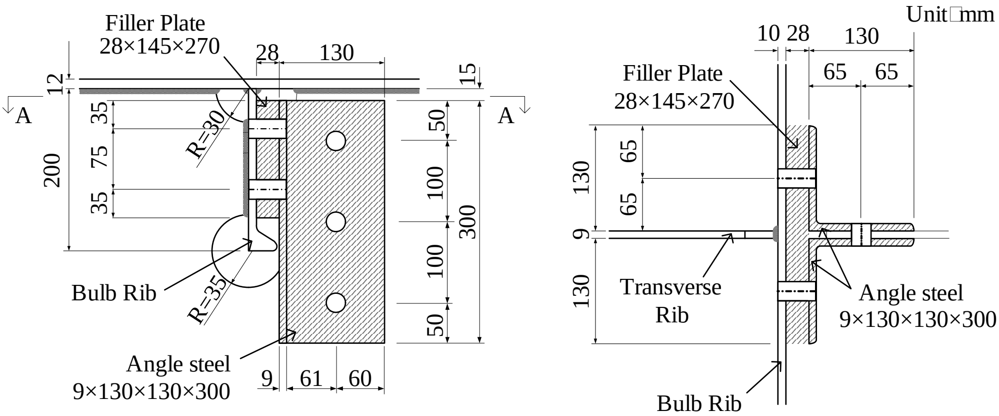


Figure 2. Configurations and dimensions of the specimen

2.2 Reinforcing method

In order to reduce shearing deformation of the slit at the intersection of bulb rib and transverse rib, angle steels (9×130×130 mm) as reinforcing members are applied to the face and back of the transverse rib, and to the slit side of the bulb rib, using high-tensile bolts. Figure 3 shows the intersection of the bulb rib and the transverse rib after applying angle steels (Tabata et al. 2007).



(a) Elevation (b) A-A Plan

Figure 3. Intersection of bulb rib and transverse rib with angle steel reinforcements

2.3 Static loading test method

Figure 2 shows the 5 loading locations of the static loading test. Loading locations from D-1 to D-4 simulate two sets of double tires with 4 rubber plates (40×200×200 mm). Loading location D-5 simulates a set of double tires with 2 rubber plates. The load is 200kN. Photo 1 shows the test set-up. Figure 4 shows the locations of strain gages. By using strain gages, we measured local stresses at the slits of the intersection of the bulb ribs and the transverse rib.

Photo 1. Loading test set-up

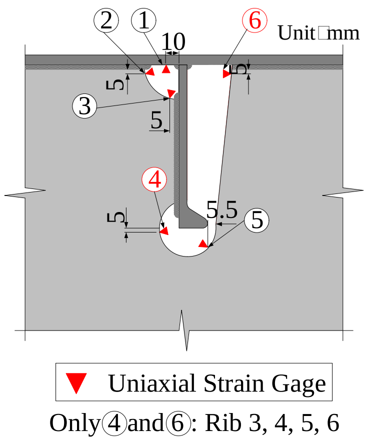


Figure 4. Locations of strain gages

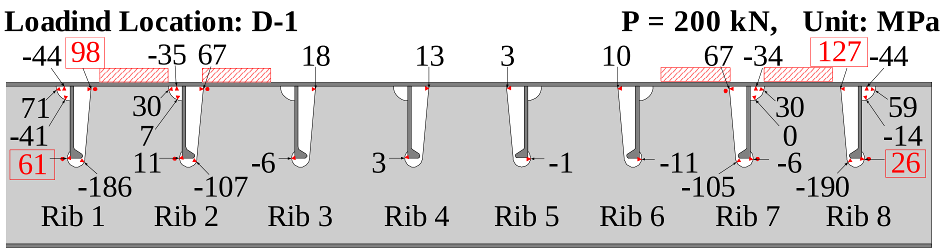
2.4 Fatigue test method

The loading pattern of the fatigue test is D-1 (see Figure 2). In the static loading test, we found that the stress of Rib 8 was higher than that of Rib 1. Therefore, we reinforced the intersection of Rib 8 and the transverse rib before the fatigue test. And, we tried to grasp the behaviour of fatigue cracking at Rib 1, and to verify the effect of reinforcing the intersection of Rib 8 and the transverse rib. The load range was 280kN and the loading rate was 3Hz.

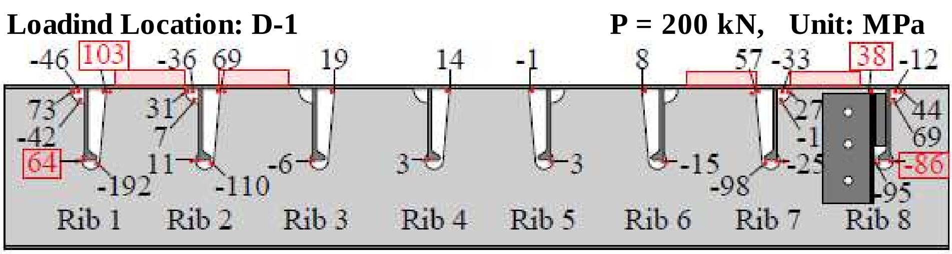
3. Experimental results

3.1 Static loading test results

Figure 5 shows the results of the static loading test, both with and without reinforcing. As shown in Figure 6, both stresses at both the upper part(⑥) and lower part(④) of the Rib 1 and Rib 8 slits were tensile stresses, and the stress at the upper part(⑥) of the slit is higher than that at its lower part(④). The stress at the upper part(⑥) of the Rib 8 slit was higher than that for Rib 1. Therefore, we reinforced the intersection of Rib 8. After applying angle steel reinforcement, the stress at the upper part(⑥) of the Rib 8 slit decreased to approximately 30% (from 127 MPa to 38 MPa), and the stress of the lower part(④) of the Rib 8 slit changed from a 26 MPa tensile stress to a 86 MPa compressive stress. The stress at the upper and lower parts of the Rib 1 slit did not change.



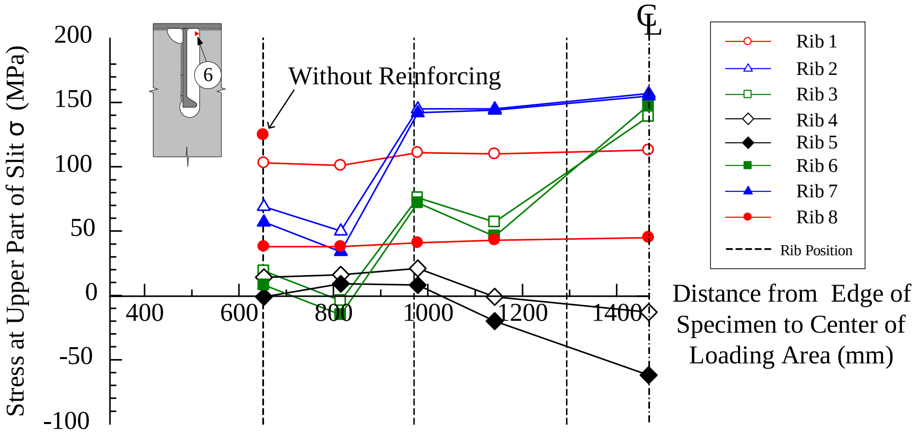
(a) Without reinforcing



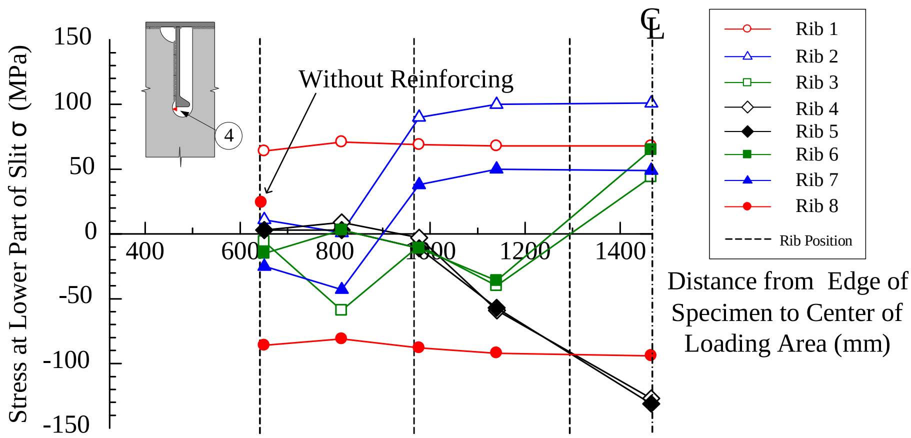
(b) With reinforcing

Figure 5. Result of static loading test

Figure 6 shows stress at the intersection of the bulb rib and the transverse rib. The stresses at the slit of Rib 1 and Rib 8 were almost constant. As loading the slit side, the tensile stresses at Rib 2, Rib 3, Rib 6 and Rib 7 slits increased. On Rib 4 and Rib 5, however, the compressive stresses of Rib4 and Rib5 slits increased. Also, we found that the tensile stress at the upper part of the slit is higher than that at its lower part.



(a) Upper part of slit



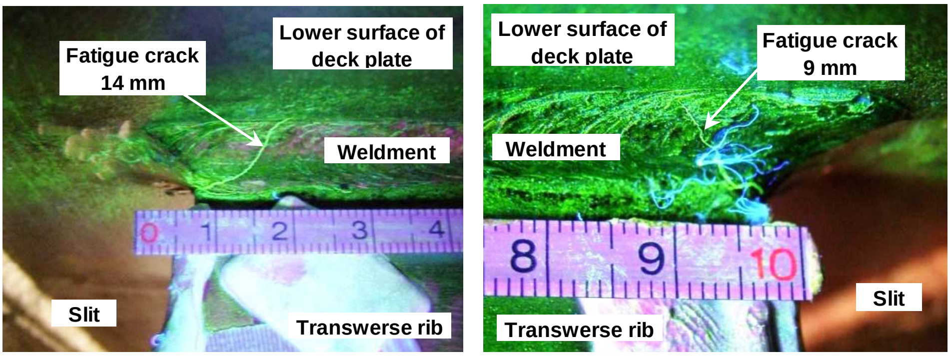
(b) Lower part of slit

Figure 6. Stress at intersection of bulb rib and transverse rib (P=200kN)

3.2 Fatigue test results

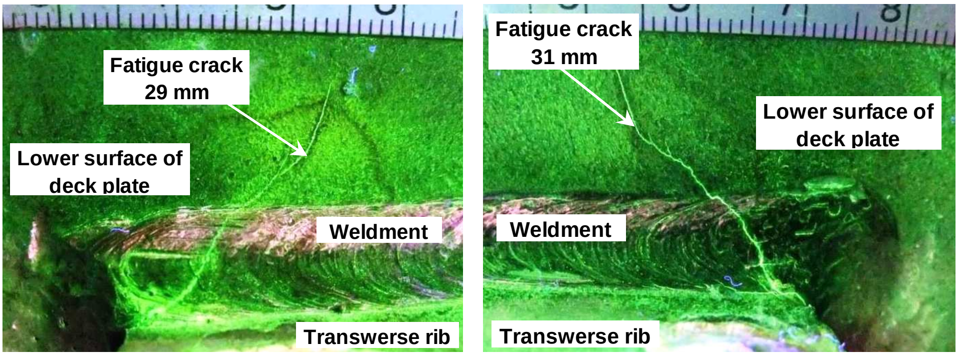
A fatigue crack of 14 mm length was detected on the weldment of the upper part of the Rib 1 slit after 0.7 Mcycles loading. Photo 2 shows the fatigue crack at this upper part of the Rib 1 slit after 0.7 Mcycles loading. It was initiated at the weld toe of the upper part of the Rib 1 slit, and propagated from the weldment into the deck plate. After 5.4 Mcycles loading, it propagated to about 30 mm length, as shown in Photo 3.

No fatigue cracking was observed at the intersection of Rib 8 and the transverse rib, which had applied angle steel reinforcement, after 5.4 Mcycles loading. Therefore, it was confirmed that the fatigue crack detection life of the welded joint between the bulb rib and the transverse rib had been improved more than eight times by applying angle steel reinforcement. We then removed the angle steels applied to the intersection of Rib 8 and the transverse rib. Without the angle steels, a fatigue crack of 2 mm length was observed on the weldment of the upper part of the Rib 8 slit after 0.1 Mcycles loading. Photo 4 shows the fatigue crack at the upper part of the Rib 8 slit after 0.1 Mcycles loading without angle steels.



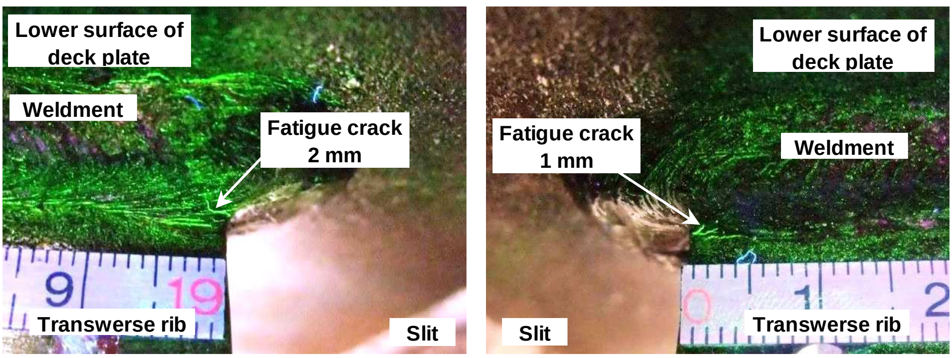
(a) South side (b) North side

Photo 2. Fatigue crack at upper part of Rib 1 slit after 0.7 Mcycles loading



(a) South side (b) North side

Photo 3. Fatigue crack at upper part of Rib 1 slit after 5.4 Mcycles loading



(a) South side (b) North side

Photo 4. Fatigue crack at upper part of Rib 8 slit after 0.1 Mcycles loading without angle steels

Figure 7 shows the relationship between the fatigue crack length and the number of loading cycles. The vertical axis represents the fatigue crack length, while the horizontal axis represents the number of loading cycles. Fatigue cracks of Rib 1 and Rib 8 continued to propagate slowly after propagating into the deck plate. After 11.1 Mcycles loading, the fatigue cracks of Rib 1 and Rib 8 propagated to about 40 mm and 25 mm length, respectively, but they did not propagate to the upper surface of the deck plate. Photo 5 and 6 show the fatigue cracks at the upper part of the slit after 11.1 Mcycles loading. Fatigue cracks were not observed in other welded joints between the bulb ribs and the transverse rib.

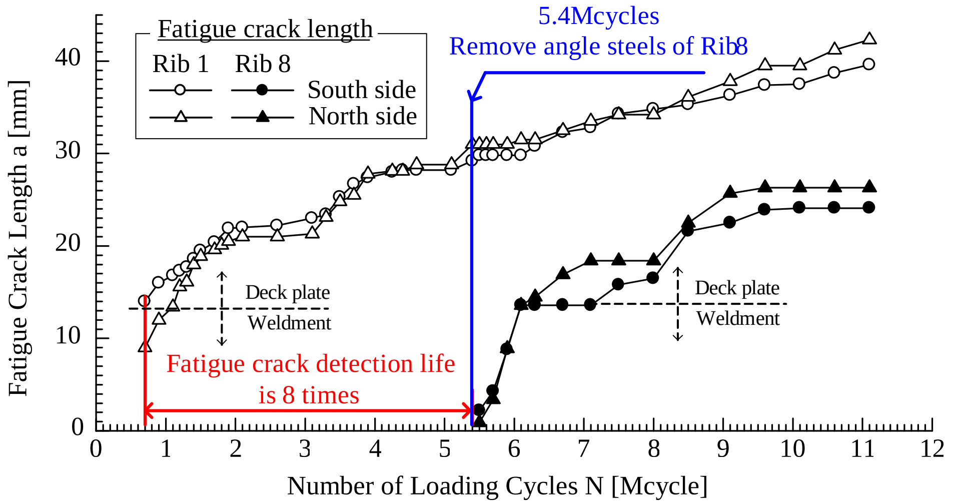
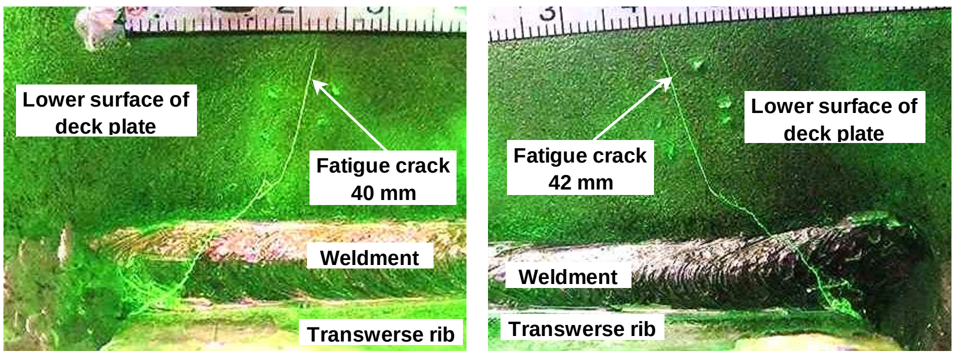
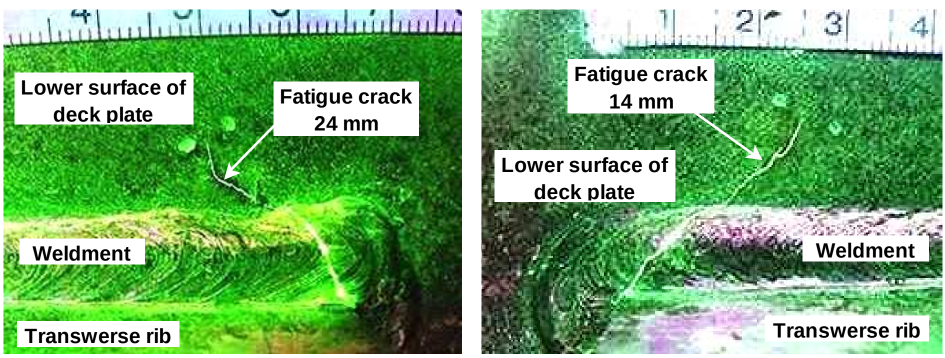


Figure 7. Relationship between fatigue crack length and the number of loading cycles



(a) South side (b) North side

Photo 5. Fatigue Cracks at Upper Part of Rib 1 Slit after 11.1 Mcycles loading



(a) South side (b) North side

Photo 6. Fatigue Cracks at Upper Part of Rib 8 Slit after 11.1 Mcycles loading

4. Conclusions

4.1 Static loading test results

1. In the case of loading the slit side of the bulb rib, the tensile stresses occurred at the upper and lower parts of the slit of the intersection of the bulb rib and the transverse rib.
2. By applying angle steel reinforcement to the slit side of the bulb rib, the stress at the upper part of the slit decreased to approximately 30% (from 127 MPa to 38 MPa), and the stress at the lower part of the slit changed from a tensile stress(26 MPa) to a compressive stress (-86 MPa).

4.2 Fatigue test results

1. Fatigue cracks were initiated at the weld toe of the upper part of the slit and propagated through the weldment into the deck plate. After propagating into the deck plate, fatigue cracks continued to propagate slowly.
2. It was confirmed that the fatigue crack detection life of the welded joint between the bulb rib and the transverse rib was improved more than eight times by applying angle steel reinforcement.

References

1. Committee of JSCE on steel structures.: The report of investigation and study subcommittee on thick plate welded joints: 155-157, 2007, (in Japanese).
2. Tabata S., Yamamura K., Hamada N., Sakota H., Sakai Y. and Sakano M.: Experimental study on the reinforcing method against fatigue damage at the welded joint between bulb rib and transverse rib in orthotropic steel decks, Proceedings of the 62^{nd} Annual Meeting of JSCE, I-003, 2007, (in Japanese).