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Static and Fatigue Bending Strength Analysis of Flash Butt Welding Joint for Light Rail Transportation

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***Abstract*—Light Rail transportation (LRT) in Indonesia is built first time in 2016. Rail is one of the important components for track at LRT. One of joint of rail for LRT is uses flash butt welding joint. The requirement of flash butt welding joint is based on BS EN 14587-2:2009. Requirements include static and fatigue bending test of welding joint. In this paper present a strength analysis of flash butt welding joint by testing in laboratory. Static bending test done for 3 type of joint rail with 5 sample for each type, which are joint of rail type of R260 – R260, joint rail type R260 – R350HT and joint rail type of R350HT – R350HT. Fatigue bending test done for type of R260 – R260 for 3 samples. Results of static and fatigue bending test are the joint rail meet the requirement based on BS EN 14587-2:2009 and this joint can be used for LRT track structures.**

***Index Terms*— LRT, track, flash butt welding joint, static test, fatigue test..**

I. Introduction

Mass transportation in Indonesia keeps growing, one of those is light rail transportation. In June 22th 2016 has been done a ground breaking as the beginning of Jabodebek LRT construction at Jakarta. The first stage construction connects kelapa Gading – Velodrone along 6 km [1]. Palembang LRT is built based on Perpres Nr 116 2015 dated October 20th 2015 concerning the acceleration of implementation of LRT in South Sumatera. LRT Palembang connects Sultan Mahmud Badarudin's Airport (SMB) II to Jakabaring Sports City (JSC). Jabodebek LRT built based on Perpres Nr 98 2015, the first construction held in September 9th, 2015. The first stage construction connects Jakarta- Bogor-Depok - Bekasi (Jabodebek) [2].

In this paper discuss about static and fatigue bending test of flash butt welding joint of rail. Test method and the requirement are based on BS EN 14587-2 : 2009. This test is used to control the quality of rail products for LRT project in Indonesia for safety concern. The rail use for LRT projects are rail with grade type of R260 and grade type of R350HT, each grade type of rail use rail profile of 54E1.

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The aim of this experimental testing are in order to find out the ultimate bending strength for static bending test and to find out a fatigue bending strength for fatigue test. Static bending test method based on clause 5.3.5 (Annex A) of BS EN 14587-2 : 2009 and fatigue test method based on clause C.4.4 (Annex C) of BS EN 14587-2 : 2009

In international, research of flash butt welding joint of rail is more developed. Some case study of fractures analysis of U71 Mn rail with flash butt welding joint is presented [3, 4]. This research has done to investigate the failure of flash butt welding joint structures. Study of fatigue of flash butt welding joint also has done in China [5, 6] and Japan [7].

II. Experiment Results

2.1 Slow Bend Test

Slow bend test or static bending test of flash butt welding joint of rail is discussed in this experiment. This test use a rail profile of R54E1 with grade type of R260 and grade type of R350HT (Heat Hardened). The test method and requirement is based on BS EN 14587-2 : 2009 [5]. There are 3 type of joint rail at this test, which are joint type of R260 – R260, joint type of R260 – R350HT and joint type of R350HT – R350HT with 5 samples for each type of joint. The picture of sample test is shown at Fig. 1 bellows [6].

Minimum bending test requirement for joint type of R260 and R350HT is 1330 kN with minimum deflection of 25 mm. In this test use a hydraulic machine with maximum capacity of 1260 kN (2 x 630 kN). The requirement of load for span of 1 m is 1330 kN, there for the span can be increase more than 1 m, but in this experiment the bending test done by use of the maximum capacity of the hydraulic machine with span of 1 m, because the bending strength of 1260 kN of flash butt welding joint is enough for LRT requirement in Indonesia with axle load of 12 ton.

Scheme of static bending test is shown at Fig.2 and picture of bending test is shown at Fig. 3.

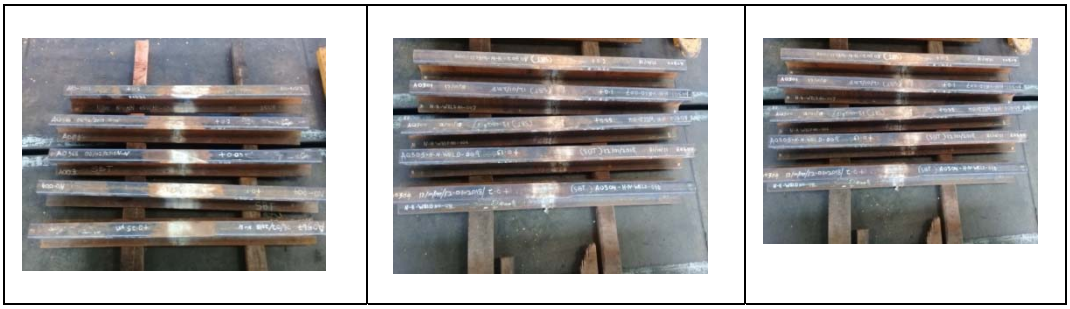

Fig. 1. Picture of flash butt welding joint sample.

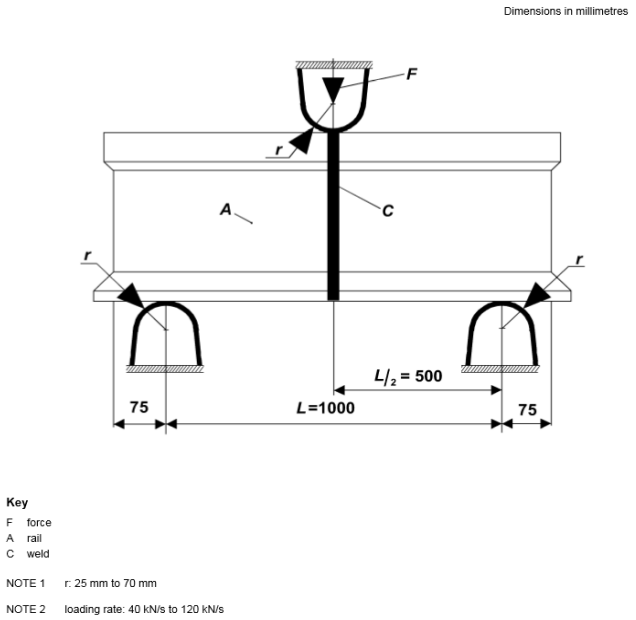

Fig. 2. Test Scheme of static bending test of flash butt welding joint of rail.

Fig. 3. Picture of test set up for static bending test

Test results of static bending test is presented at Table I, Table II and Table III.

TABLE I
TEST RESULTS JOINT RAIL R260-R260

Specimen	Load (kN)	Deflection (mm)	Remark
Specimen 1	1260	23.00	Not break
Specimen 2	1260	25.00	Not break
Specimen 3	1260	30.00	Not break
Specimen 4	1260	22.50	Not break
Specimen 5	1260	24.00	Not break
Average	1260	24.90	

TABLE II
TEST RESULTS JOINT RAIL R260-R350HT

Specimen	Load (kN)	Deflection (mm)	Remark
Specimen 1	1260	21.70	Not break
Specimen 2	1260	22.00	Not break
Specimen 3	1260	18.70	Not break
Specimen 4	1260	22.50	Not break
Specimen 5	1260	19.70	Not break
Average	1260	20.92	

TABLE III
TEST RESULTS JOINT RAIL R350HT-R260350HT

Specimen	Load (kN)	Deflection (mm)	Remark
Specimen 1	1241.0	22.00	Not break
Specimen 2	1260.0	21.50	Not break
Specimen 3	1270.6	16.75	Not break
Specimen 4	1260.0	19.50	Not break
Specimen 5	1272.0	20.00	Not break
Average	1260.0	19.95	

2.1 Fatigue Test

Test method and requirement of fatigue test is based on BS EN 14587-2 : 2009 clause C.4.4. Specimen placed to horizontal position with span of 1000 mm. Welding joint position at middle span. Maximum stresses as clause C.4.4 is 190 MPa. In this experiment use 3 samples for testing. Test scheme of fatigue test is shown at Fig. 4.

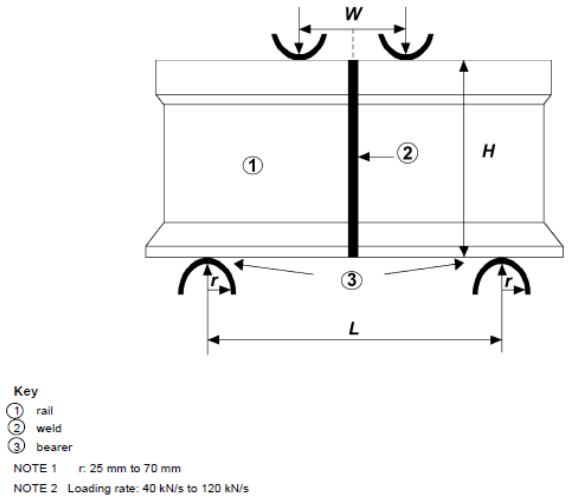

Fig. 4. Test scheme of fatigue test of flash butt welding joint of rail

In this test use the inner span (w) of 150 mm and outer span (L) of 1000 mm. To conform to the maximum stresses of 190 MPa, load calculation can use of bending formulas as describe at Equation 1. Experiment of fatigue test of flash butt welding joint of rail also has done in Turkey, the test uses inner span of 240 mm [5].

$$M = \frac{\sigma \times I}{c} \quad (1)$$

Where σ is maximum stress (MPa), M is moment (N.mm), I is moment inertia (mm^4), and c is neutral axis distance (mm). Technical data of rail profile of R54E1 are moment inertia of 233790 mm^4, c of 75.3 mm. With formulas at equation, 1 can calculate the maximum load for fatigue test is 278.23 kN and minimum stress of fatigue test based on BS EN 14587-2 : 2009 is 10% of maximum stresses, which is 27.82 kN. Test scheme for fatigue test is shown at Fig. 5.

As the maximum load of fatigue test is 278.23 kN, at this experiment use the hydraulic machine of PL 400 kN with maximum capacity of 400 kN. Picture of test set up of fatigue test is shown at Fig. 6.

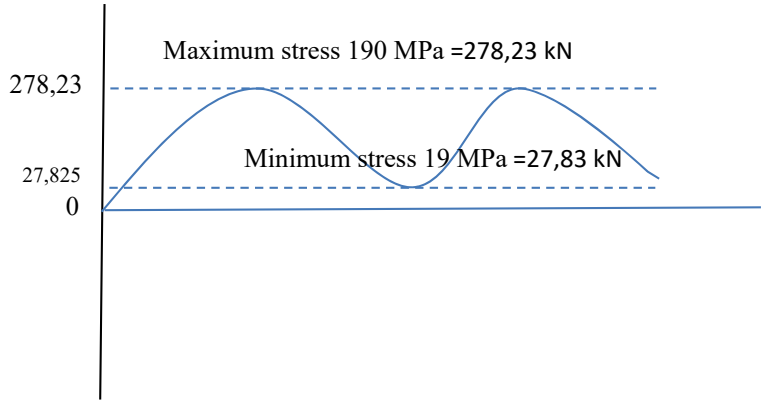

Fig. 5. Loading scheme of fatigue test

Fig. 6. Picture of test set up of fatigue test

Test result of fatigue test is shown at Table IV.

TABLE IV
TEST RESULTS OF FATIGUE TEST WITH JOINT TYPE OF R260-R260

Specimen	Maximum Fatigue load (kN)	Minimum fatigue load (kN)	Remark
Specimen 1	278.23	27.82	Not break
Specimen 2	278.23	27.82	Not break
Specimen 3	278.23	27.82	Not break

Picture of specimen after fatigue test is shown at Fig. 7.

Fig. 7. Picture of specimen with joint type of R260-R260 after fatigue test

III. Analysis and Discussion

Specimen is not break after static bending test. Result of average static bending test is shown at Table V.

TABLE V
AVERAGE STATIC BENDING TEST

Specimen	Load (kN)	Deflection (mm)	Remark
R260-R260	1260.0	24.90	Not break
R260-R350HT	1260.0	20.92	Not break
R350HT-R350HT	1260.0	19.95	Not break

Specimen (R260 – R260) condition after static bending test is shown at Fig. 8. Condition of specimen after fatigue test for other joint type is typically, there is no breaking specimen for all of specimen.

Fig. 8. Picture of specimen with joint type R260-R260 after static bending test

Based on Fig. 8, it seems that specimen of joint type of R260 – R260 has a permanent deflection, the rail is bent. The axle load of LRT is 120 kN and testing result is 1260 kN, there for specimen with flash butt welding joint able to support load for LRT train.

Track of LRT construction is built right now, Jabodebek LRT use rail type of R54E1 with welding joint type of aluminothermic welding joint and flash butt welding joint. Quality requirement and specification of flash butt welding joint use BS EN 14587-2 : 2009. The technical requirement is flash butt welding joint must stand with fatigue load of 5 million cycles. Fatigue load testing is done by maximum stress of 190 MPa (2728,23 kN) and minimum stress of 19 MPa (27,82 kN). Bending static strength of rail is up to 1260 kN. Maximum stress of fatigue test is 22% of static bending strength. The axle load of LRT track is 120 kN (12 ton), there for the fatigue test load has passed the axle load for LRT in Indonesia.

Fatigue test use scheme of four point bending. Inner span (w) is 150 mm and outer span of 1000 mm. This Fatigue test of flash butt welding joint of rail is the first time in Indonesia [6]. Fatigue test done with 3 samples and all of them able to support fatigue load until 5 million cycles.

IV. Conclusions

From the result and analysis of static and fatigue bending test of flash butt welding joint of rail, it can be concluded that Specimen of flash butt welding joint of rail meet the requirement for LRT with the axle load of 12 ton.

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