DAISUKE YAMAOKA, *yamaoka_dai_ssd@yahoo.co.jp*
Kansai University, Osaka, Japan
KAZUYA BESSHO, *bessho_ssd@yahoo.co.jp*
YOSHIHIKO TAKADA
Hanshin Expressway Management Technology Center, Osaka, Japan
Prof. MASAHIRO SAKANO, *peg03032@ipcku.kansai-u.ac.jp*
Kansai University, Osaka, Japan

FATIGUE TEST OF AN URBAN EXPRESSWAY STEEL GIRDER BRIDGE CONSTRUCTED IN 1964

BADANIA ZMĘCZENIOWE STALOWEGO MOSTU BELKOWEGO, NA MIEJSKIEJ AUTOSTRADZIE, WYBUDOWANEGO W 1964 R

Abstract In Japan, infrastructure, including numerous highway and railway bridges, was intensively constructed during the rapid economic growth era from 1960's to 1970's. We are warned that those structures are now aged and may deteriorate in the near future. Since fatigue design had not been applied to highway bridges until 2002, there is a high possibility that fatigue cracking will occur frequently in the future. In this study, we try to grasp fatigue behavior and fatigue strength characteristics of the fatigue weak points in the actual bridge through fatigue tests of steel girders which had been used on an urban expressway for more than 40 years and removed in 2005. As the result, it was confirmed that the fatigue strength of web gusset welded joint with fillet satisfies JRA Fatigue Category E which is two-rank higher than that of web gusset joint without fillet.

Streszczenie W Japonii, infrastruktura bogata w mosty kolejowe i autostradowe była intensywnie rozbudowywana podczas gwałtownego wzrostu ekonomicznego przypadającego na lata 1960-1970. Pojawiają się ostrzeżenia, że te konstrukcje starzeją się i ich stan może się pogorszyć w najbliższej przyszłości. Ponieważ testy zmęczeniowe nie były stosowane do 2002 roku, istnieje duże prawdopodobieństwo, że uszkodzenia zmęczeniowe będą coraz częstsze w przyszłości. W pracy scharakteryzowano zachowanie i wytrzymałość najsłabszych punktów w rzeczywistym moście, przez testy zmęczeniowe stalowych belek, które były eksploatowane na miejskiej autostradzie przez ponad 40 lat i zostały usunięte w 2005 roku.

1. Introduction

In Japan, infrastructure, including numerous highway and railway bridges, was intensively constructed during the rapid economic growth era from 1960's to 1970's. We are warned that those structures are now aged and may deteriorate in the near future. Since fatigue design had not been applied to highway bridges until 2002[1], there is a high possibility that fatigue cracking will occur frequently in the future. In this study, we try to grasp fatigue behavior and fatigue strength characteristics of the fatigue weak points in the actual bridge through fatigue tests of steel girders which had been used on an urban expressway for more than 40 years and removed in 2005.

2. Bridge and girders

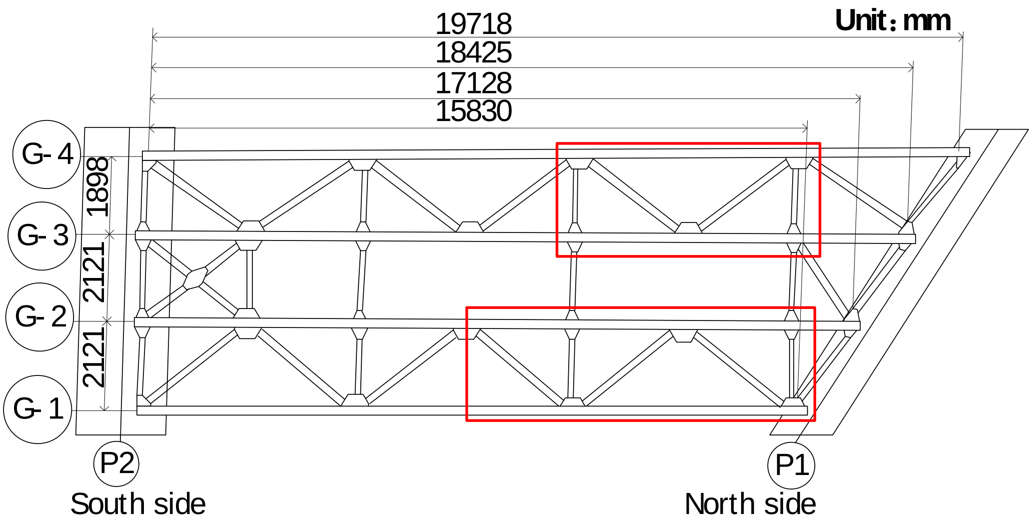

Fig. 1. Plan of Minato-machi Ramp Bridge

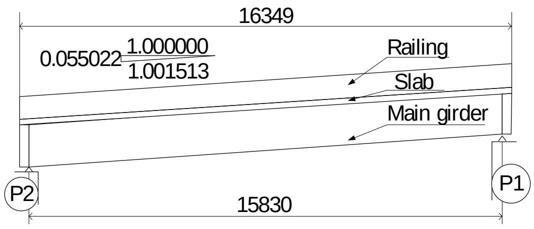

Fig. 2. Elevation of Minato-machi Ramp Bridge

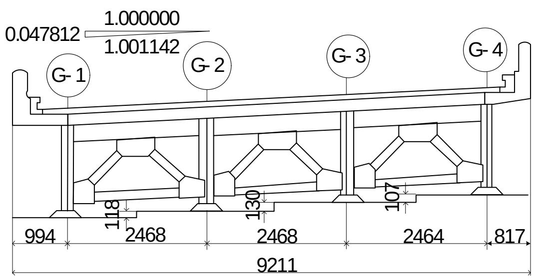

Fig. 3. Cross section of Minato-machi Ramp Bridge

The object of study is the Minato-machi Ramp Bridge, which was real urban expressway ramp girder bridge constructed in 1964, and removed in 2005. The bridge was a simply-supported composite main girder bridge. Girders have a web plate and a bottom flange with welded vertical stiffeners and gusset plates which connect cross frames and lateral bracings to main girders. Figs.1~3 shows the plan, elevation and cross section of the bridge. Test pieces were cut out from the red areas shown in Fig. 1.

3. Cracks inspection

3.1. Method

Before the fatigue tests, magnetic particle tests are conducted to detect the fatigue cracks which could have occurred under service loading. Toes of turn-round weldment are inspected in the welded joint which connects the gusset plate to the web of the main girder. The total number of inspected toes of turn-round weldment is 53 in 15 gusset plates. Fig.4 shows locations of gusset plates and inspected areas.

At first, to confirm the shape and length of paint cracks, the paint cracks are inspected. Next, the paint is removed by hammer. Finally, we tried to detect the fatigue cracks by magnetic particle test.

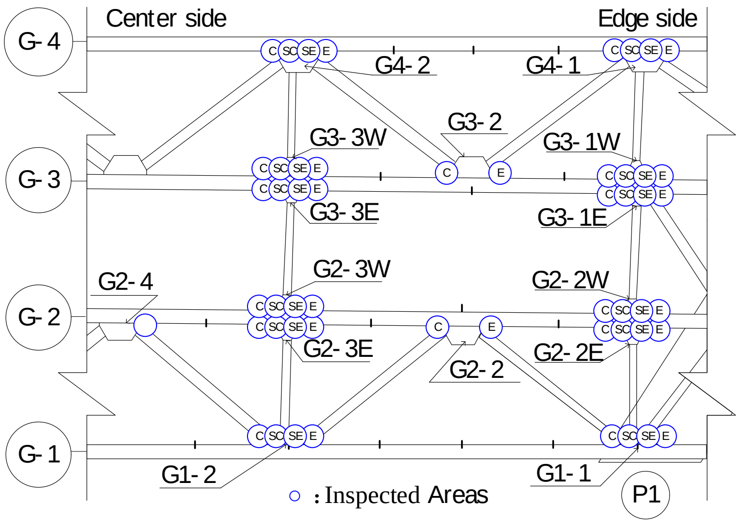

Fig. 4. Locations of gusset plates and inspected areas

3.2. Paint cracks inspection

Table 1. Result of paint cracks inspection

Gusset Plate	Inspected Area	Paint Crack Length (mm)	Note	Gusset Plate	Inspected Area	Paint Crack Length (mm)	Note
G1-1	C	12,7,7		G3-1E	C	33	
	SC	0			SC	0	
	E		Burned		E	0	
	SE		Deterioration		SE	0	
G1-2	C	83,65		G3-1W	C	0	
	SC	0			SC	0	
	E		Burned		E	0	
	SE	0			SE	3	
G2-1E	C	0		G3-2	C	13	
	SC	0			E	27	
	E	0		G3-3E	C	0	
	SE	0			SC	0	
G2-1W	C	5			E	0	
	SC	0			SE	0	
	E	0		G3-3W	C	0	
	SE	0			SC	17	
G2-2	C	13			E	0	
	E	12,9			SE	0	
G2-3E	C	23		G4-1	C	23	
	SC	0			SC	12	
	E	6			E		Deterioration
	SE	0			SE		Burned
G2-3W	C	0		G4-2	C	20,18	
	SC	0			SC	0	
	E	0			E	17,9	
	SE	0			SE	27	
G2-4		35,32					

Table 1 shows the result of the paint cracks inspection. Red and yellow areas show paint crack occurrence areas. There were 18 paint crack occurrence areas in the 53 inspected areas.

Paint cracks in the red areas are along the toes of turn-round weldment which are fatigue weak points. Paint cracks in the yellow areas are not along the toes of turn-round weldment.

In the 5 blue areas we could not judge the shape and length of the paint crack because of burning and deterioration.

3.3. Magnetic particle test

Fig. 5 shows the result of magnetic particle tests. MT signs that may indicate fatigue cracks were observed at 2 weldments among the 18 turn-round weldments with paint cracks. Several paint cracks were observed at the G1-2-C gusset plate.

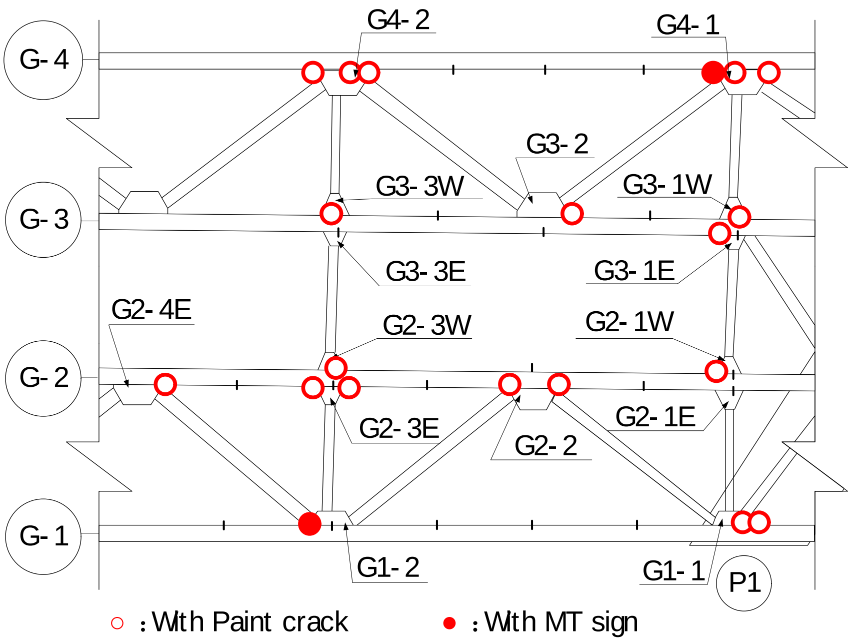

Fig. 5. Results of magnetic particle test

A MT signs of 8 mm and 1.3 mm length were observed under a 83 mm paint crack at the G1-2-C gusset plate. A MT sign of 4mm length was observed under a 23 mm paint crack at the G4-1-C gusset plate. Photos 1~4 shows paint cracks and MT signs in the G1-2-C and G4-1-C gusset plates.

There are no MT signs in the inspected areas that have no paint cracks, or that have paint cracks in places other than along the toes of turn-round weldment which are fatigue weak points.

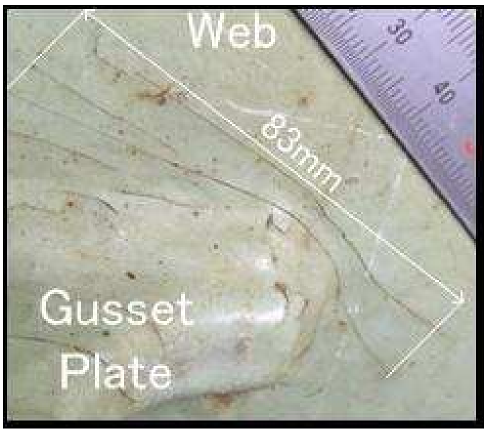

Photo 1. Paint cracks on G1-2-C

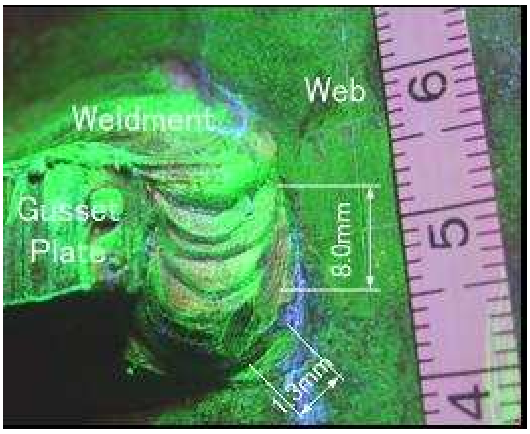

Photo 2. MT sign on G1-2-C (N=0cycle)

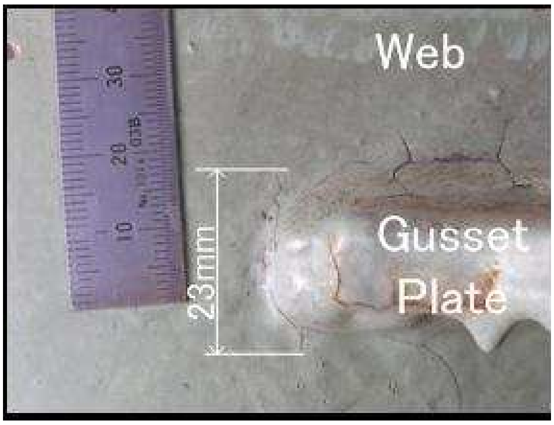

Photo 3. Paint crack on G4-1-C

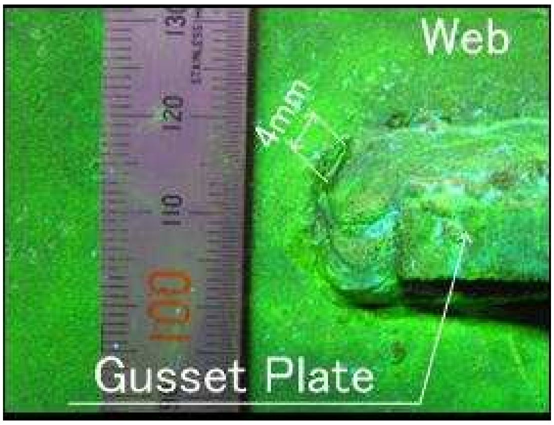

Photo 4. MT sign on G4-1-C

4. Experimental method

4.1. The configurations and dimensions of specimen

Fig. 6 shows the configurations and dimensions of G1 girder specimen. Due to the capacity of the testing machine, the depth of girder was reduced by cutting off the upper part of the girder and welded a new top flange. Photo 5 shows the gusset plate in G1 girder specimen. The gusset plate has fillets at its both ends.

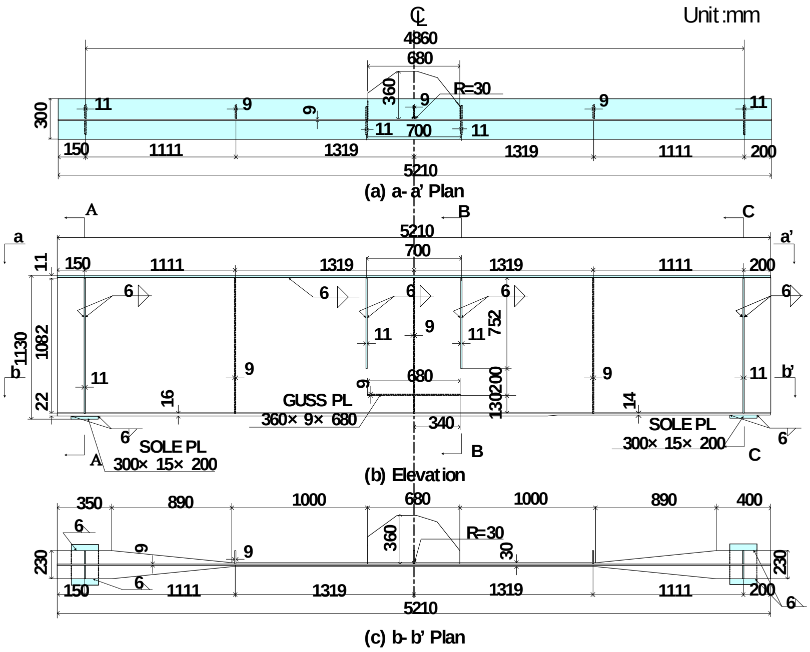

Fig. 6. Configurations and Dimensions of G1 Girder Specimen

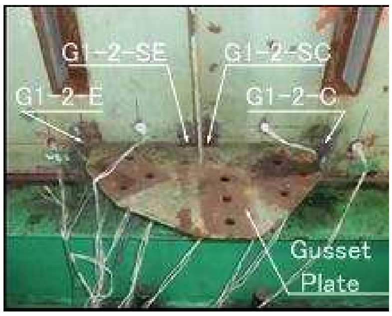

Photo 5. Configuration of Gusset Plate

4.2. Fatigue Test Method

Fatigue test was conducted in 4-point bending condition with a loading beam. Loading rate was 3 Hz. Fig. 7 shows fatigue loading history. After ΔP = 200 kN fatigue loading of

12.5 Mcycles, MT signs at the gusset plate end was propagated so little that. The load range (ΔP) was increased to 260 kN.

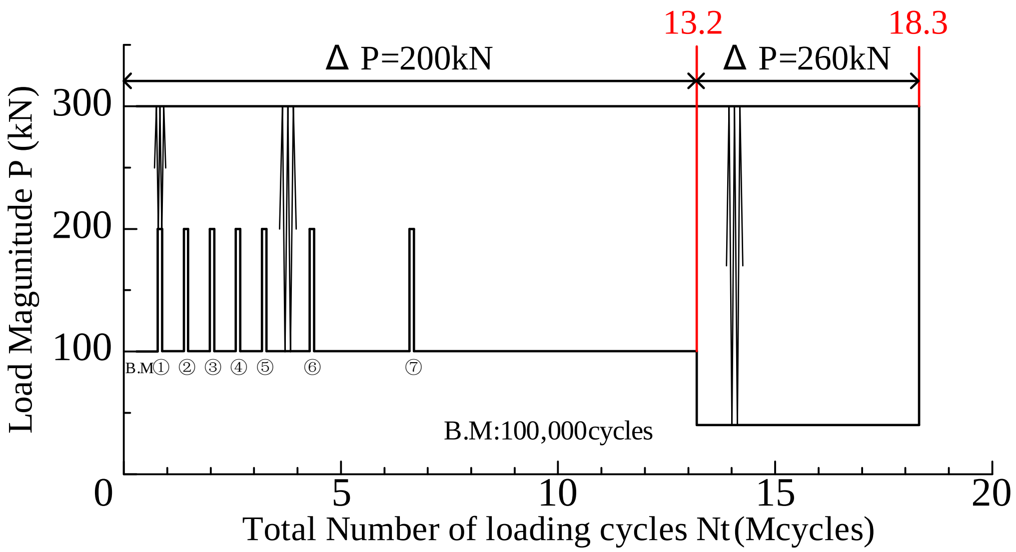

Fig. 7. Fatigue Loading History

5. Experimental Results

5.1. Fatigue Crack development and Propagation Behavior

Fig. 8 shows the relationship between the length of MT sign and the number of loading cycles. Photo 6, 7 show MT signs at the G1-2-C gusset plate. A MT sign of 0.8 mm length was detected after ΔP=200 kN loading of 0.16 Mcycles at the upper part of G1-2-C weldment. The remarkable propagation of MT signs could not be observed after ΔP = 200 kN loading of 12.5 Mcycles and ΔP = 260 kN loading of 5.1 Mcycles.

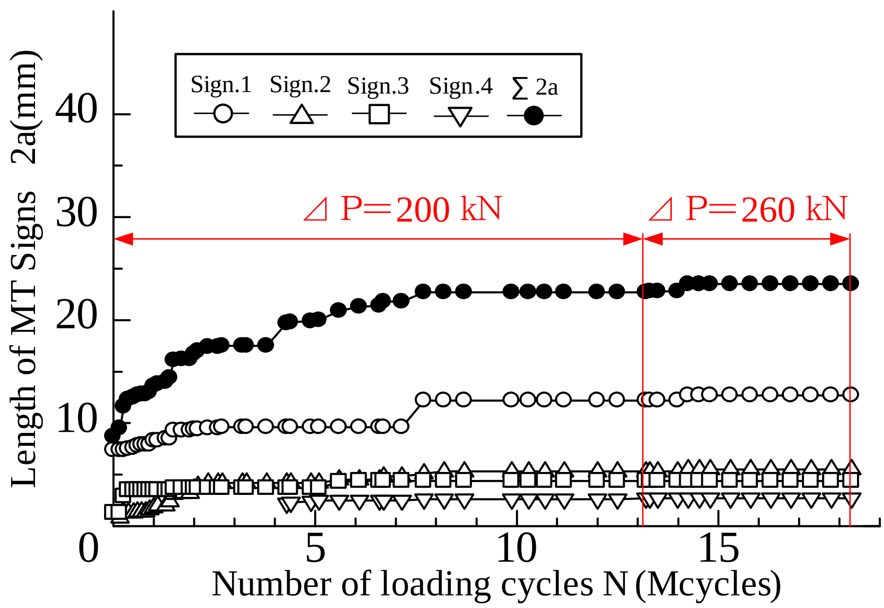

Fig. 8. Relationship between Length of MT Sign and Number of Loading Cycles

Photo 6 MT sign at G1-2-C (P=200kN,N=0.16Mcycles)

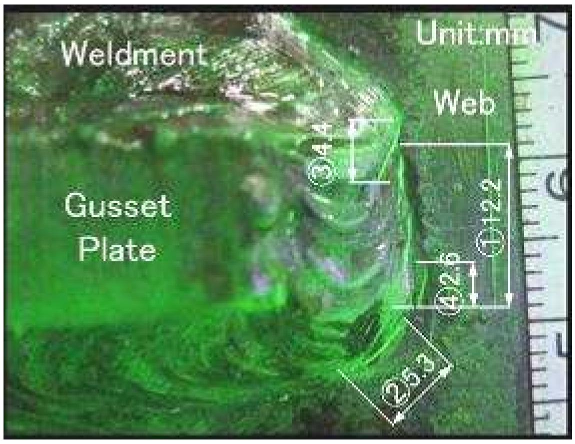

Photo 7 MT sign at G1-2-C (P=200kN,N=8.1Mcycles)

5.2. Fatigue Strength

Fig. 9 shows fatigue test results and fatigue design curves after JRA (Japan Road Association) Fatigue Design Recommendations for Highway Bridges (2002)[1]. The vertical axis represents the maximum principal stress range (Δ), while the horizontal axis represents the fatigue life Nd and Nf. Nd is fatigue crack detection life as the number of stress cycles until fatigue cracks are detected. Nf is fatigue life defined as the number of stress cycles until the fatigue crack propagates until the web depth.

No fatigue crack propagation was observed in the gusset plate welded joint after 12.5Mcycles loading under $\Delta\sigma = 51$MPa and 5.1Mcycles loading under $\Delta\sigma = 62$MPa. The fatigue strength of this type of web gusset welded joint with fillet satisfies JRA Fatigue Category E which is two-rank higher than that of web gusset welded joint without fillet.

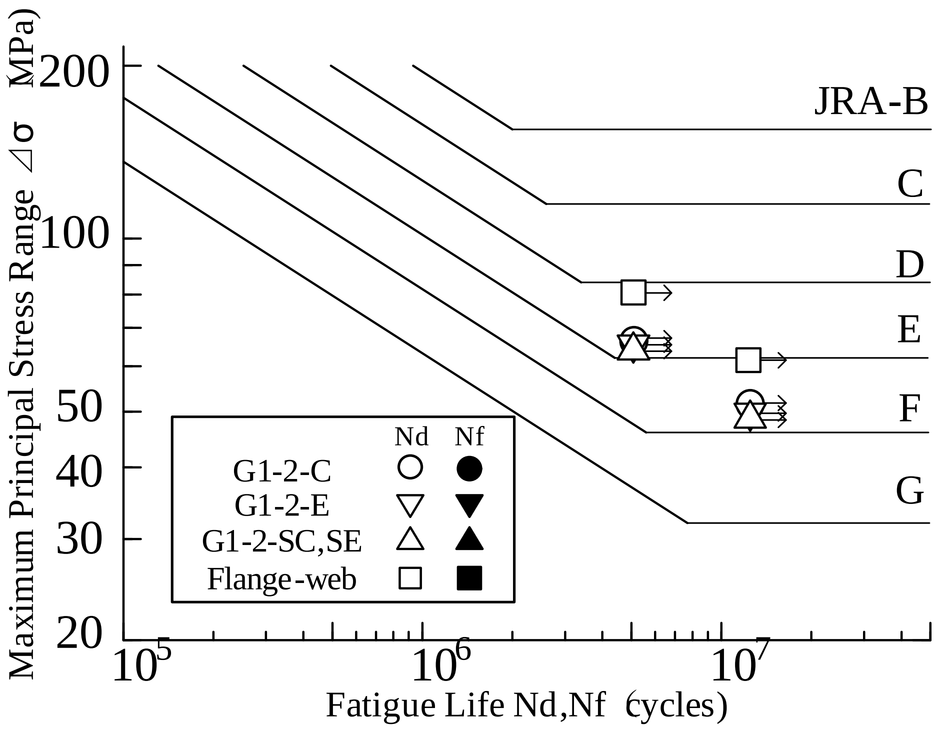

Fig. 9. Fatigue Test Results

6. Conclusions

The principal results obtained through this study are as follows.

1) MT signs that may indicate fatigue cracks were observed at 2 weldments from among 18 turn-round weldments with paint cracks.
2) A MT sign of 8mm length was observed under a 83mm paint crack at the G1-2-C gusset plate. A MT sign of 4mm length was observed under a 23mm paint crack at the G4-1-C gusset plate.
3) There are no MT signs in the inspected areas which have no paint cracks, or that have paint cracks in places other than along the toes of turn-round weldment which are fatigue weak points.
4) The remarkable propagation of MT signs could not be observed after $\Delta P = 200kN$ loading of 12.5Mcycles and $\Delta P = 260kN$ loading of 5.1Mcycles
5) It was confirmed that the fatigue strength of this type of web gusset welded joint with fillet satisfies JRA Fatigue Category E which is two-rank higher than that of web gusset welded joint without fillet.

References

1. Japan Road Association, “Fatigue Design Recommendations for Highway Bridges”, 2002 (in Japanese).
2. M. Sakano, M. Hozumi, T. Shimora and I. Mikami, "Long Term Fatigue Strength of a Web Gusset Joint in Floor-Beam-to-Main-Girder Connection", *Steel Construction Engineering*, Vol.5, No.18, pp 31–41, June 1998 (in Japanese).
3. M. Sakano, D. Nimura, K. Matumoto, A. Isoda, N. Kondo, K. Arimochi, and N. Konda, „Improving Fatigue Strength of Welded Beams by Using Fatigue Crack Arresting Steel”, *Euro Steel 2005*, Volume B, pp 1.11-25–1.11-32, 2005.