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Survey on Fatigue Damage in Steel Railway Bridges in Thailand
Dommages par fatigue de ponts ferroviaires métalliques en Thaïlande
Ermüdungsschäden an Stahleisenbahnbrücken in Thailand

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SUMMARY
The results of the survey of fatigue damage of steel bridges of the State Railway of Thailand are presented. An investigation of the characteristic and the cause of cracks occurring in the welds of stringer necks of through girder bridges was conducted.

RÉSUMÉ
Les résultats de l'étude des dommages par fatigue des ponts métalliques du Chemin de Fer National de Thaïlande (SRT)sont présentés. Une recherche a été conduite sur les caractéristiques et les causes des fissures qui se produisent dans les soudures des raccords des sommiers des ponts à poutres transversales.

ZUSAMMENFASSUNG
Beschrieben wird das Ergebnis einer Untersuchung von Ermüdungsschäden an Stahlbrücken der thailändischen Staatsbahn (SRT). Untersucht wurden die Eigenschaften und die Ursachen von Rissen in den Schweissnähten der Längsträgerhälse von durchgehenden Balkenbrücken.

1.INTRODUCTION

The State Railway of Thailand (SRT) has concentrated its effort on the use and replacement of existing facilities to ensure stable transport and increase the transport capacity and speeds.

New kinds of damage are showing up even in newly-built bridges. These new kinds of damage include fatigue damage often found characteristically in welded structure bridges in Europe and the U.S. as well as in Japan.[1)] They develop rapidly and are hard to treat. Therefore, if they are left alone as they are or treated only with conventional means, they may become a critical damage that may hinder stable transport.

These, however, can be prevented from developing into critical damage if appropriate approaches are taken.

The bridge which we examined is a through girder bridge located 73.057 km on the North line. It was built in 1969 (design load: DL-15) and rivets are used for splicing and connection.

The arrangement of stringers and the track and positions where fatigue cracks have occurred are shown in Fig.1. (the same figure used in bibliography 1)

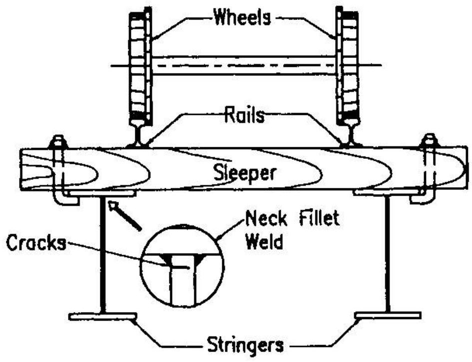

Fig.1 Wheels, track and stringer

2.OUTLINE OF DAMAGE

The model assumed so as to clarify the cause and to know the characteristics of damage is shown in Figs.2 and 3.

Fig.2 shows a crack developing about 700 mm horizontally along the toe on the weld between upper flange and web of stringer (we called "the neck's weld) just under the sleeper. It had, however, not reached the beam's end of the stringer.

Fig.3 shows a crack occurring in the beam end of a stringer advancing horizontally on the web along the bead toe. At this position, a stop hole is provided at the end of the crack, and found effective to some extent.

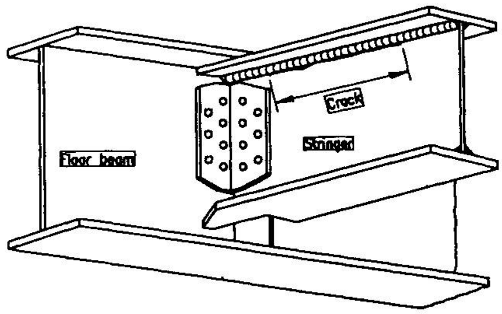

Fig.2 Crack occurring just under the sleeper

3.INVESTIGATING THE CAUSE OF DAMAGE

Investigation of the cause is an important acquirement in knowing the occurrence trend of damage of the same kind and in making measures more reasonable.

Studies were made on the basis of the data as given below.

3.1 Visual Inspection of Similar Bridges

The result of visual inspection is rearranged as follows to investigate causes.

(1) It was assumed that the crack start from just under the sleeper or from the bead toe on the web side of the neck's weld of the stringer end (some coming from the corner of the notch)

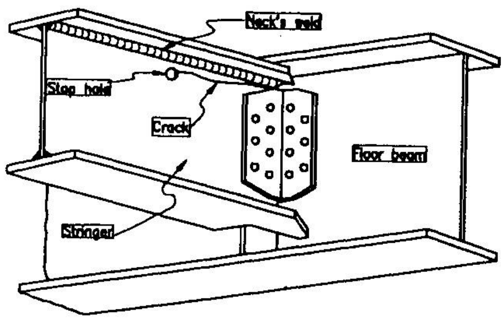

Fig.3 Crack occurring in the beam end

(2) The crack has grown nearly horizontally along the bead toe on the web side of the neck's weld or on the web near it.
(3) The crack along the neck's weld continued to progress without being stopped, parts of it extending beyond the patch plate or stop hole.

3.2 Measuring Actual Bridges

Stress behaviors were examined by sticking a triaxial gauge to the positions as shown in Fig.4 with due consideration to the foregoing.

The trains used for measurement include: The condition of contact between the sleeper and the flange is shown in parentheses.
(1) ALSTHOM: (under present conditions: in close contact inside; 0.2 to 0.5 mm apart outside) (See Fig.5)
(2) ALSTHOM: (liner inserted intentionally: 2 mm apart inside; in close contact outside) (See Fig.6)
(3) new-HITACHI (liner inserted intentionally: 2 mm apart inside; in close contact outside) The axle load and spacing of ALSTHOM and new-HITACHI is shown Fig.7.

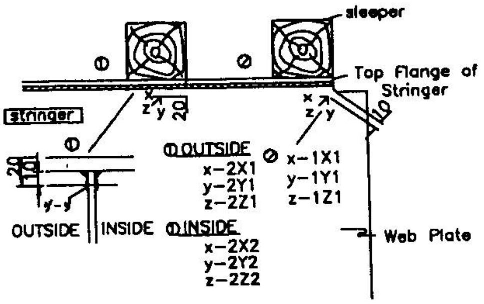

Fig.4 Position of strain gauges

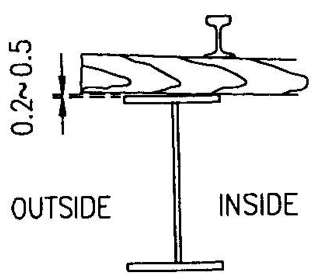

Fig.5 Present condition

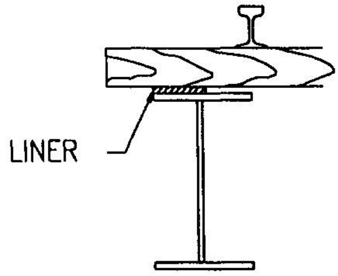

Fig.6 Liner inserted intentionally

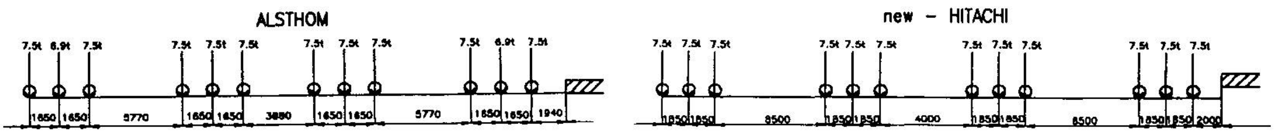

Fig.7 Axle load and axle spacing

The following are items given special attention and the results of measurement
(1) Stress in the neck of the stringer just under the sleeper. Measurements were made for ALSTHOM (the sleeper is touching the top flange). Fig. 8 shows three-component stress for the front and the back faces.

(2) Stress in the coped corner notch in the stringer end
The train for which measurements were made was new-HITACHI whose axle load is the greatest this line. (The liner plate was inserted just under the sleeper only in the halfway.)
In Fig.9, the upper three waveforms show triaxial stress in the girder end notch, and the lower two waveforms show vertical stress in the front and the back of the web in the halfway of the stringer.
(3) Effects of contact conditions between the sleeper and the flange
Stress acting on the neck just under the sleeper is affected greatly by the contact condition between the sleeper and the upper flange. Under present conditions, the sleeper and the flange are in contact on the inside of the stringer, but there is a gap of 0.2 to 0.5 mm in the outside. Lifting the sleeper manually makes the gap expand to 1 to 2 mm. Therefore, external force from the sleeper is absorbed by the inside of

the flange when loaded with a train.

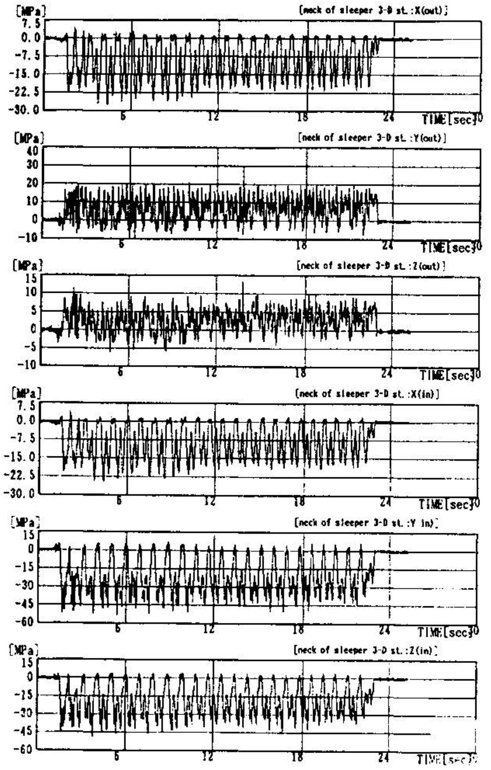

Fig.8 Stress in front and back of the neck just under the sleeper

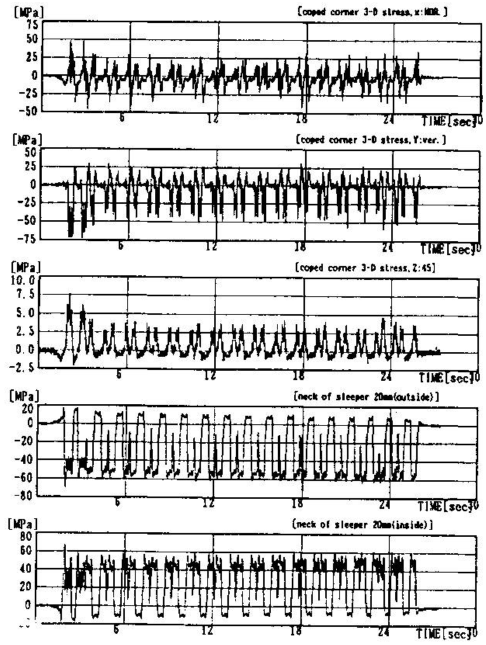

Fig.9 Triaxial stress in the girder end notch and vertical stress of the web

3.3 Evaluating Fatigue Damage in the Neck's Weld

The method and standards for evaluating fatigue were based on the fatigue design guidelines of Japanese Society of Steel Construction[2]. The result of fatigue damage evaluations is shown in Fig.10 and Fig.11.
Based on the results above,the following can be said:

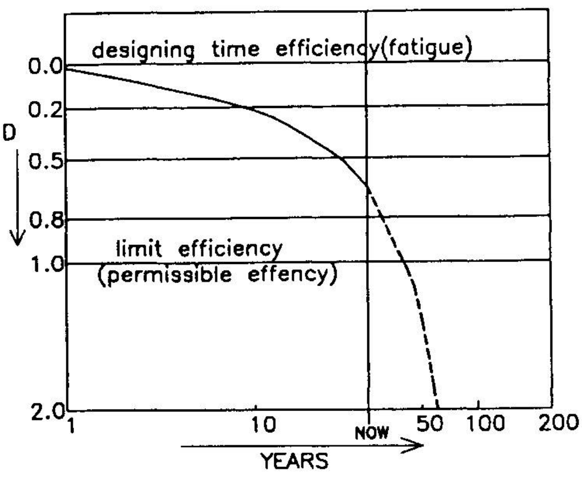

Fig.10 Fatigue crack occurring life of the stringer's crack(under the present condition)

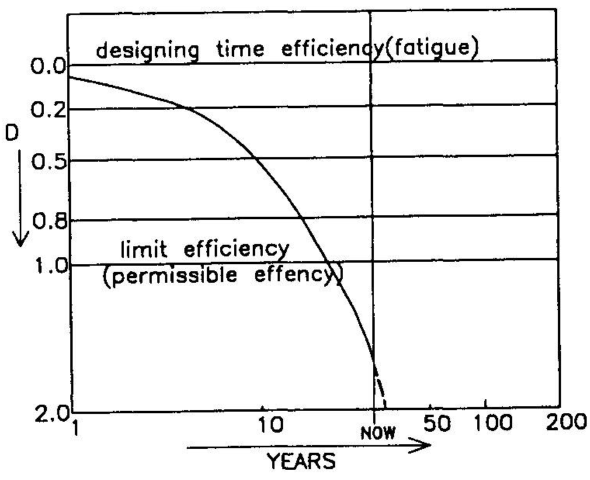

Fig.11 Fatigue crack occurring life of the stringer's neck(liner inserted)

(1) Vertical stress of about 65 MPa is acting on the neck's weld. It was greater than the stress in the axial direction of the bridge, and was in the reverse phase in the inside and the outside of the web.
(2) Vertical stress due to out-of-plane bending of the stringer neck was as large as 75 MPa.
(3) Vertical stress in the notch of the stringer's end was 90 to 100 MPa and main stress was similarly great.
(4) Fatigue crack occurrence life was calculated to be 9 years for vertical stress acting on the neck's weld. Fatigue crack occurrence life when the sleeper was in loose contact (when the sleeper was completely deviated) was calculated to be 8 years.

4. Estimating Fracture Life of Rails

For analysis, a stress waveform was obtained by simulating a stress when a typical train is run over rails where the sleeper just above a crack in the weld of a stringer's neck ceases to support the rails, and on the assumption that those rails are continuous beams with a span of 1,000 mm. The typical train was a train drawn by new-HITACHI.
Considering the live load history of this line, fatigue accumulated in the rails were obtained to calculate crack occurrence life.
Load and fatigue strength were treated in the same way as those for railroads in Japan.[3,4]

4.1 Waveforms of Stress Acting on Rails

In the analysis of the waveform of stress acting on rails, based on the fact that the crack in the neck's weld was 700 mm long, the rail was assumed as a 1,000 mm span continuous beam with one sleeper lost. In that condition, axial force acting on the rail was obtained by simulation. On this basis, stress "on the railhead in the weld joint" and "bolt holes in the joint bar" was obtained. Stress acting on the bolt holes was obtained by the FEM analysis because it could not be obtained by a simple beam stress calculation. Fig.12 shows the stress waveform and stress spectrum in top-flange of the rail obtained by simulation.

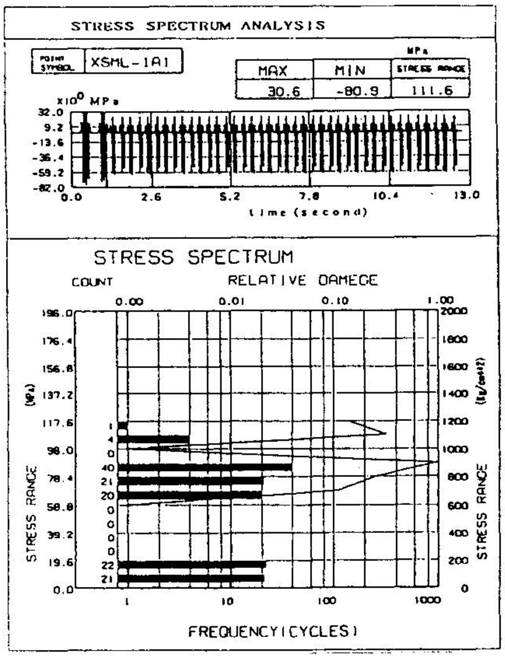

Fig.12 Stress waveform and stress spectrum obtained by simulation

4.2 Dynamic Effects of External Force

There is no clear measurements on "a" above. On the average, however, "about 30% higher than static external force"was considered a reasonable value and was used.
Concerning "b" above, recent research results [3,4] show that load used for evaluation of fatigue of thermit-welded rails with undulations was about 1.7 times those without undulations.

4.3 Stress Acting on Rail Joints

Stress acting on joints was obtained with due consideration to the conditions described above.
(1) Weld joints
Rails here are joined by thermit welding, and undulated surfaces of rails cause impact.
(2) Bolt holes
Stress distribution at a hole's periphery was obtained by FEM analysis.
The model used for the analysis is a two dimensional plane element, and the rigidity of

top and bottom flanges was considered only for board thickness. As a result, large stress was acting in the tangential direction at the hole's periphery at 45 degrees from the hole's center, that stress was used here.

4.4 Fatigue Strength of Joints Used for Evaluation

The fatigue strength curve of rails used for evaluation of fatigue was the one as shown in Fig.13 [3,4] which is usually used by former Japanese National Railways.
The S-N curve used to evaluate general parts was for corrosion fatigue (pH3.5).

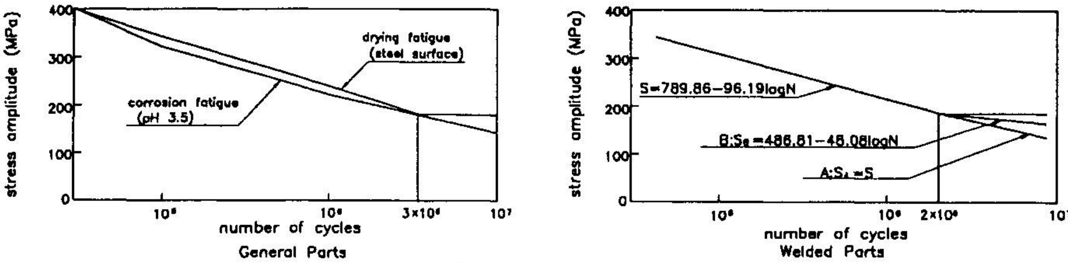

Fig.13 Rail's fatigue strength curve

4.5 Result of Estimation of Remaining Life

The time when fatigue will cracks occur on rails under said conditions was estimated as follows:

(1) The ordinary part of a rail, that is, the part without either the weld nor bolt holes does not pose any fatigue problem at once, even if, for example, sleepers are spaced one meter apart.

(2) Weld joints
In case there is no crack in the neck's weld: more than 200 years.
In case there are cracks in the neck's weld: 11 years.

(3) Bolt holes
Whether there is a crack in the neck's weld or not: 4 years.

5.Conclusions

(1) Summary of evaluation results
Stress acting in the neck of the stringer stress (out-of-plane bending to the web) due to eccentric loading from the sleeper, and is influenced by the way the sleeper and the upper flange contact with each other.

(2) Emergency breakdown repair
Immediate treatment of existing cracks is needed to prevent rail fractures and serious accidents associated with a buckling of a stringer.

(3) Causes of damage
This time cracks were found in through plate girder bridges, and their causes include:
a.Joints of sleepers were loosened, causing eccentric load in the neck.
b.Legs of beads are slightly short.
c.Shapes of beads are slightly defective.
d.The structural detail of the connection between a stringer and a floor-beam is not very good.
e.Track irregularity causes lateral oscillations while it is run over by a train.

(4) Main measures
Possible measures include improving the sitting condition of sleepers, preventing the twisting of the neck, and reducing bending stress.
Adjustable pads(resin mortal) are sometimes placed under sleepers to make them fit well with flanges and to provide sleeper supports.

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