STRUCTURAL ANALYSIS OF PLATE GIRDER BRIDGE RESPONSE UNDER THE ASSUMPTION OF DEGRADATION SCENARIOS

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1. INTRODUCTION

In the Hokuriku Area, 17% of National Highway bridges exceed 50 years after opening to traffic, and this ratio will increase to 65% in 2033, according with reports published by the Chubu Region Development Bureau (2014). Therefore, deterioration has become an issue for many highway bridges. Hence, sufficient maintenance is required to counteract this issue. In order to conduct a scientific and logic conservation of road bridges, and continue with the efforts to provide safer structures, a FEA is introduced into maintenance managements. The aim of this study is to determine the influence of different types of degradation on bridge's natural frequency and, also, its influence on the stress level of certain sections of the girder plate.

2. CLASSIFICATION OF DEGRADATION SCENARIOS

A Fault Tree Analysis was carried out in order to elaborate the degradation scenarios, Arima et al. (2014). These scenarios correspond to a steel bridge with 4 main I-girders located in the Hokuriku Highway, Japan. The analysis consists in the member's level classification, classification of damages, the defects originated by those damages, and system error. The analysis result is shown in Fig. 1. In this study, 3 degradation scenarios are assumed considering damages on the slab and main girders of the bridge. The assumed scenarios are: concrete degradation, steel corrosion and fatigue cracks in steel members. Their outline and its model representation are described on Table 1.

Table 1. Degradation Scenarios Outline and Model Representation.

Degradation Scenario	Outline	Model Representation
Concrete Degradation	Concrete is usually damaged by ASR and salts, Torii et al. (2008).	Slab's static elastic modulus is reduced assuming 3 cases: 1) $E=3.1x10^4$ N/mm^2, 2) $E=1.5x10^4$ N/mm^2, 3) $E=1.0x10^4$ N/mm^2.
Steel Corrosion	Steel corrosion is usually presented in girder ends or splice plates outside.	Thickness near to the splice plate and girder web at the end are reduced assuming 3 cases: 1) t=0mm, 2) t=2mm, 3) t=5mm.
Fatigue Cracks in Steel Members	Cases of fatigue cracks are usually presented in the nearby of sole plates and lower part of the web.	Fatigue crack length is changed assuming 3 cases: 1) L=0mm, 2) L=370mm, 3) 825mm.

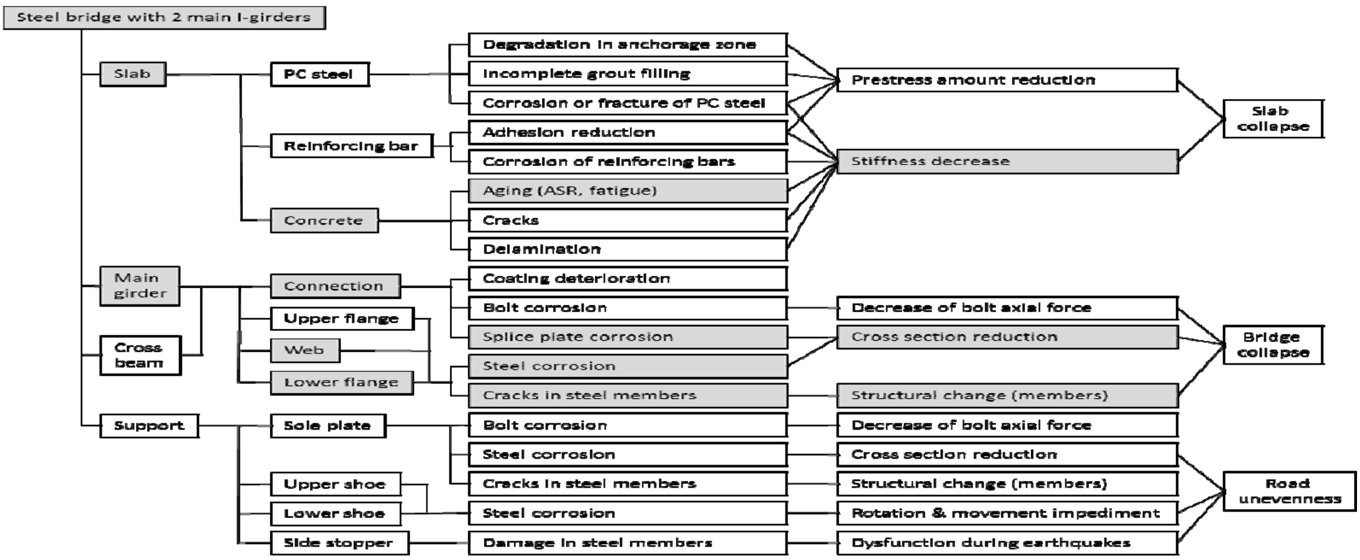

Fig. 1. Classification of Degradation Scenarios Based on a Fault Tree Analysis.
※Items filled in grey represents the items considered in this study.

Keywords: Steel Bridge, Bridge Response, Degradation Scenarios, Bridge Monitoring.
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3. FEA MODEL

The target bridge on this study is a bridge located in the Hokuriku Highway, Japan. To model the bridge, Femap with NEi Nastran is used. Bridge and FEA Model characteristics are shown in Table 2. In order to revise and validate the FEA Model, reaction forces in the model were verified, and vibration measurements for structural identification were carried out on site. Bridge natural frequency measured on site was 3.67Hz, while the frequency obtained from the model was 6.24Hz, resulting on a difference of 70% between both frequencies. In order to create a model that reflects the results obtained in the measurements carried out on site, it was necessary to increase 5×10^4 times the support spring coefficient. After the spring coefficient was changed, the obtained frequency was 3.71Hz, resulting on a difference of only 1% between this frequency and the one obtained on site.

Table 2. Bridge of Study and FEA Model Characteristics.

Characteristic	Description
Structural Type	Steel Bridge with 4 I-shaped Girders and a Non-composited RC Slab
Girder Length	117.80m
Span Length	29.10m + 29.45m×2 + 29.10m
Slab Thickness	220mm
Type of Analysis	Elastic Analysis
Main Girder	Shell Element
Slab's Concrete	Solid Element
Bridge Railing's Concrete	Solid Element
Asphalt Pavement	Solid Element

4. FEA RESULTS

4.1 Natural Frequency Variation

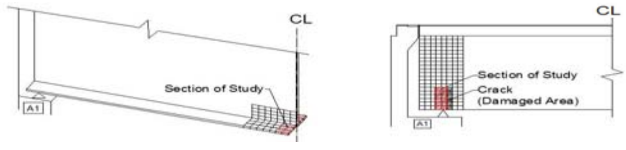
Table 2 shows bride's natural frequency variation for each case of the assumed scenarios. In concrete degradation scenario, natural frequency in the Case 3 was reduced to the 96%, compared with Case 1. Meanwhile, in steel corrosion and fatigue cracks degradation scenarios, there are not significant changes on bridge's natural frequency.

Table 2. Natural Frequency Variation for Each Scenario.

Degradation Scenario	Case 1	Case 2	Case 3
Concrete Degradation	1.00	0.98	0.96
Steel Corrosion	1.00	0.99	0.99
Fatigue Crack	1.00	0.99	0.99

4.2 Members' Stress Variation

The members' stress variation depending on the type of degradation is examined. Load arrangement applied to the bridge was determined based on a particular study made for this highway, Ishikawa (2014). The results of the FEA Model are focused on sections where the biggest variation of stress is presented. These sections are shown in Fig. 2. For concrete degradation and steel members' corrosion cases, this section is the main girder lower flange located at span's center (Fig. 2. (a)). For fatigue cracks scenario, the section of study is the main girder web in crack's vicinity (Fig. 2. (b)). Table 3 shows members' stress variation for each case of the scenarios assumed. In concrete degradation and steel corrosion scenarios, the stress in the Case 3 increased about 6% and 14% respectively compared to Case 1. In fatigue cracks in steel members' scenario, the increase of the stress in Case 3 is significantly bigger; about 29% compared with Case 1.



(a) (b)

Fig.2 Stress Variation Sections of Study.

Table 3. Members' Stress Variation for Each Scenario.

Degradation Scenario	Case 1	Case 2	Case 3
Concrete Degradation	1.00	1.03	1.06
Steel Corrosion	1.00	1.04	1.14
Fatigue Crack	1.00	1.07	1.29

5. CONCLUSIONS

A FEA Model was created considering the characteristics of a steel bridge located in the Hokuriku Area, Japan. Revision and update of the model were made based on reaction forces verification and vibration measurements carried out on site. The FEA was carried out in 3 cases, assuming 3 of the most characteristics degradation types of the corresponding area. Bridge's response was determined at each stage. For the load arrangement and damage conditions assumed in this study, it was concluded that only the remarkable degradation of the concrete can be determined examining the natural frequency of the bridge; additionally, a stress variation in the sections of study for all degradation scenarios was confirmed; and, compared with concrete degradation and steel corrosion, a tendency of bigger stress variation in the fatigue crack scenario was found.

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