# 第 I 部門 Fundamental study on Structural Health Monitoring of Bridge by focusing on displacement and slope at girder end

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## 1. INTRODUCTION

Bridge health monitoring is used to detect damages of structural members. Generally, damages can be obtained in real structures by putting many sensors along the length of the bridge. However, the installations of them take a lot of time and cost. Tremendous data processing is also needed from many sensors. Placing a few sensors at the end of girder instead of placing along the length might provide simpler bridge health monitoring. Then, in this paper, damage detection of stiffness degradation in simply supported beam is presented focusing on horizontal displacement and rotation which takes place at the girder end.

## 2. THEORY BACKGROUND

When focusing on a simply supported beam in figure 1, neglecting shear effect, the deflections can be obtained by using Conjugate beam method (CBM). If rotation angle and vertical deflection of the beam is known, horizontal displacement can be calculated as the integral of half of rotation angle over full length of beam. Location and size of damage is considered as variable.

$$\Delta_{\text{horizontal}} = \int_0^L \frac{1}{2}\left(\frac{dv}{dx}\right)^2 dx \tag{1}$$

### (1) Modeling for intact beam

20-meter-long W610x240 I-girder is taken as a healthy model assuming there is no damage. It has 31mm thick flange and 17.9mm thick web with moment of Inertia of $2.25\text{x}10^9$ $\text{mm}^4$. When load is applied, slope of end B can be obtained by using following equation.

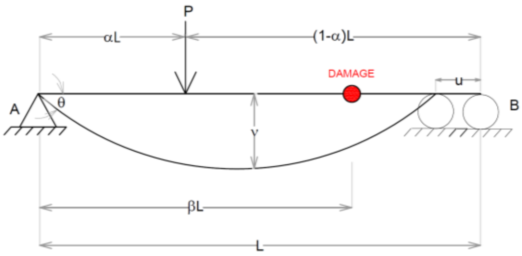


Fig-1 Free body diagram of simply supported beam (α<β)

$$\frac{\theta_A}{\theta_A)_{\alpha=\frac{1}{2}}} = \frac{8}{3}\alpha(\alpha\text{-}2)(\alpha\text{-}1) \tag{2}$$

$$\theta_B = \frac{PL}{6EI}\left(-\alpha(1\text{-}\alpha)(1+\alpha) + 3\alpha\left(1\text{-}\frac{x}{L}\right)^2\right) \tag{3}$$

$$\theta_A)_{\alpha=\frac{1}{2}} = \frac{PL^2}{16EI} \tag{4}$$

### (2) Modeling for damaged beam

In this case, corrosion is assumed which cause the beam to lose its stiffness by reducing section area. Assume that the bridge is located at the area where corrosion rate is categorized as $C_3$[1]. In damage model, flexural rigidity is assumed to be reduced near damage location from original EI to γEI. Then, the damage is defined by 2εL and its location is set as variable parameter to know the behavior of beam ε is taken as 0.015 and γ as 0.05 based on corrosion rate and amount of section loss of member.[2] Slope of end A is considered as:

$$\frac{\Delta\theta_A}{\theta_A)_{\theta=\frac{1}{2}}} = \frac{8}{3}(2\varepsilon)(1\text{-}\beta)\left(\frac{1}{\gamma}\text{-}1\right)\text{x F} \tag{5}$$

$$F = 6\beta(1\text{-}\alpha) \quad \text{if } \alpha>\beta$$

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Vertical deflection can also be obtained by:

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$$\frac{\Delta v_M}{v_M)_{v=\frac{1}{2}}} = 8(2\varepsilon)\left(\frac{1}{\gamma}-1\right) \times F \qquad (6)$$

$$F = 6\beta\,(1-\alpha)\,((1-\beta)-(\alpha-\beta)) \qquad \text{if } \alpha>\beta$$

$$F = 6\alpha^2(1-\beta)^2 \qquad \text{if } \alpha<\beta$$

Horizontal deflection by:

$$\frac{\Delta u_B}{u_0)_{u=\frac{1}{2}}} = 160 \times F \qquad (7)$$

$$F = (2\varepsilon)\,\beta^2(1-\alpha)^2\left(\frac{1}{\gamma}-1\right)(-\alpha^2+2\alpha-\beta^2)$$

$$+\,3\left((2\varepsilon)^2(1-\beta)\beta^3(1-\alpha)^2\left(\frac{1}{\gamma}-1\right)^2\right) \qquad \text{if } \gamma>\beta$$

$$F = (2\varepsilon)\,\alpha^2(1-\beta)^2\left(\frac{1}{\gamma}-1\right)(-\alpha^2+2\beta-\beta^2)$$

$$+\,3\left((2\varepsilon)^2\alpha^2\beta(1-\beta)^3\left(\frac{1}{\gamma}-1\right)^2\right) \qquad \text{if } \gamma<\beta$$

**(3) Loading**

Assume that 2.37N/mm of self weight and 1.46N/mm of concrete deck weight are applied on girder. Additionally, 325kN HL93 truck load is considered to act stationary.

## 3. RESULTS AND DISCUSSION

Relation between slope and deflection and relation between slope and shortening (figure2) shows the same pattern. Therefore, it would not go wrong if we focus on shortening instead of vertical deflection because they generally show the same behaviors. In intact beam, maximum slope of support A is obtained when the load is applied at the center (figure3-a). In damage beam case, it is obtained when load is applied at 0.75L where the damage is located. Similarly, maximum vertical deflection shifts from the center to location of damage when the load is subjected to damage region (figure3-b). The shortening of beam is obviously increased in case of damaged beam (figure3-c).

## 4. CONCLUSION

This method involves comparing of two systems to obtain the changes in displacement and slope in beam. If maximum slope is found when load is applied somewhere on beam except from the center, it could be said that damage is located at that point. In the same way, maximum shortening occurs when load is subjected to damage region.

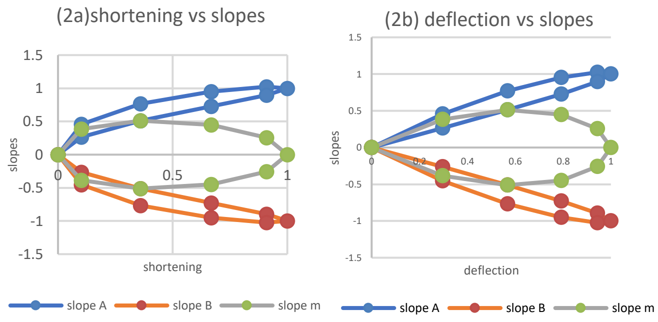


Fig-(2a) (2b) Slope versus displacements for intact beam

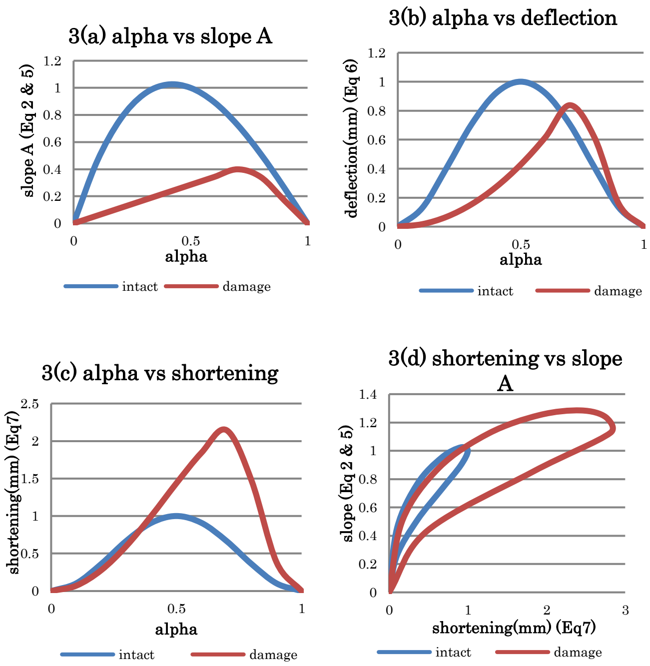


Fig-(3) Comparison of intact and damaged beam

## 5. FUTURE WORKS

I would like to do analysis of continuous beam and beam with multiple damages.

## REFERENCES

1) YYK.Win, T.Khaing, ZM.Htun, Y.Suzuki, K.Hashimoto, K.Sugiura.: Comparative Study on Atmospheric Corrosivity of Under Shelter Exposure in Yangon and Mandalay (Myanmar), *ASRJETS.:. ISSN(print)2313-4410,ISSN(online)2313-4402*

2) Yasser Sharifi : Residual web bearing capacity of corroded steel beams, *Advanced Steel Construction*, vol.8, pp.242-255, 2012