# Study on repair of corrosion on upper surfaces of orthotropic steel decks by one-side bonding of steel plates

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## Summary

Recently, corrosion damages on upper surfaces of orthotropic steel deck plates are often found during the bridge pavement repair work in urban expressways. Repair methods for these damages are required to be finished quickly, for example within one or two hours, during the pavement repair work. In addition, decrease of thickness or pitting corrosion will lead to stress increase and the acceleration of fatigue damage.

In this study, the authors focused on the repair method of bonding steel patch plates from the upper surface side. In order to investigate the basic mechanical behaviour, finite element analysis and bending tests of thickness-reduced plates repaired with bonding steel plate under bending were carried out. Simple equations for designing the thickness and length of patch plate repair were proposed.

**Keywords:** orthotropic steel deck plate, bonding repair method, steel patch plate, bonding on one side

## 1. Bending test and FE analysis

In this research, steel plates of 50x12x600mm were used as a base plate for bending tests. The thickness-reduced area in the specimen is provided at the center of the specimen. The reduced thickness of the specimen is 8mm and the length of thickness-reduced section is 5mm. A steel plate of JIS SM490Y was used as base plate. A patch steel plate of 50x2,3x300mm or 50x4,5x300mm is adhered at the center of the base plate by epoxy resin. FE analysis was performed under 2D linear elastic condition. For the base plate, patch plate and the adhesive layer a 4-node quad element was used. Figure 1 shows the stress distributions of the lower surface of the base plate obtained by the bending test and the FE analysis. In this figure, the value of composite theory calculated by structural mechanics is also shown. In this figure, stresses are normalized by the stress caused at $x$=400mm from the loading point, $\sigma_{L400}$. Test data indicate the stress when the applied load is 0,3kN. As shown in Fig. 1, FE analysis results show good agreement with the composite theory except for the regions of adhesion ends and thickness-reduced section. As generally known, the stress in base plate near the patch plate end becomes smaller than that given by composite theory because of the stress transfer lag by the adhesive layer. Therefore, the length of the patch plate should be designed by the condition that the stress in the base plate is converged to the composite theory. The required length of the patch plate is mentioned in the following chapter.

## 2. Design proposition

The main factors for stress in thickness reduced section are the attachment length and the patch plate thickness. Therefore, the design methods focused on them are discussed.



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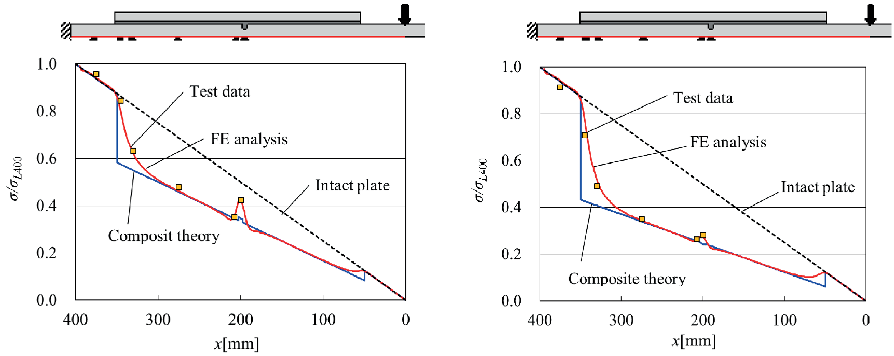


(a) Patch plate of 2,3mm thickness (b) Patch plate of 4,5mm thickness

*Fig.1: Stress distribution of lower surface of base plate*

The required length of the patch plate, $l$, can be calculated by the following equation, using the accuracy of the stress convergence to the value from composite theory, $\eta$. The stresses induced in the patch and base plates of the thickness-reduced section are given by the following equations (5) and (6).

$$l = \frac{1}{c}\cosh^{-1}\left(\frac{1}{1-\eta}\right) \tag{1}$$

$$c = \sqrt{\frac{G_e}{h}\left\{\frac{1}{E_s t_h} + \frac{1}{E_s t_p} + \frac{12(a_{h1}+a_{h2})a_{h3}}{E_s t_h^3 + E_s t_p^3}\right\}} \tag{2}$$

$$G_e = \frac{E_e}{2(1+\nu_e)} \tag{3}$$

$$a_{h3} = \frac{t_h}{2} + \frac{t_p}{2} \tag{4}$$

$$\sigma_{p\alpha} = \frac{N_{p\alpha}}{A_p} + \frac{M_{d1}}{I_p} y_{d1} \tag{5}$$

$$\sigma_{b\alpha} = \frac{N_{b\alpha}}{A_{d2}} + \frac{M_{d2}}{I_{d2}} y_{d2} \tag{6}$$

where, $E_s$ and $E_e$ are the Young's modules of steel and adhesive, respectively, $\nu_e$ is the Poisson's ratio of the adhesive, $\eta$ (<1,0) is the accuracy of stress convergence, $h$, $t_h$, $t_p$, $a_{h1}$ and $a_{h2}$ are shown in Fig.2. $y_{d1}$ and $y_{d2}$ are distance from the centroid of patch and base plates of thickness-reduced section, respectively, $A_{d2}$ is the cross sectional area of base plate of the thickness-reduced section.

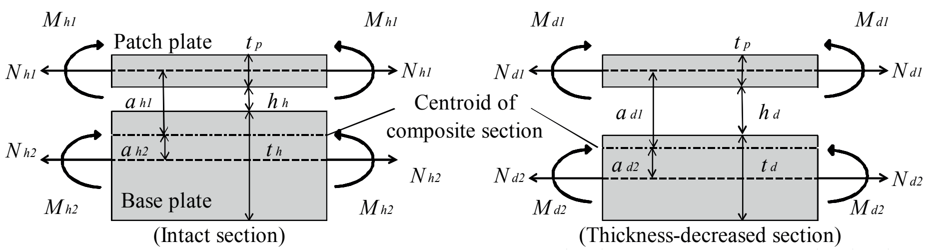


*Fig.2: Sectional forces in patch and base plates with and without thickness-reduced area*

## 3. Conclusion

(1) The stress state of thickness-reduced plates repaired with bonding steel plate under bending was demonstrated.
(2) The main factors on stress state of adhesive-bonding repair method are the attachment length and the patch plate thickness.
(3) The required patch length can be designed by using Eq.(1) with $\eta$= 0,99.
(4) Procedure of estimation of stress in the thickness-reduced area with patch plate was shown.