STUDY ON REMAINING LOAD-CARRYING CAPACITY OF CORRODED GUSSET PLATE CONNECTION BY FEM ANALYSIS

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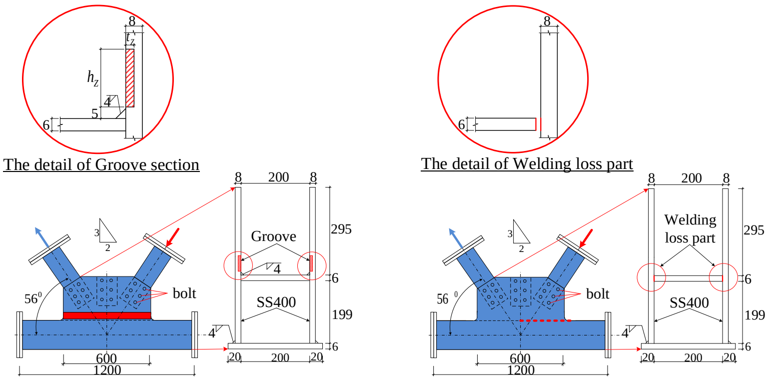
1. INTRODUCTION

Damaged steel truss bridge due to corrosion is being a concerning issue for maintenance and repairing of existing bridges worldwide. Specially, corrosion in gusset plate connection affects the bridge significantly and results (see **Fig. 1**) the reduction of load-carrying capacity that sometimes leads to the collapse of the entire truss bridge. For instance, the lower load-carrying capacity resulted from insufficient gusset plate thickness showed the historical collapse of I-35W Bridge in the USA, 2007. Therefore, this study intended to evaluate the remaining load-carrying capacity of the corroded gusset plate connection by using FEM analysis. Two different possible loss due to corrosion: loss of welding along the contact line (shown in **Fig. 1**) and loss of thickness of gusset plate were proposed to investigate the reduction of load-carrying capacity.

Fig. 1 Frequently corroded location on gusset plate connection.



(a) Specimen with cross-sectional loss part (b) Specimen with welding loss part

Fig. 2 Specimen shape.

2. PARAMETRIC ANALYSIS

2.1 Specimen shape

The specimens used in this study were of the monolith-type. These models were approximately 50% the size of the real bridge. The loss of gusset plate thickness owing to corrosion was simulated by cutting a groove (called the "Groove") with a height h_z and width t_z (see **Fig. 2a**) at the location connecting the gusset plate and the upper flange of the lower chord member. On the other hand, the welding loss part due to corrosion, was represented with a discontinuation between the gusset plate and the upper flange of the lower chord member in the compressive direction (see **Fig. 2b**).

2.2 Analysis model

Three-dimensional geometric nonlinear analysis was implemented for the gusset plate connections with and without the loss part on the gusset plate, with the displaced load type as shown in **Fig. 3**. The element type of the gusset plate connection and the loading members are the curved shell element, and the three-dimensional beam element, respectively. In the cases having the Groove section, only the Groove section is simulated in the solid brick element. The unit of finite element mesh in all of the models is 1 mm for Groove section, and 5 mm for the other members. Therefore, the total numbers of nodes and elements in the intact case and the cases with the cross-sectional loss part are 78223 and 27378, 101403 and 28476, respectively.

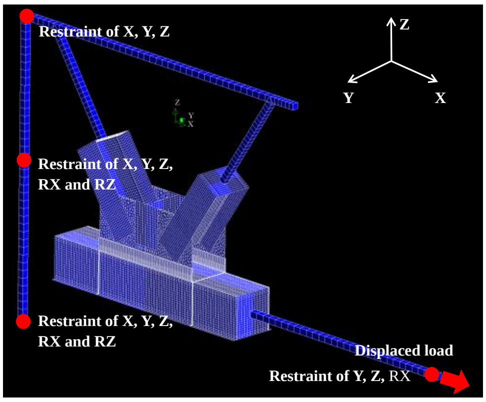


Fig. 3 Finite element analysis model.

2.3 Analysis parameters

In this study, to reach further information in the remaining load-carrying capacity of the gusset plate connection when the corrosion level increased; a parametric analysis was implemented with the parameter of the cross-sectional loss level on the gusset plate, as listed in **Table 1**. The remaining thickness of the corrosion section was assumed to be 87.5%, 75%, 62.5%, 50%, 43.75%, 37.5% and 25% of the gusset plate thickness. For each the remaining thickness level, the height of the corrosion section was taken approximately 50% and 100% of the maximum height of the potentially-damaged area. Moreover, more one of the FEM parametric analysis, with the parameter of the length of the welding loss part, was also conducted in this Section, as listed in **Table 2**.

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Table 1 Analysis parameters in the cases having cross-sectional loss part.

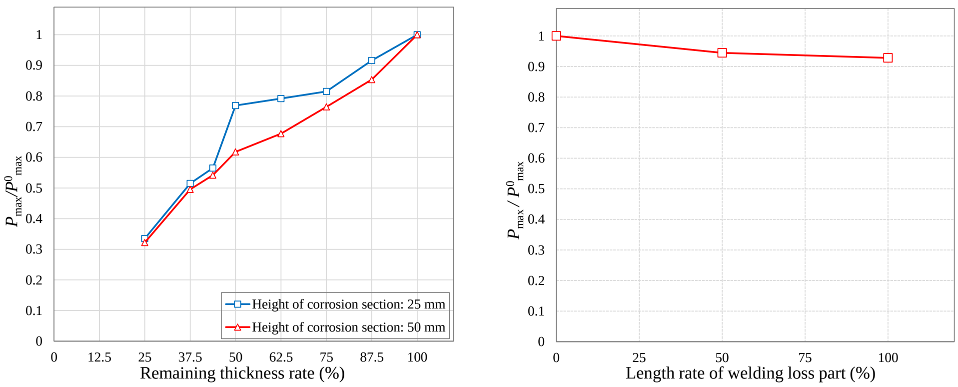
No.	Case	Remaining thickness of corrosion section / 8 mm %	Height of corrosion section / 50 mm %	Dimension of Groove section t_z (mm)	Dimension of Groove section h_z (mm)	Test frame form	Note
1	t87.5h50	87.5%	50%	1	25	Link frame	
2	t87.5h100		100%		50		
3	t75h50	75%	50%	2	25		
4	t75h100		100%		50		
5	t62.5h50	62.5%	50%	3	25		
6	t62.5h100		100%		50		
7	t50h50	50%	50%	4	25		EXP
8	t50h100		100%		50		
9	t43.75h50	43.75%	50%	4.5	25		
10	t43.75h100		100%		50		
11	t37.5h50	37.5%	50%	5	25		
12	t37.5h100		100%		50		
13	t25h50	25%	50%	6	25		
14	t25h100		100%		50		EXP

Table 2 Analysis parameters in the cases having welding loss part.

No.	Case	Location of welding loss part	Length of welding loss part / 600 mm %	Test frame form	Note
1	W50	Compressive direction	50%	Link frame	EXP
2	W100	Compressive direction + Tensile direction	100%		

2.4 Parametric analysis results

The maximum load values collected from the FEM parametric analysis when changing the cross-sectional loss level, are shown in **Fig. 4a**. Herein, P_{max} and P^0_{max} are the maximum load of the case of having the loss part, and the maximum load of the intact case N, respectively. As shown in **Fig. 4a**, losing the cross section on the gusset plate decreased significantly the load-carrying capacity of the gusset plate connection. In each the level of height of the Groove section, the relation between P_{max}/P^0_{max} and the remaining thickness rate was the same as linear. Further, the value of P_{max}/P^0_{max} reduced sharply in the case, in which there was a change of the failure condition on the Groove section. In addition, when increasing the height of the Groove section in the same level of the remaining thickness, the maximum load reduction rate of the gusset plate connection was seen considerably only in the cases appearing local buckling in the Groove section. Further, the slight reduction was seen in the case, in which shear failure or shear buckling occurred in the Groove section. This was because that the finial failure condition of the gusset plate was different in these cases. Specifically, the final failure condition of the gusset plate in the cases occurring shear buckling, was shear failure (shear strength) of the Groove section, which did not depend on the height of the cross-sectional loss part. Whereas, the final failure condition of the gusset plate in the cases occurring local buckling, was the large out-of-plane deformation, which appeared under the buckling at the plate area underneath the compressive diagonal member.



(a) The cases with the parameter of cross-sectional loss level

(b) The cases with the parameter of the length of welding loss part

Fig. 4 Remaining load-carrying capacity – loss level relation.

Additionally, when expanding the length of the welding loss part, the reached maximum loads from FEM parametric analysis are shown in **Fig. 4b**. The information of **Fig. 4b** revealed that losing the welding part reduced only slightly in the load-carrying capacity of the gusset plate connection in the range of 5% to 7%. This is understood that the compressive strength of the diagonal member, which decided the load-carrying capacity of the gusset plate connection, depended greatly on the dimension and strength of the free edges of the gusset plate in the compressive direction. As a clear acknowledge, the dimension of these free edges completely was not affected when the welding part was lost.

3. CONCLUSIONS

Based on the conducted FEM parametric analysis, the reduction of the load-carrying capacity of the gusset plate connection due to corrosion was clarified. Specifically, significant reduction in load-carrying capacity was found in cross sectional corrosion cases. Whereas a minor reduction was observed in welding corrosion cases in the range of 5% to 7%.

REFERENCES

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