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Track Response according to the Location of Rail Expansion Joint I: Finite Element Analysis

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Abstract
When additional rail stress or displacement on the track on bridge exceeds the permissible value, the REJ (Rail Expansion Joint) is constructed as one of methods to reduce the stress or displacement. The section where the REJ is constructed is the vulnerable sections that require a lot of maintenance work, so careful judgment is necessary with regard to its construction. This study is a preliminary study that finds propose reasonable standards regarding the position where the REJ should be constructed and the effects of location with regard to the construction of the REJ were analyzed through F.E. analysis. The track-bridge interaction analysis was carried out by assuming the REJ is constructed on various locations. Generally, the REJ is constructed at a location where significant additional rail stress and displacement has occurred. However, by examining various positions in the course of this study, it was found that there is a need to review the matter of responding to where to construct the REJ.

Keywords: Rail Expansion Joint, CWR, Track-bridge interaction, Finite Element Analysis.

INTRODUCTION

In the past when rail tracks were laid 25 m standard length rails were connected with joint bars and this reduced the comfort that passengers experienced due to noises and vibration from the impacts of joint sections and wheels. In addition, this form of rail track was expensive to maintain in terms of time and money due to track irregularities and breakages. The problem mentioned above was solved by using continuous welded rails instead of the installation of joint bars between rails in order to overcome such flaws. The installation of continuous welded rail can enhance safety and increase cost saving effects due to the extension of the railroad line maintenance period while improving runnability and the comfort of passengers.

In consideration of domestic geographic conditions where there are many rivers and mountains, unlike overseas construction cases that are mostly carried out in embankment sections, the stability of tracks on bridges is a very important issue. Especially, if excessive additional axial stress or displacement on the rail is expected when the continuous welded rail is installed on the bridge, REJ (Rail Expansion Joint, REJ) is installed. The KR Code [1] limits the installation position of REJ based on field maintenance experience. However, there are occasions when the installation of REJ is required on a long-span bridge. This study was conducted in order to assess the best installation position of REJ device, and changes in the response of the track on the bridge according to the position of REJ device on the bridge were analyzed through numerical analysis.

COMPOSITION AND INSTALLATION CRITERIA OF RAIL EXPANSION JOINT

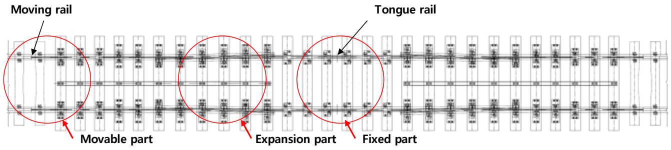


Figure 1: Composition of REJ

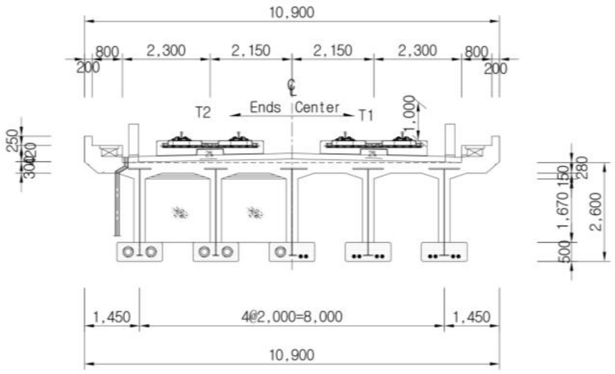
The expansion joint consists of a movable part, a tongue part, and a fixed part (Figure 1). The moving rail is a symmetrical section rail that serves to absorb the axial force of the rail by cutting the rail, and the tongue rail is an asymmetric type rail that serves to guide the expansion and contraction of the movable rail. The fixed part is a symmetrical (left side and right side) unprocessed rail that receives the excessive resistance generated on the tongue rail by mounting the fixed part between the tongue rail and the tongue rail to accommodate the resistance force when the moving rail is moved. It is possible to extend and contract the rail due to the temperature change by installing the rail expansion joint, thereby relieving the axial force and preventing buckling or breaking of the rail. Table 1 shows the installation criteria for rail expansion joint. As shown in Table 1, the installation criteria of rail expansion joint varies from country to country, but most of them are installed at the bridge end (movable end) in order to reduce the maximum additional axial stress generated at the moving end.

Table 1: Installation criteria for REJ[1-4]

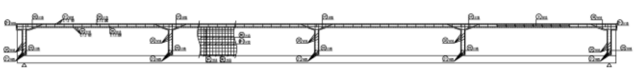
KR Code	Structural expansion joints and rail expansion joints shall be separated by at least 5 m.
THSR (Design Specifications)	The REJ shall be located adjacent to the structural expansion joint REJ shall be assumed to occupy a track length of 10 m each side of the structural expansion joint. Rail expansion joints should, where practical, be located on straight track.
ERRI Report	At least 2.5 m apart from the bridge end
DS804	The REJ shall be installed on the movable end of the bridge.

Target bridge and analysis method

The type of bridge frequently used in general lines designed for double tracks and ballasted tracks was selected as the target bridge, and the girder with a span length of 40 m in the form of steel and girder composite was chosen (Figure 2).



(a) Cross-section



(b) Longitudinal section

Figure 2: Section of girder for analysis

LUSAS [5], was used for the track-bridge longitudinal interaction analysis. 840 m was selected for the whole length for the analysis by assuming a 300 m embankment section on both ends of the bridge section. The rail and bridge deck section were modeled using the 3D Timoshenko beam element. The nonlinear joint element (elasto-plastic joint) that assess elastic-plastic behavior was used for the track bed. A Rigid Beam Element which represented the distance from the neutral axis of the bridge deck to the bridge pier was added and a constraint equation was applied to show a longitudinal relative displacement between the abutment or the bridge pier and the neutral axis of the bridge deck when bending displacement occurred on the bridge deck. (Figure 3) The properties of the rail and bridge girder in the analysis are shown in Table 2. The effects of bridge bending and ground conditions were not considered and the effects on the expansion were analyzed by applying the temperature load.

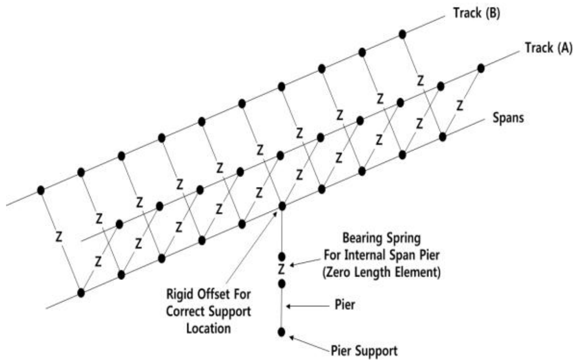


Figure 3: Overview of connection for track - girder – piers[5]

Table 2: Properties of rail and deck

Member	Rail (UIC60)	Deck
Cross-sectional area [m^2]	0.015	10
Young's modulus [N/m^2]	2.1×10^{11}	3.2×10^{10}
Thermal coefficient [/℃]	1.2×10^{-5}	1.0×10^{-5}
Moment of Inertia [m^4]	3.055×10^{-5}	15.2
Depth [m]	-	2.6
Distance from the center of gravity to the top [m]	-	1.13

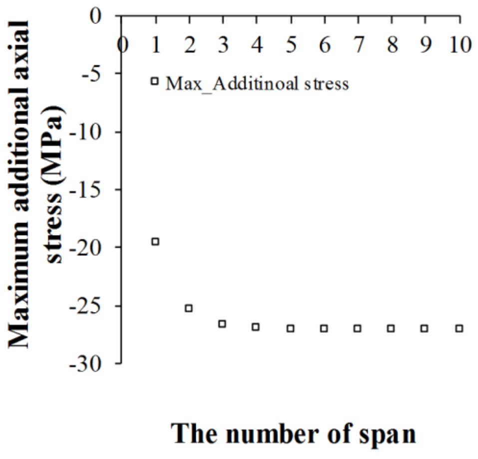
In order to analyze the response of the track on the bridge where the REJ device was installed, temperature load was applied to the upper structure (girder) as well as the rail, and 50℃ and 25℃ were applied to the rail and the bridge deck respectively[6].

SPAN NUMBER AND LOCATION OF REJ

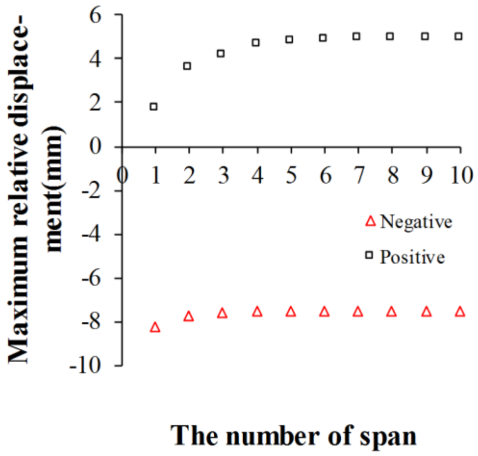
Selection of span number for the target bridge

In order to examine the effects of span arrangement, the span number, on the increase in the response, an analysis was carried out by increasing the span number. 1~10 spans were considered for the analysis.

The additional axial stress and rail-girder relative displacement according to the installation location of the REJ were set to analyze the track response. As shown in Figure 4, the additional axial stress (a) and rail-girder relative displacement (b) of the rail converged on 4~6 spans and 6 or more spans were targeted for simplifying the analysis time and model.



(a) Variation of stress of rail



(b) Variation of relative displacement

Figure 4: Response of analysis results according to span number

Selection of installation location of REJ device

The installation position of the REJ was considered as shown in Figure 5. A one-sided REJ was applied in the numerical analysis, and the installation location of the REJ including the movable end on the abutment (A2) and the embankment section from the middle of the span was assumed, and in order to carry out the analysis of the response according to the installation location of the REJ, locations for analysis at intervals of 20 m were selected.

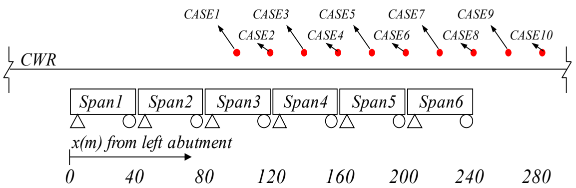
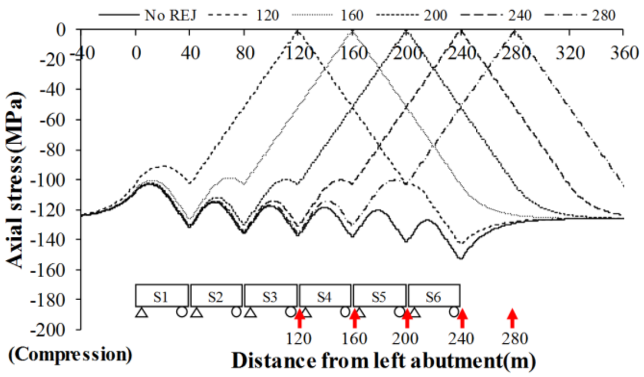


Figure 5: Installation case of REJ

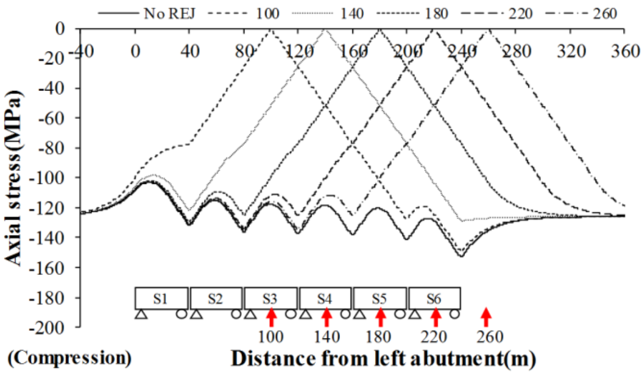
Analysis of response according to the installation location of REJ

a. Stress on rail

Figure 6 (a) shows the stress on the rail according to the installation position on the bridge in the case where the REJ is installed on the bridge expansion joint, and (b) shows the stress on the rail in the case where the REJ is installed in the center of the bridge girder.



(a) Located at the end of girder



(b) Located at the center of girder

Figure 6: Rail stress according to the locations of REJ

The maximum compressive stress on the rail according to the position of the REJ in Figure 6 (a) and (b) is as shown in Table 3.

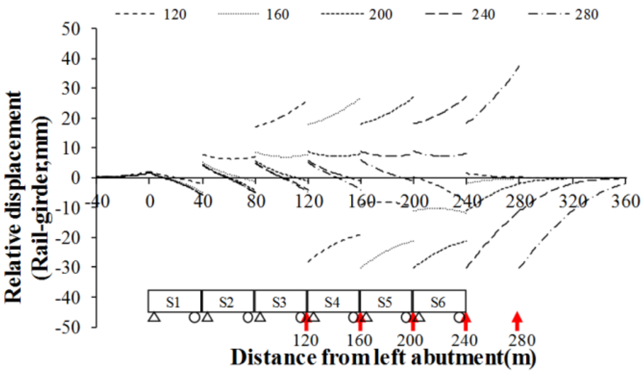
Table 3: Maximum compressive stress of rail from the analysis result

Distance from the left abutment(m)	Location	Max. Compressive stress(MPa)
100	center	149.2
120	end	143.1
140	center	128.9
160	end	126.1
180	center	129.4
200	end	130.4
220	center	133.6
240	end	134.7
260	embankment	135.5
280	embankment	135.7

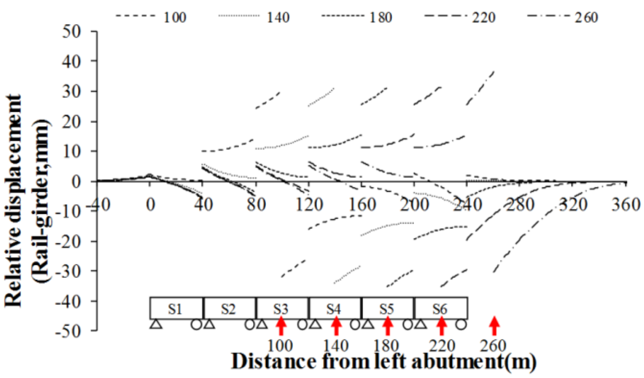
As a result of analyzing the maximum compressive stress on the rail, the minimum value was shown to be near approximately 160 m from the left abutment regardless of the center and the end of the girder. The stress is 0 at the installation position of the REJ, and the stress characteristics at the unmovable section of continuous welded rail are shown after approximately 100 m from the left and right sides of the REJ. Generally, it seems better to install the REJ on a location where the maximum additional axial stress occurs when installing the continuous welded rail on the bridge. In the case of the target bridge, the largest additional axial stress occurred at a position of 240m, so the installation of the REJ at a position of 160 m reduces the overall stress by approximately 8MP in comparison to the installation of the REJ at a position of 240 m. Therefore, it is considered reasonable to select the installation position after reviewing the position where the maximum additional axial stress occurs as well as various positions on the bridge for reducing overall rail stress.

b. Relative displacement of rail and girder

Figure 7 (a) shows the relative displacement of rail and girder according to the installation position on the bridge in the case where the REJ is installed on the bridge expansion joint, and (b) shows the relative displacement of rail and girder in the case where the REJ is installed in the center of the bridge girder.



(a) Located at the end of girder



(b) Located at the center of girder

Figure 7: Relative displacement of rail and girder according to the locations of REJ

Table 4: Maximum relative displacement(rail-girder) from the analysis result

Distance from the left abutment(m)	Location	Max. Relative displacement(mm)
100	center	31.74
120	end	28.05
140	center	34.02
160	end	30.21
180	center	35.30
200	end	30.21
220	center	35.30
240	end	30.29
260	embankment	36.39
280	embankment	37.26

The maximum relative displacement according to the position of the REJ in Figure 7 (a) and (b) is as shown in Table 4. As a result of analyzing the maximum relative displacement of rail and girder, a smaller displacement occurred when the REJ was installed at the end of the girder in comparison to the installation of the REJ at the center of the girder. Also, a higher relative displacement occurred as the REJ was installed closer to the movable end of the bridge, and when the REJ was installed on the embankment section, a higher relative displacement occurred. If the REJ is installed on the bridge expansion joint, the maximum relative displacement may be reduced, and this shows that the relative displacement may decrease if the REJ is installed on the bridge rather than the position of the abutment on the movable section. Therefore, it is considered reasonable to devise the installation position after reviewing various positions on the bridge in order to reduce the relative displacement.

CONCLUSION

In this study, track-bridge interaction analysis was conducted by applying the temperature load in order to analyze the track response on the bridge. Generally, the REJ is constructed on a location where the additional axial stress or displacement of the rail exceeds the permissible value. However, the need to review various positions was confirmed through the numerical analysis study. The stress of the rail is reduced at the installation location of the REJ device, and the rail-girder relative displacement increases significantly. As a result of this study, it is judged that a significant disordering of ballast will occur on the section where the REJ device is installed in comparison to the section where no REJ device is installed due to the effects of increasing relative displacement and the effects of distance from the bridge girder ends, that is, the installation location of the REJ device, will not be significant. However, it is difficult to identify the effects regarding the distortion of the track in the ballasted track when the REJ is constructed based only on a numerical analysis, so additional analyses of the effects regarding the distortion of the track are required.

ACKNOWLEDGEMENTS

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