Creep-Coupler가 설치된 KHSR교량의 종방향 동적거동

Longitudinal Dynamic Behavior of KHSR-Bridge Installed Creep-Couplers

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국문요약

경간 사이에 creep-coupler가 설치된 경부고속철도 교량에 TGV-K 열차의 제동에 의한 교량의 종방향 동적거동을 해석하였다. 교량은 40m 길이의 2경간 연속교이며, 종방향 충격 하중을 인접 경간 혹은 교대로 전달하기위한 목적으로 인접하고 있는 두교량 사이에 creep-coupler가 설치되었다. 철도교의 경우에는 레일에 대한 종방향 축력검토가 매우 중요하므로, 이를 지지하고 있는 교량의 하부구조(교각과 기초)의 영향을 고려한 교량의 동적거동 해석이 요구된다. 본 연구에서는 TGV-K의 실제 제동하중에 의한 KHSR(Korea high speed railway)에 건설중인 실제교량의 동해석을 하부구조의 동특성치를 고려하여 수행하였다. TGV-K는 객차사이에 대차가 위치하므로 전체 열차의 모델링이 한꺼번에 이루어 져야한다. 동해석을 위해서 열차의 3차원 수치모델링이 이루어 졌다. TGV-K의 제동은 동력차의 전기적인 제동에 의한 회생제동력(regenerative braking force)과 객차의 기계적인 판제동(disk braking)으로 이루어 진다. 이러한 제동작용의 고려에 실제 TGV-K의 제동함수가 사용되었다.

주요어 : 제동하중, 교량-열차 상호작용해석, 고속철도, creep coupler

ABSTRACT

Longitudinal behaviors of the bridge for KHSR(Korea high speed railway) are investigated due to TGV-K braking considering creep couplers installed between the bridges. The bridges are being constructed with two continuous spans of 40m. Creep couplers are installed between adjacent bridges in order to distribute and transfer longitudinal impact forces to adjacent bridges or abutments. It is necessary to investigate the behaviors of the bridge considering the effects of substructure(piers and foundations) dynamically. In this study, the behaviors of actual bridges in KHSR lines are analyzed dynamically using real braking forces by TGV-K considering properties of substructure. Full modeling of overall train system is required because each body of TGV-K is connected through articulate bogies. It is formulated in three dimensions numerically for dynamic analysis. The brake of TGV-K is achieved by the combination of regenerative braking force of electric braking for the power car bogie and mechanical disk braking for the passenger car bogie. Actual braking function of TGV-K is applied to consider braking action.

Key words *: braking load, bridge-train interaction analysis, high-speed train, creep-coupler*

1. Introduction

After earlier theoretical studies of analyzing the dynamic behavior of railway bridges by Inglis$^{(1)}$, various researches of applying newly developed and revised train and bridge models have been accomplished. The researches on the impact of concrete railway bridges by freight trains have been carried out by Chu et al.$^{(2)}$ Cai$^{(3)}$ studied wheel/rail interaction with considering the various irregularities of railroad. However, previous studies had limitations that they did not consider nonuniform speed of train. The study on dynamic longitudinal behaviors of bridge due to trains riding with high

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speed has rarely performed with focusing on the braking load by train.

The high-speed railway is constructed in South-Korea adopts the train system(as called TGV-K) which has noticeable features of articulated truck system. The vibrations of bridges caused by high-speed train with considering bouncing and pitching motions of train in 2-dimension are analyzed by Chang et al.[(4)] In the present study, 3-dimensional models for TGV-K including forwarding motions to investigate the dynamic behavior of bridge structures are formulated. The bridge analyzed is Shin-Jeong bridge which is constructed in section 4-1 field, Korea. It is composed of 6 concrete one-cell box girder bridges with continuous 2 spans.

2. Numerical modelling of TGV-K

The high-speed train system, that will be running in South-Korea(so called TGV-K) differs from general train system. In general, train system is a series of cars that consist of one body and two trucks(or bogies) independently, but as shown in Fig. 1, TGV-K adopts articulated truck system which has a truck and longitudinal dampers between each passenger car. Therefore, for scrutinizing the behavior, full modeling of overall train system is required. The high-speed train system investigated in this study consists of 2 power cars, 2 motorized trailers, and 16 passenger cars. A power car is composed of 2 trucks like general power cars, but a motorized trailer has one independent truck and shares one articulated truck with a passenger car. An articulated truck exists between each passenger car. And, each truck has 2 axles. Consequently, TGV-K with total length (distance between first axle and last axle) of 380.15m has total number of 20 carbodies, 23 trucks, and 46 axles

Assumption that primary and bolsterless secondary suspension system of the bogie is idealized by combination of linear spring and viscous damper is applied for modeling, and all wheels

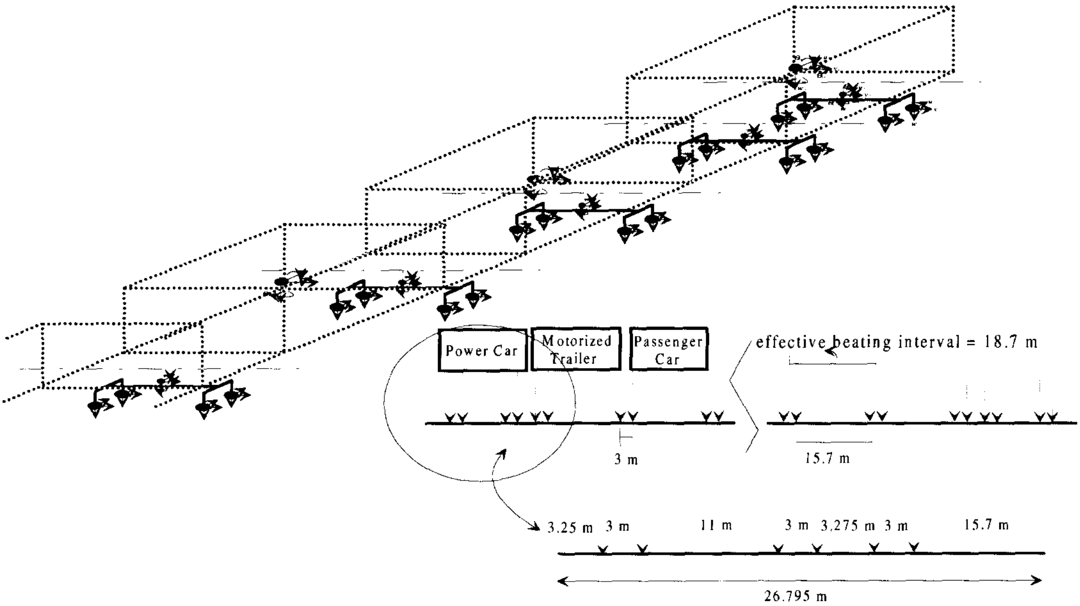

Fig. 1 KHST and the distance between each axle of KHST

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of the train are assumed to remain in contact with the riding surface.

As shown in Fig. 2, to define the relationship between an articulated bogie and its forward and backward car-bodies, the relative displacements are assumed as

$$u_r = u_t - \frac{u_{bi} + u_{bj}}{2}$$

$$v_r = v_t - \left\{ \frac{v_{bi} + v_{bj}}{2} - l(\theta_{bzi} - \theta_{bzj}) \right\}$$

$$w_r = w_t - \left\{ \frac{w_{bi} + w_{bj}}{2} + l(\theta_{byi} - \theta_{byj}) \right\} \qquad (1)$$

where u, v, and w mean forward, transverse, and vertical movements. Using similar procedures of power car and applying Eq. (1), the equations of motion for motorized trailers and passenger cars can be established. Overall equations of motion are skipped because of space limitation and the formulations in details are recorded in reference.[5] In the absence of grade and neglecting drag, braking forces can be expressed in mathematical form as[6]

$$F_B(\nu) = mg\mu(\nu) \qquad (2)$$

where, m is a mass of vehicle, g is a gravitational acceleration, ν is a velocity of train and μ is a frictional coefficient.

The braking system of high-speed train is separated into electric braking and mechanical braking.

For KHST, the combination of two braking systems will be in use - regenerative braking force of electric braking for a power car bogie and disk braking of mechanical braking for a passenger car bogie.[7] Fig. 3 shows braking forces per bogie versus its velocity for regenerative and disk braking force used in this study.

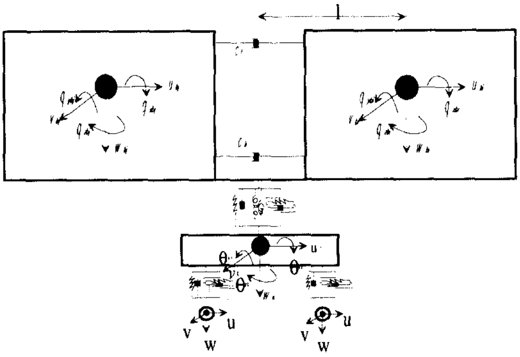


Fig. 2 Articulated bogie

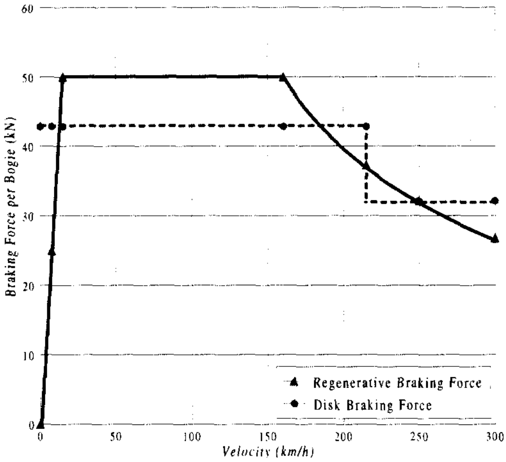


Fig. 3 Braking force of KHST

3. Numerical consideration on the bridges for KHSR

The bridge system used in this study is composed of 6 bridges which have two continuous span and are made of concrete box girder of one cell. The individual bridge has a span length of 40m and a width of 14m. The bridge system is modeled using space frame elements including piers, bearings and creep couplers installed between each bridge under the expansion joints. Superstructure is supported by one pot bearing on the center pier and two pad bearings on side piers. Two creep couplers are installed between adjacent bridges. Each coupler has axial stiffness of 171.7MN/m.

Pot bearing is idealized as rigid link for translational movement and pad bearing is simulated using linear spring of which constant is 11,850MN/m and 12.23MN/m to vertical and horizontal directions, respectively. Schematic feature of the bridge system is shown in Fig. 4.

4. Numerical examples

In the present study, Newmark-β direct integration algorithm[9] with a predictor-corrector iteration scheme is employed for solving the equations of motion. Using the present approach explained above, parametric studies are performed.

The effects of creep-couplers on the dynamic longitudinal responses in Shin-Jeong bridge are investigated through numerical studies. Riding speeds of the train are varied up to design speed of 350km/hr before brake starting time. Braking of the train on the bridge is activated at various positions. Fig. 5 shows typical time history of responses of the bridge. Fig. 6 and Fig. 7 show maximum responses of the bridge according to braking positions and initial riding speeds. Fig. 8 shows the ratio of responses ignoring creep-couplers to those including couplers.

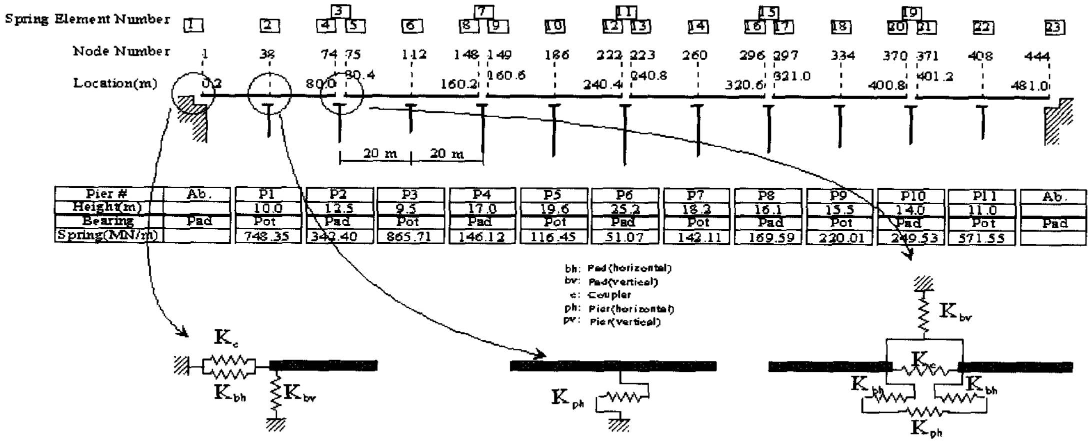
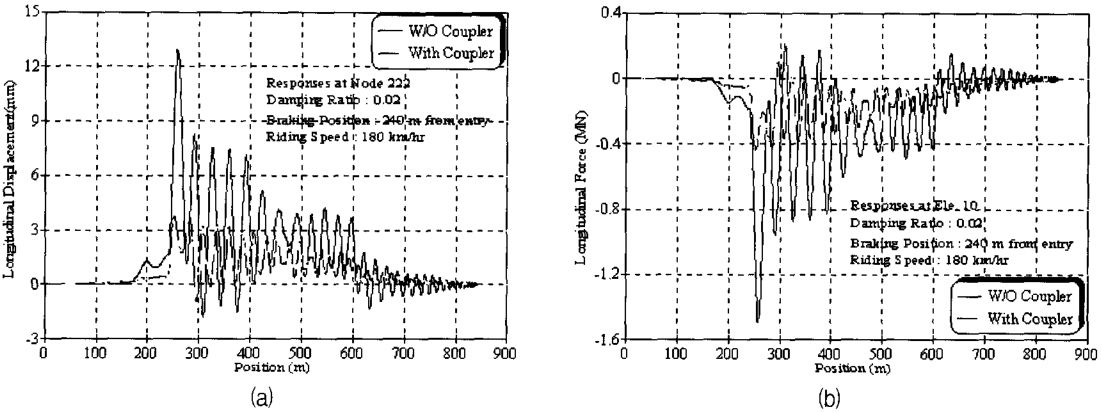


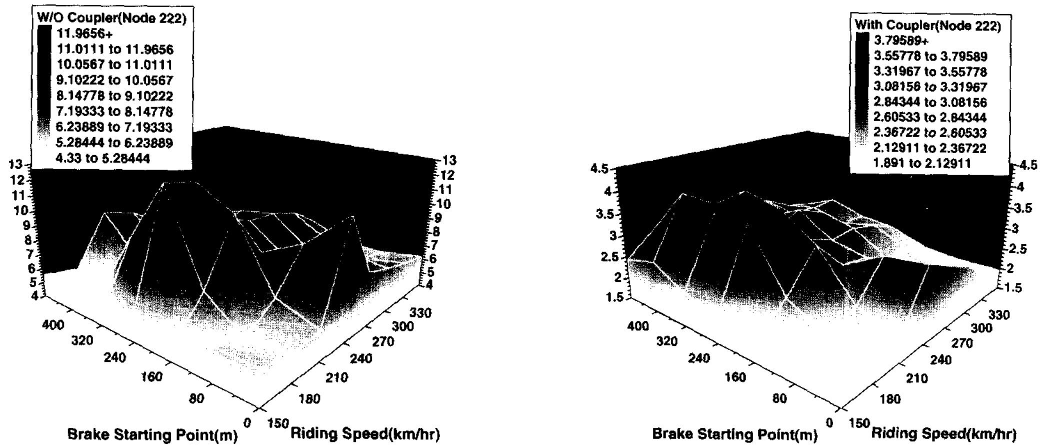
Fig. 4 Idealization of Shin-Jeong bridge in KHSR



(a)

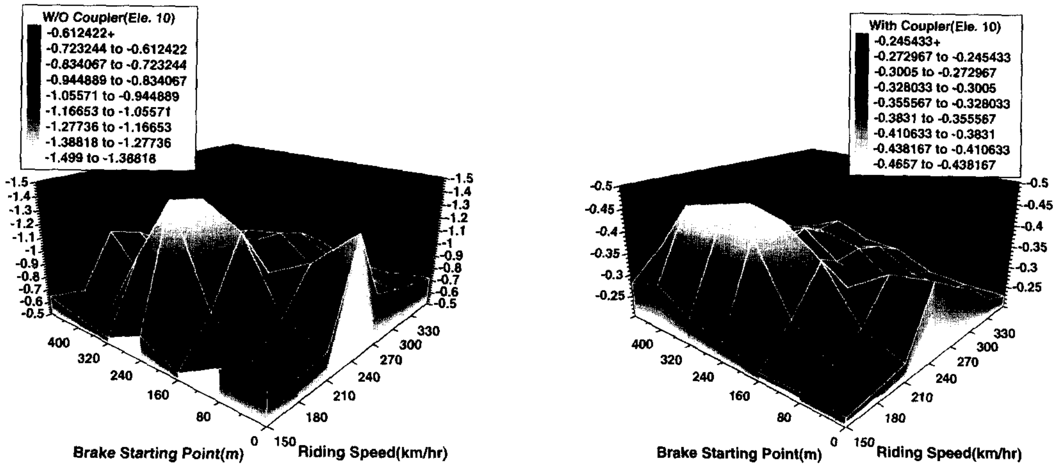
(b)

Fig. 5 Typical responses of Shin-jeong bridge due to braking of TGV



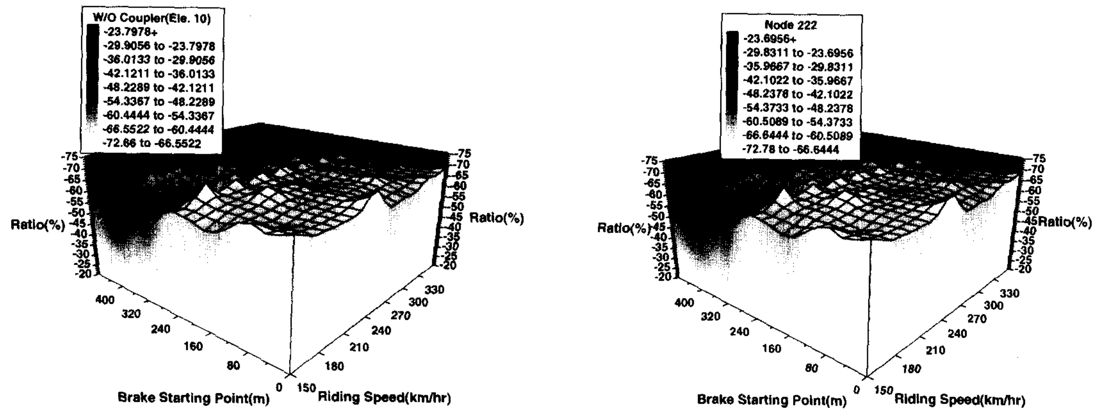
(a) w/o coupler (b) with coupler

Fig. 6 Variation of maximum longitudinal displacement(mm) at node 222



(a) w/o coupler (b) with coupler

Fig. 7 Variation of maximum longitudinal forces(MN) at element 10



(a) (b)

Fig. 8 Variation of diffenences (a) in displacements at node 222 (b) in forces at element 10

5. Conclusion

In this study, following conclusions are drawn from this study.

(1) Creep-couplers are effective in the reduction of longitudinal displacements along to the bridges.
Displacements of the bridge with coupler are much less than those of the bridges without it with maximum 70% reduction.
(2) Creep couplers are effective in the re-distribution and the reduction of longitudinal forces along to the bridges.
(3) Effects of creep couplers on the re-distribution and the reduction of longitudinal forces are significant at center pier. However, the effects are very small at bridges close to abutments.
(4) Experimental study will be necessary to verify this study.

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