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A Simplified Numerical Model for an Integral Abutment Bridge Considering the Restraining Effects Due to Backfill

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Abstract

This paper presents the simplified but more rational analysis method for the prediction of additional internal forces induced in integral abutment bridges. These internal forces depend upon the degree of restraint provided to the deck by the backfill soil adjacent to the abutments and piles. In addition, effect of the relative flexural stiffness ratio among pile foundations, abutment, and superstructure on the structural behavior is also an important factor. The first part of the paper develops the stiffness matrices, written in terms of the soil stiffness, for the lateral and rotational restraints provided by the backfill soil adjacent to the abutment. The finite difference analysis is conducted and it is confirmed that the results are agreed well with the predictions obtained by the proposed method. The simplified spring model is used in the parametric study on the behavior of simple span and multi-span continuous integral abutment PSC beam bridges in which the abutment height and the flexural rigidity of piles are varied. These results are compared with those obtained by loading Rankine passive earth pressure according to the conventional method. From the results of parametric study, it was shown that the abutment height, the relative flexural rigidity of superstructure and piles, and the earth pressure induced by temperature change greatly affect the overall structural response of the bridge system. It may be possible to obtain more rational and economical designs for integral abutment bridges by the proposed method.

Keywords : integral abutment PSC beam bridge, thermal expansion, earth pressure, soil-structure interaction, finite difference analysis

1. Introduction

Bridge superstructure expands and contracts due to ambient temperature change. Traditionally, these temperature changes inducing movements have been accommodated by such components as expansion joints and bearings. However, these expansion joints and bearings are expensive to install and require continuing maintenance. These joints are critical parts for deterioration of the superstructure and substructure caused by deck leakage contaminated with deicing chemicals[1)].

A cost-effective alternative increasingly popular among bridge engineers is the use of integral abutment bridge, terms generally referring to simple-span or multiple-span continuous jointless structures with capped-pile stub-type abutments.(Fig. 1)[2)]. The major advantages of integral abutment bridges include reduction of initial construction costs and long-term maintenance expenses, elimination of costly expansion joints and bearings, decrease of impact loads, improvement of riding quality, and simple construction procedures[3)].

Integral abutment bridges have been used successfully in many countries, particularly in U.S.A. and Canada, where overall deck length up to 358.4m have been constructed[1)]. In U.K., it has been proposed that all bridges with length up to 60m and skew of less than 30° be constructed integrally. The construction of this practical type of bridge is also tried in Korea and Japan. The 3-span continuous PSC beam bridge (total length of 90m) has been successfully built and monitored its in service performance in Korea[4)]. The inte-

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gral bridge system (total length of 28.3m) in which the one span plate girders with steel pile was also built in Japan.

Although many of the integral abutment bridges in service perform satisfactorily, there is still some uncertainties such as the degree of restraint provided by the surrounding soil to the bridge. An accurate assessment of this restraint is essential for the estimation of additional forces and moments induced in the deck caused by its longitudinal length change; such expansion takes place in response to temperature increases, and leads to increases in axial stress and hogging moment in the deck[5].

In the traditional design, the restraining effects provided by the surrounding soil and substructures are neglected in the design of superstructure of integral abutment bridges. Only deck-abutment joints are designed conservatively by assuming under the maximum passive earth pressure (Rankine or Coulomb passive earth pressure) condition[6].

However, thermal expansion of the deck of integral abutment bridges is restrained by the lateral soil adjacent to abutment and pile foundation, and the actual earth pressure behind the abutment is a function of the magnitude and nature of the wall displacement, changing between at rest earth pressure and passive earth pressure depending on the amount of displacement[7]. In addition, structural effect of the relative flexural stiffness ratio among foundation piles, abutment, and superstructure is an important factor that affects the behavior of integral abutment bridges. Therefore, in order to understand the actual behavior of integral abutment bridges, it is always desirable to analyze the integral abutment bridges considering the full restraining effects by the surrounding soil and substructures including the soil-structure interaction. In order to show the restraining effects of backfill soil behind the abutment as well as the structural restraining effect by relative rigidity of members, it is proposed the simplified spring modeling method for backfill soil reactions induced by thermal expansion of the superstructure. For the sake of simplicity, the integral abutment bridge is modeled with a plane frame element, and the equivalent cantilever model is used to take into account for the soil-pile interaction[7].

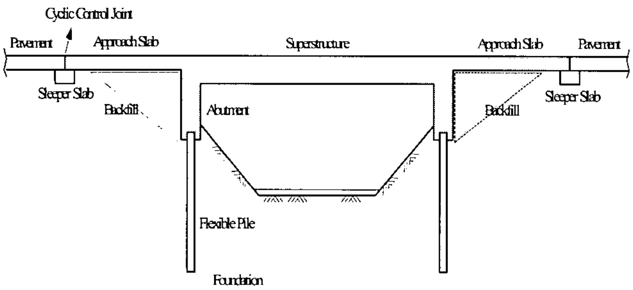


Fig. 1 Integral abutment bridge

The abutment wall and backfill soil interaction is introduced by taking the elastic springs whose mechanical constants are determined by using the relations between wall displacements (translation, rotation) and the corresponding earth pressure.

In this paper, we also performed the parametric study by varying abutment height and flexural rigidity of piles, and the graphical form of results is presented. The integral abutment bridges considered in the parametric study are simple-span and multi-span (2, 3) continuous PSC beam bridges, which is composed of KHC's (Korea Highway Corporation) standardized 30m prestressed concrete (PSC) beam.

2. Soil-structure interaction

2.1 Relations between earth pressure and wall displacement

The modes of wall displacement can be classified into five types; horizontal translation (T-mode), rotation about the wall top (RT-mode), rotation about a point above the wall top (RTT-mode), rotation about the wall base (RB-mode), and rotation about a point below the wall base (RBT-mode)[8]. The modes of wall displacement concerned in this research are T-mode, RB-mode, and RBT-mode that may possibly occur in the integral abutment by the thermal expansion of bridge deck.

In order to investigate the soil reaction with respect to the magnitude and mode of abutment wall displacement, the commercially available computer program FLAC (Fast Lagrangian Analysis of Continua v3.3, 1995) was used. Fig. 2 shows the computational modeling of 4m high backfill adjacent to the abutment wall generated by finite difference grids. Stress-strain relationship of backfill soil material was modeled by Mohr-Coulomb model. Material properties

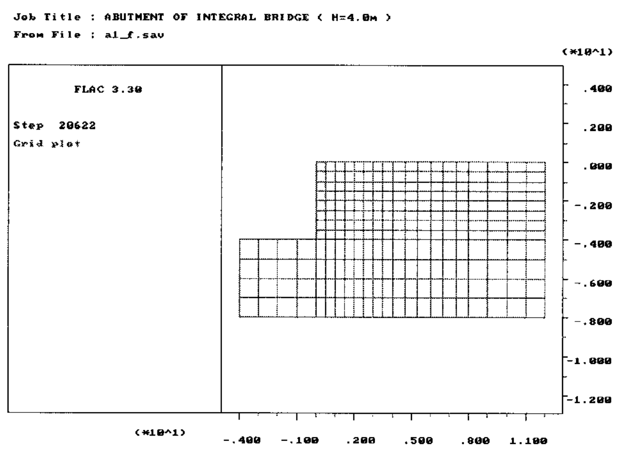


Fig. 2 Modeling of abutment wall and backfill

Table 1 Material properties of backfill

E_s (kgf/cm^2)	ν	c (tonf/m^2)	ϕ (°)	γ (tonf/m^3)
409	0.3	0.0	35	2.0

where, E_s : elastic modulus, ν : Poisson's ratio
c : coefficient of cohesion, ϕ : internal friction angle
γ : unit weight

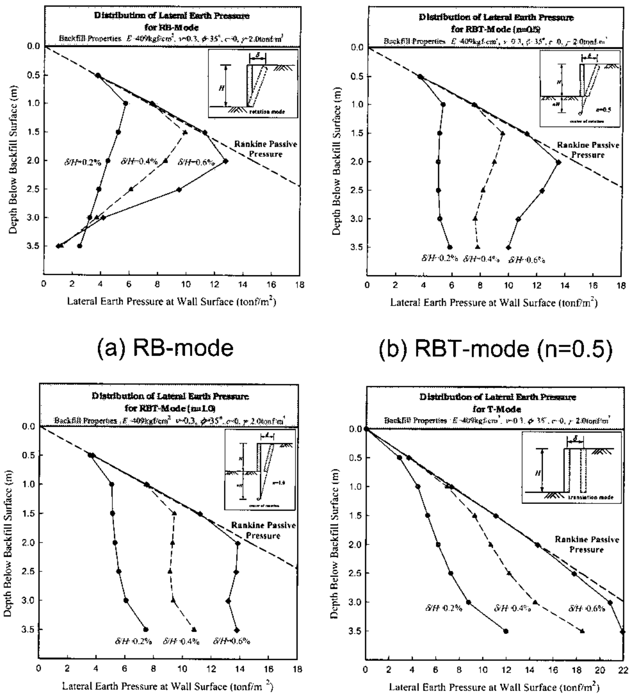
of backfill soil were assumed to be those of the gravel or sandy gravel with few fines as shown in Table 1[9].

In order to apply the displacement loads, the nodes at the vertical side of backfill adjacent to the abutment are taken as supports. According to the types of abutment displacement, such as T-mode, RB-mode, and RBT-mode, the displacement loads are applied at those supports, respectively, and the reaction of each support and the earth pressure are investigated.

Fig. 3 shows the earth pressure distribution for RB-mode, RBT-mode (n=0.5), RBT-mode (n=1.0), and T-mode, respectively. The parameter n indicates the location of center of rotation. As shown in Fig. 3(d), earth pressure distributions were linear and the resultant force of earth pressure was located at about $H/3$ above the wall base in the case of T-mode. However, in the case of RB-mode, the earth pressure distributions were nonlinear and the resultant force of earth pressure was located at about $0.55H$ above the wall base (see Fig. 3(a)). The trend of distribution of earth pressure for each case was agreed well with that of published test result[8].

As shown in Fig. 3(b) and 3(c), earth pressures were almost uniformly distributed up to the line of Rankine's passive earth pressure in the case of RBT-mode (n=0.5~1.0) which could be the displacement mode induced by thermal expansion of deck in the integral abutment bridge.

Fig. 4 shows the horizontal earth pressure coefficient (K) with respect to the relative wall displacement to abutment height (δ/H) for T-mode and RB-mode, respectively. The coefficient K was defined as the ratio of the horizontal component of total resultant force to $\gamma H^2/2$. It was found that both the displacement mode and the magnitude of displacement affect the magnitude and distribution of the earth pressure.



(a) RB-mode (b) RBT-mode (n=0.5)

(c) RBT-mode (n=1.0) (d) T-mode

Fig. 3 Distribution of horizontal earth pressure

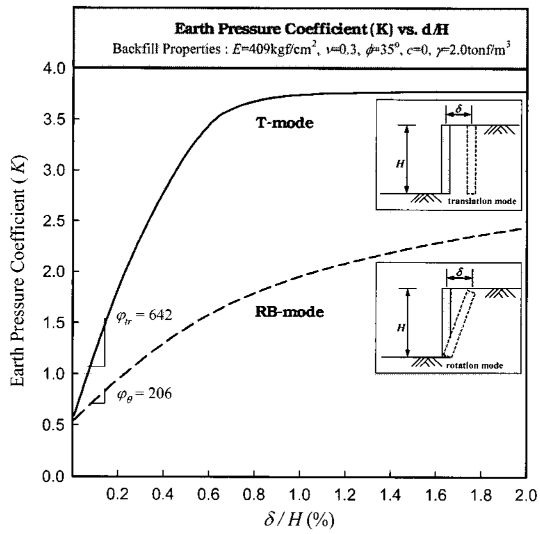


Fig. 4 Variation of earth pressure coefficient K with wall movement for T-mode and RB-mode

2.2 Conventional method for the application of earth pressure

The integral abutment bridge is a classical example of a soil-structure interaction system. This soil-structure interaction applies to the lateral soil pressure acting on the abutment and foundation piles.

The soil-pile system is usually modeled as an equivalent cantilever beam element whose length can be expressed as a function of surrounding soil properties and rigidity of piles. This reduces the nonlinear soil-structure system to the equivalent linear structural system, which is valid only for the assumed loading and displacement level. Previous research results by finite element simulation and experiment revealed that the equivalent cantilever model was conservative and sufficiently accurate[7, 10].

At present, a simple and reliable way of predicting the relationship between earth pressures and abutment movements is not available[11]. According to the survey report conducted in U.S.A., some agencies even do not consider soil pressure within a certain abutment size limit, and other agencies do not consider the earth pressure at all in their design. When the earth pressure is considered in the design, the earth pressure is assumed as a uniform or a triangular distribution, and it is recommended that the two third of full passive pressures is used only for the design of integral abutment[1, 12].

However, as mentioned in section 2.1, the earth pressure behind the abutments depends on temperature induced by displacement of the abutment. Therefore, it is needed to predict the earth pressure in the form of abutment displacement considering the soil-structure interaction with reasonable accuracy and simplicity.

3. Spring modeling for the earth pressure behind the abutment

In this part of the paper, we discussed the formulation of an elastic spring model for the earth pressure of backfill soil induced by the thermal expansion of deck in integral abutment bridges in order to predict the additional internal forces. In previous work[13], it was concluded that the effect by thermal contraction of bridge deck and its corresponding active earth pressure could be neglected in the design of integral abutment bridges. Therefore, only the thermal expansion of bridge deck and its corresponding passive earth pressure were considered in the formulation of the numerical spring model.

3.1 Modeling for the earth pressure with respect to the abutment wall displacement

Fig. 5 illustrates the displacement shape of abutment wall induced by the thermal expansion of deck. Horizontal displacements at the top and bottom of the abutment are denoted by d_t and d_b, respectively.

For the small flexural displacement of abutment, rotation of the abutment wall (θ) is obtained by Eq. (1).

$$\theta \approx \tan\theta = \frac{d_t - d_b}{H} \tag{1}$$

Assuming that the earth pressure of backfill soil is proportional to the wall displacement up to the passive earth pressure, the total resultant force (P_T) of earth pressure induced by the abutment displacement as illustrated in Fig. 5 can be obtained by arithmetic summation of at rest earth pressure (P_o), the increase of earth pressure induced by horizontal displacement d_b (ΔP_{tr}), and the increase of earth pressure induced by rotation θ (ΔP_θ), and it can be written in the form:

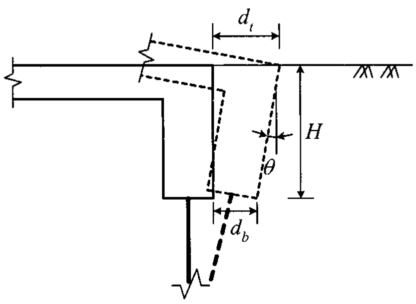


Fig. 5 Assumed displacement shape of abutment wall

$$P_T = P_o + \Delta P_{tr} + \Delta P_\theta \tag{2}$$

In Eq. (2) ΔP_{tr} and ΔP_θ are defined as

$$\Delta P_{tr} = P_{tr} - P_o \quad (3a), \quad \Delta P_\theta = P_\theta - P_o \quad (3b)$$

Defining the earth pressure coefficients K_{tr} for the translation mode and K_θ for the rotation mode as shown in Eqs. (4), the relations between the earth pressure coefficients, K_{tr} and K_θ, and the relative wall displacement to abutment height, δ/H, can be obtained and the results were shown in Fig. 4.

$$K_{tr} = \frac{2 \cdot P_{tr}}{\gamma \cdot H^2} \quad (4a), \quad K_\theta = \frac{2 \cdot P_\theta}{\gamma \cdot H^2} \quad (4b)$$

Under the condition that the abutment displacement is small, the earth pressure coefficients K_{tr} and K_θ can be assumed linear function of the relative wall displacement to abutment height as follows:

$$K_{tr} = K_o + \varphi_{tr} \cdot \frac{d_b}{H} \tag{5a}$$

$$K_\theta = K_o + \varphi_\theta \cdot \frac{d_t - d_b}{H} \approx K_o + \varphi_\theta \cdot \theta \tag{5b}$$

In Eqs. (5), K_o is at rest earth pressure coefficient, φ_{tr} and φ_θ are the slopes of the earth pressure coefficients K_{tr} and K_θ depicted in Fig. 4, respectively. The estimated values of φ_{tr} and φ_θ for backfill soil whose material properties are given in Table 1 are 642 and 206, respectively.

By substituting Eqs. (5) into Eqs. (4), and then substituting the ensuing equations into Eqs. (2), the total resultant force of backfill soil earth pressure induced by the abutment displacements d_b and θ can be obtained as

$$P_T = P_o + \alpha \cdot \{\varphi_{tr} \cdot d_b + \varphi_\theta \cdot H \cdot \theta\} \tag{6}$$

where, $\alpha = \gamma H/2$.

3.2 Spring modeling for the earth pressure

The displacement mode of integral abutment wall is neither T-mode nor RB-mode but RBT-mode. Therefore, as mentioned in section 2.1, the earth pressure distribution and the location of its resultant force are different from those of conventional Rankine passive earth pressure.

It is assumed that the total resultant force of earth pressure is located at $H/2$ above the wall base and the earth pressure is uniformly distributed behind the abutment ($q=P_T/H$). This assumption was based on the valid results obtained by the finite difference method using FLAC as illustrated in section 2.1 and the existing experimental data[14], where the location of resultant force of earth pressure behind the integral abutment wall was $0.46H \sim 0.56H$ above the wall base.

Fig. 6(a) shows the assumed earth pressure distribution (q) and resultant force (P_T).

Fig. 6(b) presents the substitution of equivalent nodal force at the top and bottom of abutment for the uniformly distributed earth pressure using the fixed end moments and forces. At rest earth pressure (P_o) is constant determined by abutment height and backfill soil material properties. ΔP_{tr} and ΔP_θ are functions of the horizontal displacements d_t and d_b, and the rotation of abutment θ. In Fig. 6(b), R_t, M_t and R_b, M_b can be expressed in matrix form as follows:

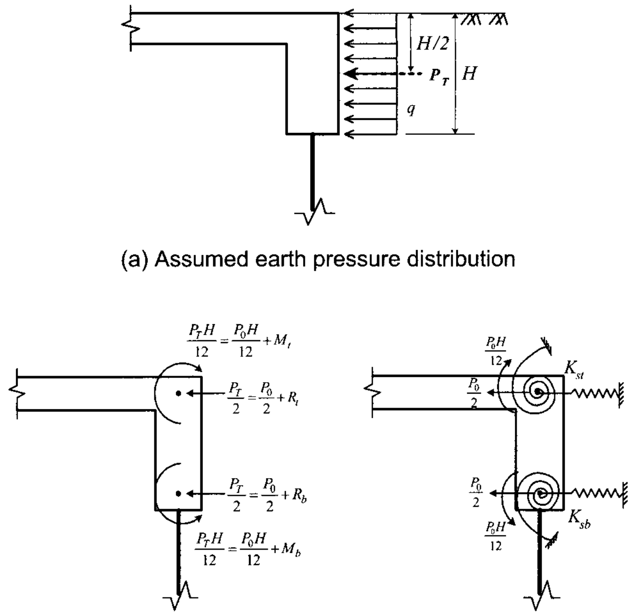
$$\begin{Bmatrix} R_t \\ M_t \end{Bmatrix} = \underbrace{\frac{\alpha}{12}\begin{bmatrix} 6\cdot\varphi_{tr} & 6\cdot H\cdot(\varphi_\theta-\varphi_{tr}) \\ H\cdot\varphi_{tr} & H^2\cdot(\varphi_\theta-\varphi_{tr}) \end{bmatrix}}_{K_{st}} \cdot \begin{Bmatrix} d_t \\ \theta \end{Bmatrix} \quad (7a)$$

$$\begin{Bmatrix} R_b \\ M_b \end{Bmatrix} = \underbrace{\frac{\alpha}{12}\begin{bmatrix} 6\cdot\varphi_{tr} & 6\cdot H\cdot\varphi_\theta \\ H\cdot\varphi_{tr} & H^2\cdot\varphi_\theta \end{bmatrix}}_{K_{sb}} \cdot \begin{Bmatrix} d_b \\ \theta \end{Bmatrix} \quad (7b)$$

Finally, the bridge system shown in Fig. 6(b) can be modeled as a framed structure as shown in Fig. 6(c) with elastic springs whose stiffness matrices are identical to the coefficient matrices K_{st} and K_{sb} in Eqs. (7).

Considering the restraining effect of backfill soil behind the abutment, the overall stiffness matrix can be formed by assembling the coefficient matrices K_{st} and K_{sb} to the corresponding degrees of freedom.

The load vector consists of nodal forces due to at rest earth pressure and thermal expansion of bridge deck. By solving the ensuing simultaneous linear equations using the direct stiffness method, the behavior of integral abutment bridge due to the thermal expansion of bridge deck can be investigated.



(a) Assumed earth pressure distribution

(b) Equivalent nodal force (c) Spring modeling of backfill soil pressure

Fig. 6 Spring modeling for earth pressure

4. Numerical analysis

In this study, the numerical analysis was conducted by using the FLAC program for the purpose of verification of the results obtained by the simplified structural spring modeling method. Simple-span, 2-span, and 3-span continuous integral abutment bridges whose superstructure consisted of the KHC's standardized 30m PSC beam were considered.

For the temperature increase of ΔT = 20 °C, the overall structures were modeled as follows:

1) The slab-on-girder-type superstructure is modeled with an effective width of the slab. Accordingly, the abutment is idealized to have a tributary width equal to effective width of the slab. Similarly, the piles per effective width are considered, and its stiffness is lumped to obtain a single pile element for analysis purposes.
2) A roller support is used as boundary condition at the pier connection.
3) The effect of frictional forces between the approach slab and soil underneath as well as between the wing-wall and backfill, resulting from movements due to temperature variation, is ignored.
4) Geometric condition of the bridge is symmetric and skew angle is not considered.
5) An equivalent cantilever pile is used for the modeling of soil-pile system.
6) The lateral and rotational restraints provided by the backfill soil are modeled as linear elastic spring for longitudinal translation and rotation.

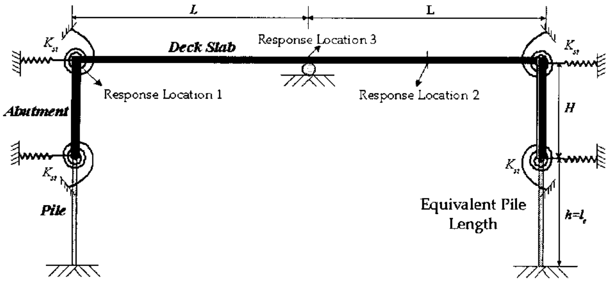


Fig. 7 Modeling for 2-span integral abutment bridge

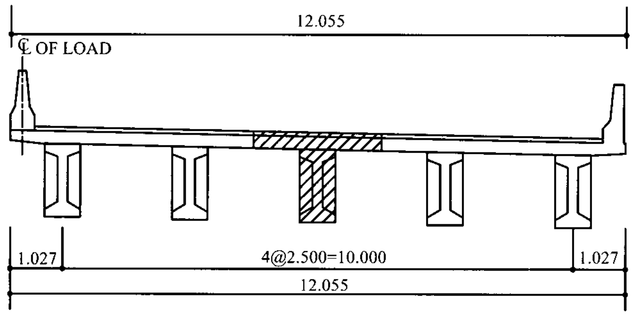


Fig. 8 Cross section of PSC beam bridge for analysis

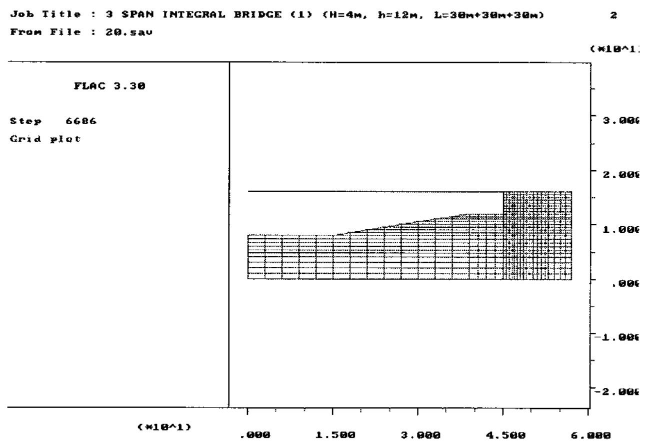


Fig. 9 Modeling of integral abutment bridge system

Fig. 7 illustrates typical structural frame model of the 2-span continuous integral abutment PSC beam bridge. Full continuity at the abutment-deck connecting joints was considered for the final bridge structure.

The response locations for design purpose are also indicated in Fig. 7 and Fig. 8 illustrates the cross section of the PSC beam bridge. The material properties and the cross-sectional properties considered in the analysis are listed in Table 2. The coefficient of thermal expansion for concrete was taken as 1.0 X 10^{-5} / °C according to the Korea highdway bridge specification.

Fig. 9 shows the half of integral abutment bridge system consisted of superstructure, abutment wall, pile foundations, and adjacent soil generated by finite difference grids.

Table 2 Cross-sectional properties and material properties for internal girder and abutment

	E (kgf/cm^2)	I (cm^4)	A (cm^2)
Slab-on-girder	280,000	79,134,179	12,637
Abutment	246,475	9,140,625	19,500

where, E : elastic modulus, I : moment of inertia
A : cross sectional area

Table 3 Comparisons of results

Results \ Modeling method		Simplified structural spring modeling	FLAC finite difference method
Simple Span	M (tonf· m)	-52.10	-58.24
	u_t (mm)	2.88	2.91
	u_b (mm)	0.58	0.06
	h (m)	2.00	2.00
2-Span Continuous	M (tonf· m)	-92.80	-90.84
	u_t (mm)	5.61	5.75
	u_b (mm)	2.61	2.47
	h (m)	3.00	3.00
3-Span Continuous	M (tonf· m)	-118.2	-121.3
	u_t (mm)	8.25	8.54
	u_b (mm)	4.12	4.08
	h (m)	3.50	3.50

where, M: bending moment at deck-abutment connection due to temperature increase of 20 °C
u_t : displacement at the top of abutment (positive for backfill soil direction)
u_b: displacement at the bottom of abutment (positive for backfill soil direction)
h: equivalent cantilever pile length

Superstructure, abutment wall, and pile foundations were modeled as beam elements and backfill soil was modeled as plane strain elements. The abutment height was 4m, and the pile was modeled as the actual length of 12m. A single row of steel HP 300 X 305 piles was considered. The pile spacing was 1.25m and the piles were oriented to develop weak axis bending in the longitudinal direction of the bridge. Stress-strain relationship of backfill soil material was modeled as Mohr-Coulomb model. The properties of backfill soil were listed in Table. 1.

Table 3 shows the comparisons of the bending moments at deck-abutment (M) and the displacements at the top and bottom of abutment (u_t, u_b) due to thermal increase (ΔT =20 °C) predicted by using the FLAC and the simplified structural spring modeling. Both sets of predictions are seen to be in relatively good agreement. Since the pile foundation model in the FLAC analysis is different from that in the proposed spring modeling method, equivalent cantilever pile length obtained by FLAC analysis is applied in the proposed method.

5. Parametric study on the flexural behavior induced by thermal expansion of the deck

The major factors affecting the structural behavior are abutment height, flexural rigidity ratio between the superstructure and piles. The parametric studies were performed to investigate the effect of those major factors on global behavior of integral bridges. The abutment height was changed 2m and 4m, respectively, considering the characteristics of stub type abutment. The relative flexure rigidity ratio (β) between superstructure and piles was varied from 100 to 800, considering the practical application of H piles as shown in Table 4. The equivalent cantilever length for piles was assumed to be 2m.

The overall modeling of structure was illustrated in previous section and schematic view of modeling of 2-span continuous integral abutment bridge is shown in Fig.7 for example. The equivalent nodal forces of thermal expansion of deck ($\Delta T=20^{\circ}C$) are applied at the ends of superstructure.

Simple-span, 2-span, and 3-span continuous integral abutment bridges were analyzed by using frame analysis based on the proposed structural spring model. The same integral abutment bridges were also analyzed according to the conventional method by applying the Rankine passive earth pressure.

The results for the negative bending moment at deck-abutment connection (response location 1) due to the thermal expansion of deck are plotted in Fig. 10. The results for the positive bending moment at deck-pier connection (response location 3) are plotted in Fig. 11. The results for the 2m high abutment are shown in Fig. 10(a) and 11(a), and the results for the 4m high abutment are shown in Figs. 10(b) and 11(b). In Figs. 10 and 11, the horizontal axis is the rigidity ratio of superstructure and piles, and the vertical axis is the bending moment at each response location due to thermal expansion of deck.($\Delta T=20^{\circ}C$)

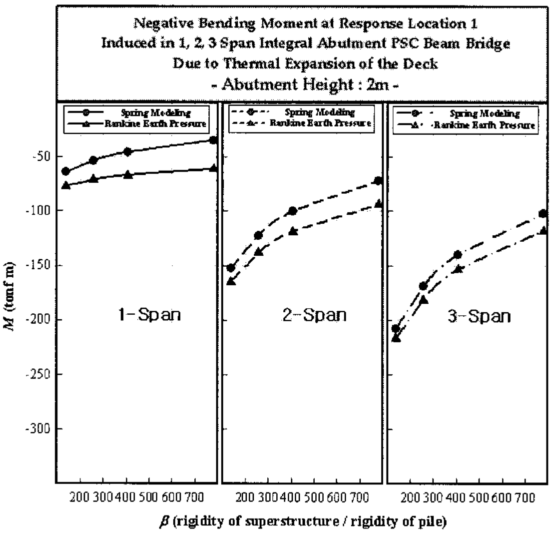
The negative bending moment at deck-abutment connection (Fig. 10) and the positive bending moment at deck-pier connection (Fig. 11) are additional internal forces induced by the restraining effect provided by substructure and surrounding soil behind the abutment, and those moments do not occur in the conventional joint bridge.

Table 4 Bending properties of piles

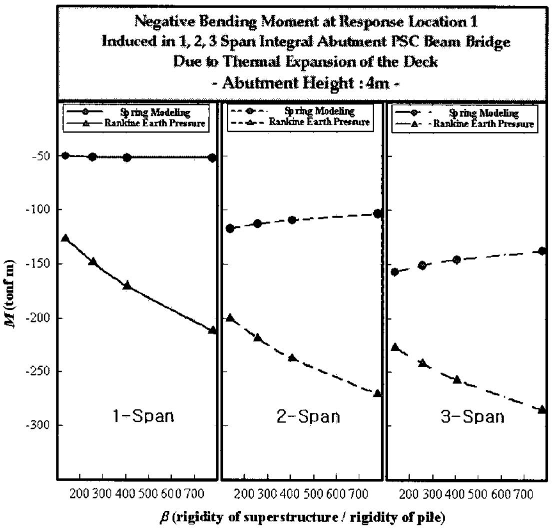
	I (cm^4)	A (cm^2)	β
H 350 X 350 strong axis of bending	40300	173.9	137.5
H 300 X 305 strong axis of bending	21500	134.8	257.6
H 350 X 350 weak axis of bending	13600	173.9	407.3
H 300 X 305 weak axis of bending	7100	134.8	780.2

The additional bending moment obtained by using the conventional method was larger than that obtained at the deck-abutment connection by using the proposed spring modeling method. The primary reason of discrepancy between the results obtained by the conventional method and by the proposed method is in fact that the conventional method considers a full passive earth pressure behind the abutments, whereas the proposed method considers only a effective passive earth pressures as a function of wall translation and rotation.

It is noteworthy that the maximum negative bending moment of 210tonf· m at deck-abutment connection by the proposed method is smaller than the cracking moment of 215tonf· m for the slab-on-prestressed-concrete-girder cross section shown in Fig. 10.

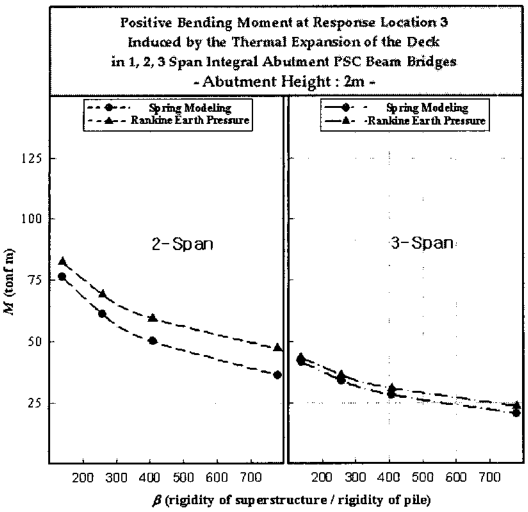


(a) Abutment height (H): 2m

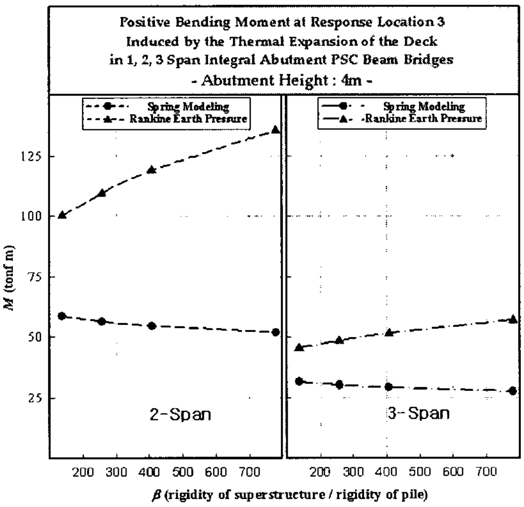


(b) Abutment height (H): 4m

Fig. 10 Negative bending moment at deck-abutment connection due to thermal increase ($\Delta T=20^{\circ}C$)



(a) Abutment height (H): 2m



(b) Abutment height (H): 4m

Fig. 11 Positive bending moment at deck-pier connection due to thermal increase (ΔT =20 °C)

As shown in Figs. 10(a) and 11(a), increasing the rigidity ratio of superstructure and piles, the additional bending moment at deck-abutment connection and deck-pier connection induced by thermal expansion of bridge deck gradually decreased when the height of abutment was 2m. As shown in Figs. 10(b) and 11(b), the additional moments calculated by the conventional method increased as increasing the rigidity ratio of deck and pile when the abutment height was 4m. Whereas, the values calculated by the proposed spring modeling method decreased as increasing the rigidity ratio of superstructure and pile.

As shown in Figs. 10 and 11, smaller additional moments are obtained when the height of abutment is low and the pile is flexible. Therefore, stub type abutment and flexible pile foundations are desirable conditions to reduce the additional bending moments caused by the backfill soil reaction induced by the thermal expansion of deck.

6. Conclusion

The earth pressure at the abutment induced by ambient temperature increment affects the overall structural response of the integral abutment bridge system. Therefore, an accurate assessment of this restraining effect is essential for the estimation of the additional forces induced in superstructure caused by its longitudinal length change. In this study, a simplified structural spring model was proposed to investigate the behavior of integral abutment bridges subjected to a typical thermal change. The simplified linear elastic spring for the longitudinal and rotational restraints provided by the backfill soil is written in terms of the soil stiffness. The finite difference analysis by commercial program was also conducted, and the results were compared with those by proposed method. It was confirmed that the results were agreed well with predictions obtained by the proposed method. Using the proposed model, the behavior of simple span and multi-span continuous integral abutment bridges was investigated by performing the parametric study where the abutment height and the flexural rigidity of piles were varied.

The results obtained from the proposed modeling method were compared with those by the conventional method. From the parametric study, it may be concluded that the results obtained by the proposed method are more rational than those obtained by the conventional method. It was also found that the relative rigidity of superstructure and piles and the abutment height greatly affected the overall structural response of the integral bridge system. Therefore, the use of the stub type abutment and flexible foundation piles is desirable to mitigate the additional internal forces resulting from the thermal expansion of deck. In this study, the result of computational analysis was used to define the slope of earth pressure coefficient with respect to the type of abutment displacement. In practical case, those values may be a function of mechanical properties of backfill soil and height of abutment. Therefore, the rational method to predict the slopes of earth pressure coefficient needs to be developed.

Furthermore, the effect of skew angle of bridge on the global behavior also needs to be investigated.

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