ORIGINAL ARTICLE

The effect of long-term creep and prestressing on moment redistribution of balanced cantilever cast-in-place segmental bridge

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Abstract

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This paper addresses the effect of long-term creep and prestressing on moment redistribution for large prestressed concrete segmental bridge constructed by the balanced cantilever method. The Pathum Thani bridge across the Chao Praya River is investigated in this paper as a case study. Following the typical practice of bridge design, the bridge superstructure is modeled as an assemblage of three-dimensional linear beam elements where each element represents a cast segment of the bridge. The partial creep factors are calculated based on the Norwegian code. The creep strain is calculated for each element and applied on the element as restrained deformation. The result shows that the creep can increase the magnitude of negative moment, rather than decreases it as widely understood. A simplified method commonly known to practising

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designers is to estimate the creep effect from the fraction of dead load moment at completion and that in the continuous state. The finite element analysis shows that this simplified treatment may lead to a considerable error in creep estimation in case of prestressed concrete bridge. Sensitivity study demonstrates that the top cantilever prestressing has a noticeable effect on creep redistribution while the bottom continuity prestressing has little relative impact. Since cantilever prestressing counteracts the gravity, a higher level of top prestressing results in a smaller decrease in long-term negative moment. If the prestress is beyond a threshold value relative to the bridge dead weight, the creep may increase the magnitude of negative moment. The simplified formula for estimating the long-term moment could not predict the increase in negative moment magnitude, and is therefore not always valid for prestressed concrete bridge. The rational analysis should trace the construction sequence of segmental casting and prestressing order.

Keywords: Creep, balanced cantilever construction, moment redistribution, cast-in-place segmental bridge

บทคัดย่อ

อมร พิมานมาศ

ผลของการคืบระยะยาวและการอัดแรงต่อการจัดเรียงโมเมนต์ในสะพานคอนกรีตอัดแรงก่อสร้างเป็นช่วงด้วยระบบแขนยื่นสมดุล

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บทความนี้กล่าวถึงผลของการคืบระยะยาวและการอัดแรงต่อการจัดเรียงโมเมนต์ในสะพานคอนกรีตอัดแรงก่อสร้างด้วยระบบแขนยื่นสมดุล โดยยกตัวอย่างสะพานปทุมธานีที่กำลังก่อสร้างข้ามแม่น้ำเจ้าพระยา มาเป็นกรณีศึกษา ในการวิเคราะห์ใช้วิธีไฟไนต์อิลีเมนต์ และได้จำลองโครงสร้างสะพานส่วนบนโดยใช้อิลีเมนต์คาน 3 มิติ โดยให้อิลีเมนต์แทนส่วนของสะพานที่ทำการก่อสร้างยื่นออกไป ในการวิเคราะห์ผู้วิจัยใช้สัมประสิทธิ์การคืบบางส่วนซึ่งกำหนดไว้ในมาตรฐานการออกแบบคอนกรีตของประเทศนอร์เวย์ เพื่อคำนวณความเครียดที่เกิดขึ้นจากการคืบตัว และนำความเครียดนั้นกระทำต่ออิลีเมนต์ ผลการวิเคราะห์แสดงให้เห็นว่าการคืบระยะยาวสามารถเพิ่มขนาดของโมเมนต์ลบได้เช่นกัน และไม่จำเป็นต้องลดขนาดของโมเมนต์ลบลงตามที่ได้เข้าใจกันมา สูตรอย่างง่ายที่ใช้ในการประมาณค่าโมเมนต์คืบตัวจากส่วนของโมเมนต์ที่เกิดขึ้นเมื่อตอนก่อสร้างเสร็จ และส่วนของโมเมนต์ที่เกิดขึ้นในสภาวะที่โครงสร้างมีความต่อเนื่อง อาจนำไปสู่การคำนวณค่าโมเมนต์คืบตัวที่ผิดไปจากค่าจริงมาก การวิเคราะห์เชิงพารามิเตอร์ได้แสดงให้เห็นว่าการอัดแรงแขนยื่นด้านบนมีผลอย่างมากต่อการจัดเรียงโมเมนต์เนื่องจากการคืบ ในขณะที่การอัดแรงต่อเนื่องด้านล่างมีผลน้อยกว่า ถ้าการอัดแรงมีค่าสูงเกินกว่าค่าหนึ่งเทียบกับน้ำหนักของสะพาน การคืบอาจจะทำให้ขนาดของโมเมนต์ลบเพิ่มมากขึ้น สูตรอย่างง่ายที่วิศวกรออกแบบนิยมใช้ไม่สามารถทำนายการเพิ่มขึ้นของขนาดของโมเมนต์ลบนี้ได้ ดังนั้นจึงไม่สามารถใช้ได้กับสะพานคอนกรีตอัดแรง การวิเคราะห์ที่ถูกต้องควรจะต้องพิจารณาลำดับการก่อสร้าง การเทคอนกรีต และ ขั้นตอนการดึงลวดอัดแรง

ภาควิชาวิศวกรรมและเทคโนโลยีโยธา สถาบันเทคโนโลยีนานาชาติสิรินธร มหาวิทยาลัยธรรมศาสตร์
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The cantilever construction method is usually suitable for medium to long span bridges with span ranging from 60 to 200 m. In Thailand,several bridges across the Chao Praya River, for example, Pra Nangklao bridge, Rama III bridge, Rama V bridge,Rama VII bridge,Somdej Pra Pinklao bridge,Pra Pokklao bridge, King Taksin bridge were built by this method. Currently, The Pathum Thani bridge is being constructed and scheduled to finish in 2006. The major advantage of this method is the elimination of scaffolding and temporary works, which are prohibited in the river due to navigational purposes.

In the balanced cantilever method, the bridge is built by a succession of segments symmetrically cantilevering from the pier in both directions. The segments may be either cast-in-place by means of formwork traveler or prefabricated and lifted to place with appropriate equipment (Poldony and Muller, 1982). The previous segment carries the weight of the next segment. Each segment is connected to the previous ones through prestressing cables provided in the top slab. In this method, the structure will be cantilevered shortly during construction and becomes continuous in the final form. In principle, the analysis and design of the bridge must follow the construction stages in order to account for the alteration in the structural system (Bishara and Papakonstantinou, 1990). The weight of the bridge girder is carried by the cantilevered bridge during construction while the superimposed load and traffic load are carried by the finished continuous bridge structure.

Since concrete creeps and produces time dependent deformation (Robertson, 2005; ACI Committee 209), the dead weight moment is redistributed with time (Veen *et al*, 1994; Ghali *et al,* 2002; Branson *et al*.,1970). The moment redistribution due to creep is often estimated as a fraction of dead load moment immediately after construction plus that in the continuous state. As a result,the negative cantilever dead load moment over the pier is generally reduced, whereas the positive dead load moment in the span is increased in the longterm. This moment readjustment is typical of reinforced concrete only. For prestressed concrete, however,the prestressing force counteracts the dead weight, hence creep may decrease or increase negative and positive moments, depending on the relative magnitude of prestressing and dead weight. This paper addresses the effect of creep and prestressing on moment redistribution, considering the Pathum Thani bridge as a case study. It aims to clarify the limitations of the above-mentioned simplified treatment of creep. The case study of the actual bridge will provide a practical example to gain a better insight into the creep behavior.

Significance of research

In Thailand and other countries worldwide, many large bridges with span in the region of 60 to 200 m are built with the balanced cantilever method.In this method,the bridge passes through several stages of construction with changes in statical system before reaching the final structural form. The long-term concrete creep has a significant effect on the force redistribution within the structure.Some engineers simply estimate the creep based on a fraction of moment obtained from cantilever and continuous state. This simplification does not take into account the effect of prestressing and may thus lead to a considerable error in the creep estimation. The creep effect has to be rationally considered by taking into account the construction sequence and segmental casting and prestressing order. This paper demonstrates that the simplified method of creep estimation is valid for reinforced concrete bridge,but not so for prestressed concrete bridge. The effect of both top and bottom prestressing is discussed in connection with creep. To provide a real practical example, The Pathum Thani bridge being constructed across the Chao Praya River is analyzed and presented in this paper as a case study.

Creep factor

As mentioned, the dead weight moment will be redistributed from the instant of bridge completion to the long-term state due to creep. Hence, the long-term moment generally lies between the value immediately after construction and in the long term as shown in Figure1.As a simplification,engineers often estimate the long-term moment (and other internal forces) by the following formula (Hewson, 2003)

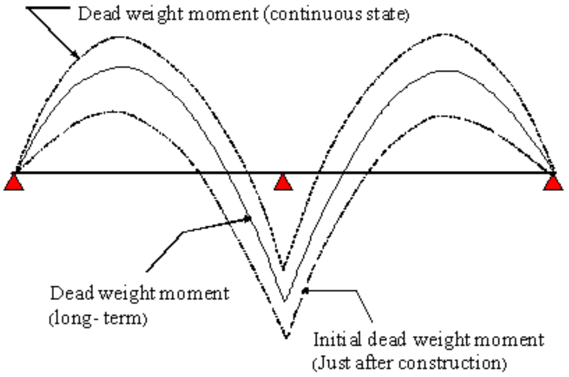


Figure 1. Redistribution of moment due to creep

$$M = e^{-\phi} MG + (1-e^{-\phi})\, M_{Gcont} \qquad (1)$$

Based on the above equation,the redistribution of dead weight moment caused by creep (ΔM_G) is

$$\Delta MG = (1-e^{-\phi})\, (M_{Gcont} - M_G) \qquad (2)$$

where M is the long-term moment, M_G is the dead weight moment at the end of bridge construction taking into account stages of construction,M_{Gcont} is the dead weight moment assuming that the bridge weight acts simultaneously on the finished continuous structure and ϕ is the creep factor.

The above equation is widely used due to its simplicity and clear physical meaning. It estimates the effect of several factors on creep such as relative humidity (RH), concrete compressive strength,cross -sectional geometry, time duration and age of concrete when first loaded through a creep factor (ϕ). The creep strain ε_{CR} is related to the creep factor and instantaneous elastic stress as follows,

$$\varepsilon_{CR} = (\sigma_c/E_c)\, .\, \phi(t, t_0) \qquad (3)$$

where σ_c is the instantaneous elastic stress of concrete, E_c is the elastic modulus of concrete and $\phi(t, t_0)$ is the creep factor. The variable t_0 is time when concrete is first loaded, and t is time being considered. In this paper, the creep factor provided by the Norwegian standard NS3473E (Norwegian standard, 1992) is used. It is noted that other design codes such as CEB-FIP model code 90 (CEB-FIP code, 1993) and the British Standard BS5400 (British standard, 1990) also provide creep formulae which are close to that provided in the Norwegian standard. Hence, the Norwegian standard is supposed to provide reasonable values for creep factor. The code formulae takes into account the relative humidity through factor ϕ_0 and β_h which can consider both dry and humid atmosphere. As for temperature effect,the average daytime temperature in Bangkok is 25°C -33°C which is not severe and is within the recommended temperature range of the code. Based on these reasons,the Norwegian standard is adopted in this study.

Based on the Norwegian code, the creep factor can be calculated from the following formulae,

$$\phi(t, t_0) = \phi_0\, \beta_1 \beta_2\, \beta_c\, (t-t_0) \qquad (4.1)$$

where

$$\phi_0 = 1 + (1-RH/100) / (0.08\, h_0)^{1/3} \qquad (4.2)$$

$$\beta_1 = 8.3 / (3 + f_c^{\,0.5}) \qquad (4.3)$$
$$\beta_2 = 2.4 / (0.1 + t_0^{\,0.18}) \qquad (4.4)$$

$$\beta_c\, (t-t_0) = \{(t-t_0)/(\,\beta_h + t - t_0)\}^{0.3} \qquad (4.5)$$

$$\beta_h=1.5\{1+0.00012(RH/50)^{18}\}h_0+250\leq 1500 \qquad (4.6)$$

where t is the age of concrete in days, t_0 is the age of concrete when first loaded, RH is the relative humidity in percent, f_c is the compressive cylinder strength of concrete at 28 days and h_0 is the effective cross-sectional depth in mm and defined as,

$$h_0 = 2\, A_c / U \qquad (5)$$

where A_c is the area of concrete cross section and U is the length of the perimeter exposed to evaporation. In case of a box section, U is the sum of external perimeter and half of the internal perimeter.

The creep factor during the time t1 to t2 can be computed as,

$$\Delta\phi(t_2, t_1) = \phi_0\, \beta_1\, \beta_2\, \Delta\beta_c\, (t_2-t_1) \qquad (6)$$

where

$$\Delta\beta_c\, (t_2-t_1) = \{(t_2-t_0)/(\beta_h + t_2 - t_0)\}^{0.3}$$
$$-\{(t_1-t_0)/(\beta_h+t_1- t_0)\}^{0.3} \qquad (7)$$

The above equations are derived for plain concrete. For reinforced section,the reinforcing bars restrain the free creep deformation, hence the above creep factor is multiplied by a reinforcement factor no greater than 1.0 to arrive at a creep factor for reinforced concrete.

A case study of Pathum Thani Bridge

1. The Pathum Thani bridge

The existing Pathum Thani bridge was constructed across the Chao-Praya River in 1983 to connect the western and eastern part of Pathum Thani province in Thailand. The original bridge consisted of two lanes. Due to a recent rapid increase in traffic demand, the Department of Highways (DOH) planned to construct a new 4-lane bridge parallel to the existing one.After construction, the new bridge will be combined with the existing one to form a six-lane bridge with three lanes in each traffic direction. The elevation of the Pathum Thani bridge is shown in Figure 2. The superstructure consists of two parallel identical box girders. Each box girder has its own pier supported by a common foundation. The cross section of the box girder is shown in Figure 3.The width of the top slab is 10.8 m.The width of the bottom slab is 5.5 m.The height of the cross section is 4.07m at the pier and 3.0 m at the mid-spam.

The balanced cantilever method was adopted to construct the bridge. The final bridge structure consists of four continuous spans with two side spans and two main spans as shown in Figure 2. The side span is 47.0 m long and the main span is 73.0 m long. The bridge is supported by slide bearings on pier 2 and 4 and cast integrally withpier 3. The longitudinal prestressing layout is shown in Figure 4. Each prestressing tendon consists of 12 strands. The strand is 15.2-mm diameter 7-wire low the existing one to form a six-lane bridge with three lanes in each traffic direction. The elevation of the Pathum Thani bridge is shown in Figure 2. The superstructure consists of two parallel identical box girders. Each box girder has its own pier supported by a common foundation. The cross section of the box girder is shown in Figure 3. The width of the top slab is 10.8 m. The width of the bottom slab is 5.5 m. The height of the cross section is 4.07 m at the pier and 3.0 m at the mid-span. relaxation type. The number of top tendons is 38 in the main cantilever and 20 in the side cantilever. The number of bottom continuity tendons is 16 in each main span and 12 in each side span. The tendons are initially stressed to 70% of the ultimate tensile strength (UTS).

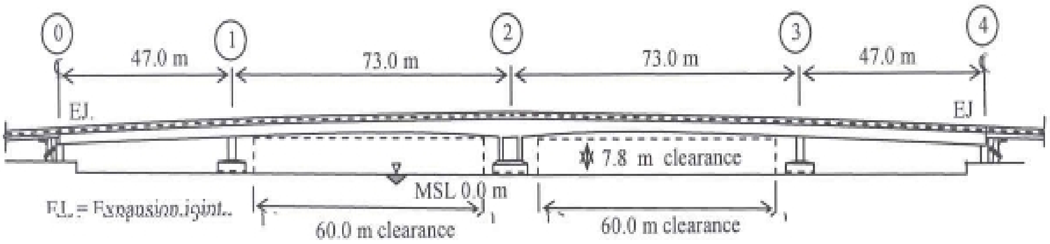


Figure 2. Elevation of Pathum Thani bridge

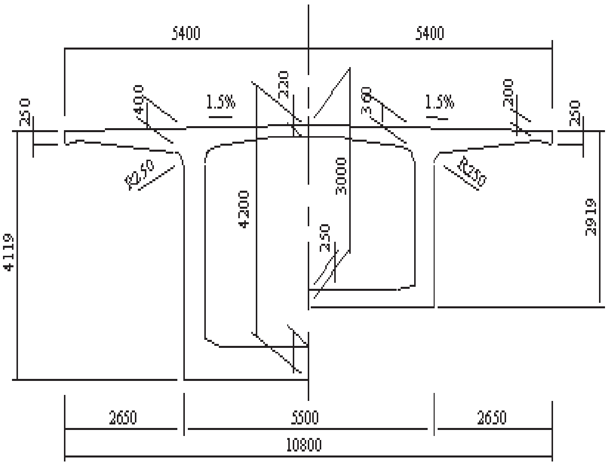
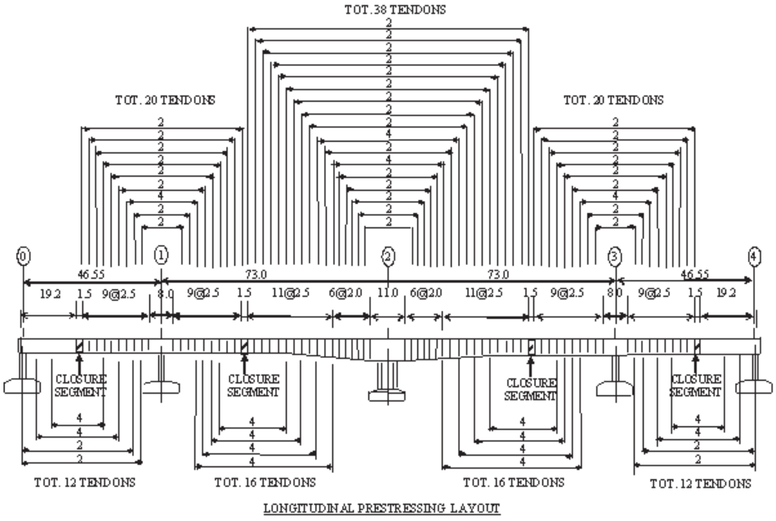


Figure 3. Cross section of bridge girder



Figture 4. Longitudional prestressing layout

2. Construction procedure

The construction procedure must be precisely determined since the creep redistribution depends on the dead load stress at the end of construction. The stages of construction of this bridge are illustrated in Figure 5 together with associated schematic plot of bending moment. First, the pier heads on axes 1, 2 and 3 are cast on scaffoldin Then, the bridge is incrementally constructed as balanced cantilever from piers 1, 2 and 3 as shown in Figure 5(a). Pier axis 2 consists of 17 cast-in-place segments on each side of the pier. Pier axes 1 and 3 consist of 9 cast-in-place segments on each side of the pier. On the two sides of the river,the 20 m long abutment span is cast on temporary scaffolding, which remains until the side and main cantilevers are connected.

During construction, piers 1 and 3 are temporarily fixed to the superstructure by means of vertical prestressing to avoid instability produced by unbalanced cantilever moment. During construction, the cantilever structure produces negative dead weight moment throughout the span as shown in Figure 5(a).As seen,the moment is greatest at the pier and zero at the tip of the cantilever.

After the construction of balanced cantilever, the side and main cantilevers are connected by a 1.5 m closure segment. The moment produced by formwork traveler supported by the side spans is shown in Figure 5(b). The dead weight of the wet closure also generates moment in the side and main cantilevers as shown in Figure 5(c). In order to assure the same elevation of the joined cantilevers, the formwork traveler is supported by both side and main cantilevers during closure casting.

After the closure segment hardens, the side and main cantilevers are connected and the formwork travelers are removed from the bridge. The moment caused by the removal of formwork traveler is shown in Figure 5(d). Then the bridge is connected to the abutment span via a 1.5 m closure segment. After the closure segment hardens, bottom tendons are prestressed while the 20 m abutment span is still supported by the temporary scaffolding. The parasitic (secondary) moment caused by bottom prestressing is shown in Figure 5(e). It should be noted that during cantilever construction, there is no parasitic (secondary) moment produced by top tendons since the cantilever structure is statically determinate.

After bottom tendons are prestressed, the temporary scaffolding is dismantled and the structure achieves the continuous form. The weight of the 20 m abutment span and closure segment is then transferred to the finished structure with the resulted moment as shown in Figure 5(f). Any load applied afterwards, for example, the superimposed load including asphaltic wearing surface and safety barrier, traffic loads and other live loads will act on the continuous structure.

The total accumulative moment M_T and the dead weight moment M_G in the bridge immediately after construction can be expressed as,

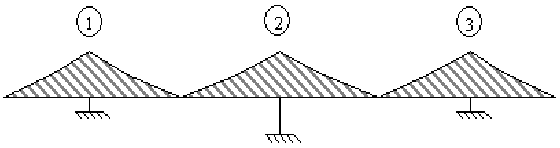
$$M_T = M_{GC} + M_{BB} + M_{WC} + M_{BBR} + M_{PT} + M_{SCF} \quad (8)$$

$$M_G = M_{GC} + M_{WC} \quad (9)$$

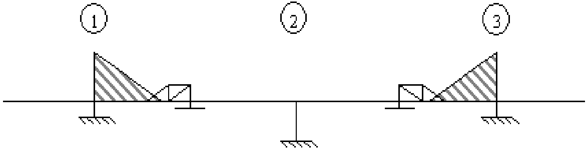
where

M_{GC} is the moment caused by superstructure weight during cantilever construction (Figure 5(a)), M_{BB} is the moment caused by formwork traveler for concreting closure segment (Figure 5(b)), M_{WC} is the moment caused by the weight of wetconcrete closure (Figure 5(c)),M_{BBR} is the moment caused by the removal of formwork traveler after closure segment hardens (Figure 5(d)),M_{PT} is the parasitic (secondary) moment caused by bottom continuity prestressing (Figure 5(e)) M_{SCF} is the moment caused by 20 m concrete abutment span cast on temporary scaffolding (Figure 5(f))

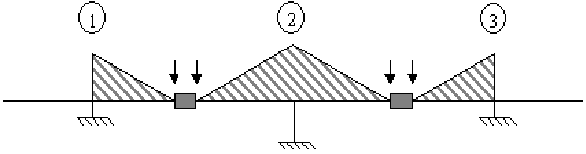
Figure 6 compares the total moment (M_T line II)with the cantilever dead load moment (M_G,line I).



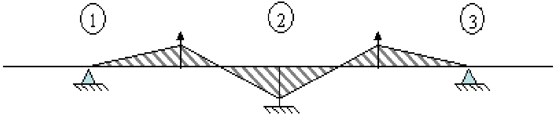
(a) Balanced cantilever construction



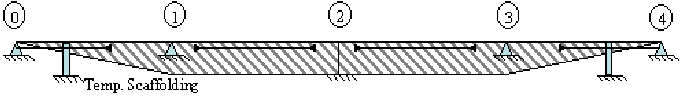
(b) Form traveler on side cantilever for casting closure segment



(c) Dead weight of wet closure segment



(d) Removal of formwork traveler



(e) Parasitic (secondary) moment caused by prestressing of bottom tendons

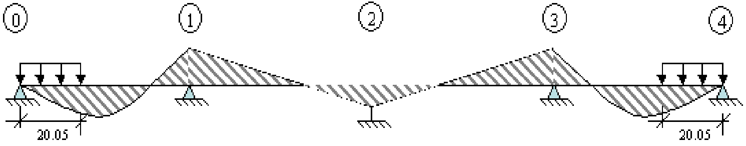


Figure 5. Bending moment produced at various stages of construction

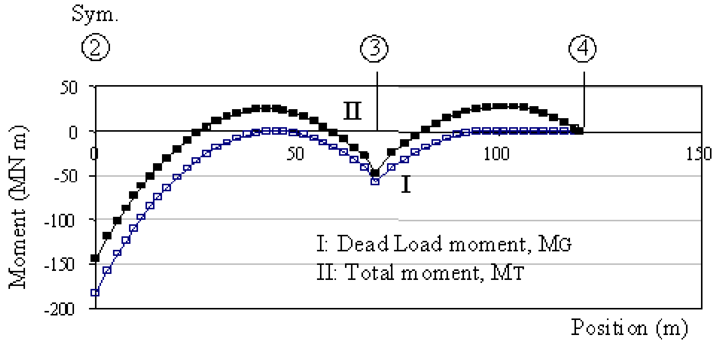


Figure 6. Dead load moment and total moment

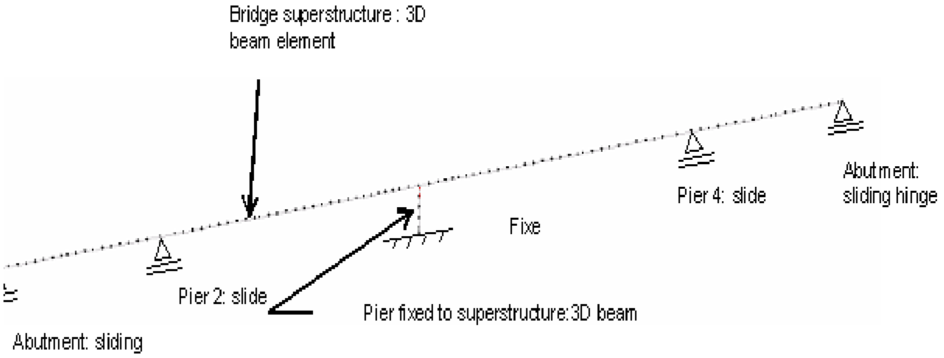


Figure 7. FEM model of the bridge

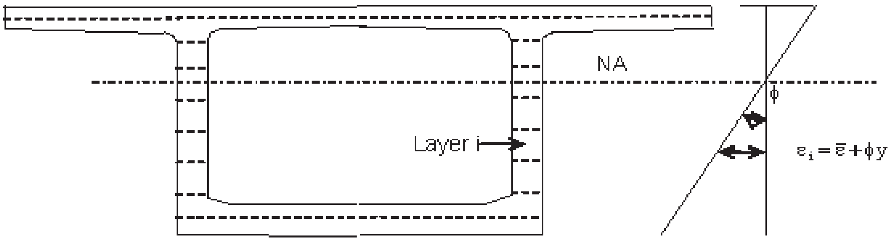


Figure 8. Euler-Bernoulli In-Plane assumption

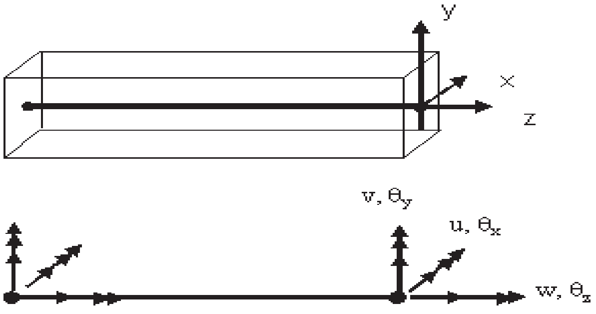


Figure 9. 3D linear beam element

3. FEM model of bridge structure

The bridge superstructure is modeled as an assemblage of 2-node three-dimensional linear beam elements as shown in Figure 7. Each segment represents the cast segment of the bridge. The beam element is of layer-type, that is, the cross section of the element is divided into several layers as shown in Figure 8. Each layer may consist of concrete, reinforcing bar and prestressing tendon. Each node of the element consists of 3 translational degrees of freedom and 3 rotational degrees of freedom with respect to the local axes of the element as shown in Figure 9. The generalized strains of the element consist of centroidal axial strain, curvature, shear strains and twisting strain about the principal axes. The corresponding generalized forces are axial forces, moments, shear forces and torsion. These forces are obtained from integrating corresponding layer stresses over the entire cross section. In the formulation of stiffness matrix, the Bernoulli-Euler assumption of "plane section remains plane" is adopted (Figure 8). The detailed derivation of the stiffness matrix for the element can be found in literature (Maekawa, 2003).

Since the central pier (pier 3) is integrally cast with the superstructure, it is modeled as 3D beam elements to account for the moment transfer between superstructure and pier. As for pier 2 and pier 4, the fixity is assumed in the construction stage analysis due to temporary vertical prestressing that provide stability when the bridge is being cantilevered. The sliding hinge is assumed in the final model since the bridge is placed on slide bearing after connecting with abutment span.

4. The Effect of creep

Immediately after the bridge construction, the dead weight cantilever moment is locked in the structure. In the long term, this moment will be readjusted due to the time-dependent creep. Since the rate of creep deformation decreases with time, a period of ten years (3,650 days) is considered sufficiently long for the calculation of creep. It is noted that only the partial creep factor during the period from connection of cantilevers to long term state is relevant to the calculation of moment redistribution. Since each segment is cast at different times and has variable cross section, the partial creep factor will not be the same for all segments. The segment cast before will have a smaller partial creep factor than that cast after. Table 1 shows partial creep factors calculated for the main cantilever from the Norwegian code with the relative humidity (RH) of 80% and concrete compressive cylinder strength of 40 MPa. In the table, t_0 is the age of concrete at the time of prestressing, which is 2 days in accordance with the construction schedule. Segment 17 is the firstly cast segment at the pier. Segment 0 is the closure segment that connects the main and side cantilever.

The effect of creep is considered as the restrained deformation imposed on the element. The axial creep strain at any layer of the cross section can be computed as,

$$\varepsilon_{CR} = (\sigma_c/E_c) \cdot \Delta\phi(t_2, t_1) \qquad (10)$$

where σ_c is the axial stress, t_1 is the time at connection of cantilevers and t_2 is the long-term state (10 years). For prestressed concrete structure, σ_c is obtained by the following equation,

$$\sigma_c = (M_G - Pe) \cdot y/I \qquad (11)$$

where P is the effective prestressing force, e is the eccentricity of prestressing tendon relative to the cross-sectional centroid, y is the distance from centroid of the cross section to the layer considered and I is the moment of inertia of the cross section. The above strain is imposed on each element to obtain internal forces.

Results and Discussions

Figure 10 compares moment redistribution due to creep obtained from the FEM analysis with the simplified formula given in eq. 2. In eq. 2, the average long-term creep factor is calculated to be 1.20, based on the average effective sectional height (h_0) of 440 mm, the relative humidity (RH) of 80% and the concrete compressive cylinder strength of 40 MPa. It is observed that there is a vast difference

Table1. Calculated partial creep factors used for calculation of moment redistribution due to long-term creep.

Cast segment	t_0 days	t_1 days	t_2 days	h_0 (mm)	$\Delta\phi(t_2, t_1)$
17	2	53	3650	502	1.032
16	2	50	3650	494	1.045
15	2	47	3650	488	1.058
14	2	44	3650	488	1.071
13	2	41	3650	475	1.087
12	2	38	3650	475	1.102
11	2	35	3650	475	1.118
10	2	32	3650	456	1.138
9	2	29	3650	456	1.156
8	2	26	3650	456	1.177
7	2	23	3650	431	1.203
6	2	20	3650	431	1.228
5	2	17	3650	431	1.256
4	2	14	3650	408	1.294
3	2	11	3650	408	1.334
2	2	8	3650	376	1.395
1	2	5	3650	376	1.471
0	2	2	3650	376	1.800

between the simplified equation and the finite element analysis. The finite element analysis predicts the negative creep moment for the entire bridge length while the simplified equation predicts the positive creep moment for the entire span.The FEM analysis of this particular bridge reveals that the creep does not always reduce the magnitude of negative cantilever moment as widely understood. In contrast, it may increase the magnitude of both negative and positive moments. The simplified equation may lead to the opposite prediction of the creep effect, hence its limitation should be clearly identified before bringing it into a practical usage.

Figure 11 shows the relation between the creep redistribution and magnitude of top prestressing.The level of prestressingis specified in terms of percentage of the ultimate tensile strength (UTS). It is seen that there is a strong correlation between top prestressing level and magnitude of creep redistribution. When the top tendons are not prestressed, i.e., 0% UTS, the moment redistribution produced by creep is positive, demonstrating that the creep reduces negative dead load moment over pier and increases positive moment in the span. Physically, the top un-prestressed tendons do not oppose the creep movement of the bridge. As the level of top prestressing increases, the magnitude of creep redistribution is reduced because top prestressing restricts creep movement produced by sustained self-weight stresses. When the level of top prestressing is raised to 70% of the ultimate tensile strength (UTS), the creep redistribution is reversed. The creep increases negative moment magnitude,

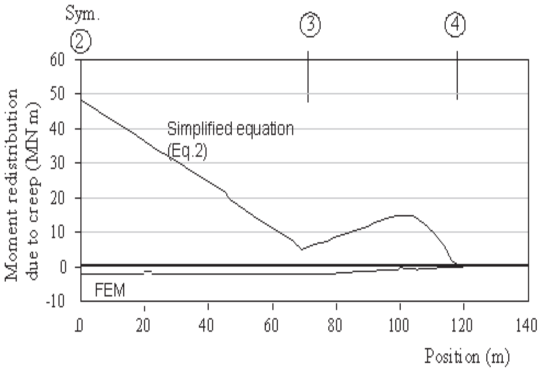


Figure 10. Moment redistribution due to creep

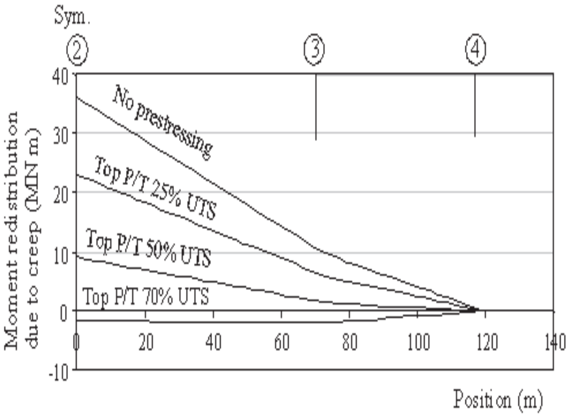


Figure 11. Effect of top prestressing on creep moment redistribution

rather than decreases it as predicted by the simplified equation. Physically, this indicates that a high level of top prestressing moves up the cantilever tip against gravity.

Figure 12 shows the comparison between the creep moment redistribution predicted by simplified equation (eq. 2) and FEM result for hypothetically non-prestressed bottom and top tendons. As shown, the simplified equation produces result agreeable with FEM. A certain deviation is supposedly caused by the use of the average partial creep factor = 1.20 for all segments in the simplified equation while in FEM, the partial creep factors are different for each cast segment in accordance with the sequence of segmental casting and prestressing (Table 1). The average partial creep factor of 1.2 is based on the average effective sectional height of 440 mm. This value is considered as an average value of partial creep factors shown in Table1 excluding a particularly large value of 1.80 for cast segment 0. It is shown that the partial creep factors vary between 1.0-1.47, hence an average value of 1.20 is deemed appropriate for the comparison.

The effect of bottom prestressing on creep redistribution is examined for two cases, 0% and 70% UTS top cantilever prestressing. In each case, the level of bottom prestressing is 0, 25, 50 and 70% of the ultimate tensile strength.The results are shown in Figure 13. The analysis demonstrates that the bottom prestressing does not have a significant effect on the creep redistribution, as compared with the top prestressing(Figure 11). The inconsequential effect of bottom prestressing is obviously attributed to its smaller quantity compared with top tendons. Additionally, the bottom prestressing is applied to the continuous bridge, thus generating both positive and negative moments along the bridge length as shown in Figure14. This leads to the negligible resultant effect.On the contrary, the effect of top cantilever prestressing is not marginal. As shown in Figure 14, since the moment caused by top prestressing is directly opposite to the gravity moment, the creep due to gravity is nullified by the top prestressing. If the combined effect of top and bottom prestressing overcomes that of gravity, the reversed creep may occur as demonstrated for this particular bridge. This may result in the increase in the magnitude of the long-term support negative moment.

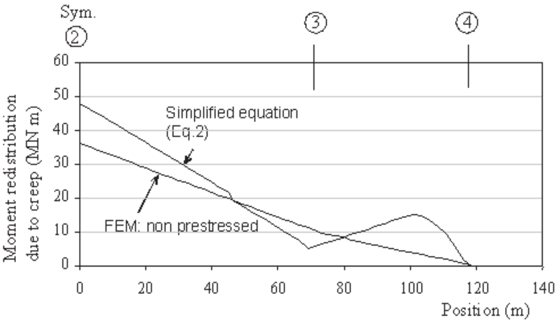


Figure 12 Comparison between simplified equation and FEM result for non-prestressed case

Figure 12. Comparison between simplified equation and FEM result for nonprestressed case

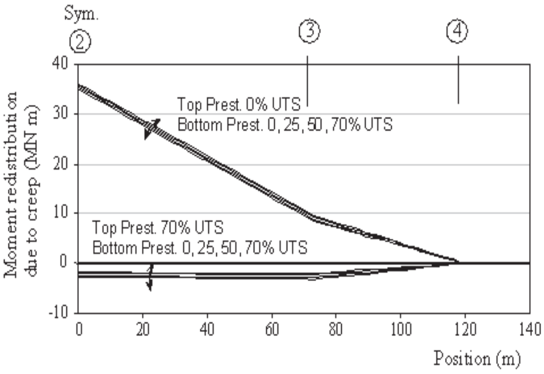


Figure 13. Effect of bottom tendon prestressing on moment redistribution due to creep

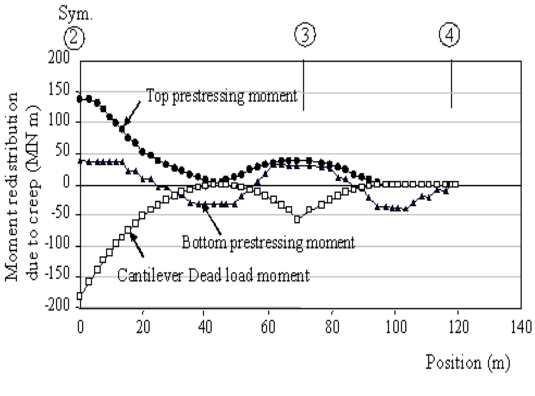


Figure 14. Moment due to dead weight, top and bottom prestressing

Conclusions

This paper investigates the effect of long-term creep and prestressing on the moment redistribution for the balanced cantilever cast-in-plac segmental bridge. To provide a real practical example,The Pathum Thani bridge being constructed across the Chao Praya River is addressed in this paper as a case study. From the analysis results, the following conclusions can be drawn,

1. The simplified method of creep estimation may lead to a considerable error in the prediction of moment redistribution for prestressed concrete bridge.nitude of the long-term support negative moment.

2. The rational analysis of creep effect should follow the sequence of construction as well as segmental casting and prestressing order.

3. There is a threshold of top prestressing level. Below this threshold, the gravity dominates the creep and the moment redistribution is positive. Above the threshold, the top cantilever prestressing dominates the creep and the moment redistribution is negative. The magnitude of support negative moment is decreased in the former case and increased in the latter.

4. For this particular bridge, the level of top cantilever prestressing has a marked effect on the magnitude of moment redistribution, whereas the bottom continuity prestressing has a little relative impact.

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