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Estimation of Flexural Strength with respect to Atypical Composite Section Pile member by Continuous CIP Construction Method

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Abstract:- This study performs a section analysis for an atypical composite section by continuous CIP construction method and suggests the transformed section to calculate flexural strengths. The constant strength reduction coefficient was derived with the reinforcement ratio as a variable and the circular transformed section was used with respect to the special casing section through a section analysis. With using this coefficient, the proposed section analysis method was confirmed to be appropriate because it showed less than 5% error rate between the flexural strength of the actual composite section and the sum of the flexural strengths of both the special casing and the circular casing.

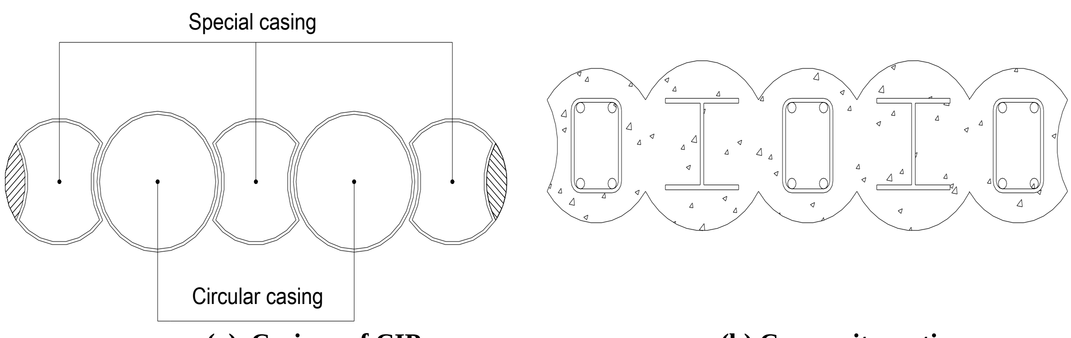
Keywords:- *Flexural strength, CIP, Section analysis, Composite section, Pile*

I. INTRODUCTION

The continuous CIP construction method [1], [2] is a sheathing structure which is popularly used in constructions recent days and it shows an excellent verticality because it uses a specially produced casing. Also, it does not need an extra waterproofing method since the wall is continuously formed with panels like an underground continuous wall due to the depositing concrete at once. However it is difficult to estimate the flexural strengths because the shape of the section of pile that was formed by continuous CIP construction method is a specific shape which is neither rectangular nor circular. In this study, the section analysis is conducted with respect to the atypical composite cross section caused by continuous CIP construction method and the transformed section is suggested for the calculation of the flexural strength.

II. CONTINUOUS CIP CONSTRUCTION METHOD

The continuous CIP (Cast-In-Place concrete Pile) construction method, shown in Fig. 1, forms a composite section after excavation using the special casing and the circular casing. Each casing needs extra space for installation of the tremie pipe in order for placing of concrete and since the 80mm of specified concrete cover in contact with ground should be secured in accordance with ACI318-14 code [3], the diameter of the special casing is designed to more than 500mm and the diameter of circular casing is designed to be 50mm bigger than that of the special casing. The pile of special casing is generally designed with a reinforced concrete section and the pile of circular casing is designed with a steel section using H-shaped steel pile, steel-reinforced concrete section, or reinforced concrete section. After depositing concrete, the sections of both circular casing and special casing become one and the atypical composite section is formed.



(a) Casings of CIP **(b) Composite section**

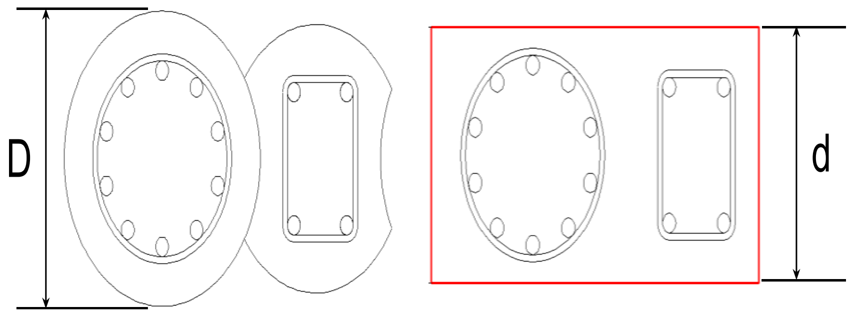
Figure 1 Continuous CIP construction method

III. SECTION ANALYSIS

Since the continuous CIP section is an atypical composite section, it is difficult to estimate the effective width and depth for calculation of the flexural strength, as it is for rectangular and circular sections. Thus, it is required to present the transformed section with respect to the continuous CIP composite section in order for easier estimation of the flexural strengths. In order to present the transformed section, in the preliminary step, the bending of an actual composite section was analyzed using the XTRACT, which is a non-linear section analysis program, and the bending of the transformed section was analyzed for various assumed shapes and the results were compared. The materials used for the section analysis are concrete C24, Steel SD400, H-shaped steel SM490 and the diameters of the circular casing and special casing were designed with three types as 550mm-500mm, 600mm-550mm, 650mm-500mm respectively.

(1) Rectangular transformed section with respect to the entire composite section

As shown in Fig. 2, the section analysis was performed by using the widths of special casing and circular casing as effective widths and by setting the effective depth, d, according to the assumed shape of the transformed section as a variable. With the assumption of 4 effective depths of rectangular transformed section, 1.0D, 0.9D, 0.85D, 0.8D and diameter of circular casing as D, the axial force(P)-moment(M) interaction diagram, as shown in Fig. 3, was obtained through the section analysis and comparing the result, it showed that the effective section of the rectangular was not appropriate because the transformed section with 0.8D of the effective depth is also estimated to big in a certain sector comparing to the flexural strength of actual continuous CIP composite section.



(a) Entire composite section **(b) Rectangular transformed section**

Figure 2 Rectangular transformed section

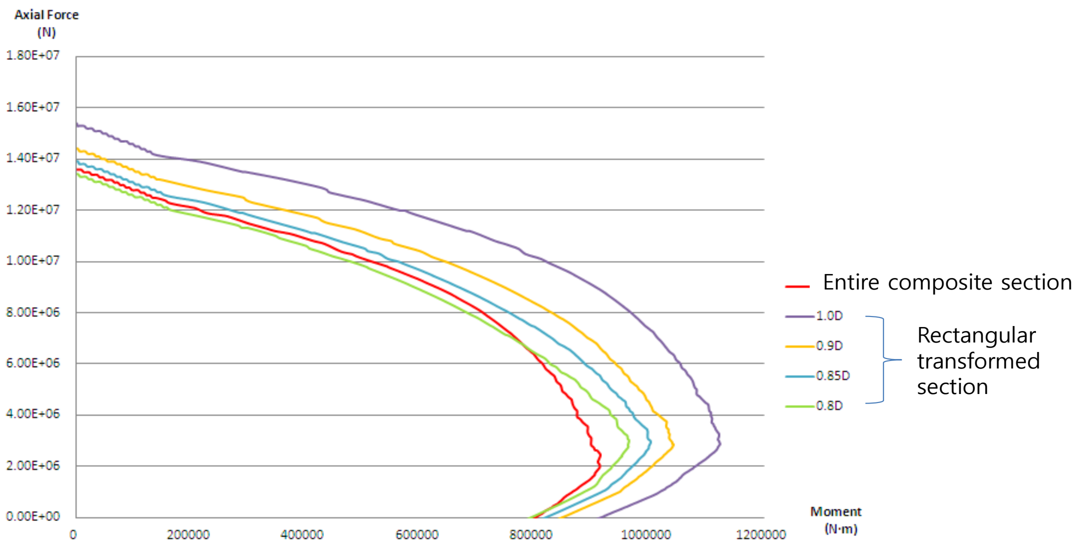


Figure 3 P-M interaction diagram for composite section

(2) Rectangular transformed section with respect to the special casing

The circular casing estimates the flexural strength with the circular section and the section analysis was performed with an assumption of special casing to the transformed section, and the flexural strength was also evaluated by cumulative stiffness. With assumption of diameter of special casing as D, the section analysis was performed with decreasing D. As shown in Fig. 4, in the entire region of compression force, the flexural strength of the transformed section is to be evaluated as safe, the effective depth should be assumed as 0.63D and it was not suitable for use as the transformed section because of the large error rate between regions.

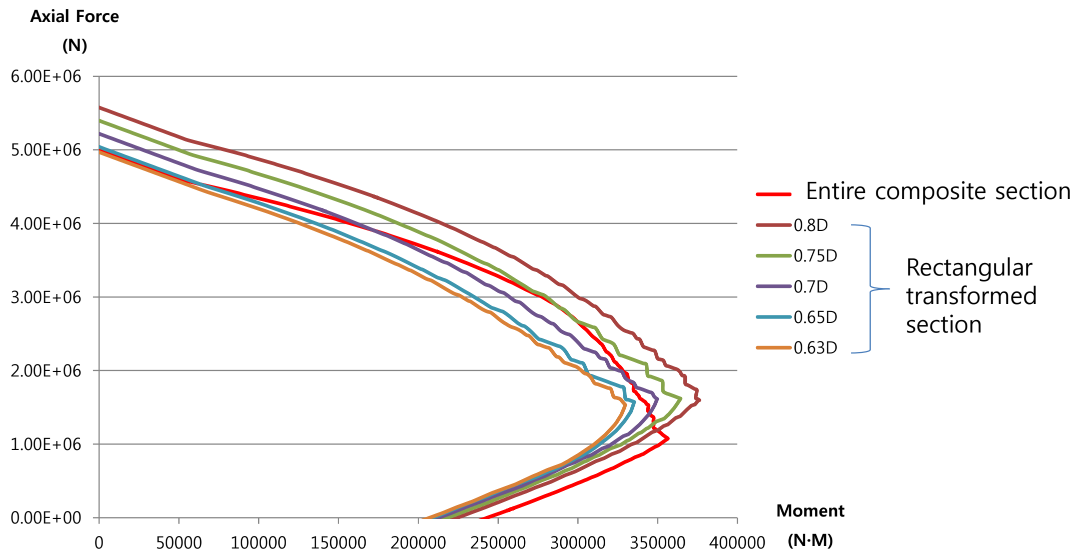


Figure 4 P-M interaction diagram for special casing (Rectangular transformed section)

(3) Circular transformed section with respect to the special casing

After the section analysis was performed with assumption of both circular and special casing as being circular, the flexural strength was evaluated. As a result of comparison the flexural strength between of actual section and circular transformed section for the special casing, it is known that stiffness decreased at a relatively constant rate. Based on this, it is judged that the application of the strength reduction coefficient to the circular transformed section with respect to the special casing is suitable for the calculation of the flexural strength of the composite section. In order to present the reliable strength reduction coefficient, the section analysis was performed on the special casing with diameters of 500mm, 550mm, 600mm respectively and reinforcement ratio (ρ), which can be arranged, as a variable. As a result (as Fig. 5), the strength reduction coefficient of the axial force k_P and, the strength reduction coefficient of the bending moment k_M are evaluated as equations (1) and (2).

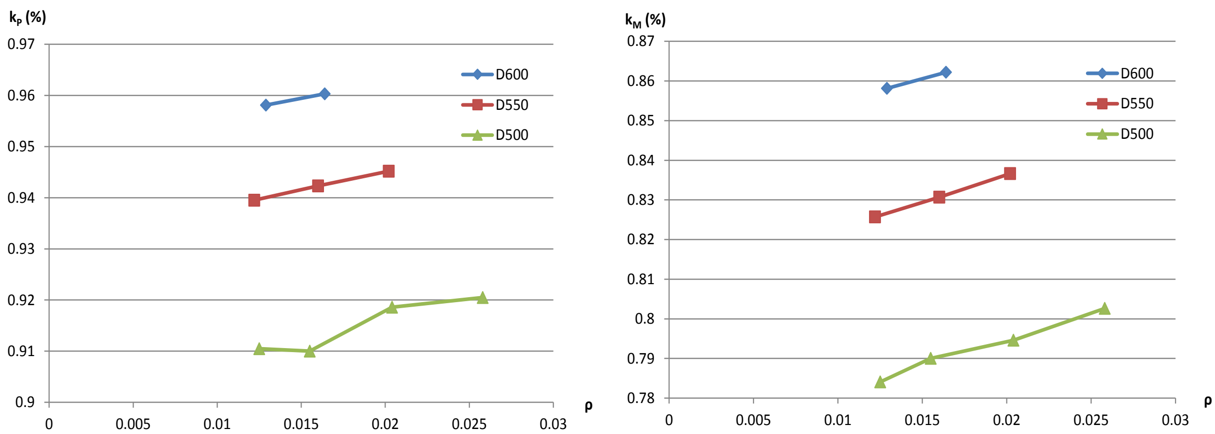


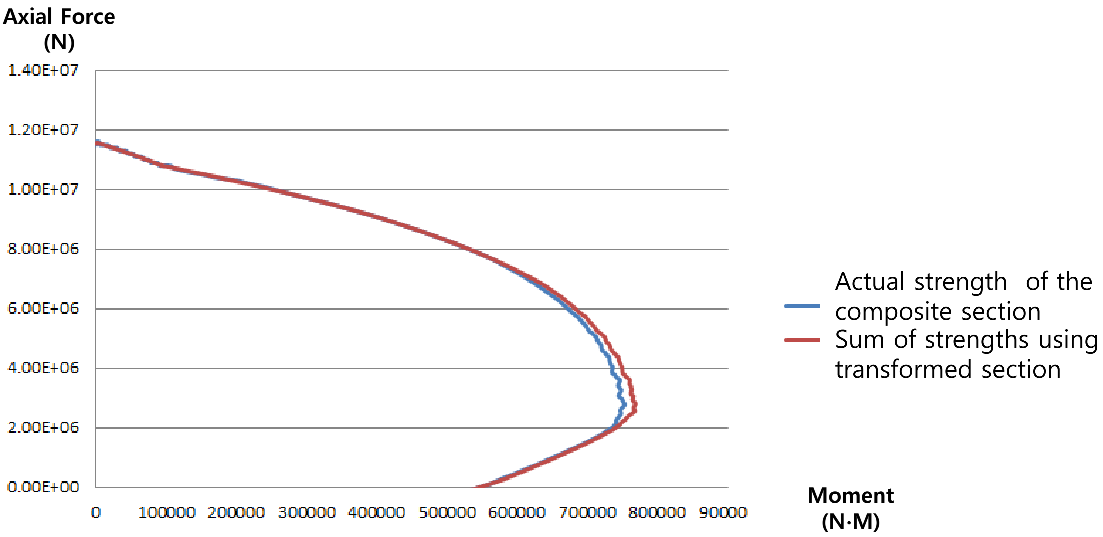
Figure 5 Strength reduction coefficients (Circular transformed section)

$$k_P = 0.7\ \rho + 0.93 \qquad (1)$$

$$k_M = 1.3\ \rho + 0.8 \qquad (2)$$

(4) Error rate in flexural strength by transformed section

By accumulated summation of both the section flexural strength obtained by applying the strength reduction coefficients (k_P, k_M) of special casing and section flexural strength of circular casing, and comparing it to the actual flexural strength of the composite section, as shown in Fig. 6, it showed maximum 5% of error rate when the section of circular casing is reinforced concrete. For steel-reinforced concrete, it showed max 2% of error rate. These results show that the flexural strength calculation method by section analysis proposed in this study is suitable.



IV. CONCLUSION

The section analysis was performed for estimation of flexural strength of an atypical composite section formed by continuous CIP construction method and the results are as follows;

1) The rectangular transformed section estimation method for the entire composite section does not appear to be suitable because it is difficult to present effective depth to estimate the flexural strength of composite section.

2) It was possible to obtain the constant strength reduction coefficient with reinforcement ratio as a variable regardless of diameter of casing by using circular transformed section for special casing section.

3) When comparing the flexural strength by the sum of the flexural strengths obtained by applying the strength reduction coefficient for special casing and the flexural strength of composite section, the error rate was within max 5% and it is known that the section analysis method proposed in this study is suitable.

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