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Concrete breakout failure strength evaluation considering foundation rebar in exposed column base

Yang Xiaoyu[1], Kishiki Shoichi[2], Tatsumi Nobuhiko[3], Ishida Takanori[4], Yamada Satoshi[5]

[1]*Tokyo Institute of Technology, yang.x.ag@m.titech.ac.jp*
[2]*Tokyo Institute of Technology, kishiki.s.aa@m.titech.ac.jp*
[3]*Tokyo Institute of Technology, tatsumi.n.aa@m.titech.ac.jp*
[4]*Tokyo Institute of Technology, Ishida.t.ae@m.titech.ac.jp*
[5]*Tokyo Institute of Technology, yamada.s.ad@m.titech.ac.jp*

Abstract— **Exposed column base is wildly used in the low-to-medium rise steel structures which is needed to transfer axial force, shear force and moments from the upper structure to the foundation. It is important to avoid concrete breakout failure as a brittle failure mode in exposed column base for expecting the full strength of anchor rods in design, however, the proportion of the column longitudinal rebar`s strength to the cone failure strength is not clear. In this paper, the database is established to confirm the effectiveness of column longitudinal rebar in the strength of concrete breakout failure.**

I. Introduction

Focusing on one of the failure modes: concrete breakout failure, this part will show the analysis result on the applicability of the current formula calculating cone failure strength based on the existed experiments [2-7] considering the concrete breakout failure in the exposed column base.

II. Evaluation of the Concrete Breakout Failure Formula

A. Explanation of the formula

As mentioned in the AIJ Recommendation [1], the cone failure strength is calculated by the formula below:

cTu=Ta+0.7Tr

To confirm the availability of this formula, the related experiment data is collected and compared. As illustrated in Fig.1, the cone failure strength cTu is calculated by the formula below:

cTu=Mmax/(dt+dc)-N/dt

In this formula: M_{max} is the maximum moment when the strength get deterioration, d_t and d_c are the distance from the center of steel column to the center of tension anchor bolts and compression column edge. N is the axial force applied on the column base. The cone failure area Ac which is used to calculate Ta and the counting method of longitudinal rebar`s number related to Tr are illustrated on Fig. 1. Ac is the area of circle on the concrete column with the radius of embedded length of anchor bolts from the edge of anchor plate. Tr is the yield strength of the longitudinal rebars in the range of Ac as marked in the solid circle. The hollow circle refers that they are not counted into the calculation of Tr.

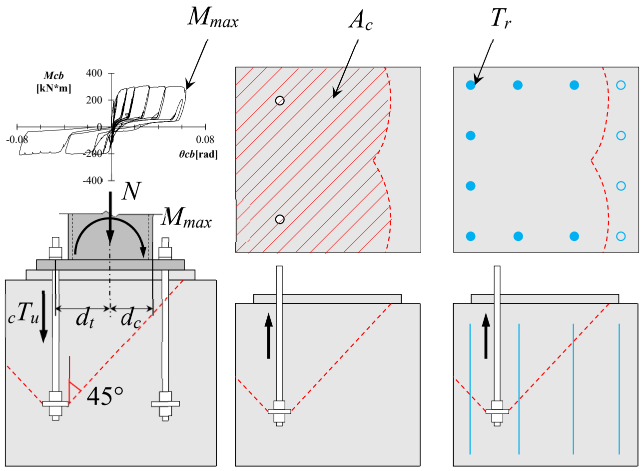

Fig. 1 Explanation of cone failure strength calculating definition

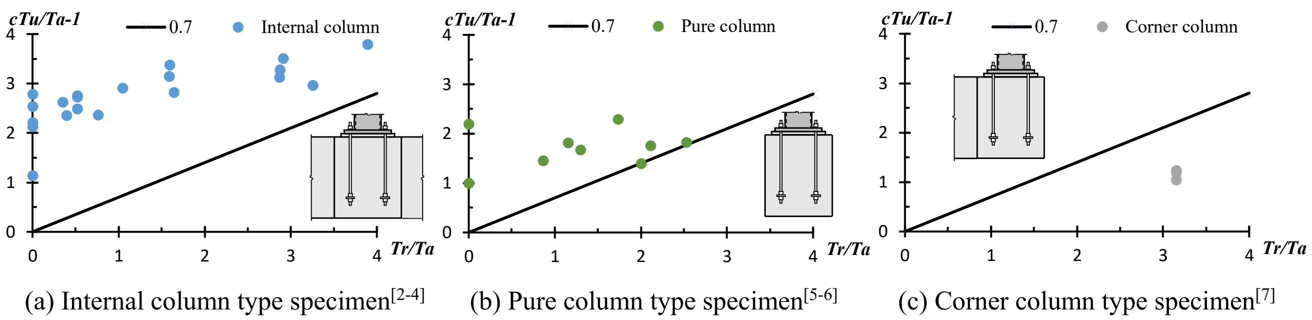

Fig. 2 Cone failure strength evaluation of different types of specimens

Based on the calculation with the definition above, the experiment result database is established as shown in Tab. 1. There are three types of specimens contained in the database: internal column(with both sides' beam), pure column(without beam) and corner column (with one side beam). To give the non-dimensional comparison, the cone failure formula is transformed to:

$$cTu/Ta-1=0.7*Tr/Ta$$

The relation of *cTu/Ta*-1 and *Tr/Ta* is listed in the Fig. 2(a) to (c) for all types of specimens, as the line gives the limit of 0.7. From the Fig.2 we could find that the cone failure strength evaluation method is in the safety range for the internal column specimens. While, for the specimens without beam, there are two specimens reached the limit of the evaluation level. However, for the corner column type specimen, the cone failure strength is lower than the calculation value from the formula, which means this formula might not fit all types of column base to give the accurate cone failure strength.

III. Effect of Foundation Beam on Concrete Breakout Failure

As the existing of foundation beam in the specimens considered in the database, the effect of foundation beam should be also considered in the design of the column base because of the increasing of the cone failure area and correspondingly the effect of beam hoops in that area. The Fig. 3 lists another definition of Ac and Tr considering the effect of foundation beam. The effective beam hoops are marked with solid gray circle. Calculation result is shown in Fig.4, the strength of specimen of corner column are still below the formula level. While one of the specimens in the internal column series becomes under the line, because the number of reinforcing rebars as column longitudinal rebars are too much, and they cannot be as effective as the number contains.

IV. Conclusion

In this part, the evaluation of cone failure formula is discussed by the database from the previous experiment results. The cone failure formula keeps in the safety region except the case of corner column specimen.

Acknowledgment

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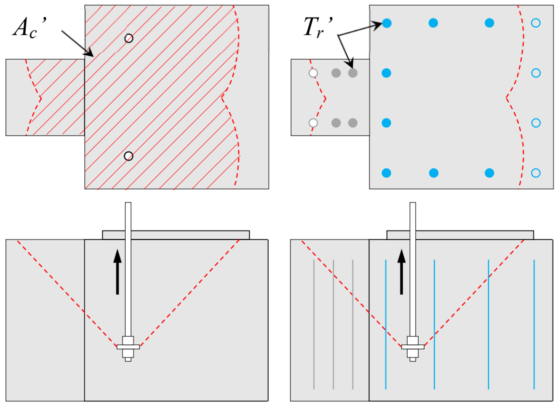

Fig. 3 Cone failure strength calculation considering beam

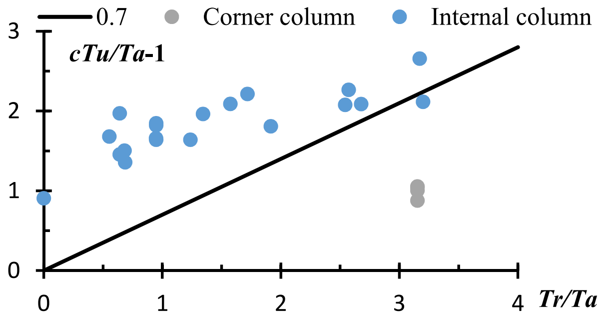

Fig. 4 Calculation result considering beam effect

References

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Tab. 1 Database of experiment focusing on cone failure

ID		Concrete			Anchor bolt	Column longitudinal rebar			Calculation
paper ID	specimen	*Fc* [N/mm²]	*Ac* [*10⁴mm²]	*Ta* [kN]	Embedded length(D)	n [-]	d [mm]	*Tr* [kN]	*cTu* [kN]
[2]	CB-4D etc.	27.2	14.8~28.2	159.2~303.8	4~12	0	13	0.0	340.5~975.2
[3]	CB-8D/R1 etc.	27.2	21.5	232.0	8	6~16	10~13	176.2~756	780.1~920.6
	IB-C0	26.8	24.9	266.0	10	0~4	16	0~138.7	940.4~926.9
[5]	B-5D etc.	20.5	7.3~27.3	68.8~255.8	5~20	0~5	19	0~540.1	219.9~705.9
[6]	0-D19	43.7	22.8	311.7	15	0	19	0.0	624.0
	3-D16 etc.	29.5	22.8	256.1	15	3~6	16~19	221.9~443.9	629.2~844
[7]	MA490 etc.	23	30.3	299.8	20	20	13	945.1	671.3