Methodological Aspects in Measurement of Strand Transfer Length in Pretensioned Concrete. Paper by Ho Park, Zia Ud Din, and Jae-Yeol Cho

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Discussion by José R. Martí-Vargas

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The discussed paper presents an interesting study on experimental methodological factors that might affect transfer length estimation. The authors should be complimented for producing a detailed paper which aims to determine reliable methods for measuring transfer length and for providing recommendations to minimize trial-and-error in transfer length estimation tests. The discusser would like to address the following comments and questions for their consideration and response.

1. Transfer length is defined as the distance over which the strand should be bonded to the concrete to develop the effective prestress (f_{se}) in the prestressing steel[1]. This effective stress is transferred to the concrete in a complete manner when concrete stresses are assumed to have a linear distribution, which occurs outside dispersion length[22]. The authors seem to define transfer length as dispersion length.

2. The current ACI Code equation for transfer length first appeared in ACI Code 318–63[23] and still remains today in spite of several proposed modifications based on experimental studies[19,24,25]. That is, there are many frequently referenced test results which have not been reflected in design codes.

Why do the authors state that transfer length estimations by several recognized researchers remain inconsistent?

3. The gauge length of ERSGs for concrete strains is around 2-3 in. (50-75 mm), but it is not necessarily shorter than that of DEMEC gauges. That is, for longitudinal measurements on the same line, ERSGs can report readings only at each gauge length interval, whereas by using DEMEC, readings can overlap (for example at 1 in. (25.4 mm), or less) to obtain more information, even with a longer gauge length.

4. The discusser would like to offer more complete information about the ECADA test method[26] to clarify some aspects stated by the authors. The ECADA method is a testing technique based on a bond behavior analysis by measuring prestressing strand force. This method was conceived after analyzing the state of the art for transfer and development length measurement, which included techniques such as the strand end slip and longitudinal concrete strains –by using ERSGs, DEMEC, X-Ray, photoelasticity, etc–. The ECADA method provides more reliable results than procedures based on measuring free end slip or longitudinal concrete strains[18,26,27]. When using the ECADA method, the ideal AMA system must have the same sectional rigidity as the specimen. For the various test conditions, different AMA systems should be designed, but it does not sound really feasible and it is unnecessary to design an AMA system for each specific test condition. In this way, the AMA system requirements to determine transfer length[26] and its change with time[27] are known and have been applied in short-term[28-30] and long-term analyses[31-32]. In addition, the ECADA method provides a value of transfer length –and of development length[25,28,33]– and it can yield information of not only prestressing strand force, but also of strain distribution in the transfer zone[32] and of end slip[18,33].

5. The authors generate expentancy when stating that transfer length measurements by all three gauge types used –DEMEC, ERSG, and LVDT– were compared under the same conditions. However, rare cases of slip measurement by LVDT were successful, and the transfer length estimation was impossible when the DEMEC gauges were used. Therefore, only transfer length

measurements by ERSGs have been reported and no comparisons have been made with other methods.

6. Prestressing strands are usually tensioned at 75% of strand tensile strength. Why were the strands tensioned at 70% of strand tensile strength?

7. Regarding DEMEC measurements: a) Where were the DEMEC gauges located in specimens S1 and S2? As there are two ends –two transfer lengths– in each specimen, why were the DEMEC gauges attached in an odd number in specimens S1 and S2?; b) In Fig. 5, it seems that the readings have been represented at the corresponding end gauge length location –from the near end specimen–, and not at the middle gauge length location; is this right? In this case, a longer transfer length will be measured because the average concrete strain obtained from each gauge is assigned to the point with a maximum strain for the same gauge; c) Many researchers have used DEMEC gauges and they have at times stated some faults, but it has been generally possible to determine transfer length. In the discusser's opinion, the data shown in Fig. 5 are uncertain and questionable because of the variability of the readings (until +/- 20000 microstrains) and because there are no concrete tensile strains in a concentrically pretensioned concrete specimen at prestress transfer as measured by the authors.

8. According to the transfer length definition presented in remark no. 1, the 95% AMS[14] is not applicable to obtain transfer lengths from strand gauges. In Figs. 6 and 7, transfer length directly corresponds to the beginning of the plateau for strand gauges, while dispersion length corresponds to the beginning of the plateau for the ERSGs attached to the concrete surface. As dispersion length is longer than transfer length, some methods, such as the 95% AMS[14] or the Slope-Intercept[34] can be used to obtain transfer length from a longitudinal concrete strain profile. Therefore, as the transfer of the prestress from strands to concrete requires a certain length, why is there no difference between the concrete strain and tendon strain profiles in Fig. 8?

9. Regarding Fig. 7, it seems that some data for the tendon strain at the cut end are missing (the 96.5 in. (2450 mm) gauge). This fact, together with remark no. 8, implies having to revise the transfer

length values included in Table 1 from the tendon strain curves of Figs. 6 and 7, as follows: a) for specimen S1, the transfer length at cut end 49.1 in. instead of 43.0 in., and 33.4 in. instead of 26.0 in. at the dead end; b) for specimen S2, the transfer length at cut end 59.1 in. instead of 50.3 in., and 33.4 in. instead of 28.2 in. at the dead end.

10. Based on the comparison made of the transfer lengths at the cut end of specimens S1 and S2 using concrete gauge readings, the authors state that employing strand gauges does not significantly disturb the bond behavior of strands and concrete. However, this fact cannot be stated when using strand gauges. Indeed the opposite applies because the specimen with more strand gauges presents a shorter transfer length. In addition to the limited number of samples tested, the discusser suggests that the release procedure may have a stronger effect than the number of strand gauges, and also that two strand gauges can disturb the bond behavior in a similar way as six do. Therefore, more tests are required, including cases without strand gauges.

11. The authors should contemplate certain design implications[35]: a short transfer length increases stresses and the risk of cracking, whereas a long transfer length reduces the available member length to resist bending moment and shear. Consequently, a longer transfer length can be considered conservative and also non-conservative.

12. The authors have made efforts to conclude that ERSGs are feasible to obtain the transfer lengths of pretensioned strands. To this end, some data are detailed as a reference for the error in transfer length determination. However, Wan et al.[21] used internal strain gauges at 10 in. (254 mm) intervals instead of the mentioned 5.9 to 9.8 in. (150 to 250 mm), and they no reported the error in the transfer length determination. Unfortunately, it seems that there is an erratum: the obtained transfer lengths[21] are within approximately 30 to 60 in. (750 to 1500 mm) –in the main text[21]: 3 to 6 in. (75 to 150 mm)–, and it is possible the authors have confused changing the transfer length values with the error range.

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