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Bond Deterioration in Reinforced Concrete Members Subjected to Seismic Loading

Diminution de l'adhérence dans des éléments en béton armé soumis à des séismes

Das Zerrüttungsprozess des Verbundes in Stahlbetongliedern bei seismischer Belastung

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SUMMARY
A theoretical investigation was made of bond deterioration in reinforcement to concrete in RC members subjected to seismic loading. A computer program assessing bond was developed and slippage of reinforcing bars in beam-column joints was examined.

RÉSUMÉ
L'étude concerne le processus de détérioration de l'adhérence entre béton et armatures dans des éléments en béton armé sous l'effet de charges sismiques. Un logiciel a été développé et permet d'évaluer la valeur de l'adhérence et le glissement des armatures dans un assemblage poutre-colonne.

ZUSAMMENFASSUNG
Eine theoretische Untersuchung über den Zerrüttungsprozess des Verbundes der Bewehrung von Stahlbetongliedern, die seismischer Belastung ausgesetzt sind, wird vorgestellt. Ein Computerprogramm wird entwickelt, das die Verbundeigenschaften auswertet und darüber hinaus das Ausweichen von Bewehrungsgliedern in Knoten zwischen Stützen und Balken untersucht.

1. INTRODUCTION

In Japan and in other countries, there are many test results available concerning reinforced concrete beam-column joint sub-assemblages subjected to repeated reversible loading representing earthquake excitations. The conspicuous features observed in many such test results are the degradations in strength or stiffness in load-deformation curves. These hysteresis curves are usually referred to as "pinched" and the cause of such degradation may be deterioration in bond of reinforcement to concrete in joint mainly.

A theoretical investigation was made into the deterioration process of bond of reinforcement to concrete, and a computer program assessing bond was developed. Then phenomenon of slippage of reinforcing bars in beam-column joint under seismic loading was clarified.

2. ANALYTICAL MODEL OF BEAM-COLUMN JOINT REGION AND ANALYTICAL METHOD ADOPTED

2.1 Idealization of Beam Column Joint Region under Seismic Force

Regarding a beam-column sub-assemblage as a portion of a highrise structure under seismic horizontal force, a typical moment diagram of the frame is shown in Fig. 1. The situation of bond of beam or column reinforcement continuous through the joint is considered to be as shown in Fig. 2.

Hypothesizeing the upper and lower reinformcements of beam are equal, an analytical model of a beam-column joint region is made as shown in Fig. 3. Beam-column joint region is represented by steel elements, concrete fiber elements and bond links.

2.2 Hysteresis rules for each element

Hysteresis rules for each constituent element are shown in Fig. 4 and these relationships are described as follows.

- Concrete $c\sigma = C(c\varepsilon)$ ..... (1)
- Steel $s\sigma = f(s\varepsilon)$ ..... (2)
- Bond link $\tau = B(S)$ ..... (3)

2.3 Bond equation in Bond region and moment of hinge

In the bond region, the following bond equations are solved in succession:

Si : given ..... (4)

$\tau i = B(Si)$ ..... (5)

$s\sigma i = (s\sigma i_{-1} \cdot sAi_{-1} - \tau i \phi i \Delta x)/sAi$ ..... (6)

$s\varepsilon i = f^{-1}(s\sigma i)$ ..... (7)

$Si_{+1} = Si - s\varepsilon i \cdot \Delta x$ ..... (8)

where Si : slip of i-th bond link.
sAi : area of i-th steel element.
Δx : bond length between each link.

Strain of concrete in a hinge is decided by the deformation of the boundary to the beam side concrete face, and linear distribution is assumed.

$c\varepsilon u = -S_1/DHL$ ..... (9)

$c\varepsilon L = Sn_{+1}/DHL$ ..... (10)

$$c\varepsilon i = -\frac{c\varepsilon u - c\varepsilon_L}{d} \times cLi + \frac{c\varepsilon u + c\varepsilon L}{2} \quad \text{..... (11)}$$

where, $c\varepsilon u$, $c\varepsilon_L$: concrete strains at level of upper steel and lower steel, respectively

DHL : hinge length

d : distance between upper and lower reinforcing bars

cLi : distance of i-th concrete fiber from center of beam section

$c\varepsilon i$: strain of i-th concrete fiber

From equation (1) and (11)

$$c\sigma i = C(c\varepsilon i) \qquad \text{..... (12)}$$

the equilibrium equation at the hinge is

$$\Sigma c\sigma i \cdot cAi + s\sigma_1 \cdot sA_1 + s\sigma n \cdot sA_N = 0 \qquad \text{..... (13)}$$

If the equilibrium equation (13) is satisfied, then the moment and rotation of end hinge are calculated by the following equation

$$M = \Sigma\, c\sigma i \cdot cAi \cdot cLi + s\sigma_1 \cdot sA_1 \cdot \frac{d}{2} + s\sigma_N \cdot sA_N \cdot \frac{d}{2} \qquad \text{..... (14)}$$

$$\theta = (S_1 + S_N)/d \qquad \text{..... (15)}$$

2.4 Computational flow and transitions of deviated forces

The flow diagram of the computer program is shown in Fig. 5. Bar-slip at column face in tension side is hypothesized, then bond equation in joint is solved. And then equilibrium of section in hinge is examined. Further convergence is attempted by varying bar-slip at column-face.
In Fig. 6, transitions of deviated force in an actual calculation case are shown.

3. ANALYSIS OF BEAM-COLUMN JOINT REGION

3.1 Specimen analyzed

Bond deterioration processes of beam-column joint region of two experimental specimens were analyzed.(A and O-specimens)[1]
A-specimen has 30 cm column width and O-specimen has 60 cm column width and beam reinforcements are equal. Postulated hinges and bond properties in joints are shown in Fig. 7. Bond strength of pullout side is weak and push-in side is strong. This general tendency of bond is obtained from bond test conducted in our laboratory.[2]

3.2 Analytical results

Analytical results of moment-rotation curves of end hinge are shown in Fig. 8. A-specimen, pinched shape hysteresis was gained, while O-specimen showed spindle type of hysteresis curve.

Pullout and push-in of beam reinforcemnet at column face are shown in Fig. 9. In A-specimen pullout and push-in were each large amount, while in O-specimen, push-in didn't occur.

Bond-stress-slip history of A-specimen is shown in Fig. 10.

From this analysis the pullout behavior of beam reinforcement from joint under seismic force was clarified.

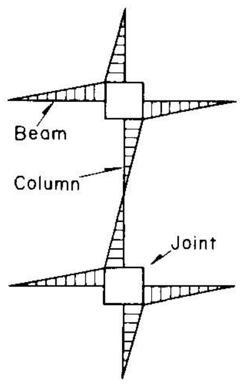


Fig. 1 Moment diagram of frame under seismic force

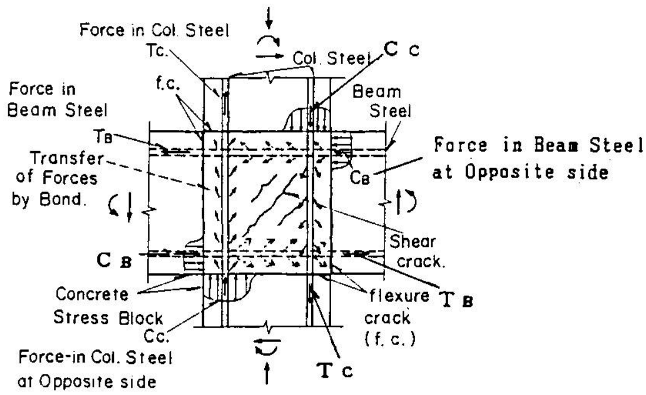
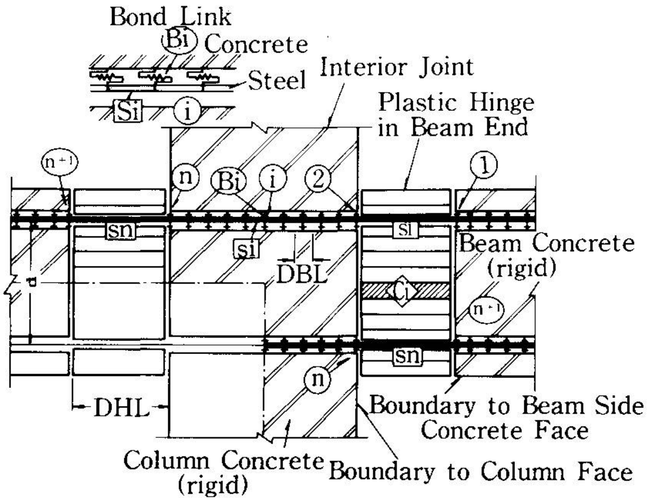
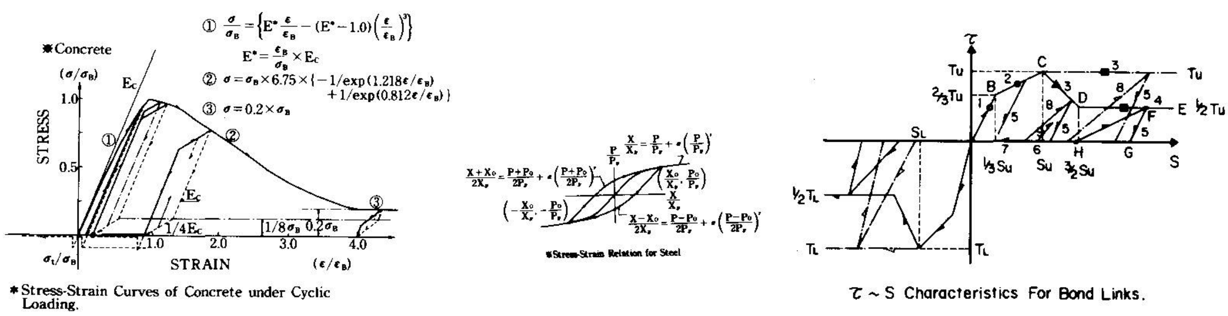


Fig. 2 Forces in joint



i ; Nodal Point on Straight Bar
Si ; Steel Element
Bi ; Bond Link in Interior Joint
Ci ; Concrete Fiber Element in Hinge
DHL ; Hinge Length
DBL ; Bond Length of Each Link

Fig. 3 Analytical model



a) Concrete

b) Steel

c) Bond link

Fig. 4 Hysteresis rules for each element

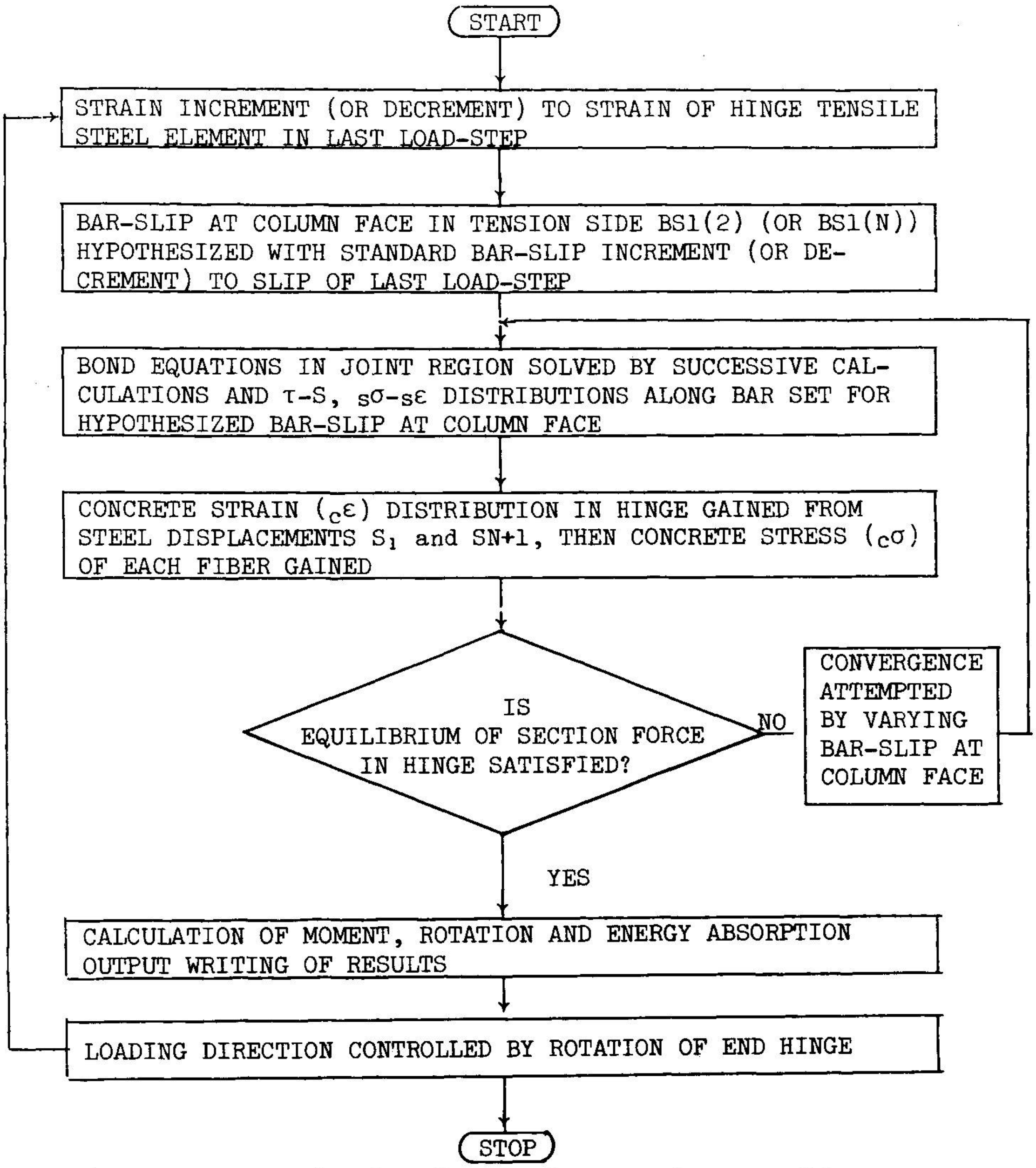


Fig. 5 Flow diagram for computer program

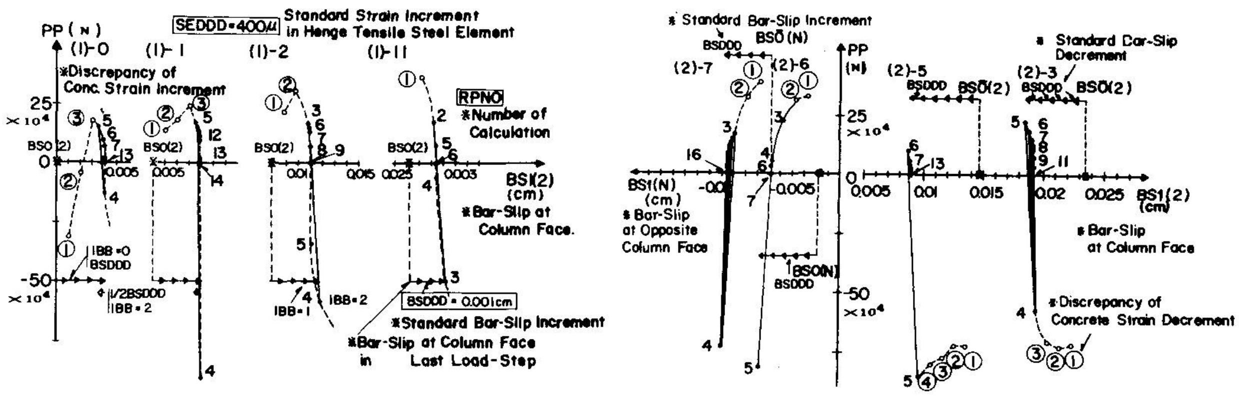
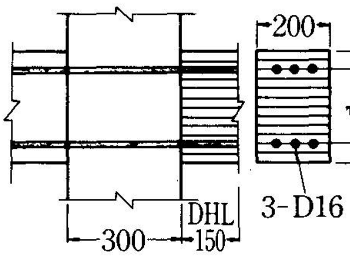
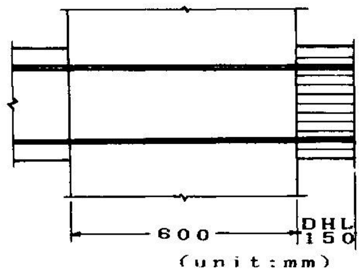


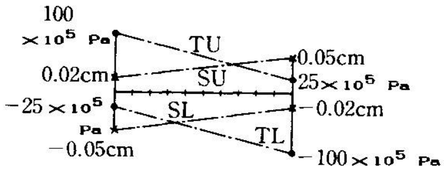
Fig. 6 Transitions of deviated forces in an actual calculation



A-specimen



O-specimen



TU-SU, TL-SL, Distribution in Joint

Bond properties in joint

Fig. 7 Postulated hinges and bond properties in joint

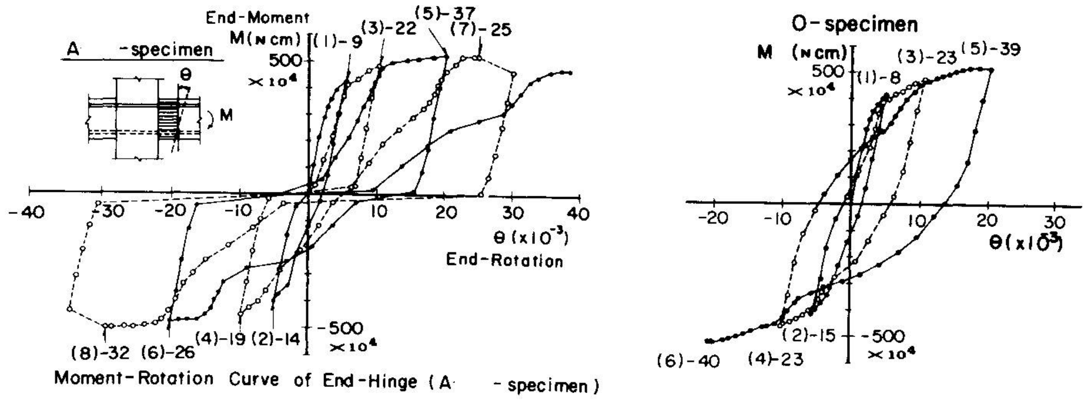


Fig. 8 Analytical moment-rotation curve of end hinge

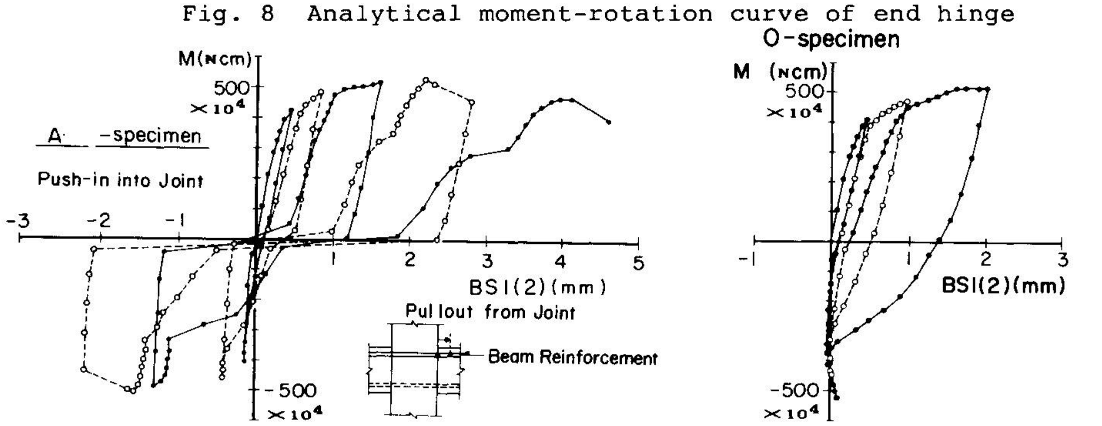


Fig. 9 Pullout and push-in of beam reinforcement at column face

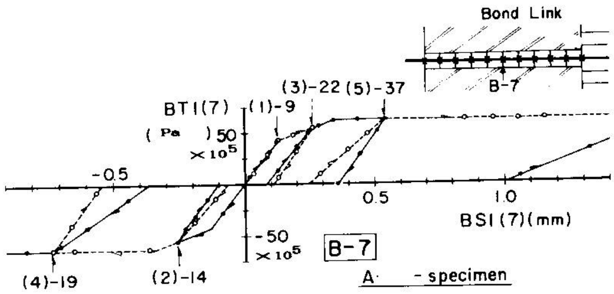


Fig. 10 Bond stress-slip histories in A-specimen

4. ACKNOWLEDGEMENT

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5. REFERENCES

1. T.Tada, T.Takeda, Research on Reinforcement of Beam-Column Joint Panel for Seismic Resistant Reinforced Concrete Frame (part-1) Pullout of beam reinforcement from joint and deformation characteristics of beam end plastic hinge.
   Journal of Structural and Construction Engineering (Transactions of AIJ) June, 1985
2. T.Tada, T.Takeda, Research on Reinforcement of Beam-Column Joint Panel for Seismic Resistant Reinforced Concrete Frame (part-2) Bond test of deformed bar and it's analysis. ibid. May, 1986
3. T.Tada, T.Takeda, Analytical Research on the Deformation characteristics of End Plastic Hinge and Bond Deterioration Process of Adjacent Region in Reinforced Concrete Member (part-1) Analytical Model and Method for Solution. Proceeding of Annual Kanto Chapter Symposium of the AIJ, 1980

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