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NOTATION

a = shear span
b = width of the member
d = effective depth of the member, or distance from extreme compression fiber to tension reinforcement
d_{c_1} = ratio of the thickness of concrete cover under compression surface to the effective depth d
d_{t_1} = ratio of the thickness of concrete cover under tension surface to the effective depth d
h = overall thickness of the member

j = arm of inner forces
(a/d) = shear span ratio
$(a/d)_T$ critical shear span ratio, given by eq.(1)
D = diagonal member for truss analogy
G = tensile yielding of longitudinal reinforcement
H = inside height or clear span of the restrained column 2a, see Figs. 2 or 3, or horizontal member for truss analogy
$\bar{H}_T$ = critical shear span ratio, $(=(H/h)_T)$
I' = compression fracture of concrete in compression side
L = longitudinal member for truss analogy
M = moment
N = working axial load
N_0 = yield axial load of centrally loaded column, given by eq.(3)
N_B = number of cycles until fracture
$T(X)$ = multiaxial fracture condition of plain concrete, given by eq.(2)
X = axial load level ratio, or ratio of working axial load N to yield axial load N_0, $(= X = N/N_0)$
P = lateral load
Q = shear load, in metric ton
$\bar{Q}_y^B$ = bending yield resistance index of a reinforced concrete restrained column, given by eq.(4)
$\bar{Q}_y^S$ = shear yield resistance index of a rainforced concrete restrained column, given by eq.(5)
R = relative storey displacement angle
R_a = relative storey displacement angle amplitude
LC = long column
SC = short column, or shear cracking
TC = tensile cracking
f'_{cu} = specified compressive strength of concrete, in kgf/cm^2
f_y = specified yield strength of longitudinal reinforcement
ω = reinforcement index $(=(f_y/f'_{cu})\rho)$
ρ = ratio of tension reinforcement
ρ_W = ratio of web reinforcement
ϕ = diameter of reinforcement, in mm
δ = relative displacement of the shear span
δ_a = relative displacement amplitude of the shear span

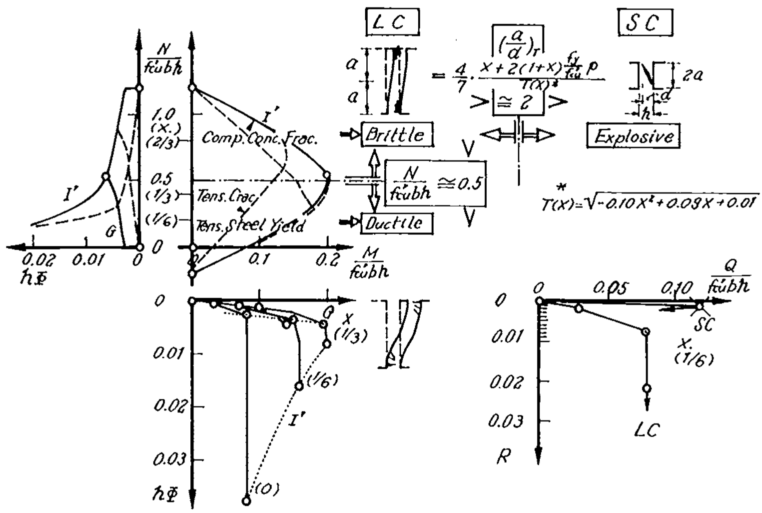

Fig. 1 Classification of the Deformation and Fracture Characteristics of Reinforced Concrete Columns (2)

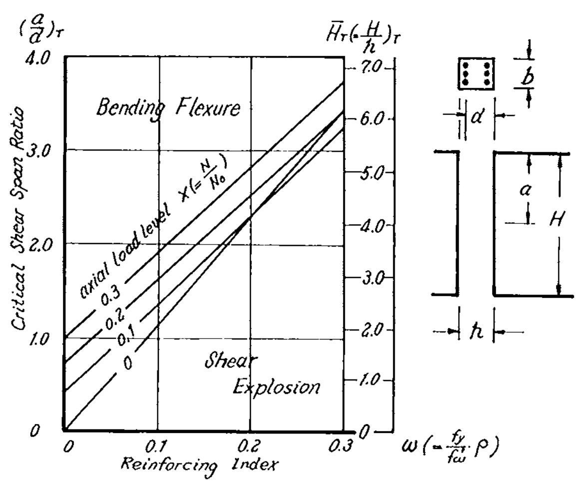

Fig. 2 Critical Shear Span Ratio $(a/d)_T$ or Critical Length to Depth Ratio $\bar{H}_T$ (= $(H/h)_T$) between Longer and Shorter Columns

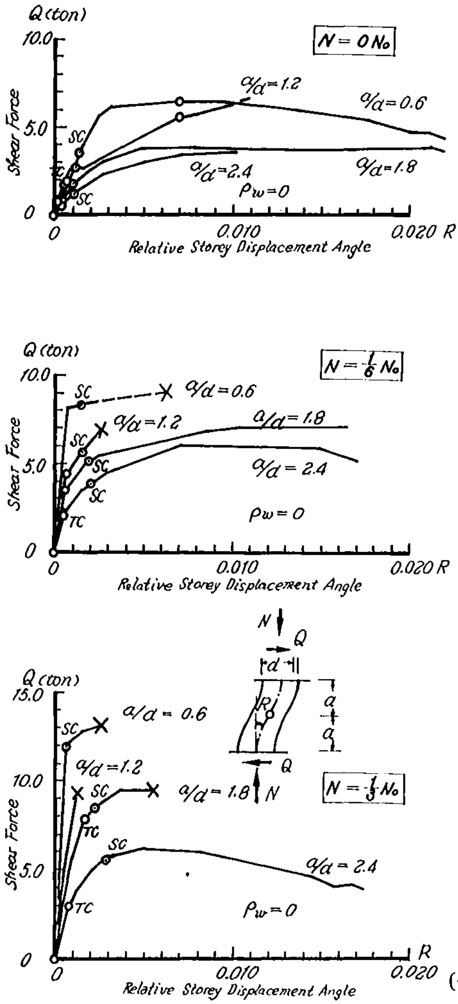

Fig. 4(a) Shear Load - Relative Storey Displacement Angle Relationships of Reinforced Concrete Columns (1)

Fig. 4(b) Influences of Shear Span Ratios (a/d), Axial Load Level Ratios X = (N/N_0) upon the Fracture Modes (Tested)

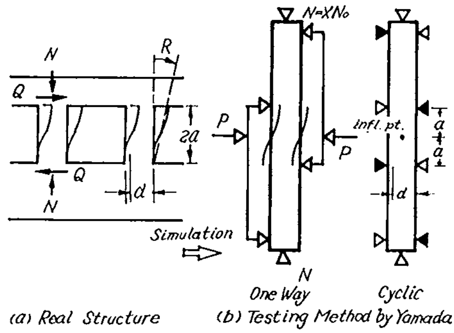

Fig. 3(a) Deformation State of Restrained Columns

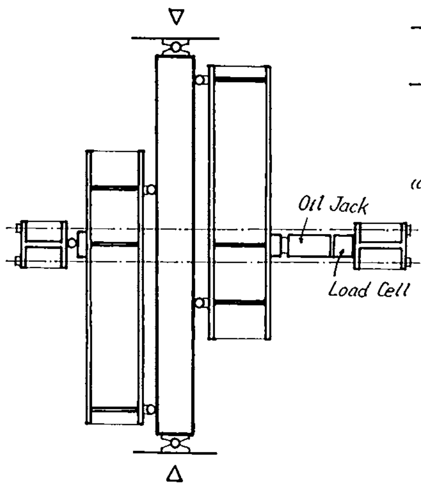

Fig. 3(b) Loading System

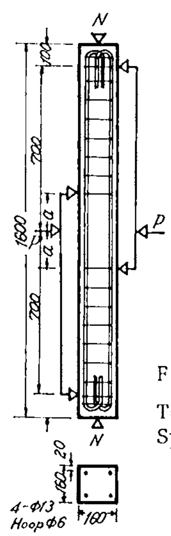

Fig. 3(c) Test Specimen

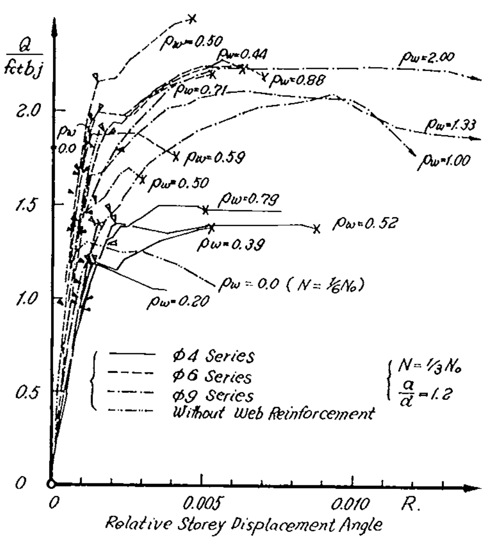

Fig. 5 Influences of Web Reinforcement Ratio ρ_w upon the (Q-R) Relationships

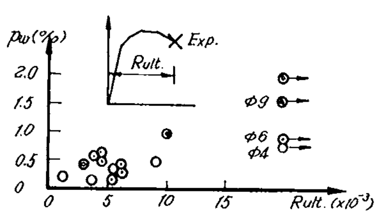

Fig. 6 Effect of Web Reinforcement Ratios ρ_w upon the Ductility of Reinforced Concrete Short Columns (7)

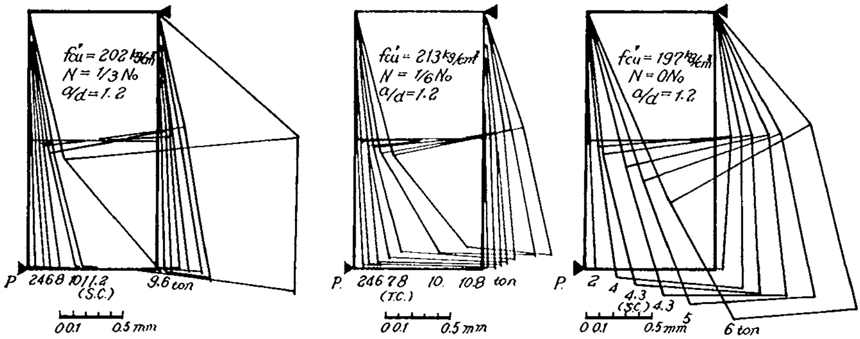

Fig. 7(a) Measured Deformation Process of Reinforced Concrete Short Columns under Double Curvature Bending with an Inflection Point

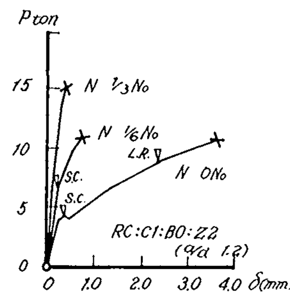

Fig. 7(b) Measured Deformation of Reinforced Concrete Short Columns under Double Curvature Bending with an Inflection Point

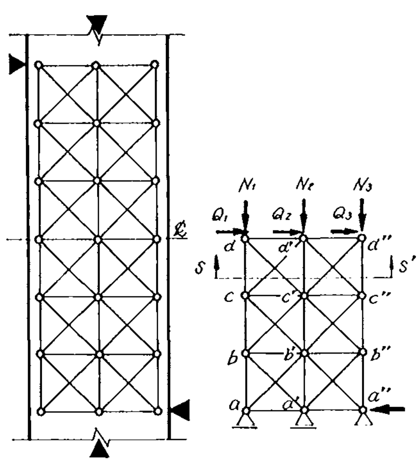

Fig. 8(a) Truss Analogy for Analysis (12)

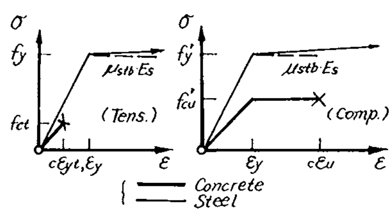

Fig. 8(b) Assumed Stress-Strain Relationships (12)

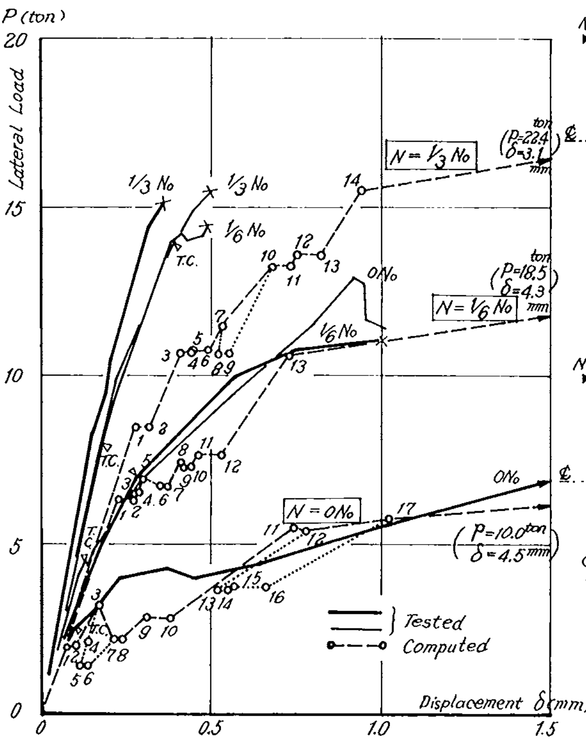

Fig. 9 (Q-R)-Relationships Computed by Truss Analogy (12)

(Numerals Correspond to the Stress State of Truss with the Same Number in Fig. 10)

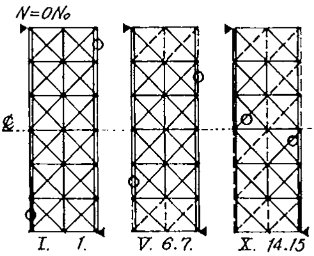

Fig. 10(c)

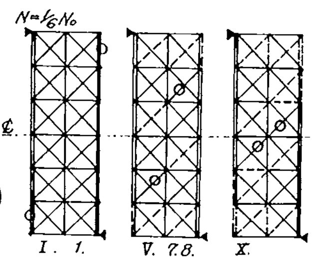

Fig. 10(b)

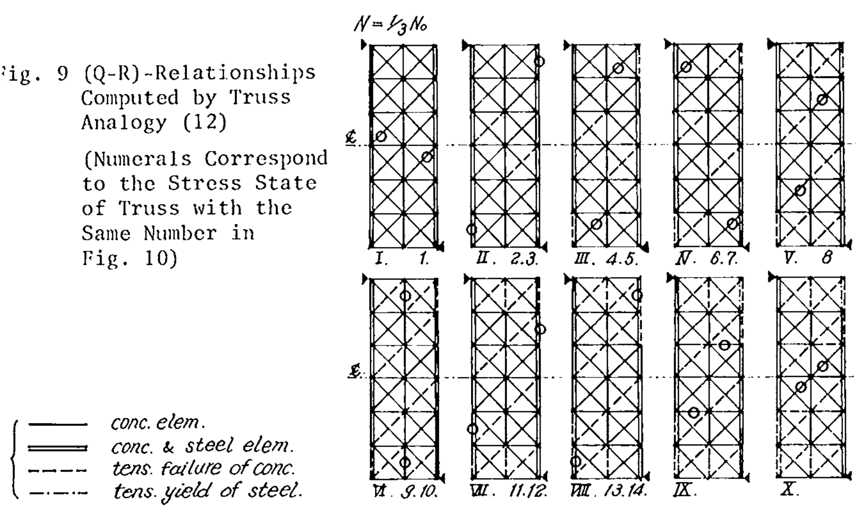

Fig. 10(a) Fracture Processes of Idealized Trusses (12)

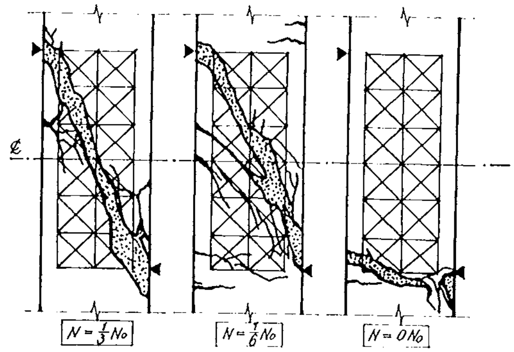

Fig. 11 Fracture Modes of Tested Specimens

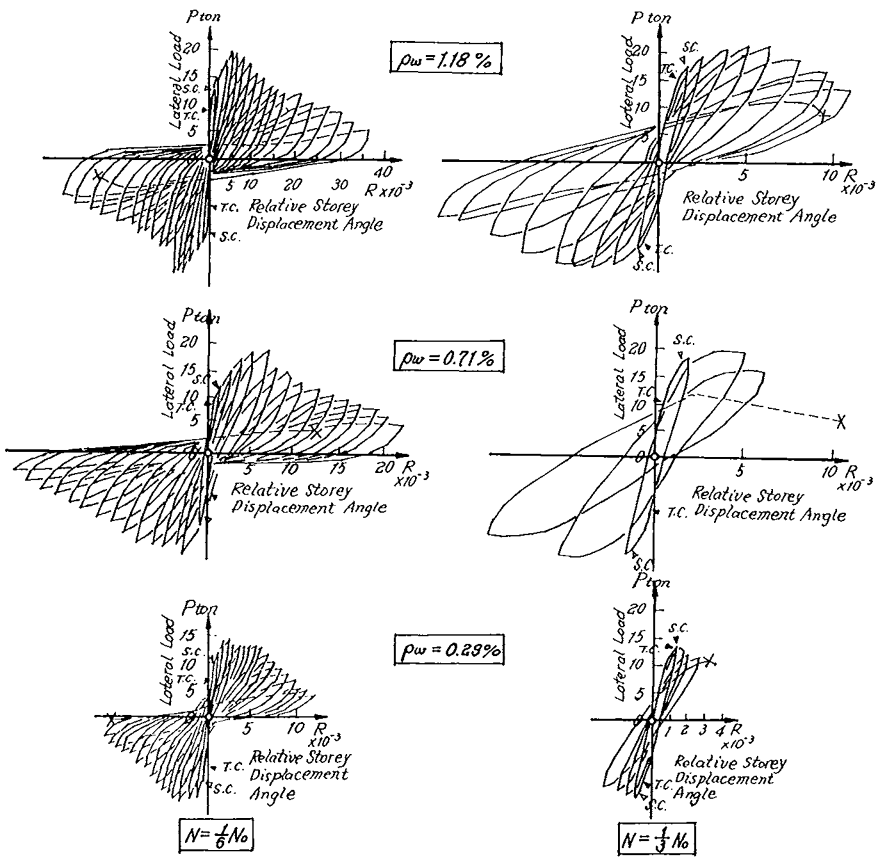

Fig. 12 Hysteresis Loop Characteristics of Incremental Displacement Amplitude Tests with (a/d) =1,20

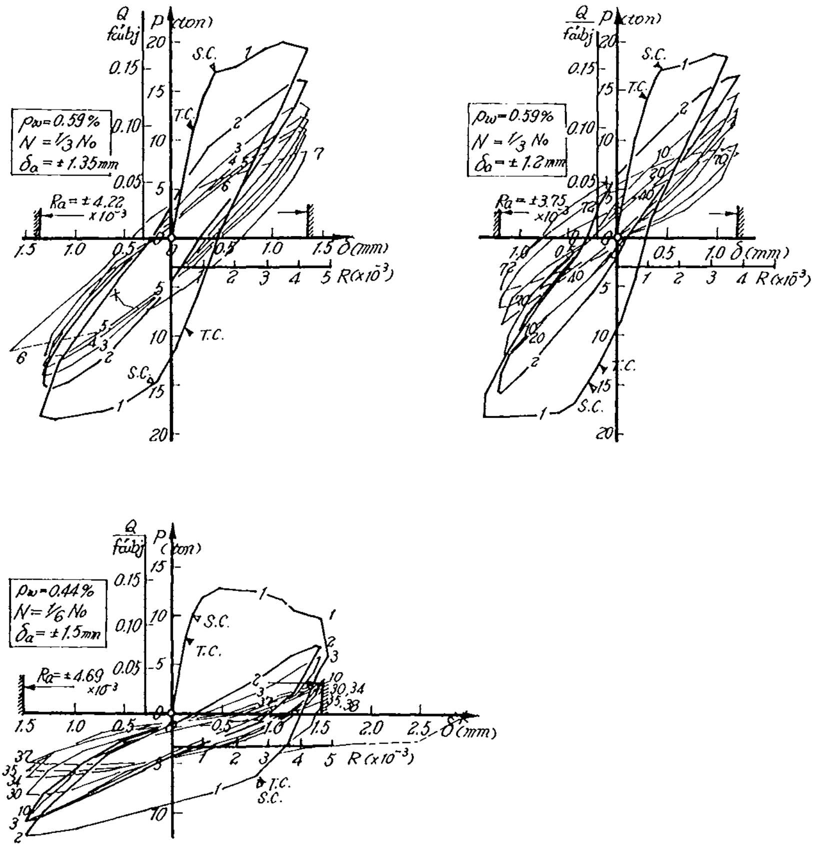

Fig. 13 Hysteresis Loop Characteristics of Constant Displacement Amplitude Test with (a/d) =1,20

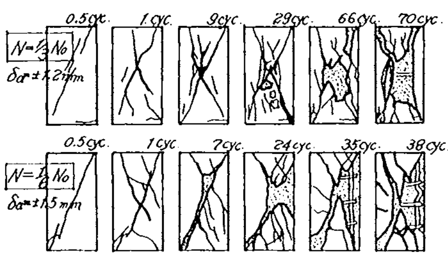

Fig. 14 Fracture Processes

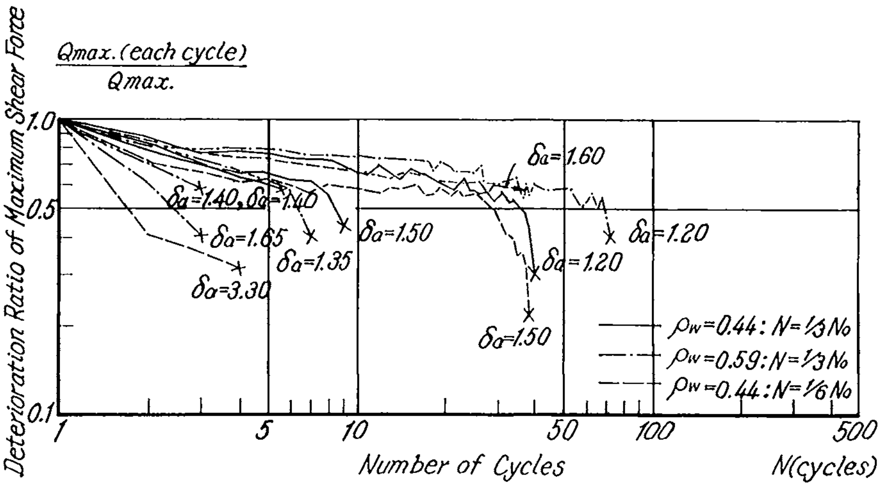

Fig. 15 Deterioration Processes with the Increasing Number of Cycles

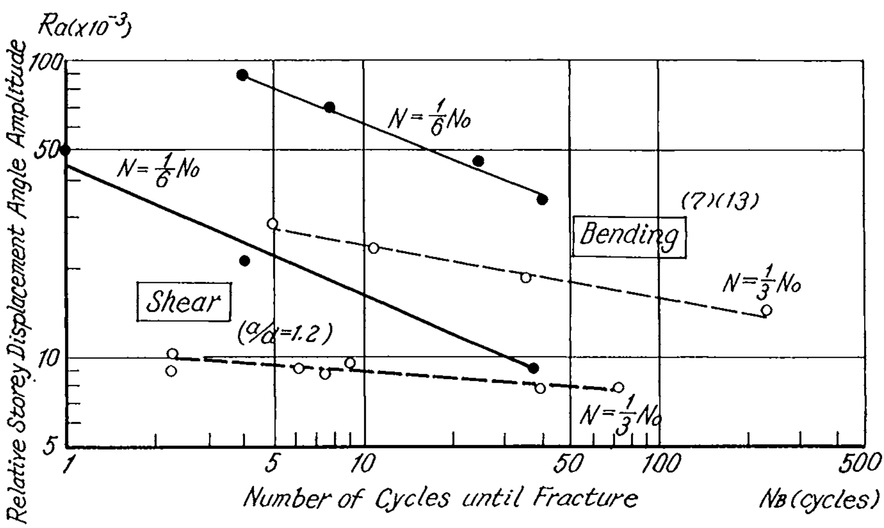

Fig. 16 Relationships between Relative Storey Displacement Angle Amplitude R_a and Number of Cycles until Fracture N_B