CRACK WIDTH AND DEFORMATION OF RC BEAM WITH HIGH STRENGTH REBAR

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1. INTRODUCTION

Usage of high strength rebar has significantly increased in construction of RC members. It allows the designer to provide lighter and economical cross-sections and it facilitates higher ductility in structures specially designed for earthquake protection. There are many researches to investigate the effect of high strength rebar on seismic performance. The knowledge about crack width and deformation, however, is limited which are important design variables in serviceability condition. This paper investigates crack width and deformation of RC beams with SD-685 rebar considering the combination of concrete strength, and the applicability of JSCE design code is discussed.

2. SPECIMEN AND MEASUREMENT CONDITIONS

To provide comparative study for influence of high strength rebar on cracking pattern and deflection, 4 beams were tested. Each beam was constructed of either different compressive strength of concrete or yield stress of rebar as mentioned in Table 1. That is, SD-345 and SD-685 rebar were prepared by considering the combination of compressive strength of about 30 and 70 Mpa. To have better understanding of flexural cracking pattern, a constant moment span of 1m was maintained with two point loading at mid-span. Cross-section and reinforcement for all the beams was considered same. While to prevent shear cracking shear reinforcements were also provided. Detailed outline of test specimen is described in Fig. 1. In order to measure crack width, after the initiation of cracks at several loading stage was observed, beams were unloaded and Pi-shape displacement transducers were installed across cracks. In order to measure displacement of beams, LVDT transducers were used at mid span and loading points except beam 1. Purpose of measuring deformation at 3 points is to compare moment curvature relationship with design equation.

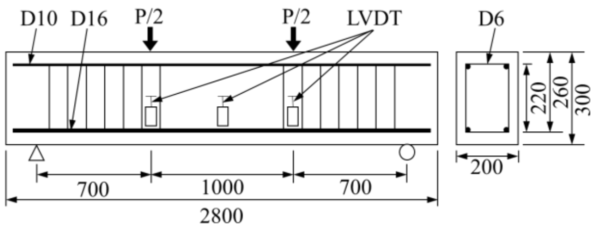

Fig. 1 Outline of Specimen

Table 1. Properties of Materials

Beam	Concrete		Rebar	
	f_c' (MPa)	E_c (GPa)	f_y (MPa)	E_s (GPa)
C-N,S-N	33.7	26.1	SD-345	197.2
C-N,S-H	33.7	26.1	SD-685	193.2
C-H,S-N	70.0	34.1	SD-345	197.2
C-H,S-H	73.0	35.1	SD-685	193.2

3. LOAD DISPLACEMENT RELATIONSHIP

Fig. 2 shows load displacement relationship at mid-span until the propagation of yielding. Red and black lines show the results of beams with SD-685 and SD-345 respectively. Solid and dashed lines show the results of beams with high strength and normal strength concrete respectively. For the beams with SD-685, observed yield load and yield displacement were approximately two times of the beams with SD-345. The curves of beams with SD-345 show almost same yield points even with different cracking points, but for the curves of beams with SD-685, we observe different yield points depending on the combination of different concrete compressive strength. The combination of high strength concrete and high strength rebar sustains slightly larger load.

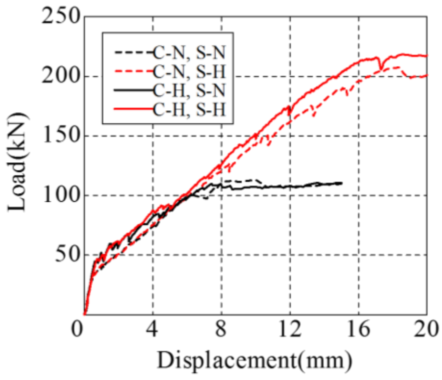

Fig. 2 Load Displacement Relationship

4. CRACKING PATTERN

Fig. 3 shows cracking pattern just before yield load within constant moment span. Numbering of crack indicates the order of crack initiation. Fig. 4 shows the change of maximum crack space at different loading stages. Maximum crack space in design is also calculated by JSCE equation (JSCE, 2012) as shown in Eq. (1), in which maximum crack space corresponds to $L_{max} = 1.1\, k_1\, k_2\, k_3 (4c + 0.7(c_s - \Phi))$. Applicability of this equation is confirmed up to SD-490.

Keywords: SD-685 rebar, Flexural Cracking Pattern, Maximum Crack Width, Deformation.
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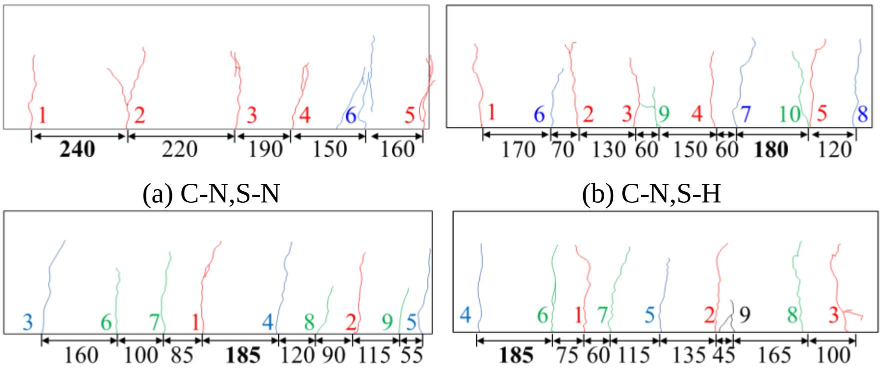

(a) C-N,S-N (b) C-N,S-H

(c) C-H,S-N (d) C-H,S-H

Fig. 3 Cracking Pattern

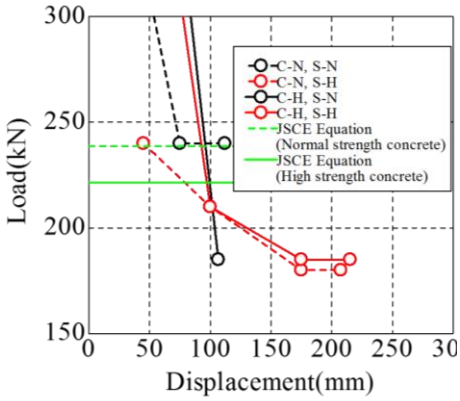

Fig. 4 Change of Maximum Crack Space

$$w = 1.1\,k_1\,k_2\,k_3\left(4c + 0.7(c_s - \Phi)\right)\left(\frac{\sigma_{se}}{E_s} + \varepsilon'_{csd}\right) \qquad (1)$$

Maximum crack space of beam C-N,S-N is similar with the JSCE equation. Beam C-H,S-N shows smaller maximum crack space due to the effect of concrete strength. For the beam C-N,S-H and C-H,S-H, subsequent cracks occurred in larger loading stage than the yield load of beams with SD-345 and maximum crack space decreased. We observed that the usage of high strength rebar with normal and high strength concrete cause smaller values of maximum crack space, but the influence of concrete strength is not significant. These values are smaller than the design values.

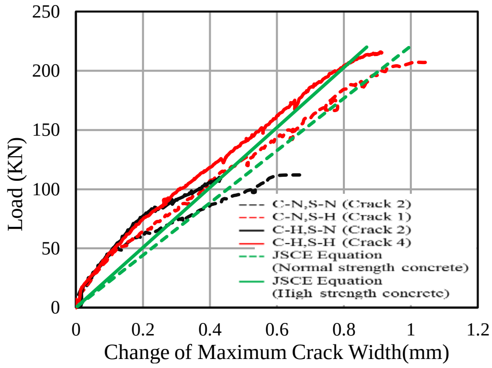

Fig. 5 Change of Maximum Crack Width

5. CRACK WIDTH

Fig. 5 shows the change of maximum crack width along with design values obtained from Eq. (1), in which the effect of ε'_{csd} is neglected. The crack number shown in index corresponds to crack with maximum width. Although concrete strength influences the crack width, the effect of high strength concrete for the beams with SD-345 and SD-685 is quite similar. The changes of crack width for the beams with SD-685 show almost linear increase until yield load. This means that larger strains and stress levels of SD-685 do not affect the crack width significantly. Moreover maximum crack width obtained from design equation ensured the safety side value of maximum crack width.

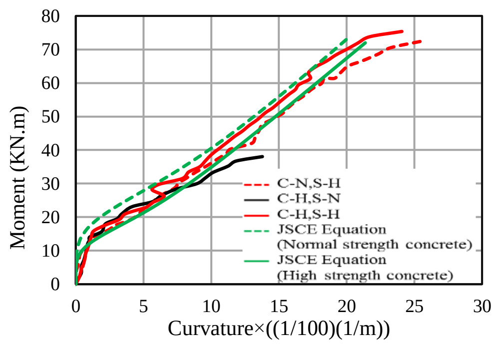

Fig. 6 Moment Curvature Relationship

6. DEFORMATION

Fig. 6 shows the moment and average curvature relationship within constant moment span along with design values obtained from Eq. (2) (JSCE, 2012).

$$I_e = \left(\frac{M_{cr}}{M_d}\right)^3 (I_g) + \left(1 - \left(\frac{M_{cr}}{M_d}\right)^3\right) I_{cr} \qquad (2)$$

Trend of moment curvature graphs for beams with SD-685 shows linear behavior until yield load after cracking, which shows that higher stress and strain levels do not affect curvature. The curves are identical with design values for both high and normal strength concrete.

7. CONCLUSION

The effect of high strength rebar on crack width and deformation was investigated experimentally considering combination with concrete strength. The effect of high strength rebar was not significant. It is confirmed that applicability of JSCE equations for maximum crack width and deformation is valid for rebar strength until SD-685.

REFERENCES

Standard Specifications for Structures-2012, Design, JSCE, 2012.