SUMMARY

題　目　　Shear Creep Failures of Reinforced Concrete Beams without Shear Reinforcement

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The present study experimentally and analytically investigated the shear performance of RC beams due to a sustained load under three different loading rates, namely a normal loading rate, a slow loading rate, and a very slow loading rate. Loading rates that were 100 times and 1000 times slower than the normal loading rate were selected to reveal creep effects due to the sustained load. This study proposed loading tests of RC beams under different loading rates as an alternative approach to verify the shear performances of RC beams due to sustained loads. Different loading rates were applied on specimens until failure was reached. The shear displacement, the strain of the concrete at the top surface of the beams, and the total crack width of the beams were monitored during the loading tests. The experimental time could be better controlled and that the shear strengths at diagonal cracking as well as at failure could be obtained from the experiment. After the verification of the experimental results, the discussion in this study is extended to the examination of RC beams failing in different modes by varying the ratio of shear span to the effective depth of the beams using non-linear finite element (FE) analysis.

The experimental works revealed that although the creep effects had been observed during the experiment, the shear strength was almost constant at the occurrence of the significant diagonal cracking and increased at failure. In the case of the RC beams that were mainly loaded under the slower loading rate, the height of flexural compression zone could increase and made the inclined cracks more challenging to penetrate deeper into the beams. Furthermore, the aggregate interlock that contributed to the shear resistance of the RC beams might also increase potentially due to the more branched cracks that occurred around the significant diagonal crack. With no significant difference on the shear critical opening, the more branched cracks could provide the more shear interface for aggregate interlocking. These could compensate for the adverse effects caused by the creep of the concrete.

The numerical analysis presented that under slower loading rates, the reduces of shear capacity became more significant with the decrease of the shear spans resulting in the higher contribution of compressive creep. These numerical analysis results were following the tendency obtained in the experiments. On the other hand, a slight improvement of shear strength occurred with the increases length of the shear span. The greater bending moments were required for the failures of the beams resulting in the relatively higher compression zone under slower loading rates. The penetration of inclined shear cracks higher into the beam becomes relatively difficult in this case. Furthermore, the possibility of the increased of aggregate interlocking due to the better redistribution of stresses around the inclined shear cracks (as observed in the experiments) could be represented by a rise in fracture energy under slower loading rates and sustained load. The change of fracture energy of concrete only significantly affected the beams which fail in flexural and shear-tension modes. In the case of the beams with very short spans, the influence of the increased of fracture energy is greatly depreciated.

In conclusion, sustained loadings and slower loading rates resulting in the higher flexural compression zone and a better redistribution of stresses around the diagonal cracking. Besides, the long-term strength development of concrete and the occurrence of creep recovery at some cracks tips under sustained loadings (which were not covered in this study) also can have positive effects on the shear strengths. Considers those benefits, a reduction in shear strengths of the RC slender beams and RC short beams (with a shear span/depth ratio between 1.0 and 6.5) may not be required in the design. The application of the reduction factor should be more appropriate for RC very short beams (with a shear span/depth ratio smaller than 1.0).