Shear Capacity of Concrete Beams under Sustained Loading

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Summary

Long-term tests on large-scale concrete beams without shear reinforcement, which are tested for more than two years under sustained loading close to the ultimate shear capacity (load ratio ranging from 87% to 95%) under climate controlled condition, show that sustained loading has no significant effect on the shear capacity. Although many flexural and shear cracks develop, the beams carry the load for a long time. The tests show that crack formation takes place only within some days after the load application, but after a week the cracks stabilize and become dormant.

Keywords: Shear capacity, Concrete beams, Sustained loading, Time effect.

1. Introduction

The design and construction of concrete bridges systems with long-term durability is a significant challenge for bridge engineers. Another challenging topic was and still is the failure behaviour of concrete slabs and concrete beams (or slab strips) without shear reinforcement. Yet little attention has been paid to the behaviour of shear cracks under long-term sustained loading. The goal of this research is to predict the time-dependent mechanical behaviour of concrete beams without shear reinforcement subjected to sustained loading and to quantify the possible shear capacity loss due to long-term loading. For that reason, several test series are carried out on concrete beams subjected to high shear loads close to the short-term failure load, for periods ranging from 3 months to nearly 3 years, during which the deflection, crack development and crack widths are monitored.

2. Experimental tests on concrete beams

18 concrete beams (subdivided into 6 groups; groups 2-7, see Table 1) are tested under long-term sustained loading. Together with these beams, 24 extra beams are tested in short-term loading as a reference of the ultimate shear capacity. The beams are reinforced longitudinally at the bottom to prevent bending failure. No shear reinforcement is used. The geometry of the beams is illustrated in Fig. 1. Dimension of the loading plate and supports is 100 mm × 200 mm which covers the whole width of the beam.

2.1 Long-term loading

The concrete beams are subjected to long term loading for a period between 3 months and 3 years. The goal is to study the behaviour of wide and long shear cracks under high sustained loading. These cracks only occur when the load is close to the ultimate shear capacity. A load ratio between 87% and 95% of the P_{max} is applied to the beams. During the long-term loading tests, the crack opening and crack length development and the appearance of new cracks in time were recorded periodically (1 hour, 1 day, 7 days, 30 days, etc).

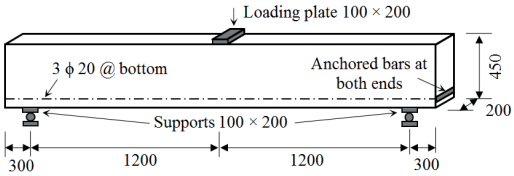

Fig. 1: Geometry of the beams

https://doi.org/10.2749/222137813806474264

2.1.1 Crack length in time

The progress of every single crack on the surface of the beam is monitored periodically in time. The results show that the development of the crack length is not necessarily limited to the large cracks; sometimes small cracks show considerable progress, while there is no progress in large cracks. The test results indicate that there is a limit to the crack length development. Another observation during the long-term tests is that the cracks do not propagate after 6 months of loading.

2.1.2 Crack opening in time

Periodically monitoring of the crack opening in time shows that in some of the cracks, the width increases in time while some other cracks remain dormant. However, it is also noticed that during the tests, the width of the cracks generally becomes dormant after one week, indicating that there is also a limit to the crack width opening under sustained loading.

2.1.3 Appearance of new cracks

In order to avoid the development of shrinkage cracks in time, the concrete beams are tested at an age of 70 days or more. However, a comparison between aged concrete specimens and fresh concrete beams shows that the development and appearance of new cracks, which are observed in periodically monitoring of the beams, are noticeable in fresh concrete beams. As a result, most of the new cracks, which appear in time, are shrinkage cracks. It has also been observed that shortly after loading, the crack pattern is mostly developed in the middle of the beam, while after some time new cracks appear closer to the supports.

2.1.4 Ultimate shear capacity

In order to investigate the effect of sustained loading (any possible reduction in capacity of the beam) three beams were loaded to failure at the end of sustained loading. According to these tests, the ultimate shear capacity of the beams at the end of sustained loading corresponds to the estimated shear capacity (calculated numerically) and no effect of the previous sustained loading was detected.

2.1.5 Failure of the beams shortly after initial sustained loading

Due to the reckless growth of the shear crack, two specimens (G4B6 and G7B6) failed under sustained loading. The beams failed shortly after initial loading, when they were still in the crack initiation stage. Sustained loading time of specimen G4B6 was almost 145 minutes and specimen G7B6 failed after 44 hrs. As shown in Fig. 3 (left), the crack opening displacements at both sides of the beam were stabilized after 1.5 hour, but suddenly the shear crack on the right side opens and the beam fails.

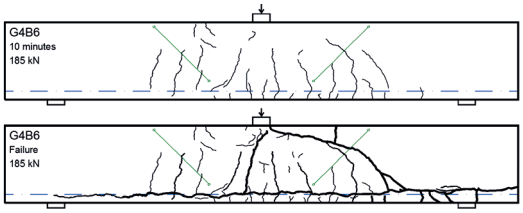

Fig. 2: Failure of G4B6 after 145 minutes

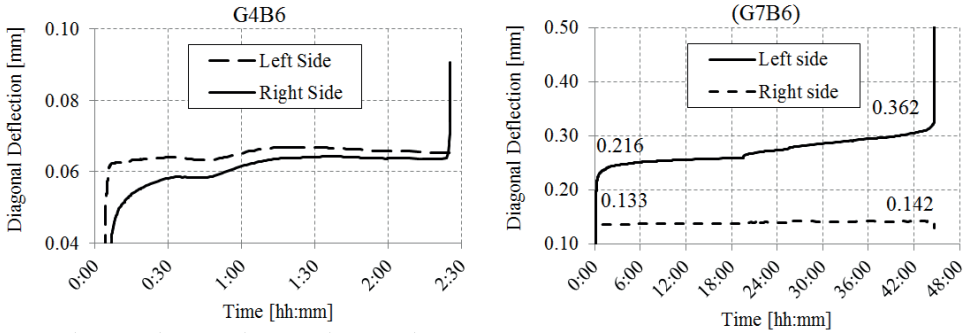

Fig. 3: Fracture of two specimens shortly after application of sustained loading