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Behavior of hollow composite steel-concrete members under long-term axial compression

Antanas Šapalas[a]*, Gintas Šaučiuvėnas[b], Konstantin Rasiulis[c]

[a, b,c]*Department of Steel and Timber Structures, Vilnius Gediminas Technical University, Saulėtekio al. 11, Vilnius LT-10223, Lithuania*

Abstract

Research results related to the behavior of hollow composite steel-concrete members under short-term loading are well known. Such members consist of two materials — steel and concrete with very different properties. They have different rheological behavior. Steel rheological behavior can be neglected at normal temperatures, but deformations are significant for concrete creep. Concrete creep phenomenon is well examined, but such knowledge cannot be applied directly to a composite member. Permanent actions are responsible for a large portion of external actions acting on compressed structural members. Research of composite members under long-term actions is necessary to ensure the reliable design of such structures.

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Keywords: composite; steel; concrete; long-term loading.

1. Introduction

Compressed structural members from steel or reinforced concrete are the most popular in framed structural systems. Both types have certain advantages and disadvantages. Steel structures are light but thin-walled, therefore, inclinable to local buckling. Besides, the fire resistance level of steel structures is low. While concrete structures are heavy, but have no buckling issues and are significantly fire resistant. It is possible to receive all advantages of steel and concrete while avoiding the disadvantages. This can be done by making one structural composite member. In the case of compression, it can be assumed that longitudinal deformations of steel shell and concrete core are the same, but,

* Corresponding author. Tel.: +37067241760.
E-mail address: Antanas.Sapalas@vgtu.lt

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because Poisson's ratio is different, radial stresses will appear in the steel–concrete contact surface. These radial stresses will arise from the radial compression of the concrete core. Experimental investigations into bearing capacities of compressed composite steel–concrete members show that due to complex stress–strain conditions in the steel shell and the concrete core, the composite effect can increase the strength of the hollow section from 5 to 25 % [1,2,3]. Combining different materials in composite cross section arise new positive properties [4,5,6]. Many scientific publications are related to the behavior of concrete-filled steel tubes with a solid concrete core and only some of them have a hollow concrete core. Almost all experimental tests are executed with short term loading or with members with solid concrete core [7]. Concrete is one of the materials, from which the composite cross section is made. It is sensitive to long-period loading. It is necessary to investigate time-dependent stresses and deformations to ensure the safe design of compressed steel-concrete composite members and experimental investigations are the most reliable for such a purpose.

2. Experimental investigations of long-term deformations of composite members

Steel tubes with the external diameter of 250, 200 and 140 mm, the wall thickness of 2 mm, and the yield strength of 260 MPa have been used for the production of test specimens. The hollow concrete core has been formed by filling a steel tube with fresh concrete mix and spinning it on a rubber belt centrifuge. Eight groups of test samples were produced consisting from nine

Fig. 1. Shape of the cross-sections of a composite steel–concrete member.

specimens with same geometrical and physical properties. For the control of the concrete strength on the day the external long-term compression was applied, and on the final day of long-term observations, the circular hollow core and prismatic (100x100x400mm) concrete specimens were tested. Prismatic test samples were compacted by vibration, and circular hollow core samples were centrifuged. All of the test specimens were stored in the same room at the same temperature and moisture conditions. For the comparison, concrete members have been produced at the same time from the same concrete mix and with the same centrifuging technology as the composite members. The external steel shell was removed from some of the specimens in one test group just before testing with the short-term static load or just before applying long-term loading on them. Such preparation of concrete tubular test samples ensures same hardening conditions for composite as well as concrete members.

Three composite and three concrete circular concrete members from each group were placed in the equipment for long-term axial compression. The control composite and concrete members were tested with the short-term static load for axial compression on the same day. The intensity (the ratio between the long-term load and the ultimate load) of long-term external load η was in the range 0.5–0.8. Long-term observations of compressed members under the constant axially applied load lasted from 100 to 400 days. Longitudinal deformations were measured during the entire observation period. Members were unloaded after these observations and tested for axial compression with a static load. Some of the composite members were tested in the long-term loading equipment with the purpose to investigate