V. Kozlejova, V. Kvocak, D. Dubecky
Technical University of Kosice, Slovakia,
Faculty of Civil Engineering

DEFORMATION IN COMPOSITE STRUCTURES UNDER LOAD-TERM LOADS

Structures carry various types of load during their exploitation. The effects of a long-term load component are significant mainly for the structures in which concrete fulfils its static function. Besides some instant effects; however, there are rheological properties of concrete that manifest themselves under applied forces. Creep, for instance, is time-dependent, and its effects can considerably influence deformation in composite steel and concrete structures. In order to verify some theoretical assumptions in practice, several specimens of composite steel and concrete deck bridges were made, containing encased filler beams. These specimens were subjected to constant long-term loading, and deflections and deformations that occurred in them were monitored and recorded.

Key words: composite structures, load-term loads.

В. Козлейова, В. Квочак, Д. Дубецькі
Технічний університет в Кошице, Словаччина,
факультет будівництва

ДЕФОРМАЦІЇ В КОМПОЗИТНИХ КОНСТРУКЦІЯХ ПРИ ДІЄ ТРИВАЛОГО НАВАНТАЖЕННЯ

Конструкції несуть різні види навантаження під час експлуатації. Ефекти довгострокової складової навантаження значні, головним чином, для конструкцій, в яких бетон виконує свою статичну функцію. Крім деяких миттєвих ефектів, є реологічні властивості бетону, які проявляються під прикладними силами. Наприклад, повзучість залежить від часу, і її вплив може суттєво вплинути на деформацію композитних сталевих та бетонних конструкцій. Для перевірки деяких теоретичних припущень на практиці було зроблено декілька зразків композитних сталевих та бетонних мостів, що містять ущільнювальні балки. Ці зразки піддавали тривалому навантаженню, а прогини та деформації, що виникали в них, контролювали та фіксували.

Ключові слова: залізобетонна балка, похилі перерізи, методика.

Introduction. Long-term load tests were launched on five different types of beam specimen marked as N1 to N5. The specimens had been designed based on the concept of deck bridges with concrete-encased filler beams. The design and verification of these structures is governed by STN EN 1994-2: Eurocode 4 – Design of composite steel and concrete structures. Part 2: Composite steel and concrete bridges. Nevertheless, issues concerning creep in beams with both composite flanges are not included in the relevant standard. More precise calculations can be found and adopted from STN EN 1992-1-1: Eurocode 4 – Design of concrete structures. Part 1-1: General rules and rules for buildings, and such composite structures may be regarded as reinforced concrete structures.

Types of loaded beams. In the experiment, N1 beams were made of encased hollow steel sections. The hollow section was created by welding a 6 mm thick U-shaped steel plate, creating the upper flange and web of the section, to another 6 mm thick steel plate, creating the lower flange of the section with protruding ends. Holes 50 mm in diameter were flame-cut in the web at an axial distance of 100 mm.

Reinforcement bars 12 mm in diameter were threaded through every third hole. Similarly, holes were flame-cut in the upper flange, having a uniform diameter of 50 mm and spacing of 100 mm. The holes were arranged in an alternate manner, i.e. they occurred either in the web or flanges across the section of the composite beam. Both the cross-section and longitudinal section of N1 beam are illustrated in Figure 1.

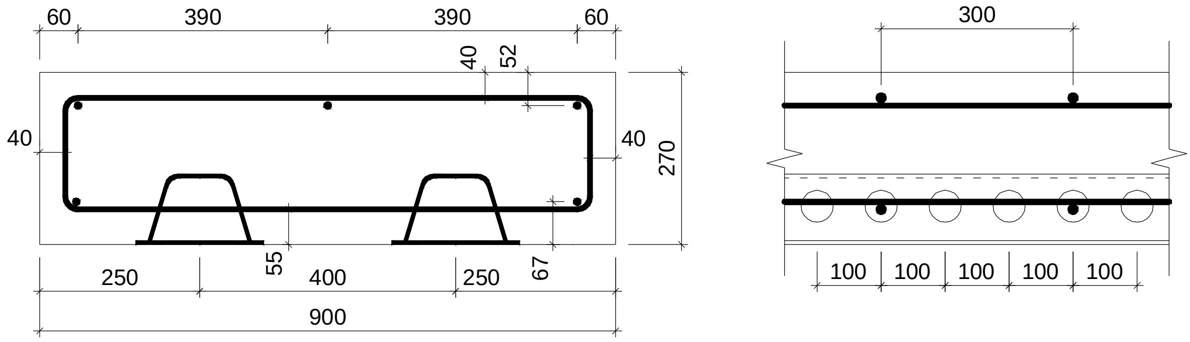

Fig. 1. Diagram showing N1Beam

N2 beams, as shown in Figure 2, were made from concrete-encased steel T-sections. These T-sections were made by cutting a rolled steel IPE 220 section straight into halves. Transverse reinforcement bars 12 mm in diameter were threaded through holes at an axial distance of 100 mm, whereas the holes, having a diameter of 20 mm, were flame-cut in the web, 55 mm above the bottom edge of the section.

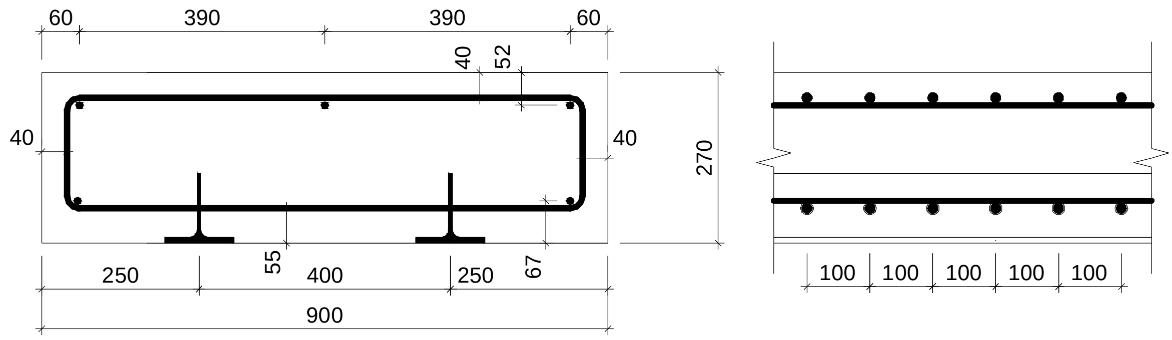

Fig. 2. Diagram showing N2 Beam

The third variant of specimens marked as N3 beams was made in the same manner as N2 beams, from concrete-encased rolled steel IPE 220 sections. The section was cut into halves in a comb-like manner, thus creating two T-sections with comb-like edges, as can be seen from Figure 3. Transverse reinforcement bars were placed in every tooth at an axial distance of 105 mm, 90 mm above the bottom edge of the section. The corresponding cross-section and longitudinal section are shown in Figure 3 [5].

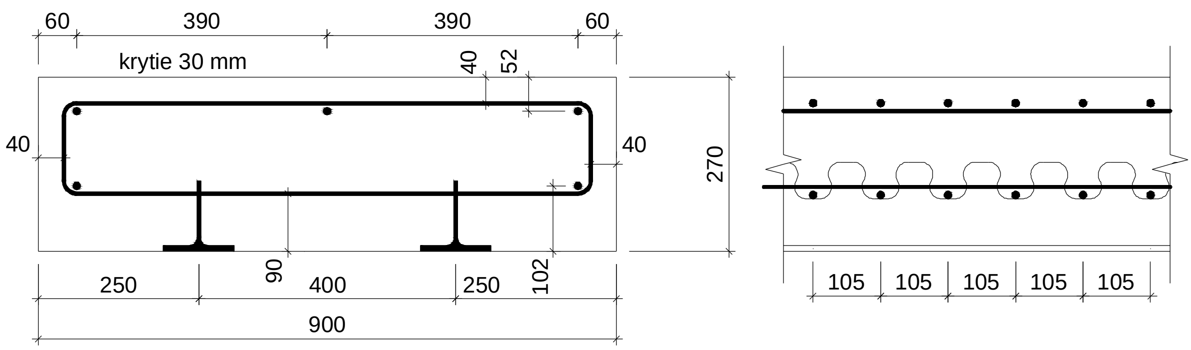

Fig. 3. Diagram showing N3 Beam

N4 beams were also made from rolled steel IPE 220 sections by cutting it in such a manner that a perforated stripe along its edge was created. Holes 32 mm in diameter were flame-cut, arranged alternately in two rows at an axial distance of 45 mm. Transverse reinforcement bars were threaded through every third hole as shown in Figure 4 [5].

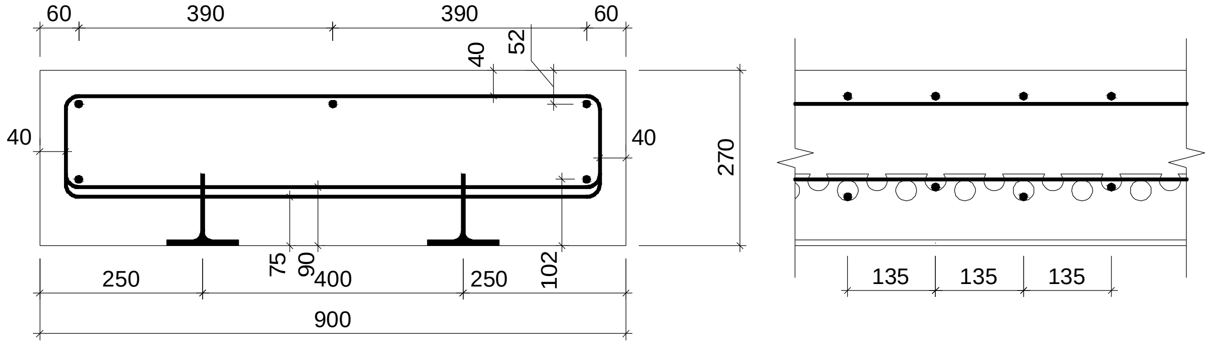

Fig. 4. Diagram showing N4 Beam

The fifth type of beam specimen was marked as N5 as given in Figure 5. As in the previous specimens, N5 beams were made by cutting rolled steel IPE 220 sections into two T-sections. Once again, transverse reinforcement bars 12 mm in diameter were threaded through the holes at a distance of 300 mm, 40 mm above the bottom edge of the section. Composite action was ensured by looped bars made of reinforcing steel with the dimensions 50 x 100 mm. These bars were welded horizontally to the steel section web, 60 mm above the bottom edge of the section.

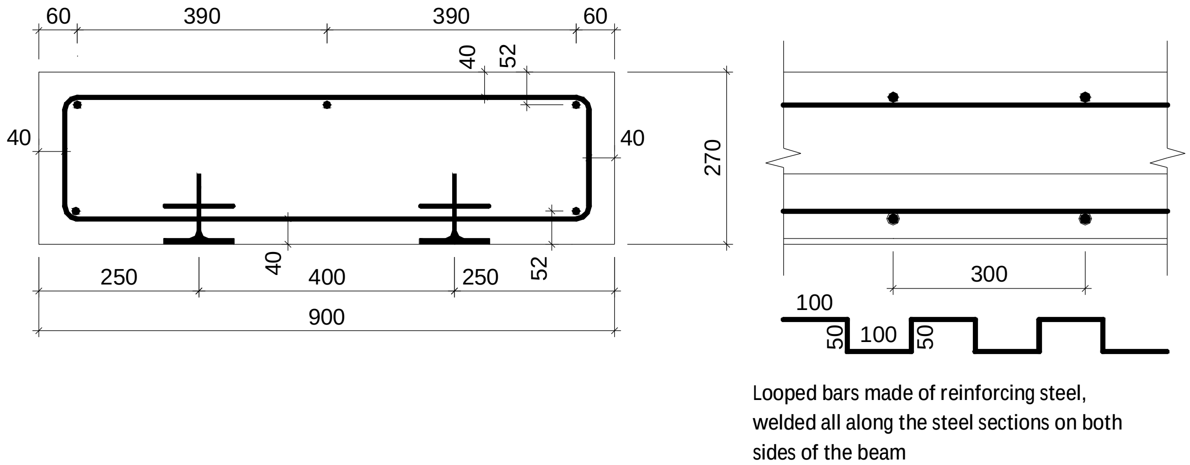

Fig. 5. Diagram showing N5 Beam

Loading beams . The beam specimens were placed in pairs into the loading frames. They were then loaded by compression introduced through air pillows connected to a compressor, generating constant compression force. The magnitude of the loading for each specimen type had been determined in advance so as to take into account the resistance and stiffness of the individual beam specimens. These were as follows:

N1 beams – compressed at 35 kPa
N2 beams – compressed at 20 kPa
N3 beams – compressed at 20 kPa
N4 beams – compressed at 18 kPa
N5 beams – compressed at 25 kPa

Upon a period of two hundred days of constant loading, the specimens were additionally loaded by 5 kPa, with the exception of N3 beams, being additionally loaded by 3 kPa only.

The process of loading is shown in Fig. 6.

Measurement results. Deflections and deformations in extreme concrete and steel fibres were measured during the load application and the entire loading experiment (Fig. 7).

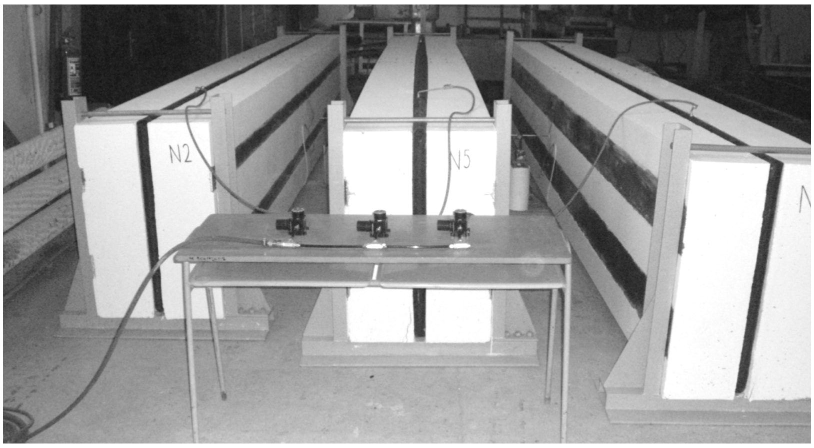

Fig. 6. Loading beams

Fig. 7. Measurement of deflections and deformations

The below graphs show correlations between deflections and loading durations during the experiment (Fig. 8).

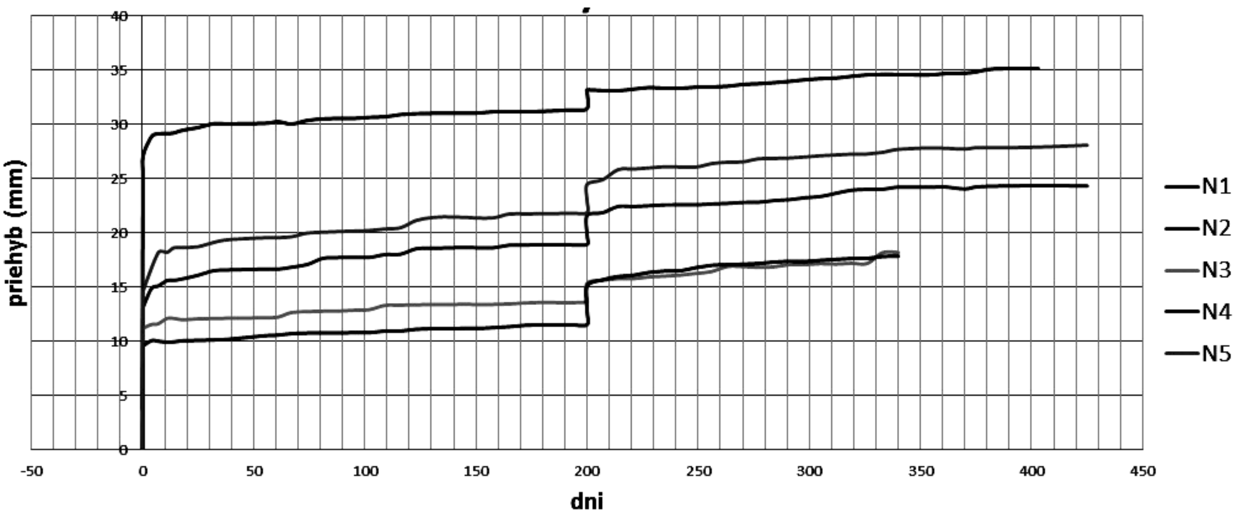

Fig. 8. Diagrams showing correlations between deflections and loading durations

The evaluation of deformations caused by creep was based on par. 3.1.4 Creep and shrinkage of STN EN 1992-1-1 and Appendix B therein [1, 2, 3, and 5]. All values of material properties and initial deformations in the calculations were based on real measurements.

In the paper presented, the calculations given for N4 beams are as follows:

- t_0 The age of concrete at the time of loading = 103 days
- t_1 The age of concrete at the time of additional loading = 303 days
- t_2 The age of concrete at the time of specimen evaluation = 510 days
- $\Delta\varepsilon_{c,0}$ Deformation of the concrete caused by loading = 274.3 µm/m
- $\Delta\varepsilon_{c,1}$ Deformation of the concrete caused by additional loading = 70.1 µm/m
- $\varepsilon_{c,2,exp}$ Deformation at the time of specimen evaluation = 452.5 µm/m
- $f_{c,k}$ Characteristic compressive cylinder strength of concrete = 33.84 GPa
- h/b Nominal dimensions of the composite section/element h = 270 mm, b = 900 mm
- h_0 Substitute depth $h_0 = 2.h.b/(2.h+b) = 337.5$ mm
- Average humidity = 65 %
- $\varphi(t_0,t_2)$ Calculated creep coefficient, defining creep between times t_0 and t_2 = 1.01
- $\varepsilon_c(t_0,t_2)$ Calculated deformation of the concrete caused by creep
$$\varepsilon_c(t_0,t_2) = \varphi(t_0,t_2).\ \Delta\varepsilon_{c,0} = 276.8\ \mu m/m$$
- $\varphi(t_1,t_2)$ Calculated creep coefficient, defining creep between times t_1 and t_2 = 0.84
- $\varepsilon_c(t_1,t_2)$ Calculated deformation of the concrete caused by creep
$$\varepsilon_c(t_1,t_2) = \varphi(t_1,t_2).\ \Delta\varepsilon_{c,1} = 49.6\ \mu m/m$$
- $\varepsilon_{c,2,calc}$ Calculated total deformation at the time of specimen evaluation
$$\varepsilon_{c,2,calc} = \Delta\varepsilon_{c,0} + \varepsilon_c(t_0,t_2) + \Delta\varepsilon_{c,1} + \varepsilon_c(t_1,t_2) = 670.8\ \mu m/m$$

As shown above, the deformation measured in N4 beams during the experiment was 452.5 µm/m. When adding the deformations caused by loading to the expected deformations caused by creep (the compressive and creep deformations of the concrete), the resulting value was assumed to reach 670.8 µm/m. Nevertheless, the difference accounted for 48 per cent. Similar differences occurred in the other beam types (N1, N2, N3, and N5), although the measurement results are not presented in this paper.

Conclusion. This paper provides the results of long-term measurements on beams loaded constantly for a period of 463 or 407 days. During this period, deformations in the individual beams were monitored and ambient temperatures and values of relative humidity recorded regularly. The deformations measured in real beams greatly differed from those assumed and calculated according to the standards currently in force. Since the evaluations of the experiment in question are still in progress, further steps will be taken to explore behavioural differences between concrete-encased filler-beam sections and reinforced steel sections, particularly as far as creep is concerned. Another analysis will focus on the examination of external aspects, having impacts on rheological properties, and on the consideration of such aspects in the calculation models currently used in practice.

Acknowledgements. The article was written with the support of the ITMS project No. 26220220124: “Design of bridges with concrete-encased filler beams of modified sections” and project VEGA 1/0188/16.

1. STN EN 1994 – 1 – 1: Eurocode 4 – Design of composite steel and concrete structures. Part 1 – 1: General rules and rules for buildings. 2. STN EN 1994 – 2: Eurocode 4 – Design of composite steel and concrete structures. Part 2: Composite steel and concrete bridges. 3. STN EN 1992 – 1 – 1: Eurocode 4 – Design of concrete structures. Part 1 – 1: General rules and rules for buildings. 4. STN EN 1993 – 1 – 1: Eurocode 4 – Design of steel structures. Part 1 – 1: General rules and rules for buildings. 5. Rovňák, M. – Ďuricová, A. – Kundrát, K. – Naď, Ľ.: Spriahnuté oceľovo – betónové mosty, Košice, Elfa s. r. o., 2006, ISBN 80-8073-485-2. 6. Navrátil J.: Předpjaté betonové konstrukce, Akademické nakladateľství CERM, sro, 2004, ISBN 80-214-2649-7.