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Abstract

The paper presents the developmental background for the concrete deck slab of girder bridges, in which the arching action is harnessed to such an extent that the need for tensile reinforcement is eliminated. This deck slab, which is known as the steel-free slab, is confined in the transverse direction by tying the top flanges of the girders by means of ties or straps. Five steel-free deck slabs have already been built in Canada, and have been carrying normal vehicular traffic.

The steel-free bridge deck slab, which utilises its natural arching action, has been under development for a number of years in Canada. The concept is based on a hypothesis according to which the deck slab on girders at failure behaves as an arch or a dome rather than a plate. The hypothesis has been validated by extensive experimental investigation, which has confirmed that the strength of a deck slab is enhanced considerably if it is laterally confined by ties connecting the top flanges of the girders. For the longitudinal confinement, the deck slab relies on its composite action with the girders. The deck slabs without internal reinforcement, which have come to be known as "steel-free slabs," have been tested extensively for their strength under static loads. The fatigue resistance of steel-free deck slabs under rolling wheels has been found by full-scale tests in Canada and Japan to be higher than those of the reinforced concrete deck slabs.

The arching action has already been utilized partially in the deck slabs, which are designed by the empirical method of the Ontario Highway Bridge Design Code (OHBDC). Hundreds of these slabs, which contain about 40% less reinforcement than the conventional reinforced concrete deck slabs, have been constructed during the past two decades in different parts of the world.

Design provisions for steel-free deck slabs are specified in the Canadian Highway Bridge Design Code (CHBDC); this code requires that a steel-free deck slab have a minimum thickness of the greater of 175 mm and one-fifteenth of the girder spacing. Each strap connecting the top flanges of the girders is required to have a minimum cross-sectional area, which is a function of the spacing of the girders, the spacing of the straps, the thickness of the deck slab and the modulus of elasticity of the material of the straps. The cross-sectional area of the straps in inversely proportional to the last two factors, thus confirming that this area relates to the stiffness, rather than the strength, of the straps. To control the cracking of concrete that occurs in its early life, randomly-distributed low-modulus fibres are mixed with concrete. The CHBDC specifies the minimum requirement for these fibres. It is noted that the addition of low-modulus fibres does not increase the tensile strength of concrete.

Till date, five bridges incorporating the steel-free deck slab have been constructed in Canada; four of these bridges are on regular highways, and the fifth is on a forestry road. The deck slab of the first bridge has no cantilever overhangs; horizontal vehicle collision loads on the barrier walls are designed to be carried directly to the girders and cross-frames, as a result of which the deck slab has no tensile reinforcement at all. The deck slabs of the second, third and fourth bridges have overhangs of substantial width, thereby requiring transverse tensile reinforcement near the top of the slab. In the second bridge, the carbon fibre reinforced polymer rods are used as the tensile reinforcement for transverse negative moments, and in the fourth glass fibre reinforced polymer is used for this purpose. The deck slab of the fifth bridge, being a forestry bridge, is of precast construction.

The distress-free performance of the steel-free deck slabs of five bridges in Canada from the Atlantic coast to the Pacific coast under unrestricted traffic has given solid support to the validity of the concept of arching in deck slabs. A summary of the unique features of various steel-free deck slabs is presented in the following table; this table also provides information about the cost of the steel-free deck slabs with respect to that of the conventional reinforced concrete slabs.

Constn. date	Girders	Slab thicknes s	Unique features of deck slab
Salmon River/ Dec,1995	Steel plate @ 2.7 m	200 mm	• first steel-free deck slab in new construction. • 6 % more expensive than conventional slab
Chatham/ July,1996	Steel plate @ 2.1 m	175 mm	• first barrier wall with double-headed tension bars and GFRP grid • significantly more expensive than conventional slab
Crowchild Trail/ Sept,1997	Steel plate @ 2.0 m	185 mm	• selected on competitive bidding against conventional slab
Waterloo Creek/ Mar,1998	Precast concrete @ 2.8 m	190 mm	• first steel-free deck slab on precast concrete girders • transverse confinement by studded straps • nearly the same cost as conventional slab
Lindquist Dec,1997	Steel plate @ 3.5 m	150 mm at crown	• first steel-free precast deck slab panel • record girder spacing to minimum thickness ratio, being 23.3 • 30 % cheaper than conventional deck slab panel

It has been shown in the paper that a proper harnessing of the arching action in a concrete deck slab supported by girders can lead to deck which is entirely devoid of tensile reinforcement. The elimination of steel from the deck slab has the effect of enhancing its durability and reducing its thickness, it being recalled that the thickness of a deck slab is usually governed by the depth of cover over its reinforcement.

The economical OHBDC empirical method of deck slab design is being used in Canada and some parts of the world for more than twenty years. It is still not a recognized method of design in most of the world. The authors wonder when the steel-free deck slab will be recognized by the engineering community at large outside Canada.