Report on the shear and moment capacity of pre-cast concrete ribs with in-situ concrete

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Introduction

A total of five ribs were tested in shear and eight ribs were tested in bending. The object of this test was to determine the shear and moment capacity of the ribs. The ribs were 150 mm in width, as this is commonly found in industry. Ribs were sourced from two suppliers, labelled R and O. The depth of the ribs in bending were varied between 255 and 300 mm, similar to what is commonly used in practice. A summary of the ribs are shown in table 1. The ribs were supplied by Royal Concrete.

Table 1: Rib properties and labels

ID	Test type	Supplier	Depth (mm)	Width (mm)	Length (mm)
M1	moment	R	300	150	3800
M2	moment	R	300	150	3800
M3	moment	O	300	150	3800
M4	moment	O	255	150	3800
M5	moment	R	255	150	3800
M6	moment	R	255	150	3800
M7	moment	R	300	150	3800
M8	moment	R	300	150	3800
S1	shear	R	300	150	1500
S2	shear	R	300	150	1500
S3	shear	O	300	150	1500
S4	shear	O	300	150	1500
S5	shear	O	300	150	1500

Material Properties

The concrete for the ribs was designed as 40 MPa. The diameter of the pre-stressed bars were 4.25mm and they were deformed in the long direction to provide better bond. The wire strands were tested in tension to determine their axial capacity. The steel bars were cut to lengths of 250mm. The bars were firmly gripped at both ends to prevent slippage. A rate of 3mm/min was applied and an extensometer was used for the test.

The test was conducted according to DIN EN ISO 6892-1 standard. A typical stress-strain curve is shown in Figure 1. The results are shown in Table 2. The minimum ultimate tensile strength specified by the manufacturer is 1697 MPa. The minimum and maximum values found were 1707 and 1812 MPa, respectively. This corresponds to between 1 and 7 % additional strength, hence all the wires were acceptable.

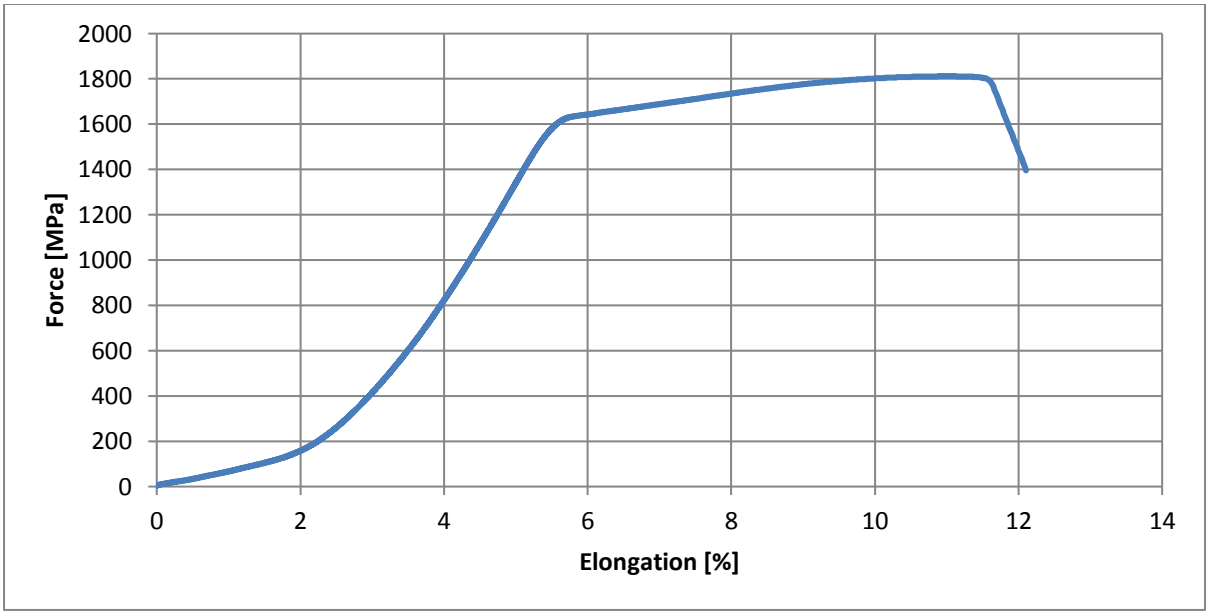

Figure 1: Typical force vs strain for strands

Table 2: Average ultimate strength of pre-stressed wires

Samples	Supplier	Avg. Fu (MPa)
M 1,2,5,6,7,8	Supplier R	1756
M 3,4	Supplier O	1802
S 1,2,3	Supplier R	1990
S 4,5	Supplier O	1770

The concrete used in the tests was mixed by an electric concrete mixer. The concrete mix design for the lab mix was designed as a 25 MPa mix. The stone size was 19 mm and a water cement ratio of 0.55 was used. The mix ratio was approximately 1:3:3.

A total of 24 cubes were cast in total to get a 7, 14, 28 and day of test results. The cubes were tested as per SANS 5861-2 (2006) and they were moulded in 100 × 100 × 100 mm cubes. The cubes were kept at a temperature of between 20 and 25 degrees Celsius and a relative humidity of 90%, until they were removed for testing. The cubes were tested in a King cyber-plus evolution testing machine. The compression tests were conducted as per SANS 5860 (2006). As expected, the cubes failed in an hourglass shape. The cube results are shown in table 3.

Table 3: Cube test results

Specimens	Avg Strength (MPa)
M 1-8	31
S 1-5	38

Specimen preparation

The ribs were delivered precast to the materials laboratory at the University of Johannesburg. Formwork was prepared for the ribs and fresh concrete was cast on top of the ribs. The shutter work was braced to ensure that the beams stayed within their required dimensions. Care was taken to ensure that the concrete was cast on the rough face of the ribs. No additional roughness was conducted on the ribs. The in-situ concrete were compacted using a 25 mm needle on a poker vibrator and a temping rod. The beams were cured with plastic on them to control moisture loss and prevent cracking.

Test set-up and procedure

The beams were tested for bending and shear in a 250kN and 500kN Instron machines respectively. A constant rate of 3mm/min was used for all the tests. This ensued that the natural failure mode was achieved and the failure could be observed carefully.

For the shear tests, two roller supports were placed at 900mm apart. The beam was loaded in the centre with the load actuator. The load, time and displacement were logged in a National Instruments data logger.

Figure 2: Test setup for beam in bending test

The beams that were tested for bending had two roller supports placed at 3500mm apart. The load was applied to an I-section which loaded the beam at third points. Strain gauges were attached to the beams at mid-span, both on the compression and tension faces. Linear variable displacement transducer's (LVDTs) were also used at the centre to measure the vertical deflection.

Failure modes

The short beams failed by shear failure while the long beams all failed in flexure.

Figure 3: showing midpoint cracking of beams failing in bending

Figure 4: Crack pattern of beam in bending

Test results for short beams

The test results are shown in table 4.

Table 4: shear results

ID	Depth	Supplier	strands	Fcu (MPa)	Fu avg (MPa)	Failure load (kN)	failure mode
S1	300	R	7	38	1990	120	diagonal shear
S2	300	R	7	38	1990	100	diagonal shear
S3	300	R	8	38	1990	99	diagonal shear
S4	300	O	7	38	1770	98	diagonal shear
S5	300	O	8	38	1770	105	diagonal shear

The results show that on average the samples from Royal concrete were 5% higher than the samples from supplier O. It should be noted however that shear forces are complex and they do not consistently failure in the same range.

When compared to the royal load tables, the failure loads exceeded the specified maximum load significantly. The shear load was specified as 39.3 kN/m and 62.4 kN/m for the 255 and 300mm ribs respectively.

Test results for long beams

The test results for the long beams are shown in table 5.

Table 5: Moment results

ID	Depth (mm)	Supplier	strands	Fcu (MPa)	Fu avg (MPa)	Failure moment (kN.m)
M1	255	R	5	17.8	1730	17
M2	255	R	7	17.8	1730	23
M3	255	O	8	17.8	1802	19
M4	300	R	5	30.2	1802	23
M5	300	R	7	30.2	1740	36
M6	300	R	8	30.2	1735	38
M7	300	O	8	30.2	1802	30
M8	300	O	8	30.2	1803	44

For the 255mm ribs, the 7 wire of Royal concrete had a 21% higher load carrying capacity when compared to an 8 wire rib from the other supplier. When these results were compared with the results from Royal concretes load tables, the tested beams have a significant amount of additional capacity.

CONCLUSIONS

13 beams were tested in shear and bending. The beams failed as expected and the results show that the actual capacity of the beams are higher than the load tables. The beams from Royal concrete also had higher shear and moment capacity when compared to another supplier.