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07/12/2004

Attention Attilio Angelucci

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Dear Mr. Angelucci

Report on structural tests on reinforced concrete beams – Testing of different beam systems

1. Introduction

Reinforced concrete beams were delivered to the Civil Engineering laboratory at the University of Cape Town. Beams consisted of composite concrete beams (Shellcrete precast L members) and monolithic reference beams. According to the test parameter, the beams were tested in bending or shear until failure. The ultimate failure loads, bending moment / shear capacity, and the failure mode were monitored.

According to the client, all beams were made of 25 MPa concrete with 75 mm slump and 13mm coarse aggregate.

2. Test specimens

All composite systems consisted of Shellcrete precast L-members with concrete infill. Precast L-members were made with different amounts of polystyrene bubbles:

- No polystyrene bubbles (in this report termed "COBUTE 1")
- 33% in volume of the aggregates replaced by polystyrene bubbles[1] (in this report termed "COBUTE 2")
- 50% in volume of the aggregates replaced by polystyrene bubbles (in this report termed "COBUTE 3")

Monolithic beams were tested as a reference. **Table 1** summarizes beam systems, dimensions, and test parameter.

Table 1: Beam dimensions and test parameter

Beam no.	Dimensions [mm]			System	Test parameter
	length	width	height		
1 2 3	3000	230	300	monolithic	bending capacity
4 5 6	2000	230	300	monolithic	shear cpacity
7 8 9	3000	230	300	COBUTE 1	bending capacity
10 11 12	2000	230	300	COBUTE 1	shear capacity
13 14	3000	230	300	COBUTE 2	bending capacity
15 16	3000	230	300	COBUTE 3	bending capacity

All beams tested in bending had the following reinforcement:

- 4 Y12 bottom
- 2 Y10 top
- Stirrups Y5.6 @ 225 mm centre spacing

All beams tested in shear had the following reinforcement:

- 4 Y20 bottom
- 2 Y12 top
- Stirrups Y5.6 @ 225 mm centre spacing

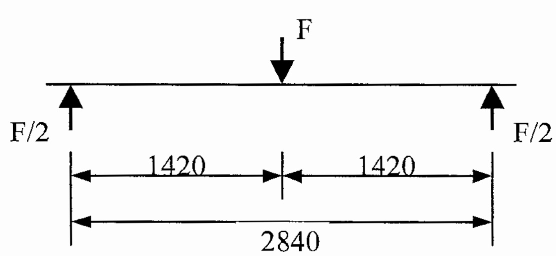
3. Test set-up

3.1 General

All specimens were tested on a Denison hydraulic compression machine. The rate of load application was 2±0.5 kN/sec.

3.2 Bending tests

Beams in bending were tested in a 3-point load set-up (**Figures 1 and 2**).



$$BM_{max} = F \times L / 4$$

Figure 1: schematic of test set-up for bending tests

[1] Information on the amount of polystyrene bubbles was supplied by the client

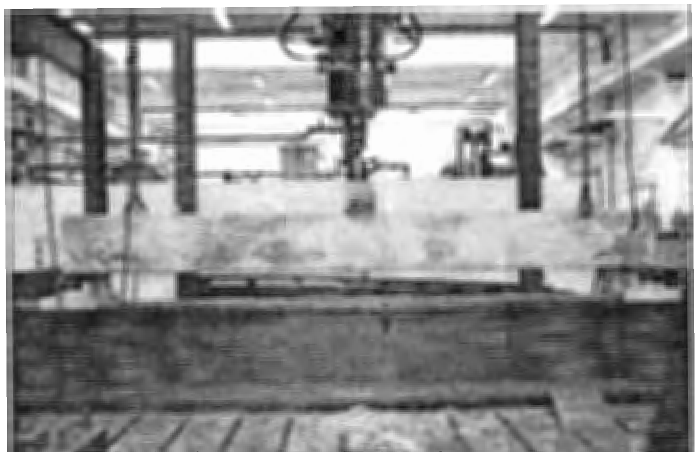
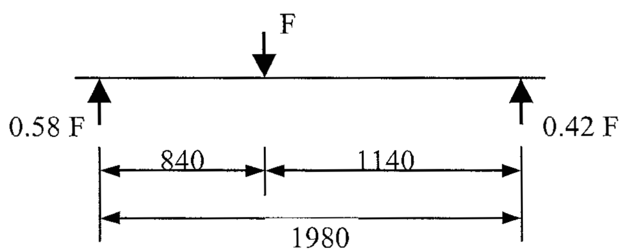


Figure 2: Photograph of test set-up for bending tests

3.3 Shear tests

Beams in shear were tested in a 3-point load set-up (**Figures 3 and 4**).



$V_{max} = 0.58$ F,
$\tau_{max} = 0.58$ F / (b x d)

Figure 3: schematic of test set-up for shear tests

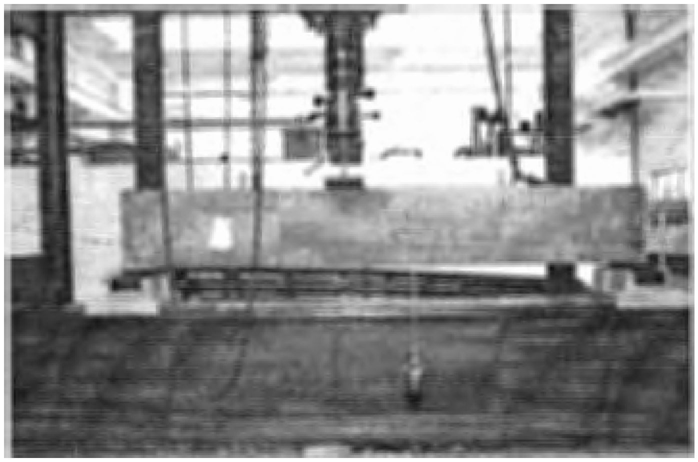


Figure 4: Photograph of test set-up for shear tests

4. Test results

4.1 Bending tests

All beams tested for maximum bending capacity showed typical bending failure. Bending cracks started to develop at midspan from the bottom of the beam specimens and proceeded towards the top as failure was approached. Failure occurred by concrete crushing in the compression zone. Subsequently, the load continued to increase slowly in connection with rapidly increasing deflection as the compressive steel in the top of the beam was carrying the compressive load by itself. Failure was defined as the moment at which the concrete crushed and the deflections started to increase rapidly (**Figure 5**).

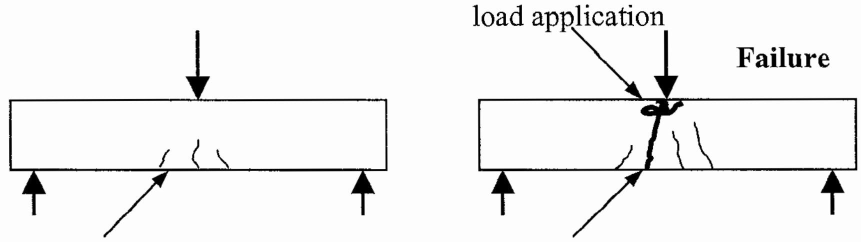


Figure 5: Typical failure pattern of beams in bending

Test results are presented in **Table 2**.

Table 2: Test results for beams in bending

Beam no.	System	First cracks at [kN] single	First cracks at [kN] mean	Failure load [kN] single	Failure load [kN] mean	BMU[2] [kNm]
1		30		91		
2	monolithic	48	42	92	90	63.7
3		49		86		
7		30		92		
8	COBUTE 1	22	30	98	96	68.2
9		38		98		
13	COBUTE 2	44	45	96	95.5	67.8
14		46		95		
15	COBUTE 3	31	45	96	95	67.5
16		58		94		

UGO'S NOTE ! CALCULATED ULTIMATE MOMENT = 41.7kN-m

All composite beams consisting of Shellcrete precast L-members and concrete infill failed at a higher load compared to the monolithic reference beams. The difference in bending moment capacity between different systems (COBUTE 1-3) was insignificant. The increase in load bearing capacity observed on the composite beams,

[2] BMU = ultimate bending moment, calculated as a mean value from single beam results

in comparison to monolithic beams, was approximately 10%. The higher load bearing capacity might be a result of the additional reinforcement provided by the wire mesh inside the precast L-members.

The load of first crack appearance was very similar for all specimens, showing that COBUTE beam systems performed like monolithic members in the serviceability state.

Figures of beams 7 (COBUTE 1), 13 (COBUTE 2) and 16 (COBUTE 3) after failure are presented in Figures 6-8. All beams showed the typical bending failure that can be expected to happen with monolithic beams.

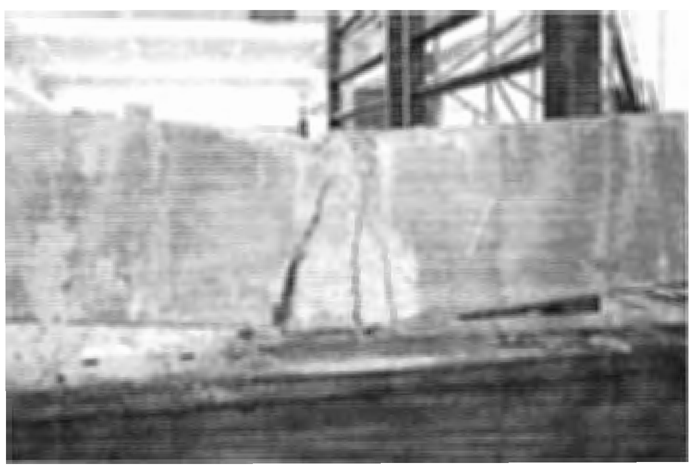


Figure 6: Beam 7 (COBUTE 1) after failure in bending

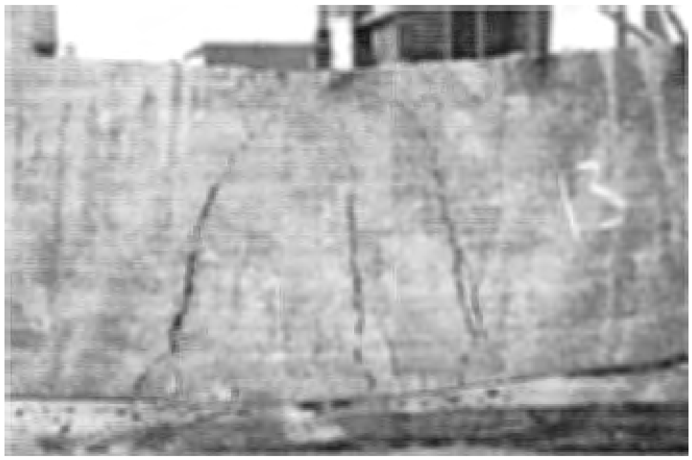
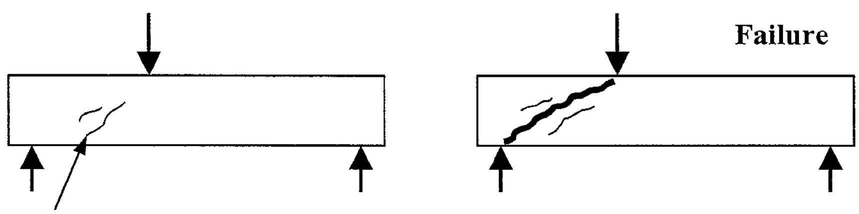


Figure 7: Beam 13 (COBUTE 2) after failure in bending

Figure 8: Beam 16 (COBUTE 3) after failure in bending

4.2 Shear tests

Monolithic beams showed typical shear failure. Shear cracks started to develop between the point of load application and the nearest support. Sudden failure occurred with the appearance of a large shear crack between the point of load application and the nearest support, as shown in **Figure 9**.

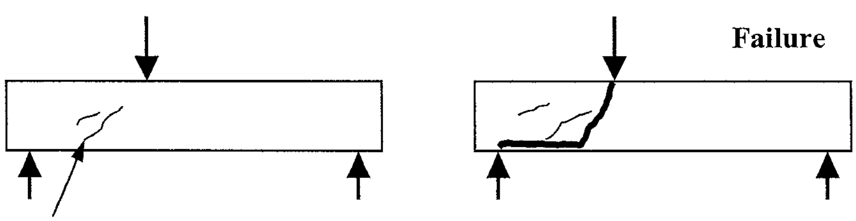


Appearance of first cracks

beam cracked across its whole depth between support and point of load application

Figure 9: Typical failure pattern of monolithic beams in shear tests

Composite beams consisting of Shellcrete precast L-members and concrete infill showed the same typical shear crack development as was observed on the monolithic specimens. However, failure in these beams occurred along the interface between the precast section and the concrete infill as shown in **Figures 10 and 11**.



Appearance of first cracks

Crack development at failure

Figure 10: Typical failure pattern of composite beams in shear tests

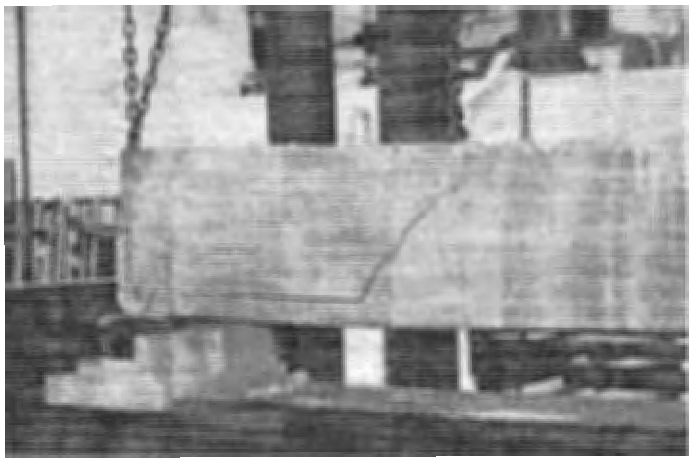


Figure 11: Beam 10 (COBUTE 1) after shear failure

Test results are presented in **Table 3**.

Table 3: Test results of beams in shear

Beam no.	System	First cracks at [kN] single	First cracks at [kN] mean	Failure load [kN] single	Failure load [kN] mean	V_{max} [kN]	τ_{max} [MPa]
4	monolithic	136	128	237	217	126	1.99
5		82		212			
6		166		201			
10	COBUTE 1	150	151	218	210	122	1.93
11		140		222			
12		164		190			

UGO'S NOTE : CALCULATED SHEAR RES.(V)= 93 kN.

The shear strength of composite beams made of Shellcrete precast L-members was very close to that of monolithic beams. The difference in shear strength between the two beam systems was insignificant.

Cracks on composite beams appeared slightly later than those on monolithic beams, which was probably due to the additional reinforcement provided by the wire mesh in the precast members.

5. Discussion of test results, conclusion

Composite beams made of Shellcrete precast L-members with concrete infill were tested in bending and shear and compared to the load bearing behaviour of monolithic beams. The composite sections were found to have a higher bending moment capacity (approximately 10%) and practically the same shear strength capacity, compared to monolithic beams.

The amount of polystyrene bubbles in the precast sections did not influence the bending moment capacity of the composite sections.

Best regards,

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