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Technical Note

Impact Resistance of Polyolefin Fibre Reinforced Precast Units

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Abstract

The conventional steel reinforcement in precast concrete box units was replaced with varying quantities of polyolefin fibres, to see whether the fibres alone could maintain the impact resistance of these units. It was found that, with a fibre addition of 1.5% by volume, the polyolefin fibre reinforced units were able to display essentially the same behaviour as the steel reinforced units, in terms of both the fracture energy and the maximum impact load. © 1998 Elsevier Science Ltd. All rights reserved.

Keywords: impact, polyolefin fibres, fracture energy, precast concrete.

INTRODUCTION

Precast concrete boxes, consisting of a base unit and a top unit, have long been used to house electrical services. They are currently fabricated using conventional steel reinforcement, with a small volume of fibrillated polypropylene fibres to provide 'green strength' to these dry cast units and to reduce plastic shrinkage cracking. The purpose of the present study was to see whether the base units of these boxes could be fabricated using polyolefin fibres to replace the conventional steel, in order to reduce the weight and the overall fabrication costs of these units. The resistance to impact loading was the parameter used to make this comparison.

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EXPERIMENTAL PROCEDURES

The reinforcing grid for the original dry cast concrete base units is shown in Fig. 1 (drawing supplied by the manufacturer). The thickness of the concrete was about 140 mm on the sides, and about 50 mm on the bottom. Four types of units were tested, in three of which the steel reinforcing grid was replaced by polyolefin fibres:

1. the original design, with 5.3-mm diameter smooth steel reinforcing bars and polypropylene fibres;
2. 0.5% by volume 6 mil (0.5 mm diameter) polyolefin fibres, 19 mm long;
3. 1.0% by volume 15 ml (0.38 mm diameter) polyolefin fibres, 25.4 mm long;
4. 1.5% by volume 15 mil (0.38 mm diameter) polyolefin fibres, 25.4 mm long.

The results presented below are the average values for tests on three specimens for (1), (3) and (4), and two specimens for (2). The polyolefin fibres (produced by 3M, St. Paul, Minnesota) had a specific gravity of 0.91. Their mechanical properties (as supplied by 3M) include a tensile strength of 296 MPa and a modulus of elasticity of 2647 MPa (about 1.2% that of steel).

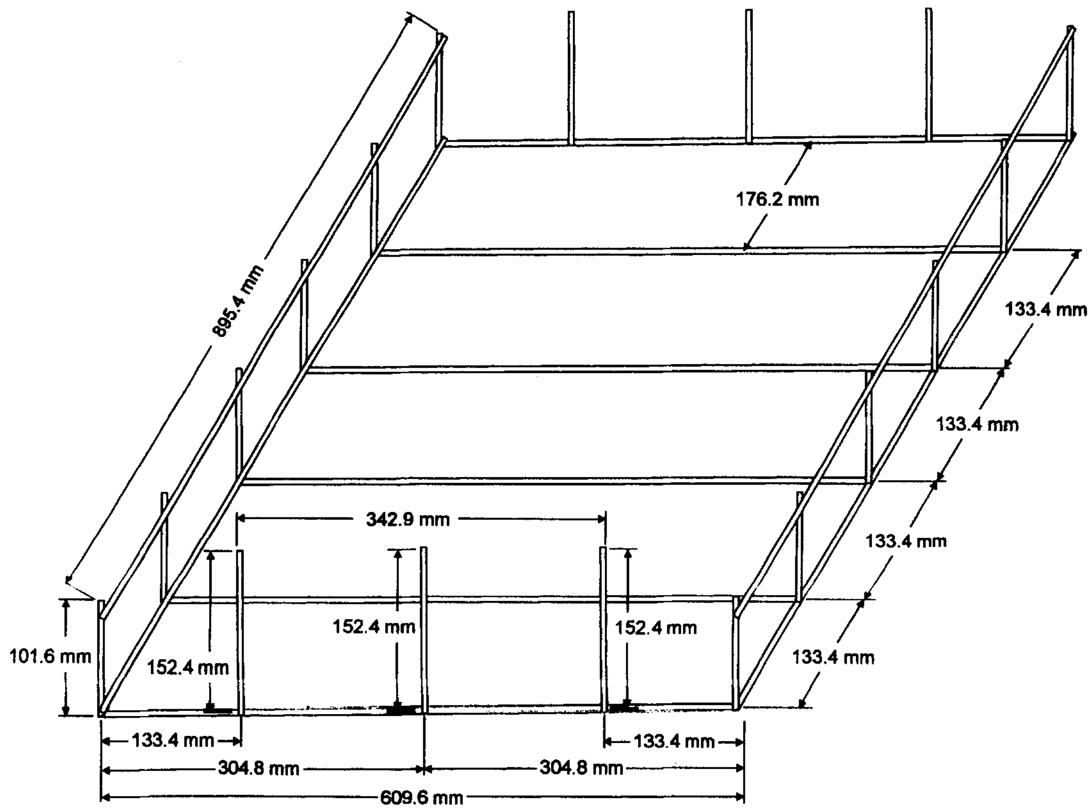


Fig. 1. Steel reinforcing grid used in the original design.

The specimens were tested in impact, using an instrumented, drop weight impact machine with the drop hammer weighing 577 kg; for these tests, the drop height was set at 50 mm.

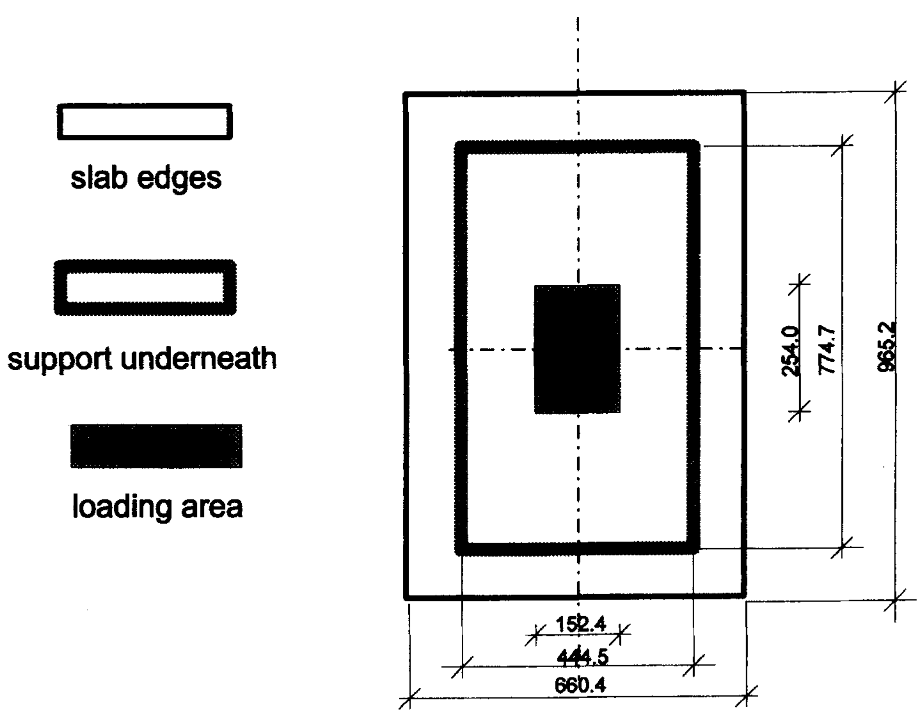


Fig. 2. Support condition and striking tup for the impact tests.

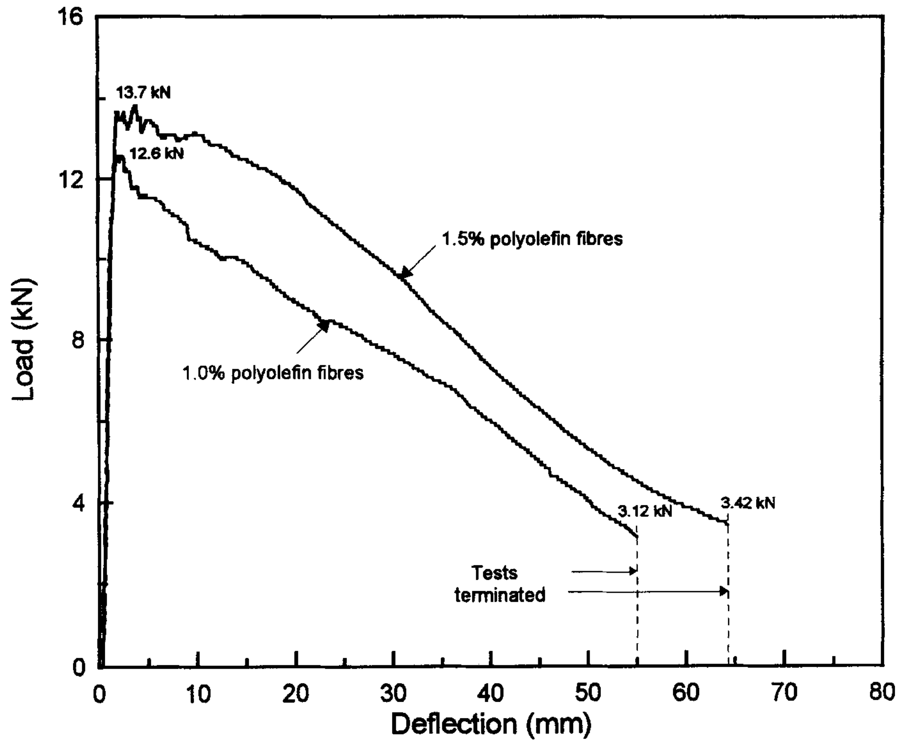


Fig. 3. Static load vs deflection curves for specimens containing 1.0% and 1.5% by volume polyolefin fibres.

Details of the impact machine have been given elsewhere.[1,2] The data were collected using a high speed PC-based data acquisition system. The specimen support conditions and the dimensions of the tup (the striking face of the hammer) are shown schematically in Fig. 2. In addition to the impact tests, two specimen (1.0% and 1.5% fibres) were tested statically, for comparison, using the same test arrangement.

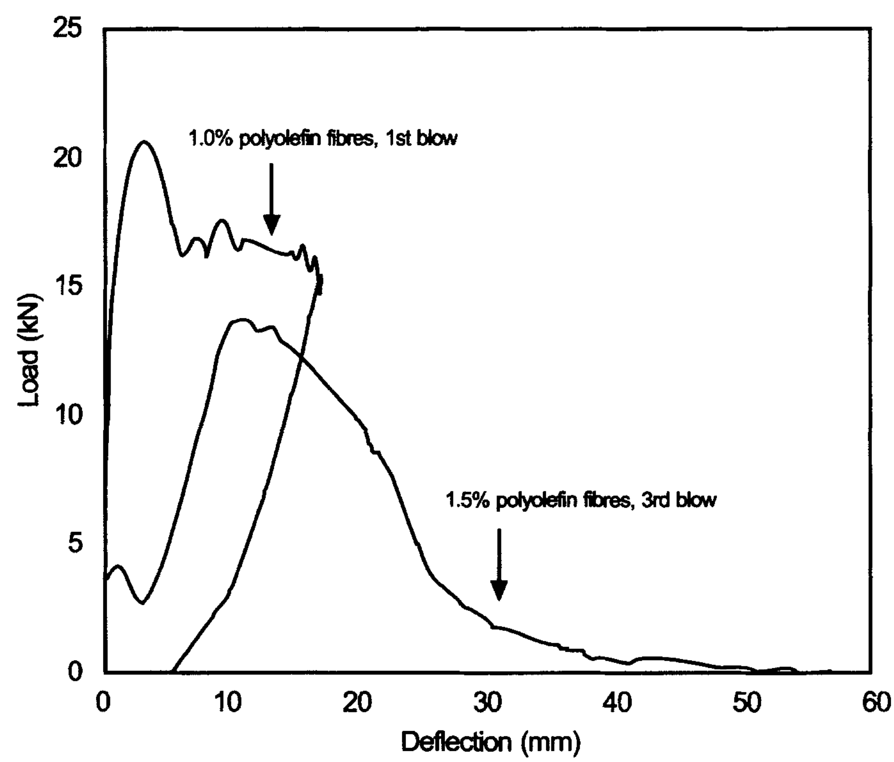


Fig. 4. Impact load vs deflection curves for specimens containing 1.0% and 1.5% by volume polyolefin fibres.

TEST RESULTS

Static tests

The load vs deflection curves for the two specimens tested statically are given in Fig. 3. Though there was only a small increase in peak load on going from 1.0% fibres to 1.5% fibres, the fracture energy (defined by the area under the load vs deflection curves out to the point at which the load dropped back to 25% of the peak load) was about 28% higher for the 1.5% fibre specimen, which reflects the greater load-carrying capacity after cracking because of the increase in fibre content.

Table 1. Maximum impact loads and damage/fracture energies

	Blow no.	*Maximum load (kN)*	*Damage/ fracture energy (Nm)*	*Cumulative energy (Nm)*
Steel bars[a]	1	24.3	325	325
	2	20.6	339	664
	3	13.8	355	1019
	4	4.9	121	1140
0.5% Fibres	1	16.0	176	176
	2			
	3			
	4			
1.0% Fibres	1	25.4	343	343
	2	16.8	219	562
	3			
	4			
1.5% Fibres	1	29.0	320	320
	2	21.6	344	663
	3	17.5	303	967
	4	5.3	93	1060

[a]Part of the energy was consumed by the yielding of the steel bars.

Impact tests

Except for the units containing only 0.5% polyolefin fibres, all of the specimens required several blows from the falling hammer to bring about failure. Typical load vs deflection curves under impact loading are given in Fig. 4, for the first blow on a 1.0% fibre specimen, and for the third blow on a 1.5% fibre specimen. It may be seen that the peak loads are not much different from those obtained under static loading (Fig. 3), but the shapes of the curves are quite different. Average values of the maximum impact loads are given in Table 1. The load values, which are an indication of the residual load-bearing capacity after each impact event, decrease with each impact, and reflect the cumulative damage to the specimens. The energies involved in damaging the specimens for each impact event, and the total fracture energies, taken as the cumulative sum of the energies consumed by each blow of the hammer, are also given in Table 1.

It should be noted that for the specimens with conventional steel reinforcement, the falling hammer could not completely penetrate the specimen, since the striking face of the hammer overlapped two of the steel bars. Failure was

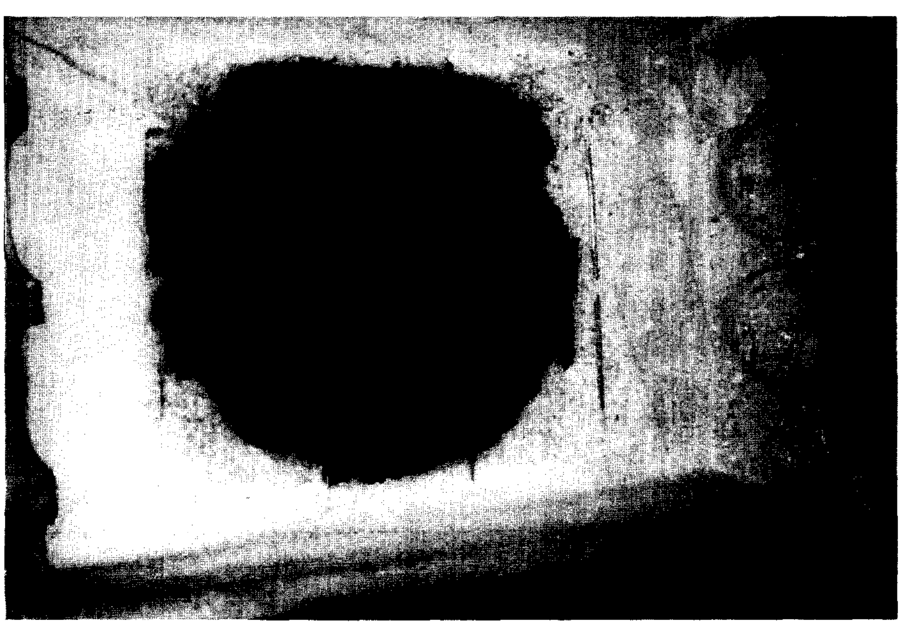


Fig. 5. Failure under impact of specimen reinforced with steel bars.

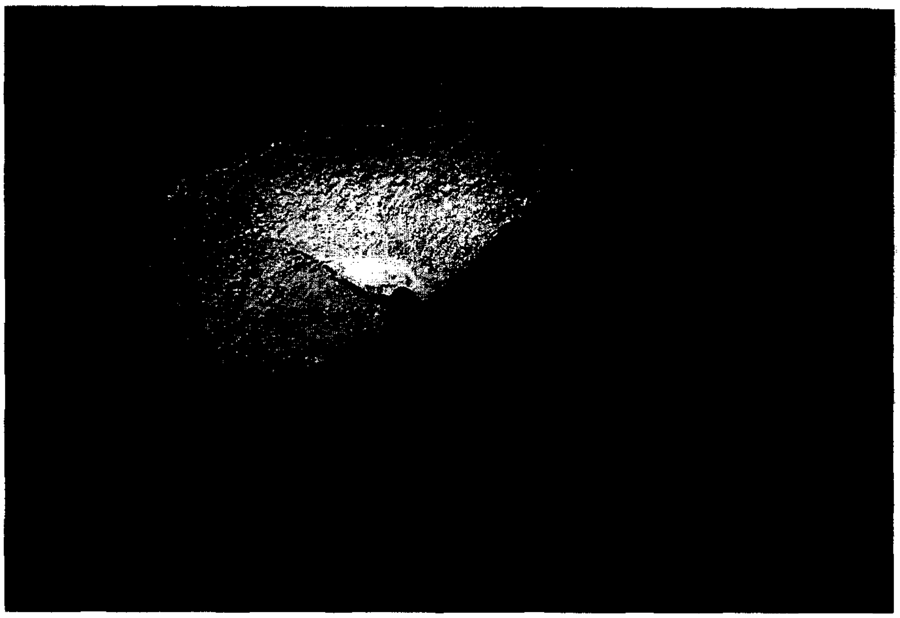
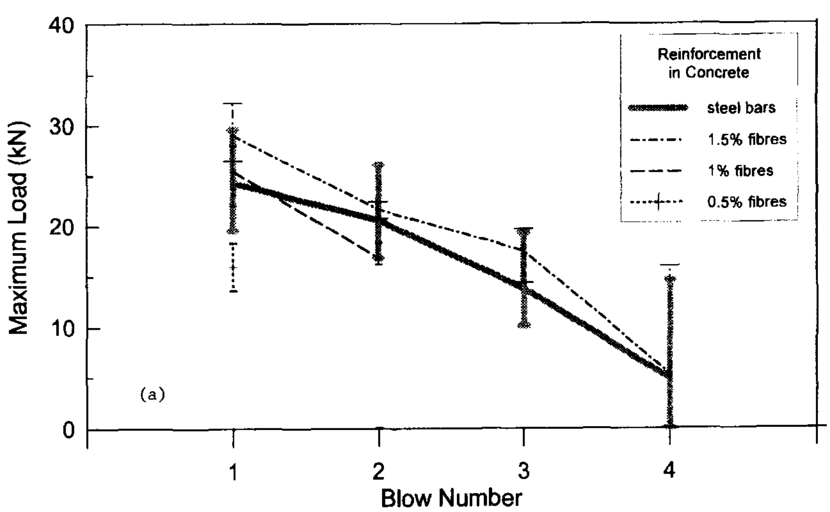


Fig. 6. Damage to specimen containing 1.5% by volume polyolefin fibres after three blows of the falling hammer.



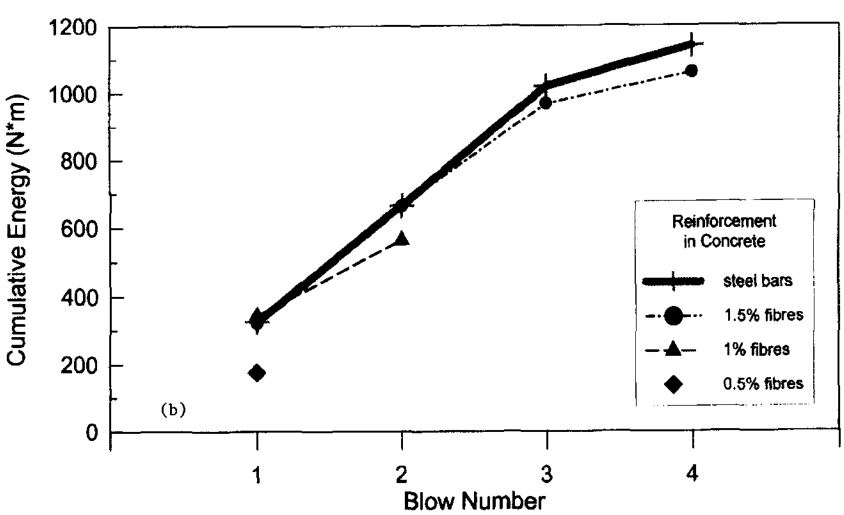


Fig. 7. (a) Decrease in load-carrying capacity of the units as a function of the number of blows; (b) cumulative damage/fracture energies absorbed by the specimens to failure.

assumed to occur when the concrete in the central portion of the specimen had completely broken away, as shown in Fig. 5. For the fibre reinforced specimens, which eventually failed essentially in punching shear, the fibres were able to bridge across the diagonal cracks that developed, as shown in Fig. 6 for a 1.5% polyolefin fibre specimen after the third blow of the falling hammer.

DISCUSSION OF THE RESULTS

As may be seen from Table 1, and more clearly when these data are shown graphically (Fig. 7), the behaviour of the concrete base units under impact loading improved considerably with increasing volumes of polyolefin fibres. While the units reinforced with only 0.5% of the fibres failed essentially in punching shear at the first blow, the units with higher fibre contents performed more satisfactorily. Indeed, the specimens containing 1.5% by volume of fibres performed almost identically with the steel reinforced specimens, in terms of both maximum loads and fracture energies. Thus, at least for this type of impact loading, it should be possible to replace the steel reinforcement with polyolefin fibres. It should be noted that the cumulative fracture energies for the 1% and 1.5% fibre specimens under impact were substantially higher than those obtained statically, which reflects the well-known strain rate dependence of cementitious composites.

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