PERSPECTIVES ON INNOVATION IN ARCHITECTURE, ENGINEERING AND CONSTRUCTION

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FOREWORD

The need for innovative approaches to design and construction is now recognised by most sectors of the construction industry. In the UK, for example, the Government has set up a Construction Best Practice Programme (CBPP) and an industry-led Movement for Innovation (M4I) which are championing the course of innovation in the construction industry. The Centre for Innovative Construction Engineering at Loughborough University was set up in April 1999 to address emerging research issues in the construction industry and to develop innovative solutions to industry problems. The CIB Task Group TG 35 and Working Commission W102 are also addressing aspects of innovation in the AEC sector. In addition to the above, there is a considerable body of ongoing research work that is geared towards innovation in the design and construction processes. The scope of these projects encompasses the use of innovative materials, innovative design concepts, innovative construction methods, novel procurement methods, innovative deployment of IT tools, etc. The aim of this conference therefore, was to act as a focal point for the dissemination of the results from ongoing studies, applications and demonstration projects throughout the world. It brought together practitioners and researchers interested in innovative approaches to architecture, engineering and construction.

This book contains the papers submitted to, and presented at, the conference. The papers address various facets of innovation in architecture, engineering and construction, and provided the basis for stimulating discussions during the conference. Two or more reviewers drawn from the International Scientific Committee and other experts reviewed each paper.

We are grateful to the following for contributing to the success of the conference: authors, participants, reviewers, the international scientific committee and the sponsors:

- The Centre for Innovative Construction Engineering (CICE)
- The Institution of Civil Engineers (ICE)
- The International Council for Research and Innovation in Building & Construction (CIB)

We are also grateful to Miss Fiona Wellby and Miss Anu Khandelwal who worked tirelessly to help put these Proceedings together.

Editors:
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A NEW MATERIAL TO BE USED AS BEARING PAD IN PRECAST CONCRETE CONNECTIONS

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ABSTRACT

Bearing pads are used in precast concrete connections to provide a more uniform distribution of contact stresses over the bearing areas and to allow relative movements between precast concrete elements, in order to prevent cracking at the connection area. Nowadays the elastomeric pads are used for loading support. While allowable relative movements between the precast concrete elements are greater than other pad types, this material has low compression strength. In this work is shown the study of an alternative material made with styrene-butadiene latex modified on Portland cement mortar with lightweight aggregate (vermiculite) and polypropylene fibbers. In some preliminary tests, the new material showed a good compression strength and lower elasticity modulus. For example, the reference mixture presented elasticity modulus of 800MPa that is approximately 1/40 of the conventional concrete one which makes it able to be used as bearing pads in the precast concrete connections.

INTRODUCTION

The presence of the connections is the basic difference between precast and conventional concrete structures regards structural behaviour.

The connections provide areas of discontinuity in the structure and their behaviour is usually complex because stress concentration. The structural system behaviour and, consequently, the success in your applications, are directly related with the behaviour of your connections. For those aspects, the connections have been received special attention in the precast concrete structures design.

For some kinds of precast connections, resting an element on a surface of the other provides the compression load transfer. In order to distribute contact stress and transmit the concentrated loads without damaging the elements surfaces, bearing pads are used.

According to BRUGGELING [2] the required properties of bearing pads are:

a) Enable deformations of the concrete element supported by them;

b) Enable fittings for difference in way of the elements;

c) To have a durability comparable to the durability of the concrete structure. If the durability is less than that of concrete structure, replacement of the bearing pad should be possible;

d) To distribute the compression stress within the contact area;

e) To reduce the transfer of horizontal forces by horizontal deformation or slipping of the elements.

Several materials have been used as bearing pads in beam to column connection. According to PCI [5] the most common are:

a) Chloroprene pads - these pads enable the greatest freedom in movement at the bearing, however compressive strength is somewhat lower than other pad types;

b) Pads reinforced with fibres - the fibres increase the load carrying capacity, however the deformability is smaller than the chloroprene one;

c) Cotton-duck fabric reinforced pads - they are used when a higher compressive strength is desired;

d) Chloroprene pads laminated with alternate layers of bonded steel or fibreglass - usually used in bridges.

e) Pads with Teflon - they are used to allow great horizontal movements.

The materials used in column-to-column connection and for load bearing wall panels are: cast in place concrete and grout.

The grout may be required for fire or corrosion protection and in other situations, required to transfer compressive forces. It can be used the following kinds of grouts: sand-cement grout and dry-pack - it should have a minimum compressive strength equal to that of the concrete elements. The grout should be kept as dry as the placement procedures will permit; flowable grout - they are used to fill small size voids. Since the water-cement ratio is relative high, such grouts have low strength and high shrinkage; non-shrink grouts - commercial non-shrink pre-mixed grout are used to reduce the shrinkage; epoxy grouts - they are grouts used when high strength is desired.

To choose what kinds of material to use for bearing pads some factors are important: the structural requirements and the material of the structure, the geometric characteristics of the connection, the economy and the aesthetics aspects.

This paper presents the study of an alternative material made with styrene-butadiene latex modified on Portland cement mortar with lightweight aggregate (vermiculite) and polypropylene fibbers. Some preliminary tests showed that the material has a good compressive strength and lower elasticity modulus so that it can be used as bearing pads in precast connections. While allowable freedom in movement at the bearing is somewhat lower than other pad types this material allow great compressive stresses.

The limitation of the freedom in horizontal movement at the bearing is not so serious, because in general in the beam to column connections the holes are filled by grout. So the displacements will be restrained. Besides, some times the columns flexibility is enough to absorber restraint forces and also possible to make easier achieve the global stability of the structure designing the connection for those forces.

MAIN COMPONENTS CHARACTERISTICS

The alternative material was made with styrene-butadiene latex modified on Portland cement mortar with lightweight aggregate (vermiculite) and polypropylene fibbers. The characteristics of the these materials are:

Vermiculite

The use of lightweight aggregate provides a decrease of the specific mass to the cement mortar. In the lightweight aggregate mortar a portion of the sand is substituted with lightweight aggregate.

The lightweight aggregate used in the studied material was mineral denominated vermiculite, whose structure is similar to the mica. The cells of air present in its interior cause great water absorption. However they provide its greatest property that is thermal-acoustic insulated. This property represents an advantage on the chloroprene pad that does not present a good behaviour under the fire.

According to NEVILLE [4], the lightweight aggregate mortars have lower elasticity modulus than the conventional ones. The low elasticity modulus leads to greater final deformations than the conventional mortars with equal strength.

Latex

The property improvements related to the incorporation of polymer in cement mortars include: increased to durability, increased flexural strength, reduce permeability, increased resistance to freezing, increased resistance to impact and increased resistance to abrasion.

The latex is an organic polymer that is dispersed in water. The inclusion of latex in cement mortars results in less water being required for a given consistency. Components in the latex function as dispersants for the Portland cement and thus, increase flow and workability of the mixture without additional water.

According to ACI [1], the surfactants used in the manufacture of latex can incorporate excessive amounts of air in the mixture. In spite of the incorporation of air reduce the mortar compression strength it increases the mortar deformability. A great deformability is necessary for a supporting material.

The compression strength related to any mortar keeps unaffected with an addition of up to 30%. Above this value the mortar compression strength decreases.

Polypropylene Fibres
Fibres can also be added to cement mortars to improve some properties. Many fibres types with different physical, mechanics and chemical properties have been used such as: steel fibres, polypropylene fibres, glass fibres, carbon fibres, Kevlar fibres, polyethylene fibres, acrylic fibres, nylon fibres and natural fibres. In this research were used the polypropylene fibres. According to MEHTA [3], because its low elasticity modulus these fibres can increase the impact and fatigue resistances of precast elements.

The main contribution of the polypropylene fibres is to reduce cracking and to increase the flexural toughness of cement mortars.

The workability of cement mortar is very affected by addition of polypropylene fibres. So it is necessary to establish a convenient proportion.

EXPERIMENTAL PROGRAM

Preliminary tests
In the first phase of the research several mixtures of styrene-butadiene latex modified on Portland cement mortar with lightweight aggregate (vermiculite) were cast. The compression and tension strength were determined for three standard 50mmx100mmcm cylinders while the elasticity modulus was determined for two ones. Through of those results it was arrived to a reference mix shown in the Table 1.

Table1: Reference Mixture

Cement	Vermiculite	Sand	Látex	Water-cement ratio
1	0,24	0,06	0,3	0,34

This mixture presented compression strength of 7,3MPa and elasticity modulus of 800MPa. This value is approximately 1/40 of the conventional concrete elasticity modulus.

Six 15mm thick 150mmx150mm plates were cast using the reference mixture and tested in compression to observe the material deformability. To simulate a possible irregularity in the contact between the connected precast elements, it was used a rough steel plate with some holes on each side of the specimen, as displayed in the Figure 1.

Figure 1 – Compression test detail

After the test, as showed in the Figure 2, it was observed the signs of the rough steel plate. This behaviour characterizes the great deformability of the developed material.

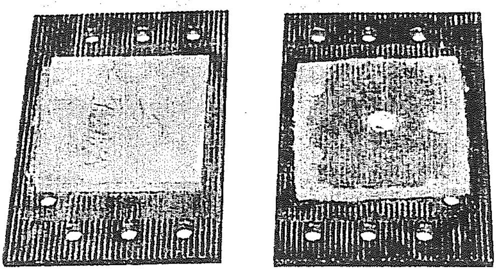

Figure 2 – Initial and Final configuration of the tested plate

Main tests

Considering the reference mixture and intending higher compression strength with low elasticity modulus it were made new mixtures adding polypropylene fibres. It was used fibres with 18 microns diameter and 12 mm length. The second column of the Table 2 shows the mixes.

Table 2: Results of the main tests

Mixes		Results (MPa)		
		Compression	Tension	Elasticity Modulus
80% Vermiculite	*CPV80F0L30*	7.3	1.1	**800**
50% Vermiculite	**CPV50F0L30**	7.2	1.2	**410**
	CPV50F1L30	12.8	1.4	**352**
25% Vermiculite	**CPV25F0L30**	**19.7**	2.4	**711**
	CPV25F1L30	**20.3**	2.2	**905**
0% Vermiculite	**CPV0F0L30**	**38.5**	4.7	**1050**
	CPV0F0L0	**59.3**	4.5	**1208**
	CPV0F1L30	**29.3**	4.4	**980**
	CPV0F1L0	**41.6**	3.1	**1290**
	CPV0F2L30	**30.5**	3.0	**801**
	CPV0F2L0	**38.3**	2.6	**1216**
	CPV0F3L30	**37.6**	3.6	**655**

Note:

CP specimen

V + number % de Vermiculite
F + number % de Fibres

L + number % de Latex

In the mixtures the aggregate mass was composed by vermiculite and sand with maximum diameter 0,6mm. It was made mixes with 80%, 50%, 25% and 0% of vermiculite. The amount of latex was 0% or 30% of the cement mass and the amount of polypropylene fibres was 0%, 1%, 2% or 3% of the mortar volume.

The water-cement ratio varied according with the amount of latex and vermiculite. In mixes without latex, the water-cement ratio was 0,4 and in those with latex it was 0,1, except for CPV80F0L30 mix that required a water-cement ratio equal to 0,34 because there was high amount of vermiculite.

For each mixture it were cast eight standard 50mmx100mm cylinders. Specimens were tested about 7 days after casting to obtain the compression and tension strength and elasticity modulus. To obtain the elasticity modulus it was placed two displacement transducers over the upper platen of the test machine as showed in Figure 3.

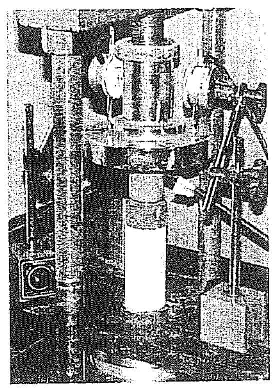

Figure 3 – Displacement transducers position

From the results obtained with the new series of mixes it was chosen the mix CPV0F2L30 to evaluate the bending behaviour and the deformability of the material. So, two 15mm thick 170mm x 470mm size plates were cast and tested in bending and three 10mm thick 150mm x 150mm size plates were cast and tested in compression.

The bending tests were realized in a 100 kN universal testing machine like shown in Figure 5. The plate was considered simply supported with 440mm span and the load was applied on the thirds in increments of 10N. The displacement in the middle of the plate was measured through a displacement transducer positioned in its lower face.

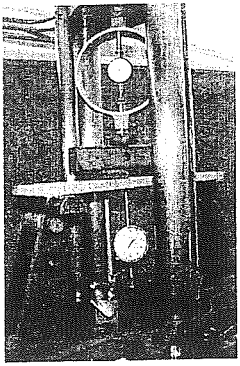

Figure 5: Bending Test Detail

For the compression plate test, each specimen was positioned centrally on a hydraulic machine for concrete between steel plates and displacements transducers with nominal course of 10mm was placed on either side of the lower inferior plate, as displayed in Figure 4.

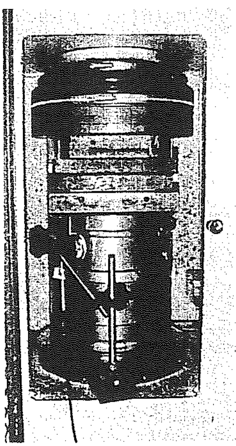

Figure 4 – Set-up of compression plate test

The specimens were loaded in increments of 2,5 kN/s until up 1500 kN. The displacements were recorded through a data acquirement system with 200 channels, denominated System 4000.

TESTS RESULTS

As previously mentioned, in the first phase of this research it was obtained a reference mixture as showed in the Table 1. After that, with the mixtures displayed in the Table 2 standard 50mmx100mm cylinders were cast. Specimens were tested about 7 days after casting to obtain the compression and tension strength and elasticity modulus.

The results are shown in the Table 2 and Figures 6, 7 and 8.

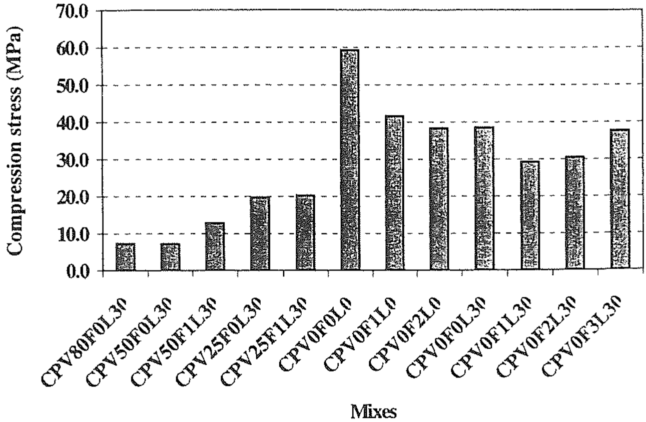

Figure 6 – Compression stress of each mixture

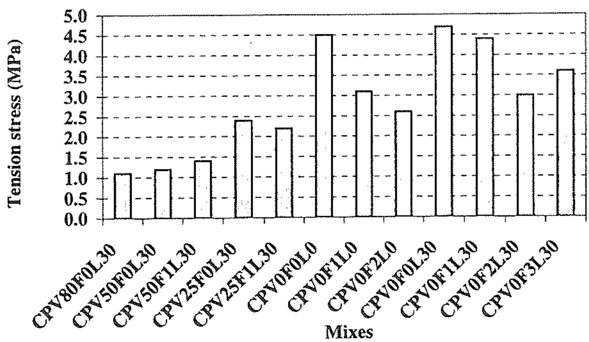

Figure 7 – Tension stress of each mixture

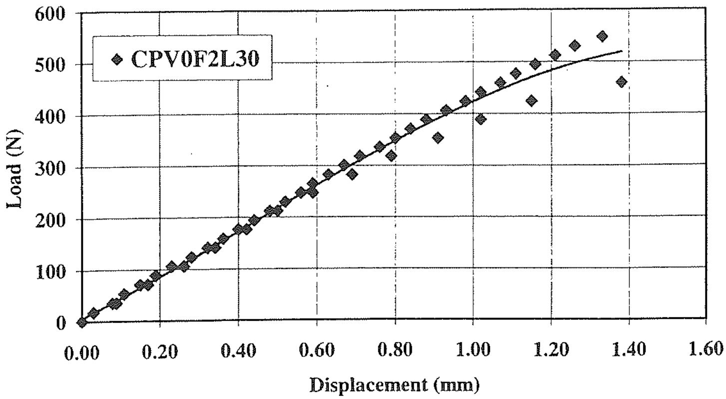

Figure 8 – Elasticity modulus of each mixture

It is observed that the increase of the amount of vermiculita reduces significantly the compression and tension strength of the mixture. In the mixes without vermiculita, it is observed that keeping the same amount of fibres and increasing the amount of latex the elasticity modulus decreases.

The mix with 3% of polypropylene fibres presented a low elasticity modulus with reasonable compression and tension strengths, but without appropriate workability for the mixture.

The decrease of the elasticity modulus due to the increase of the amount of latex and fibres reduce the compression strength.

The mix denominated CPV0F2L30 displayed in the Table 2 showed a low elasticity modulus with compatible compression and tension strength related to the precast elements usually produced. The bending behaviour of the plates cast with this mix is showed in Figure 9.

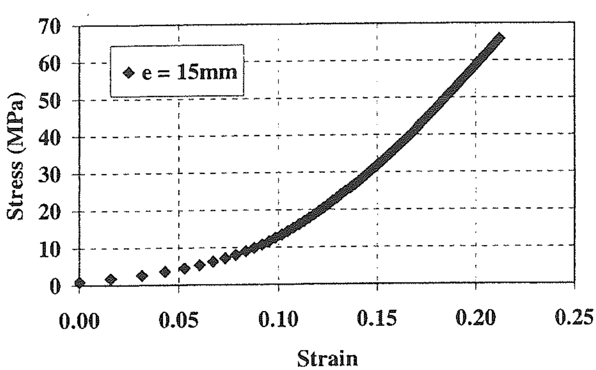

Figure 9 – Load x Displacement diagram

It was observed a linear behaviour until close to failure with an ultimate load of 500N that corresponds to a tension stress of 5,85MPa. It is worth to point out that the specimens did not fail suddenly and a great crack in the middle of the plate was observed like shown in the Figure 10.

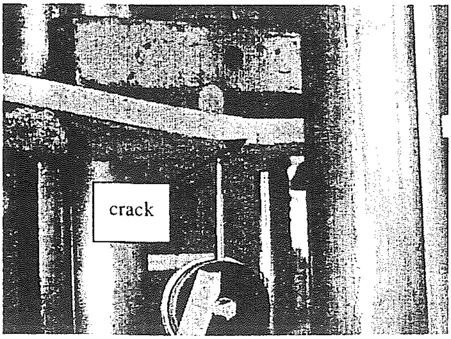

Figure 10: Crack at the middle plate

The 15mm thick plates cast with the same mix and tested in compression presented a great deformability at the beginning of the loading. Figure 11 displays the compression stress x strain diagram. Considering the linear phase of the diagram, an elasticity modulus of 505MPa is taken. The maximum displacement was 2mm what represents 20% of the plate thickness. For a 150mm width plate it would allow a rotation of 0,013 radians.

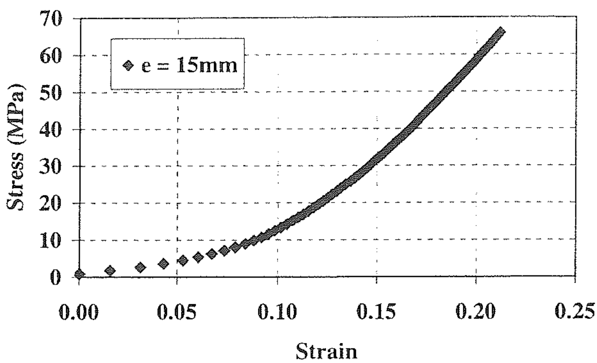

Figure 11: Stress x Strain diagram of the compression test

This value can be compared with a typical situation. A simply supported 10 meters span, 300mmx800mm beam cast using a conventional concrete with 32GPa elasticity modulus and 20kN/m loading applied would have a rotation about 0,002 radians. So, the studied bearing pad could easily absorb this rotation.

CONCLUSIONS

From the results it was observed that:

a) Using vermiculite while low elasticity modulus is reached tension and compression strength are reduced as in CPV50F1L30 mix that elasticity modulus is 352MPa and the tension and compression strength are 1,4MPa and 12,8MPa, respectively. This kind of material is recommended being used in beam to column connections where the load supporting should permit freedom in movements without higher compression strength.

b) Using latex of styrene-butadiene the elasticity modulus and compression strength reduce without significant loss of the tension strength. Besides, it reduces the water-cement ratio without loosing workability.

c) The polypropylene fibres provided larger deformability to the material, and a more ductile behaviour, without sudden failure in none of the mixes.

d) Regarding to the new material application in precast connections it was observed that the CPV0F2L30 mix presents compatible strength, 30,5MPa, related to bearing pads for supporting load when high compression stress happens.

The results of the tests demonstrate that the studied material can be used as bearing pad for loading support in precast connections since it has been made an appropriate mixture.

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