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Compression tests of cement-composite bearing pads for precast concrete connections

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Abstract

A cement-based material is developed to produce bearing pads for precast concrete connections. The material consists of sand mortar that includes additions of soft aggregate, latex, and short fibres to obtain greater deformability and high toughness. The additions used in this study were vermiculite, styrene–butadiene latex and either PVA or glass fibres. The proposed material is tested in the form of cylindrical samples, bearing pads under uniform load and bearing pad strips under concentrated loads. Based on the experimental results, the main conclusions are: (a) the largest amount of fibres should be used, within the limits of mixture workability, mainly for enhancing the bearing pad capacity to accommodate surface irregularities, (b) glass fibres perform better than PVA fibres when the material is subjected to concentrated loads, and (c) bearing pad thickness beyond 10 mm is of limited value.

Keywords: Bearing pad; Precast concrete; Connections; Cement-based material

1. Introduction

This paper presents a study of bearing pads, made with cement-based material, for precast concrete connections subjected predominantly to compressive loads. This type of connection may be: (a) by direct contact, or (b) by insertion of material between the elements. Due to the low tensile strength and quasi-brittle behaviour of the concrete, direct contact is not often used.

The material inserted between the precast elements can be flexible or effectively rigid. The rigid material may consist of metallic elements embedded in the components, so that the contact would be through these metallic elements, whereas the flexible material may be in the form of elastomer bearing pads. The most common elastomer is polycloroprene. As this material is flexible, it compensates for irregularities of the concrete surface, which promotes a more uniform distribution of stresses, and allows for relative movements between the precast elements. The ability to accommodate relative movements is essential since length changes in the elements, such as those due to thermal effects, would otherwise introduce large forces into the structure. The disadvantages of this type of material include its higher cost, lower durability compared to the concrete components, low fire resistance and relatively low compressive strength.

It is also possible to place other materials between the precast elements, such as the placement of seat mortar and the pouring or injection of infill mortar (grout). Controlling the dimensions is difficult in the case of seat mortar and the strength would also be relatively low. In the grouting process, the components are assembled leaving a space to be filled by either dry-packed mortar or non-retractile grout. For either case, additional fieldwork is required compared to the placement of ready-made products.

The primary objective is to develop a cement-based material with characteristics of greater deformability and higher toughness, compared to ordinary cement-based

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materials, to be used between precast concrete components. The material can be obtained from Portland cement and sand mortar incorporating the following ingredients: (a) soft aggregate or an additive to entrain air in the mixture, (b) latex, and (c) short fibres.

The soft aggregate (e.g., vermiculite) and/or air entraining agent significantly increase the deformation capacity of the material in the hardened state. The addition of latex to mortars improves the following properties of the material in the hardened state: durability, bending and impact strength, permeability and resistance to both freezing and abrasion [8]. Due to the presence of surfactants used in the production of the latex, a significant amount of air can be incorporated into the mixture, also increasing the deformation capacity of the material. The addition of short fibres to the concrete generally improves the impact and fatigue strength of the hardened material and increases its toughness [1]. In large quantities, the fibres reduce the workability of the mixture and can incorporate air into the hardened material, reducing its elastic modulus.

In order to analyze the applications of bearing pads made with this cement-based material, the bearing connections between precast concrete elements can be divided into two groups. Group 1 is comprised of beams bearing on columns (beam-to-column connections), and slabs bearing on beams or walls (slab-to-beam and slab-to-wall connections). Group 2 is comprised of the connections between elements of walls or columns (wall-to-wall and column-to-column connections) and connections between these elements and the foundation (wall-to-foundation and column-to-foundation connections).

For group 1 connections, the compressive stresses over the area of contact are not very high, and it is necessary to allow for relative rotation between the contact surfaces. As the proposed material is practically a variation of the concrete, it has the advantage of good durability and fire resistance. Compared to elastomeric bearing pads, bearing pads of this material would not allow the same degree of horizontal displacements between the contact surfaces and, thus, would not relieve stresses due to length variations of the supported element. To overcome this problem, the proposed material can be used on only one end of the supported element, which would still be a significant improvement. Alternatively, the proposed material can be used on both ends of the supported element. The associated restraint forces introduced into the structure can often be accommodated without significant differences in the design of the structural elements.

For group 2 connections, the compression stresses are high, and it is not necessary to allow for rotations between the connecting elements. Filled grout is normally used for this type of connection. In this case, the advantages of using the proposed material include facilitating the fabrication process in the field and the possibility of increasing the load capacity of the connection.

Thus, the use of the proposed bearing pad is advantageous for a variety of bearing connections, including group 1 and group 2 type connections described here. El Debs et al. [4] present applications of this material to beam-to-column connections and wall-to-wall connections in precast concrete systems.

This paper reports on the characteristics of the proposed material, as determined from tests of cylindrical specimens and bearing pads. For the bearing pads, two types of compression tests were performed: (a) bearing pads under uniform load, and (b) bearing pad strips under concentrated load.

2. Characteristics of the proposed material

2.1. Materials used

Early strength Portland cement and river sand, with maximum diameter of 2.4 mm, were used in this research. The soft aggregate was small-sized (maximum diameter of 2.4 mm) thermo-expanded vermiculite with a specific mass of 0.173 kg/dm^3. The latex was styrene–butadiene polymer, SB 112, with a solid amount of 50% and specific mass of 1.02 kg/dm^3 at 25 °C. Rhodia of Brazil, Ltd., supplied the latex and its specifications.

Two types of fibres were used: (a) polyvinyl alcohol (PVA) fibre and (b) Cem-FIL glass fibre. The PVA fibres (12 mm in length, equivalent diameter of 0.2 mm and specific mass of 1.3 kg/dm^3) were employed in previous research of El Debs and Naaman [7] and El Debs and Ekane [6]. The glass fibres were also 12 mm long with a diameter of 0.014 mm, as indicated by the manufacturer, and specific mass of 2.55 kg/dm^3. A superplasticizer was used for the mixtures with a great amount of vermiculite. This additive was SP 1, SPA type supplied by MBT of Brazil.

2.2. Tested mixtures

The compressive strength, tensile strength by split-cylinder test and modulus of elasticity were determined for several mixtures. The basic mixtures were chosen based on the previous studies of Barboza et al. [2] and El Debs et al. [5], in which a cement/aggregate ratio of 0.3 and a water/cement ratio of 0.4 were fixed to obtain a minimum compression strength of about 20 MPa. The water amount in the mixtures takes into account the water in the latex.

Table 1 shows the mixtures used for the cylindrical specimens. They were chosen based on the following aspects:

(a) A mixture with 5% of vermiculite, 3% of PVA fibre and 30% of latex was fixed as the basic mixture, whereas the other mixtures were variations of this basic one.
(b) The proportion of vermiculite and sand was limited to 50%. In Barboza et al. [2] this proportion reached 80%, but compression strength was significantly reduced.