International Journal of Solids and Structures 48 (2011) 2048–2059

Contents lists available at ScienceDirect

International Journal of Solids and Structures

journal homepage: www.elsevier.com/locate/ijsolstr

Strength assessment of adhesively bonded tile claddings

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A R T I C L E I N F O

Article history:
Received 23 December 2010
Received in revised form 22 February 2011
Available online 16 March 2011

Keywords:
Adhesive joints
Cohesive model
Shear-lag model
Tiles
Flooring
Pasternak foundation

A B S T R A C T

A simplified analytical approach for the assessment of bonding strength in tiled flooring is formulated and discussed. The approach is conceived for application to a specific type of failure mechanism, usually activated by differential elongation/shortening between tiles and substrate, of the type induced by thermal gradients or fresh concrete maturation. It is discussed how the failure mechanism, promoted by eccentric tile compression, can be studied as a Mode I cohesive crack propagation through the adhesive layer and a closed form estimate of the ultimate tile compression is provided. Based on closed-form solutions for the problem of stress transfer between substrate and tile through shear of the adhesive, simple formulas for the estimation of the tile compression are also derived.

1. Introduction

Floor tilings and external wall tilings are perhaps the most common type of cladding for floors and external walls of residential and industrial buildings. Tilings usually consist of three layers, as shown in Fig. 1: the tiles themselves in the upper layer (labelled with subscript t), the adhesive intermediate layer (subscript a) and the lower cementitious substrate (subscript s). Contiguous tiles are usually separated by a grouting interface (subscript g), which helps to relax compression stresses in the tile layer. The tiling parameters which, according to experience, play a role in the definition of the tiling strength are: geometric dimensions (layers thicknesses and tile length), layers and grouting elastic properties and adhesive tensile strength and fracture energy. Modern polymer-cement mortar adhesives can guarantee a reliable adhesion in the most severe conditions, though at increasing costs. This consideration motivates the industrial interest of being able to predict, with reasonable accuracy, the required strength of the joint for the design tiling conditions.

The specific, but rather common failure type shown in Fig. 2 is considered in this paper: compression stresses develop in the tiles due to either tile expansion or substrate shrinkage. Tile compression, combined with defects due to poor workmanship, may give rise to Mode I tile decohesion according to the failure mechanism depicted in Fig. 3. The differential expansion/shrinkage between tiles and substrate may be caused either by thermal gradients through the wall or floor thickness, or by the procedure followed to fix the tiles to the substrate. In particular, to speed up the tile installation in the case of flooring, tiles are often placed before maturation of the cementitious substrate. The residual substrate shrinkage transmits shear stresses through the adhesive bed, resulting in tile compression. In the presence of out-of-plane defects, as in the case of the force transmission between tiles shown in Fig. 3, the compression force may give rise to Mode I tile decohesion.

Typical defects due to poor workmanship in tile placement, such as poor surface preparation, existence of voids between tile and adhesive, tile placement on a skinny adhesive layer due to not respected adhesive opening time, not adequate tile setting pressure, have been studied and their effects statistically investigated by Zhi and Wei (1997) and Guan et al. (1997b) together with the effects of severe weathering (Guan et al., 1997a). The importance of the adhesive mix design and the effects of exposure temperature variations during tile application have been investigated by Chew (1999). Mahaboonpachai et al. (2008) carried out an experimental laboratory investigation simulating the failure conditions of external polymer-cement mortar wall tilings under the effects of solar radiation. Mahaboonpachai et al. (2010) formulated a two-dimensional cohesive interface finite element for the simulation of tile debonding. For the identification of the polymer-cement interface parameters, the authors also carried out both symmetric and asymmetric four point bending tests, and a particular type of high shear test. The fracture parameters identified from their campaign will be used also in this paper as a reference.

Based on these observations concerning the failure mechanism, the present work is intended to provide simplified closed-form

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doi:10.1016/j.ijsolstr.2011.03.012