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Experimental investigation of adhesion failure of the interface between concrete and polymer-cement mortar in an external wall tile structure under a thermal load

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Abstract

This paper aims to present an experimental method for investigating an adhesion failure of the interface between concrete and adhesive mortar in an external wall tile structure under a thermal load. The laboratory-scaled heating experiment was designed in order to represent the external wall tile structure that is subjected to solar radiation. The presented experiment successfully reproduces the interfacial delamination under the thermal load, and quantitatively gives a result in terms of the relationship between the maximum temperature supplied on tile surface and the length of interfacial delamination. Based on this experiment, together with commonly observed tile surface temperatures in the reality, the long-term durability of the interface is discussed.

Keywords: External wall tiles; Heating experiment; Thermal expansion mismatch; Interfacial delamination; Quantitative measurement

1. Introduction

External wall tile structures normally consist of concrete substrate, adhesive mortar, and tiles. Advantages of the external wall tiles, commonly used as a building finishing facade in Japan, are not only their aesthetic expression, but also an increase of concrete wall durability against environmental attacks such as carbonation and weathering. Moreover, high-rise buildings utilize the self-cleaning ability of glazed-surface tiles in order to reduce the cleaning cost of the buildings' facades during their life. However, the failure of the external wall tiles in form of the tile delamination during buildings' life certainly does not fulfill the above mentioned requirements in the tile utilizations. Moreover, the external wall tiles, upon the fall off from buildings, cause a danger to pedestrians and properties around that area.

Generally, the causes of external wall tile delamination are various, such as thermal expansion mismatch among materials, shrinkage deformation of adhesive materials, and attack of chemical pollutant, and these causes are combined in nature. Although it is difficult to clarify which one is the main cause of the failure, the problem is mainly investigated from the viewpoint of resistance and reaction at the interface.

Regarding the resistance of the interface, most of the researches were carried out to investigate the interfacial resistance of the interface between concrete substrate and adhesive mortar, where the failure is often found in external wall tile structures. For examples, ordinary-cement mortar, polymer-cement mortar, and fly-ash mortar were used as the adhesives, and the interfaces were investigated in terms of tensile and shear bonding strength [1–7]. The interfacial resistance was also investigated in terms of the interface fracture toughness in the viewpoint of interface fracture mechanics [8,9].

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On the other hand, researches have been carried on analyzing the cause of external wall tile failure [10,11] by showing that shear stress, occurring due to thermal expansion mismatch among materials, is one of the main factors that deteriorate the external wall tile structure. The shear stress is internally induced by temperature gradient at the interface between material layers, since the temperature gradient is built up across a building wall where the temperature on a tile surface outside the building and the one of concrete inside the building are not the same. As a result, the differential movement among the material layers due to thermal expansion mismatch occurs, especially at the interface between concrete substrate and adhesive mortar where the movement of the concrete is small due to the boundary conditions with the structural components such as beams and columns.

Although there are researches from the viewpoint of resistance and reaction of the interface, the former often relies on tests under mechanical loadings, and the latter on thermal stress analyses. In order to investigate the tile delamination problem and to develop a durable external wall tile structure, it is necessary to reproduce the tile delamination under a thermal load and to conduct a thermo-mechanical analysis. Thereby, the tile delamination will be understood more in terms of thermal and mechanical properties based on experiments and analyses.

This paper aims to develop a laboratory-scaled heating experiment which is designed to simulate a real external wall tile structure subjected to solar radiation, and also aims to investigate the delamination of the interface between concrete and polymer-cement mortar (PCM) in a tile structure under a thermal load. The heating experiment was carried out in order to reproduce the interfacial delamination in the laboratory, which is often observed in the reality, but not quantitatively investigated in the laboratory. From this experiment, the relationship between the maximum temperature on tile surface and the length of interfacial delamination between concrete and adhesive mortar could be obtained quantitatively, and, together with commonly observed tile surface temperatures in the reality, the long-term durability of the interface will be discussed.

In what follows, firstly, all system components of the heating experiment are explained in the next section. Then, experimental procedures, experimental results, and discussion follow. Finally, concluding remarks are given in the last section.

2. Heating experiment

In this section, the laboratory-scaled heating experiment, developed in order to represent an external wall tile structure subjected to solar radiation, is described (see Fig. 1). The heating experiment can generate temperature gradient across the laboratory-scaled specimen in the direction from tile surface to concrete substrate, and it can consequently induce shear stress at the interface between the material layers. The experimental set-up of the heating experiment is composed of a fixing device, a heat supply source, and a temperature monitoring system. After heat supplying process, the interfacial delamination checking method is used to investigate the adhesion failure of the interface between concrete and adhesive. The experimental result is quantitatively given in terms of the relationship between the temperature on tile surface and the length of interfacial delamination as also shown in Fig. 1.

The fixing device that represents the structural components of a building was designed for preventing the movement of concrete substrate by using the steel box and two steel clamps as shown in Fig. 2(a). Plaster was used to attach the steel plates to the sides of the concrete substrate in order to avoid undesirable gaps between concrete and the fixing device. Moreover, the plaster could reduce the rate of heat loss in the side direction of the specimen due

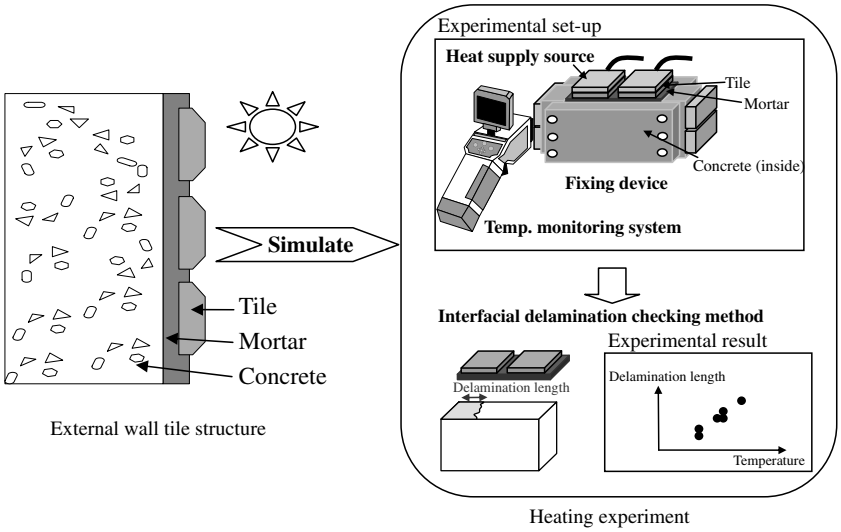

Fig. 1. External wall tile structure and laboratory-scaled heating experiment.