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Determination of the interaction between a masonry wall and a confining frame

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ABSTRACT

This paper studies the interaction between an infill masonry wall and its surrounding frame. The investigation is motivated by the lack of experimental data on the interaction regarding the contacted and detached areas between the wall and the frame and the interaction tractions at the contact regions. It is important to note that the interaction between the masonry wall and the surrounding frame plays a critical role in the frame response as it governs the shear and bending moment resultants along the frame elements. It is more critical in the case of strong infill walls surrounded by a relatively weak frame and it may lead to premature failure of the frame at an early stage of loading and affect the overall resistance of the wall-frame system. Such observations were obtained in numerous tests on masonry infilled frames subjected to lateral loading to simulate earthquake loading and in a limited number of tests on masonry infilled frames subjected to a vertical load simulating the case of loss of a supporting column. This paper investigates the interaction behaviour in terms of the infill-frame contact regions and interfacial tractions in such event of loss of a supporting column. In this scenario, the interactive action becomes critical to the structure's safety against the possible development of progressive collapse. This scenario has gained considerably less attention compared with the behaviour of this system to lateral loading. The main goal of this study is to shed light on the frame-infill wall interaction with focus on the contact zones and the contact pressures between an infill wall and a confining frame. The paper presents a new experimental methodology that follows the interaction between the frame and the infill wall along their common interfaces in order to detect the contact regions and the interaction stresses along these areas as well as their evolution and change during a loading process. The effect of monotonic and cyclic loading patterns on cracking of the infill wall and its impact on the contact regions with the frame and the interfacial tractions are also investigated. The experimental results of this study can support the development of new models that consider the infill-frame interaction and its impact on the structural response.

1. Introduction

Infill walls affect the behaviour of frame structures, under the action of vertical or lateral relative displacements, aiming at distorting the frame. It may occur in different circumstances such as foundations differential settlements, differential vertical displacement as a result of a severely damaged supporting column, different lateral load action on the structure and especially when extreme loads such as earthquake, blast, or impact are acting on the building. In such cases, the infill walls contribute to the stiffness and resistance of the structural system and may significantly contribute to the global structural stability. This contribution becomes critical when a progressive failure may develop. Numerous studies have been carried out on lateral loading on such infill walls, although attention was mainly given to the global behaviour and the development of the lateral sway. The detailed interaction between the infill wall and the frame has not been investigated. Experimental data on the contact zones between the infill wall and the surrounding frame during the loading process or information on the tractions at the contact interface were not found in the open literature. The case of vertical lateral displacement due to loss of a supporting column has received considerably less attention than the widely investigated problem of lateral action on an infilled wall due to earthquake excitations. Failure of a supporting column may affect the building overall stability and cause progressive collapse. Needless to say that information on the contact zones and the interaction tractions in this case was not found either.

This paper aims at investigating the interaction between the infill wall and a confining frame, with focus on the interaction details on

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which there is no data in the literature. This aims at identifying the contact zones between the wall and the frame during loading and identifying the interaction tractions at these contact zones. This is a fundamental problem that may be investigated when the frame is distorted due to relative lateral displacements (similar to the case of lateral earthquake loading) or due to relative vertical displacements (similar to the case of loss of a supporting column). The present study investigates the latter aiming at providing basic data on the interaction problem and shedding light on the problem of response to loss of a supporting column, which has hardly been studied so far.

A few studies that experimentally investigated the behaviour of the infill walls under the loss of an internal column are reported in the literature, see Stinger and Orton [1], Shan et al. [2], Li et al. [3] and Xavier et al. [4]. While those works focused on loss of an internal column, the peripheral columns are those that are more likely to be damaged in cases of exterior blast and impact loading on a building, and their failure may lead to a more severe and sensitive damage. Brodsky and Yankelevsky [5] showed that the infill wall significantly increases the capacity of the frame-infill wall system in a case of peripheral column loss. It was found that the failure modes that were reported in that study are entirely different from the ones observed in case of lateral loading and classified by Wood [6] and El-Dakhakhni [7]. Moreover, in all tested specimens, the failure of the reinforced concrete frame determined the overall resistance of the infilled frame, and the failure characteristics result from the interaction tractions along the column interface. These results emphasize the importance of the interfacial tractions that develop between the infill wall and the surrounding frame and their effect on the failure of the latter. Despite the significance of a reliable assessment of the contact regions between the masonry infill wall and the surrounding frame and the interaction tractions at the contact regions, these aspects were not addressed in the literature and experimental data that can be used to validate computational analysis results or support an appropriate frame design was not found. The failure modes that had been observed in earlier tests (Brodsky and Yankelevsky [5]) and their fundamental deviation from the ones observed under lateral loading of the infill-frame system also point at the difficulty in applying lateral loading models to analyse a case of a supporting column loss and to simulate the mechanism of progressive collapse it may trigger.

Numerical studies on progressive collapse of frame buildings usually represent the infill wall by models that are borrowed from the relatively known response of infilled walls to lateral loading. These lateral response models are based on numerous experimental, analytical, and numerical studies that have been carried out over the last 60 years. The majority of those aimed at exploring the behaviour of the infilled frame during a seismic event. A survey of the state of the art may be found in Tarque et al. [8] and Asteris et al. [9,10]. These studies show that the infill wall significantly affects the structural behaviour and impacts the capacity of the composite system, its stiffness, its ductility, its vibration frequencies, the load redistribution at progressive loading stages, and the ability of the system to resist repeating load cycles. Nevertheless, even in that research direction, there is almost no data on the interaction details (contact area location and size and tractions) that is the subject matter of the present study. In the experimental studies reported in the literature attention was given to the global behaviour and forcedisplacement response has been recorded, however no attention was given to the interaction details, such as the contact zone size and the interaction tractions between the masonry wall and the frame. Similarly, computational models were developed to represent the infill wall contribution to the composite wall stiffness and resistance and provide information on the global behaviour, however the wall-frame interaction has been disregarded. Relatively simplified models represent the infill wall by an equivalent diagonal single strut, or by several diagonal fixed struts, see Sasani [11], Tsai and Huang [12], Tsai and Huang [13] and Tavakoliky and Akbarpoor [14]. Such models aim at assessment of the global behaviour and they do not account for the interaction characteristics (e.g. size and location of the contact zone), thus providing a reasonable and simple means to model the global force-displacement behaviour but little information regarding localized effects. Such models were derived for lateral loading simulation and their validity with respect to vertical loading should be examined.

This paper aims to contribute to bridging the aforementioned knowledge gap and to look into the interaction and its role under monotonic and cyclic vertical loading scenarios. To face this challenge, and to investigate the interfacial behaviour under the action of vertical loading, which simulates the event of loss of a supporting column. The new experimental approach developed in Brodsky et al. [15] is adopted aiming at determination of the contact zones and the interfacial tractions during loading. This experimental investigation also aims to create benchmark data for numerical and analytical models validation and for the development of advanced modelling of the problem.

2. Experimental program

The experimental investigation includes two half-scale ($2045 \times 1400\,mm^2$) masonry infill walls made of Autoclaved Aerated Concrete (AAC) blocks with adhesive masonry joints. One is loaded monotonically and the other is subjected to cyclic loading. In both cases, the loading scenario refers to vertical relative displacements of the surrounding frame that simulates an event of a gradual loss of a supporting column.

2.1. Test setup and instrumentation

The test setup is described in detail in Brodsky et al. [15] and it includes an infill wall surrounded by a steel frame (Fig. 1). The beams and columns of the frame are made of standard U-shape steel profiles, and provide a relatively stiff frame. They are interconnected by pinned joints attempting to avoid any contribution of the steel frame to the composite system resistance. It should be noted that this setup is intended to provide a relatively stiff frame that behaves elastically and enables large relative displacements without any damage to the frame. Thus the full capacity of the infill wall may be examined and the development of its increasing damage may be followed. The test setup deviates from an actual case of a skeletal structural system, because in such real case, columns and beams of different cross sections as well as moment resisting joints are involved and their parameters affect the response, the damage accumulation details as well as the ultimate load. The present system is designed to follow the entire loading history and

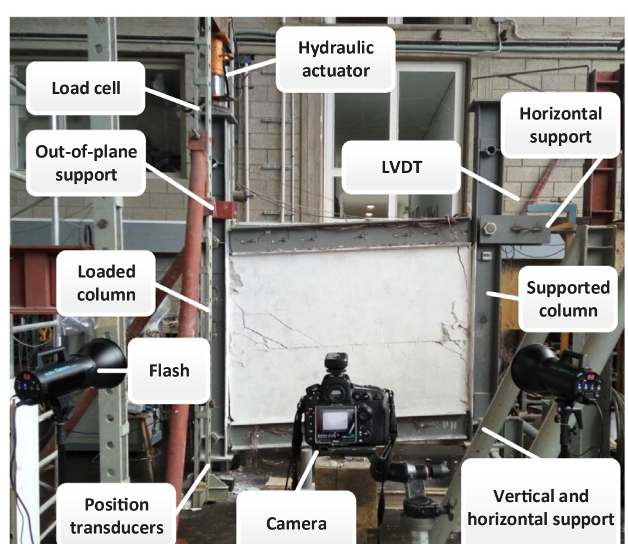

Fig. 1. Test setup.