EVALUATION OF SEISMIC PERFORMANCE AND DRIFT DEMANDS OF GLAZED FACADE SYSTEMS

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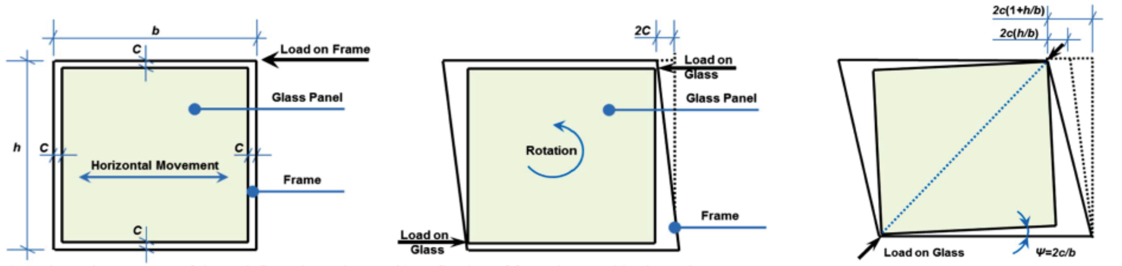
Building glazed facade systems over high-rise buildings consume approximately over 20% or more of the total construction budget and are considered to be an economically significant attribute of the building. Architectural glass exterior systems, used as the entire building skin or part of its envelope are considered to be one of the most influential building systems contributing to the proper function of the building. With the exception of a few guidelines in building design codes, there is currently a lack of design approaches provided for designers and engineers in appropriate selection of glazing details to effectively mitigate earthquake damage.

This paper reviews the existing studies related to seismic and drift demand of the non-structural building glazed facade system. Being treated as a non-structural component, seismic performance of the building facade relates to its seismic demand parameters, i.e. acceleration and drift demands. In current code provisions, the acceleration demand consists of the floor acceleration amplification factor, component acceleration amplification factor, component importance factor, and component response modification factor, which are all based on or induced by the floor response and dynamic response of the facade itself. For the glazed facade which is attached to the main structure, drift demand is an indication of the inter-story drift ratio. The in-plane seismic drift mechanism of the framed glass facade was fully developed, and the corresponding static testing protocols were implemented in codes based on several past experimental studies.

Acceleration demand of the glass facade relates to the seismic design force and corresponding parameters in current code provisions. For a general glass facade system, the calculated seismic force is smaller than the wind load, while for stone cladding and large glass panel in tall buildings, the seismic force can be larger. Almost in every seismic design provision, seismic design approaches of the general non-structural components are directly applicable to the facade systems. The equivalent inertia force calculation methods are given in many current codes, e.g. UBC, IBC, Euro code, ASCE 7–10, Iranian Seismic Code (Standard No. 2800), British standard, etc.

In order to protect the non-structural elements of buildings, seismic design codes provide limitations on story drift during the structural design phase. The story drift ratio is provided in two main directions of the story plane, and in each direction is defined as the relative displacement between the top and bottom of the story divided by the story height. These limitations are mostly based on psychological comfort of the inhabitants during severe situations (avoiding large swinging in floors) and serviceability of typical construction technologies (avoiding failure in partition walls and mechanical appliances). These limitations are hardly enough for glass facades and further considerations need to be made.

The behaviour of glass panels remains in elastic range both during the in-plane and out-of-plane deformations. The main causes of damage to glass panels during an earthquake are the in-plane deformations which occur in the curtain wall system. This is due to significant stiffness of the glass panels in that direction. Sucuoğlu et al. (1997) argues that the in-plane deformation response of a glazed curtain wall having clearance provided between the glass panel edges and the frame can be described in two phases. In the first phase the glass panel undergoes a rigid body motion within its supporting frame, without having any force exerted on it. In the second phase the two opposite corners of the glass panel start to experience a diagonal pressure from the supporting frame. Figure 1 schematizes a glass panel and its supporting frame with clearance between the panel edge and the frame. It can be observed that the panel can withstand a relative displacement according to the clearance length and the dimensions of the panel without having exerted any force on the glass panel; the displacements of the glass are only due to rigid body motion.



a) Horizontal movement of the undeflected panel b) Deflection of frame by panel horizontal movement c) Combined horizontal and rotation movement

Figure 1. In-plane drift mechanism of the framed glass panel.

The initial gap between the edge of the glass panel and the frame allows small drifts before the direct contact takes place. In this case, the stresses in the glass panel are induced by the friction forces between the panel edges, plastic gaskets, side blocks, or silicon glue sticks. The deformation of the gasket tends to absorb the kinetic energy and buffer the impact velocity. However, once the gasket or the silicon stick were damaged, or extruded out of the frame, direct contact of the glass panel and the aluminium frame will occur causing rapid increase of the stresses in the glass panels at these contact points. Cracks might be generated once the local stress exceeds the critical stress of the glass panel.

The glass facade system such as curtain wall is popular in all types of buildings including commercial, industrial and institutional structures. Historical earthquake damages to the glass facade systems demonstrated their seismic vulnerability. Seismic loads on the structure can potentially impose significant in-plane loading on the glazing system and may lead to damage if adequate detailing is not provided. To understand the seismic design and analytical approaches of facade systems, widely used code provisions and current research developments are reviewed. Besides, in this paper, codified inter-story drift limits for buildings are reviewed and seismic drift assessment methods of glazed facades in buildings are suggested with increasing accuracy and complexity. Performance of glass facade systems are then assessed with analysis results and conclusions presented.

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