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Section moment capacity tests of complex-shaped aluminium mullions

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ABSTRACT

Mullions are the vertical members used in the frames of curtain wall systems. Although they are commonly used in building construction, their structural performance under wind actions has not been adequately investigated in the past. This is because these extruded sections are available in a vast array of complex and asymmetric profiles. This paper presents an experimental investigation into the section moment capacity of aluminium mullions used in unitised curtain walls of high-rise buildings under wind pressure (positive) and suction (negative) load cases. In this experimental investigation, 30 tests were conducted where 15 complex-shaped mullion sections were tested under both positive and negative wind actions. The tested mullions included those used in the captive and structural glazing systems. This paper presents the details of the mullion tests and the test results including the failure loads and the load versus displacement curves. Furthermore, it compares the section moment capacity predictions using three different design approaches in the currently available aluminium design standards and previous research studies, namely, direct strength method, limiting stress method and total moment capacity approach, with the test results. The commonly used limiting stress method is found to be giving conservative results. Based on the comparisons, this paper recommends the use of direct strength method to determine the section moment capacities of aluminium mullion sections.

1. Introduction

The popularity and demand to use aluminium as structural members in buildings continued to grow from its first extensive usage as structural members in the Empire state building in 1931 [1]. This is due to its high strength to weight ratio, high durability, corrosion resistance and ease of manufacturing versatile shapes through extrusion. It is also an energy efficient and sustainable material since it can be recycled again without losing its inert properties. These qualities make it a preferred material for use in external building facades. Most of the low- to high-rise buildings built around the world used aluminium alloy supporting frames in external building facades.

Curtain wall system (Fig. 1) is one kind of facade systems, popularly used in high-rise buildings. The commonly used curtain walls, unitised walls, are assembled in factories as a series of panels, and they are then brought to the site and assembled through interlocking mullions and transoms. These unitised panels allow the benefits of factory fabrication in a controlled environment and quicker construction at the site which is crucial in modern high-rise buildings [2–4]. To allow for easier assembly of facade panels, a pair of mullion sections is used in aluminium framed glass panels of unitised systems. These mullions are a pair (male and female) of aluminium extrusions, which fit together as shown in Fig. 2. In most cases the male and female mullions are not connected together by any external mechanisms (using screws or clip systems). This current practice of Australian facade industry allows the movement of panels during temperature variation and building deflections. It also allows easier alteration during fabrication if any problems are discovered in the constructed facade assembly as panels can be easily isolated and removed from the curtain wall system. Therefore, these mullions are designed as individual members without considering any advantages provided by the coupling of male and female mullions. The mullions used in the Australian construction industry are made of aluminium alloy 6063 of T6 temper, which is a solution heat treated and artificially aged AlMgSi alloy.

The aluminium frames of curtain walls consist of mullions (vertical members) and transoms (horizontal members). Mullions are thin-walled with unique and complex cross-sections (Fig. 2). Extrudability of aluminium allows the manufacturing of these cross-sections. The profiles are produced by forcing the primary aluminium through a specific die. The die is milled from cast steel in order to resist high temperatures and pressures needed to form the profile. The mullions are manufactured in such complex cross-sections to allow adequate thermal movements and to enable easier connectivity between the vertical and horizontal members. Captive or structural glazing system is used based

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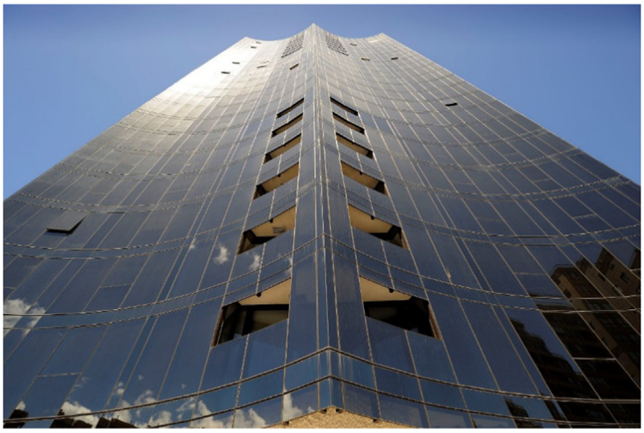

Fig. 1. Curtain wall system.

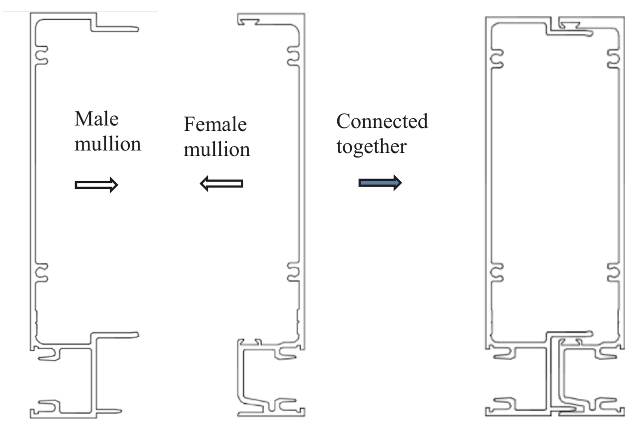

Fig. 2. Male and female mullions.

on architectural and thermal requirements. The use of more expensive structural glazing systems enhances the aesthetic appearance of the building and reduces the thermal heat transfer to the buildings. Mullions used in these systems vary in shapes as shown in Fig. 3(a)–(d). Mullion cross sections could also vary based on whether they are used in single or double glazing units (Fig. 3(b) and (c)). In terms of load carrying mechanism, the mullions do not carry any axial load from the building apart from the self-weight of the facade, which is negligible. However, they have to transfer the lateral wind loads (both pressure and suction) acting on the glass panels to the main structure. The mullions are thus subject to bending when facades are exposed to wind actions. Since mullions are asymmetric, their bending capacity could be different for the wind pressure and suction cases. In this paper, wind pressure loading is referred to as positive loading while the term negative loading is used for wind suction loading. In the past, hardly any investigations have been conducted on the bending capacity of these complex-shaped mullion sections.

Furthermore, the current increase in the use of aluminium mullions in high-rise residential and commercial buildings has prompted the need for more accurate and up-to-date design methods and standards. The design methods for aluminium members are given in Eurocode 9 [5], AS/NZS 1664 [6] and Aluminium Design Manual (ADM) [7,8]. AS/NZS 1664 [6] and ADM [7] give the same design rules. However, ADM [8] gives updated design rules, where it incorporates the direct strength method, which is becoming popular for thin-walled structures due its simplicity in designing complex sections. These currently available standards and manuals [5–8] do not cover the design of these complex aluminium cross-sections in detail, thus the design calculations are made with various assumptions and conservative approaches. Determining the moment capacity of mullions is also difficult due to the range and complexity of cross sections. Limiting stress method is the preferred method in the Australian façade industry, which may give conservative predictions.

This paper investigates the section moment capacity of complex-shaped aluminium mullion sections. In order to obtain reliable section moment capacity data of complex-shaped mullions, a detailed experimental study was performed where 15 different types of commercially used mullions were tested under both positive and negative load cases. The sections used, test methods, and test results are presented in this paper. It compares the experimental results with the capacity predictions using three different design approaches; limiting stress method, total moment capacity approach and direct strength method (DSM), and finally suitable recommendations are given.

2. Previous experimental studies

In the past a few studies have investigated the bending capacity of aluminium sections. Zhu and Young [9] performed an experimental

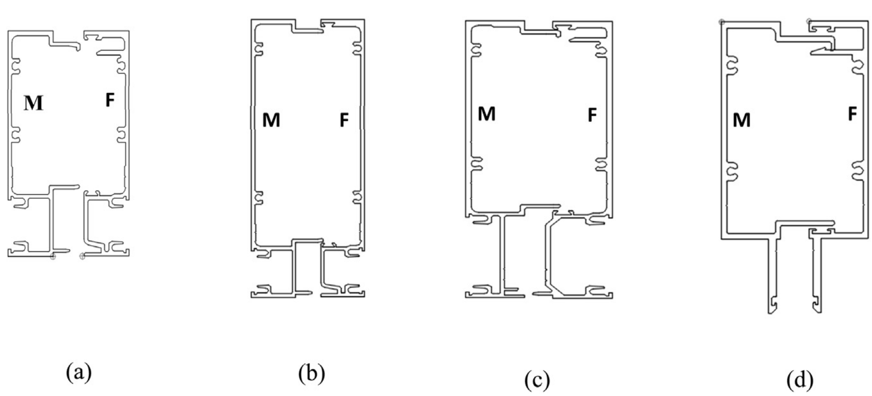

Fig. 3. Different mullion sections, (a) 100 mm deep captive mullion used in single glazed unit, (b) 150 mm deep captive mullion used in single glazing unit, (c) 150 mm deep captive mullion used in double glazing units, (d) 150 mm deep structural mullions used in single glazing unit.