# The next generation of drywall construction for low-damage design

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## ABSTRACT

Low-damage structural systems that can withstand large earthquakes with no structural damage, or localised damage in pre-defined fuses, have become commonplace in the past one to two decades. These systems, however, generally require the building to undergo large inter-storey drifts (ISD). Large ISDs can cause serious damage to the non-structural components within the building. The repair bills from such damage to non-structural components greatly reduce the benefit gained from low-damage structural systems. Traditional drywall partitions built using either timber or steel stud walls are built rigidly between floors and undergo damage at ISDs as small as 0.25%. This paper presents a novel new system for connecting partition walls between slabs that allow the partition walls to be subjected to ISDs greater than 1.0% with no damage to the plaster (gypsum) or steel studs. The connection system is fully contained within the head track of the wall and can be adopted in traditional steel stud framing systems currently available on the market. The system was experimentally assessed using a series of full-scale 3x3 m square rooms with square set plasterboard ceilings that were subject to bi-directional ISD using the Multi-Axis Substructure Testing (MAST) system at Swinburne University of Technology. The system can be tuned to achieve greater ISD levels without damage at the discretion of the designer and the manufacturer of the bracket system.

## 1 DRYWALL CONSTRUCTION IN MULTI-STOREY BUILDINGS

Drywall construction, consisting of steel stud wall framing with screw/glue fixed plasterboard/gypsum sheeting, has become a popular form of construction for non-load bearing walls in multi-storey construction (Yazdi, Hashemi and Gad, 2022). Traditional systems consist of a light gauge steel C-section bottom track fixed to the floor slab and deflection head track (DHT) or slotted deflection head track (SDHT) fixed to the soffit of the floor slab over. Light gauge steel C-section wall studs span vertically between the bottom track and head track. Plasterboard (commonly referred to as gypsum) sheets are screw/glue fixed to the wall studs. These walls are often required to be fire and/or acoustic-rated walls.

The DHT or SDHT allows for vertical movement (i.e., sag from the floor slab over), however, the combination of intersecting cross walls and square set plasterboard ceilings results in the walls being effectively rigidly constructed between adjacent floors of the building for inter-storey drift (ISD) considerations, i.e., lateral movement of the building. The adoption of a SDHT further locks up the system under ISD compared to a DHT. A typical DHT and SDHT connection is presented in Figure 1. It has shown in various experimental programs (e.g., Davies et al., 2011; Restrepo and Bersofsky, 2011; Tasligedik, Pampanin and Palermo, 2015) that these traditional systems can undergo damage from ISDs as smalls as 0.2–0.3%.

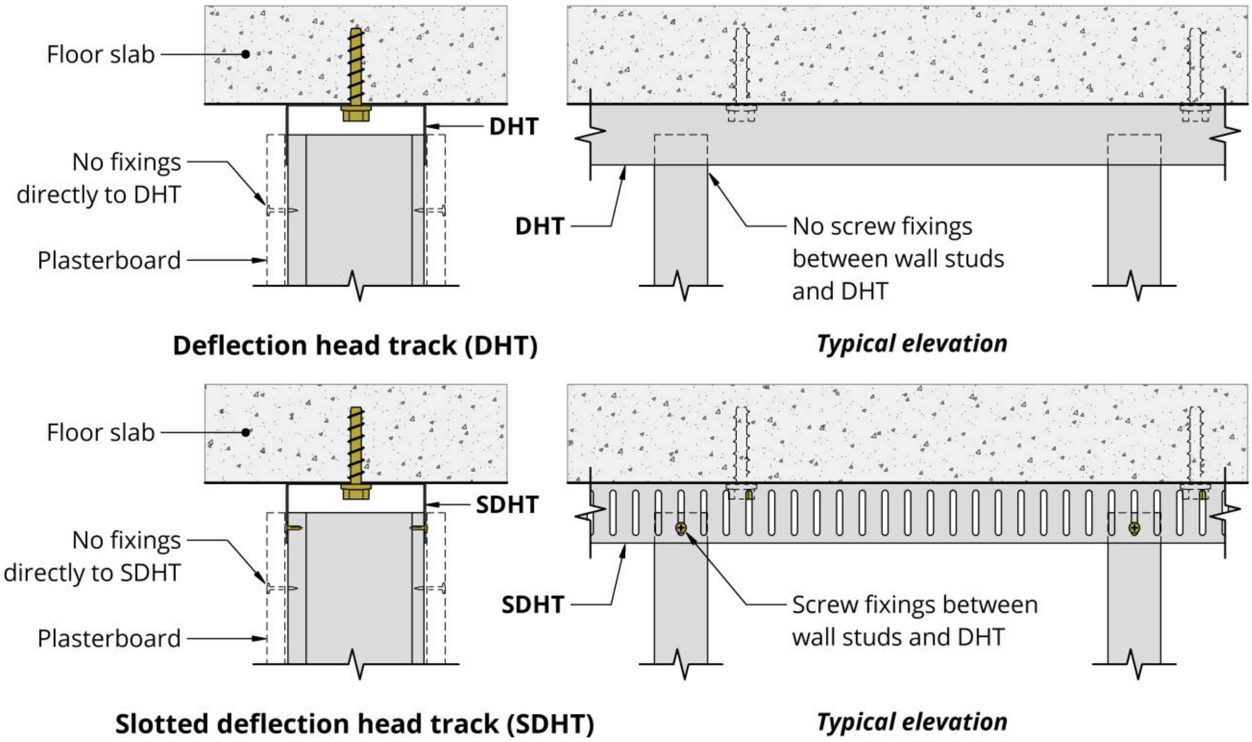


*Figure 1: industry standard DHT and SDHT connection.*

## 2 NOVEL SOLUTION TO ALLOW INTER-STOREY DRIFT IN PARTITION WALLS

In recent times there has been a transition towards low-damage structural systems that can withstand large earthquakes with no structural damage. The adoption of low-damage systems was accelerated following the 2010 and 2011 Canterbury earthquakes. These systems, as an example, include the PRESSS technology (e.g. post-tensioned precast rocking walls) (Priestley et al., 1999), the Pres-Lam system (Palermo et al., 2005) or the advanced flag-shape (AFS) system (Kam et al., 2010). Low-damage structural systems generally require the building to undergo large ISDs to resist earthquake actions. Therefore, for a building to be truly low-damage, the non-structural elements must be able to undergo large ISDs without sustaining damage. The correlation between the allowable amount of damage and the earthquake magnitude (or return period) will, for example, depend on the function of the building, the location of the building and the building's owner.

The authors have been undertaking a collaborative research project with Traxx Metal Framing Systems (Traxx MFS) to develop low-damage partition systems. The first generation of wall systems utilised a head track with a longitudinal slotted hole, which underwent testing at Swinburne University of Technology (Menegon, Hashemi and Gad, 2021) and the University of Canterbury (Bhatta et al., 2022). The second generation of wall systems, which was recently tested at Swinburne University of Technology, utilises the Qubit 360 bracket. The Qubit 360 allows multi-directional movement between the top of the wall and the floor over. It effectively isolates the wall from the building under ISD, whilst still providing a physical connection. The Qubit 360 wall system is presented in Figure 2 and an example of the system, which was used as part of the experimental program, is shown in Figure 3.

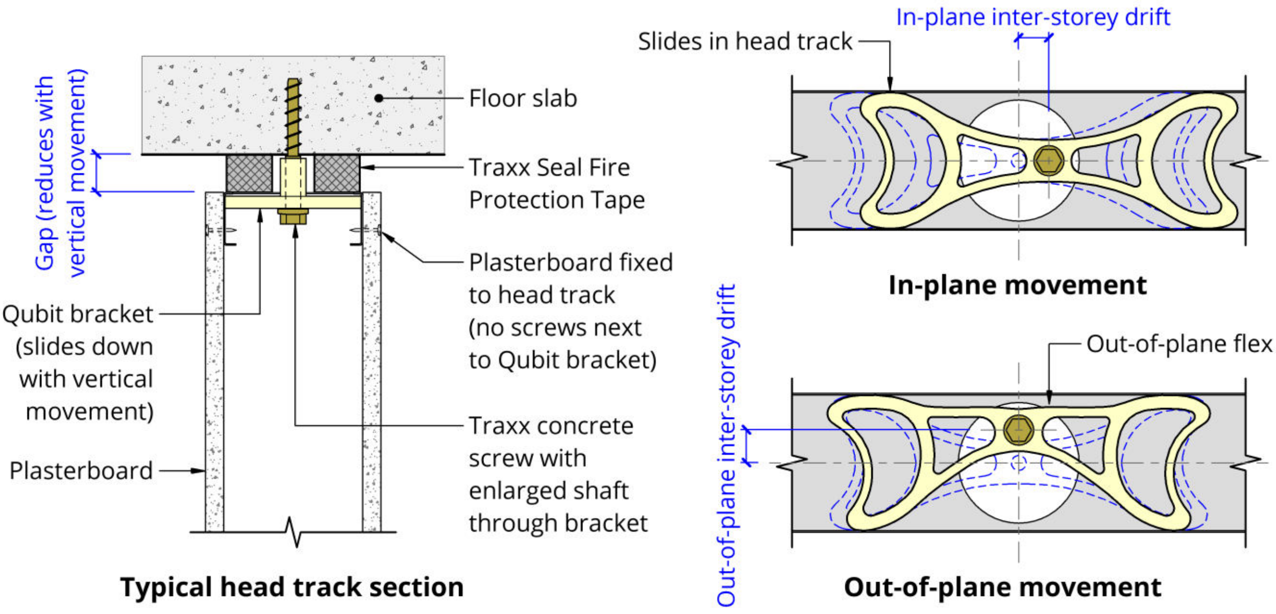


*Figure 2: Qubit 360 partition wall system.*

*Figure 3: Qubit 360 test specimen.*

## 3 EXPERIMENTAL PROGRAM

An extensive experimental program was performed to assess the behaviour and performance of the Qubit 360 partition wall system. The program included full-scale testing of 3 m wide x 3 m long x 3 m high full-scale room assemblies that were tested under bi-directional ISD; component level testing of the individual Qubit 360 brackets to assess their lateral stiffness; and an out-of-plane four-point bending test on a sub-assembly section of wall to assess the performance against face loading with the head track suspended below the soffit.

This paper presents the preliminary test results of a single full-scale room assembly test, which was performed using the Multi-Axis Substructure Testing (MAST) System (Hashemi et al., 2015). The purpose of this test was to assess the damage behaviour of the wall system when subject to sequential ISDs with increasing intensities. The acoustic recording was performed for low levels of ISD (e.g., 0.1–0.2% ISD), since the creaking of plasterboard walls is increasingly becoming an issue in high-rise towers under serviceability wind actions, however, this is outside the scope of this paper and will be reported elsewhere.

### 3.1 Test specimen details

A total of six full-scale room assembly tests were performed, which consisted of one baseline specimen that was constructed using industry standard detailing with a SDHT and five specimens constructed using iterations of the Qubit 360 bracket. The first specimen constructed using the Qubit 360 bracket will be presented in this paper, which was denoted specimen S-D-1.

Test specimen S-D-1 consisted of four walls that were each 3 m long to create a four-sided 3 x 3 m square room. The walls were 3 m high and the room had a square set plasterboard ceiling that was 2.4 m from the bottom of the wall. The specimen had a standard 900 mm wide x 2.1 m high doorway on one wall and a window on another wall. The walls were constructed using 92 mm wide prefabricated steel stud walls. Each wall had three Qubit 360 bracket connections at the top. The test specimen is shown in Figure 3. The baseline specimen (denoted S-A-3) was constructed to match S-D-1, except the head track was substituted for a standard SDHT.

Further details will be presented in the final report of the research project.

### 3.2 Loading protocol

The test specimens were tested under bi-directional ISD to assess the damage progress in the plasterboard. Prior to applying any ISD the MAST crosshead was lowered down -5 mm to simulate long-term deflection of the floor above supporting the top of the wall. The vertical displacement of -5 mm was maintained for the entire duration of the testing. The ISD was applied in a series of loading cycles using the octo-elliptical bi-directional loading protocol developed by Raza et al. (2021), which is meant to simulate the inter-storey drift behaviour of a multi-storey building subject to earthquake actions. The octo-elliptical loading protocol applies a series of bi-directional lateral movements in the shapes of ellipses. There are four ellipses with different orientations for one loading cycle (i.e., a given ISD increment). The maximum resultant ISD during the ellipse corresponds to the ISD of that loading cycle. Loading cycles 1 through 6 had ISD values of 0.1%, 0.2%, 0.3%, 0.6%, 1.0% and 1.5%, respectively.

The ISD values of loading cycles 1 through 3 were primarily selected to assess the acoustic performance of the system during a serviceability wind event, while the values of loading cycles 3 through 6 were primarily selected to assess the damage behaviour of the system during a moderate to large earthquake.

## 4 PRELIMINARY TEST RESULTS

The current version of the Qubit 360 bracket was designed to be damaged-free up to 1% ISD. This performance was affectively achieved during the testing wherein specimen S-D-1 sustained no damage during loading cycle 5 of 1% ISD, as shown in Figure 4. There was however one minor bulge/hairline crack in the plasterboard on the inside of the room. The hairline crack was perfectly horizontal and aligned with the top of the tape at a horizontal join in the sheets. The crack was believed to be due to the tape lifting, and therefore is suspected to be due to poor workmanship while constructing the specimens, since damage usually initiates first at the corners before progressing elsewhere (Menegon et al., 2021) and no damage to the corners (internal or external) was observed.

The behaviour of S-D-1 was in sharp contrast to S-A-3 where the internal corners had hairline cracks at an ISD of 0.1%, screw heads started being pulled through at an ISD of 0.3% and plasterboard sheets started to delaminate from an ISD of 0.6%.

**(a) Initial condition – external**

**(b) Initial condition – internal**

**(c) After 1% ISD – external**

**(d) After 1% ISD – internal**

*Figure 4: testing photos of specimen S-D-1 showing no damage after 1% of ISD.*

The premise of the Qubit 360 bracket is to allow a physical connection between the partition wall and the floor structure over that is: (i) stiff enough to prevent the wall from noticeably moving out-of-plane due to incidental actions from occupants (e.g., an occupant leaning on a wall) or shelving loads (e.g., kitchen cupboards or televisions being hung on the walls); while (ii) simultaneously being flexible enough to allow the structure of the building to move lateral without imposing significant in-plane lateral loads on the partitions, which result in cracking or damage. The later behaviour is shown in Figure 5, which presents the movement of the MAST (representing the structure in the building during an earthquake) and the movement of the wall system, which is minimal in comparison.

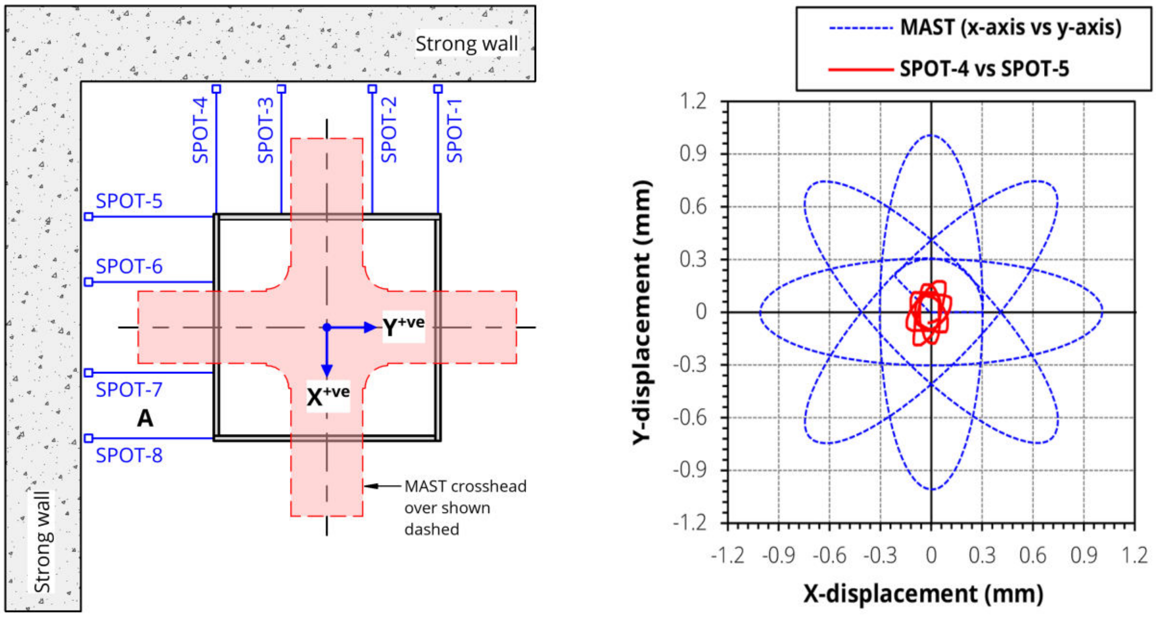


*Figure 5: movement of the MAST and the partitions during 1% ISD.*

## 5 CONCLUSIONS

This paper presents the initial and very preliminary findings of an experimental study into the behaviour of drywall partitions in multi-storey buildings during earthquake ground shaking using full-scale three-dimensional test specimens. The study focuses on the new Qubit 360 bracket, which essentially isolates the partition walls from the floor structure above during lateral movement of the building, thereby preventing any in-plane lateral actions from being attracted to the partitions and eliminating the source of damage. The version of the Qubit 360 bracket utilised in the test program was designed to allow the partition wall system (utilising a square set plasterboard ceiling) to be damage-free up to 1% ISD, which was achieved in the testing. This was in contrast to a baseline comparative specimen also tested (utilising industry standard construction details), which had minor cracking at an ISD of 0.1% and major damage to the sheets at an ISD of 0.6%.

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