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Seismic Resistant Wall-supported Cabinets with Silicone Glue

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ABSTRACT

In this paper, a non-destructive method for securing wall-supported cabinets against earthquakes is studied. It is found that to glue the cabinet to the wall with similar geometry to fillet welding, in vertical runs on each side of the component and as centered as possible with respect to its center of mass, can reduce the overturning disposition of the cabinet during earthquakes. With this arrangement, the component needs no further restraint at the base. Two series of tests were performed to characterize the performance of the silicone gluing in this study: testing parameters included two types of silicone (common commercial hardware product B&Q and structural product DC-795) and two types of surface finishes (wood veneer and paint-coated steel sheets), while the supporting wall has a normal interior concrete finish. First, static push tests were performed to determine the force-displacement curve of silicone gluing in two principal loading directions. The joint capacity was found to be directly proportional to the installation lengths of the silicone runs, which strengths of 8N/cm and 3N/cm for in-plane (interface mainly in direct shear) and out-of-plane (interface mainly under tensile stresses) cabinet loading directions, respectively; i.e., the out-of-plane loading governed the seismic resistance. Second, the dynamic shake table test was performed to verify the seismic capacity of the silicon-glued cabinet. It showed that the silicone gluing could prevent a cabinet with a 100kg-mass content from overturning under multi-directional excitations compatible with the response spectra prescribed by the AC156 non-structural components testing criteria issued by the International Code Council Evaluation Service (ICC-ES), and the intensity of the inputs complied with the seismic requirements of the Taiwanese Building Code.

***KEYWORDS*:** Operational and Functional Building Components (OFC), Building Non-structural Components (NC), Cabinet, Silicone, Seismic qualification AC156

1 INTRODUCTION

After experiencing great losses caused by major damaging earthquakes in many countries, earthquake-resistant design practices for buildings in areas of severe seismic hazards have significantly improved in recent years. Consequently, lateral load resisting systems are designed to prevent building collapse and therefore protect people from injury or death in severe earthquakes. However, the economic losses due to seismic events can not be significantly reduced unless both structural and non-structural components (NCs) of a building are properly designed (Soong, et al, 2000). NCs, providing the functionalities of a building, are also designated in Canada as the operational and functional building components (OFCs) (Foo, et al., 2007). OFCs/NCs can be categorized into three groups: 1) Architectural Components, 2) Building Service Components, Equipment, and Systems, and 3) Building Contents. As illustrated in Fig. 1, experience from past earthquakes has shown that one of the major types of damages to building contents was the toppling over failure caused by the inertial forces induced by strong horizontal accelerations. Accordingly, many researchers have studied the vulnerability of the unanchored rigid body in terms of its failure modes, including nonlinear rocking, sliding and overturning/toppling (Ishiyama, 1982; Shao and Tung, 1999; Garcia and Soong, 2003). Several national codes, standards, and official guideline documents therefore put the emphasis on enhancing the seismic security of the OFCs/NCs in terms of conscientious consideration of their anchorage/restraint design (ASCE, 2006; CSA, 2006; FEMA, 1994; ICC, 2006).

Figure 1 The toppling failure of wall-supported OFCs/NCs after earthquakes

Conventionally, one of the most common methods to secure cabinets to walls is using metal angles and screws to create a rigid joint between the cabinet and the wall (FEMA, 1994). This approach improves the seismic security of the cabinet by preventing its overturning; however, during strong shaking, damages are inflicted in both surfaces of the cabinet and the supporting walls. Such damage may

be unacceptable for expensive cabinets that demand manufacturer warranty or for hi-tech precision machinery. A recent study has assessed the performances of the furniture overturning protection devices that can be obtained from the current market (Meguro, et al., 2008). It was found that even the best anchoring practices in terms of choice of materials and workmanship could not completely eliminate the overturning problem of cabinets, especially under the higher intensity earthquakes. Consequently, a stronger and more efficient overturning protection method than mechanical anchors is needed.

In the present paper, a new securing method is studied which uses silicone to glue cabinets to a retaining wall. For light-weight cabinets placed against walls, silicone gluing joints are not only efficient for seismic protection, but they also cause no surface damage to the wall and the cabinet. Two series of experiments are performed to characterize the performance of the silicone gluing restraint. First, the strength of silicone gluing is determined with static push test and a simple equation is suggested for estimating the strength. Static push tests indentify the force capacity of the silicone gluing of providing the lateral (in-plane) resistance and out-of-plane support, as shown in Fig. 2. For in-plane loading, the wall-to-silicone runs interface is mainly subjected to direct shear stresses, and it is subjected to normal stresses while for out-of-plane loading. Second, the dynamic shake table test is performed to verify the seismic capacity of the silicone glued cabinet.

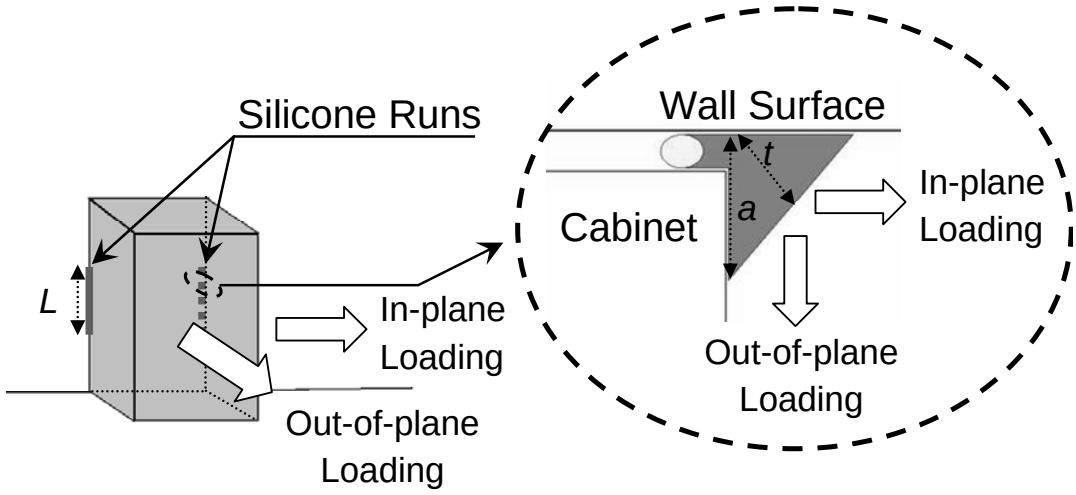


Figure 2 Silicone glued cabinets and their loading directions, where *a, t,* and *L* indicate the leg length, the throat length, and the applied length of the silicone runs, respectively

Silicone has excellent physical properties in waterproofing, anti-oxidizing and weatherproofing, with operational temperatures between -50^oC to 250^oC. There are some significantly useful properties of silicone that make it a good material choice for seismic resistant joints (Dow Corning, 2005):

1. Most types of silicone develop ultimate tensile strengths up to 0.55MPa when solidifying after a week from application.
2. Silicone has good bonding strength for many types of building materials such as wood, paint coated steel sheets (PCSS), concrete surface, and glass, etc.
3. No strongly unpleasant scent after application of silicone.

2 ESTIMATING THE GLUING STRENGTH OF SILICONE

Since silicone gluing has a geometric layout similar to fillet welding, we propose to estimate its global strength using the same concept that is applied for the strength calculation of fillet welding runs. The method is both simple and realistic. For fillet welding, the strength is calculated by multiplying the allowable stress, F_a, and the effective throat area A_e (Spiegel and Limbrunner, 1997), as follows:

$$P_s = F_a \times A_e = F_a \times t \times L = \begin{cases} \rho_i \times F_u \times 0.707 \cdot a \times L, & for \quad in-plane \quad loading \\ \rho_o \times F_u \times 0.707 \cdot a \times L, & for \quad out-of-plane \quad loading \end{cases} \tag{1}$$

where

F_u : ultimate tensile strength of the material

a: leg size of the welding runs

t: throat size of the welding runs

L: total length of the welding runs

ρ_i: reduction factor for the in-plane loading strength

ρ_o: reduction factor for the out-of-plane loading strength

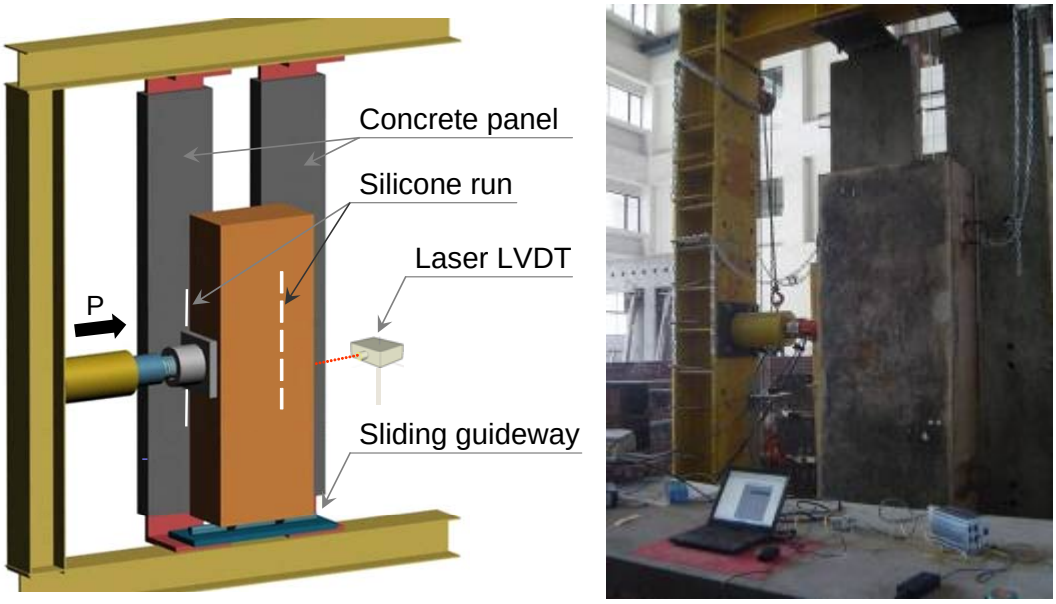
For fillet welding, the perpendicular loading strength is slightly larger than the parallel loading strength, and the strength reduction factor ρ is usually taken as 0.3 for failure in the welding material. For silicone gluing to the cabinet, the in-plane and out-of-plane loading directions correspond to parallel loading and perpendicular loading of the fillet welding, respectively. However, as expected from the basic material properties of silicone, the experimental results presented in the following section show that the silicone gluing exhibited higher strength in the in-plane direction (mainly under shear stress) than in the out-of-plane direction (mainly under tensile stress). This is a significant difference between the fillet welding and silicone gluing. Thus we propose only using $t = 0.707a$ to account for all silicone gluing runs irrespective of their loading direction, and the allowable stress F_a is calculated from multiplying the reduction factors ρ_i (in-plane loading) and ρ_o (out-of-plane loading) to the ultimate tensile strength F_u, respectively. The values of ρ_i and ρ_o for different types of silicone, interfaces and loading directions are determined by the experimental results presented next.

3 EXPERIMENTAL STUDY

Two series of experiments were performed in this study: static push tests including in-plane and out-of-plane loading, and multi-directional dynamic shake table tests. Two types of silicone were tested to identify the strength of silicone gluing runs: one is specifically for structural purpose (indentified as DC-795), and the other is a generic commercial product from the hardware store (identified as B&Q).

3.1 In-plane static push tests

The in-plane testing setup is shown in Fig. 3. Two vertical panels with finished concrete surface were simulating a concrete retaining wall in a building. These two panels were fixed at the top and bottom ends to a rigid steel frame. Only the left-hand side column of the frame is shown in Fig. 3(a) for clarity of the sketch. The corresponding real set-up is shown on Fig. 3(b). A concrete specimen was used to simulate a rigid cabinet shape or any OFC/NC alike. Two edges of the specimen were glued to the concrete panels at the back by silicone. Two runs of silicone were applied to join the specimen and the panels together.



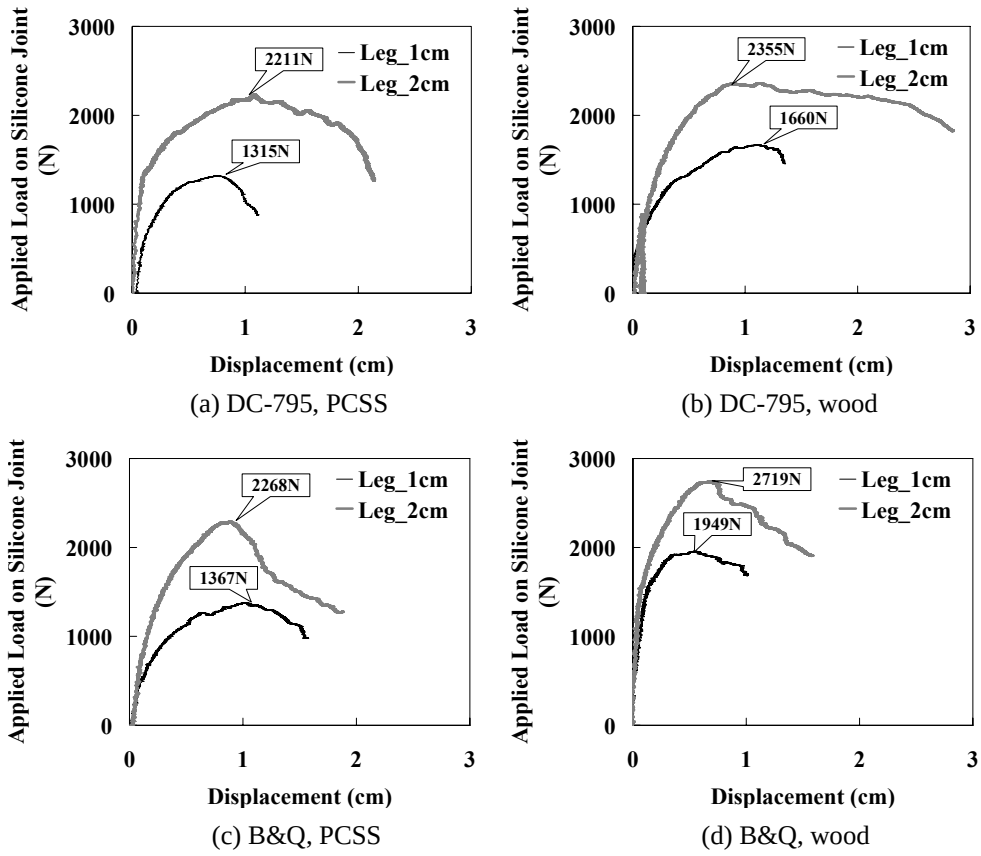
(a) Experimental equipment (b) Picture during the test

Figure 3 The in-plane loading test setup

To simulate the cabinet exterior surface, two different types of surface finishing, wood veneer and paint-coated steel sheets (PCSS), were attached on the edges of the concrete block where silicone runs were applied. Silicone gluing runs with two leg sizes, 1 cm and 2 cm, were tested for each surface finishing in order to verify the size effect of the silicone gluing runs on the strength. Static tests were performed by providing an

incremental horizontal force, about 10 *N/sec*, to push the concrete specimen until the silicone runs could no longer provide any strength. In order to reduce the frictional forces at the base and provide an accurate measure of the load carried by the silicone runs, a linear sliding guideway was placed underneath the concrete specimen and the frictional forces provided by the guideway were measured.

Results of the in-plane static push tests are shown in Fig. 4 as Load vs. Displacement curves. Overall, the results indicate that increasing the leg size from 1 cm to 2 cm did not quite double the maximum strength, which means there is a size effect that must be accounted for. The size effect is more important for the wood surface (1.40) than for the PCSS (1.68), and does not depend on the silicone type. The B&Q silicone performs just as well as the DC-795 even with a slightly higher strength of 3-4% on PCSS and 15-17% on wood. However, although the strengths of B&Q and DC-795 are similar, B&Q experiences sharper strength degradation after ultimate while DC-795, which has been designed for structural applications, has a larger ductility. Both types of silicone show a sharper decrease in strength for the wood-concrete interface compared to the PCSS-concrete interface.



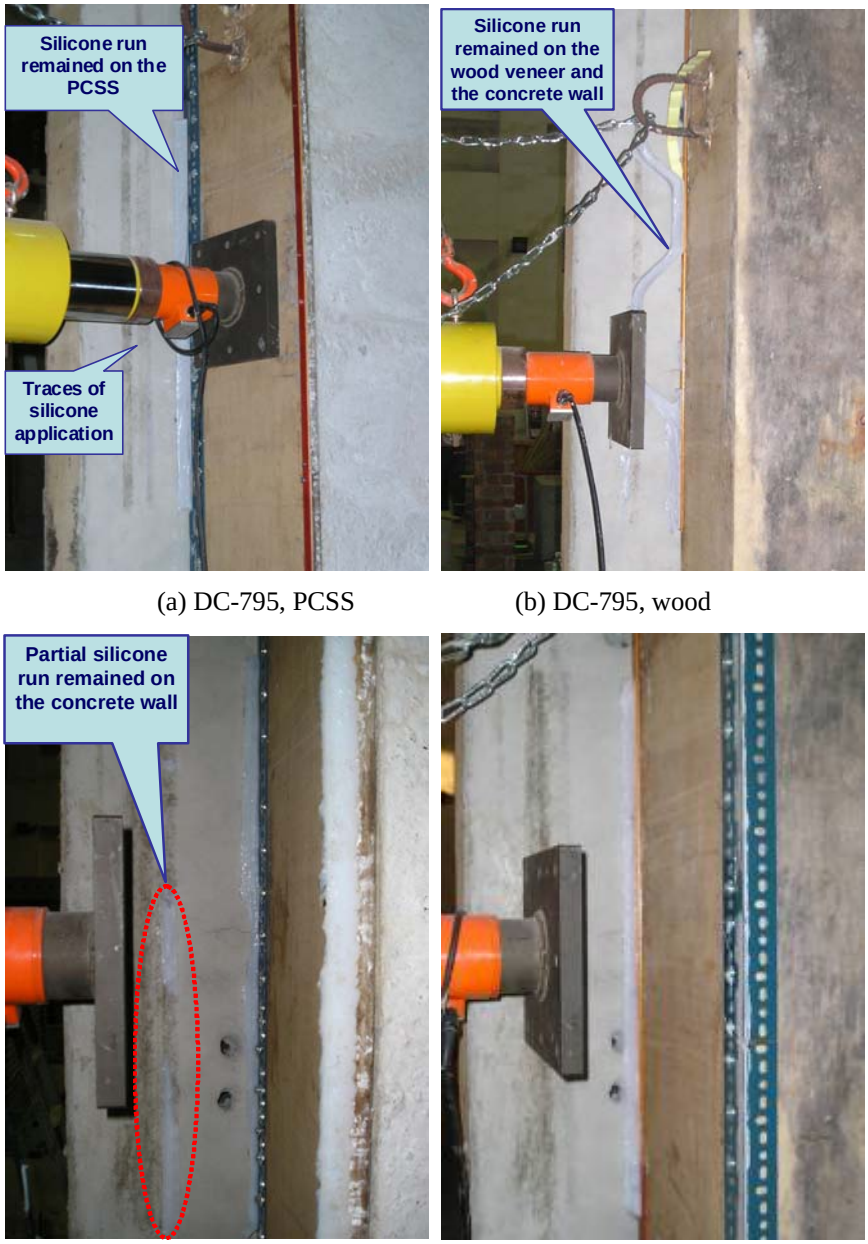
(a) DC-795, PCSS (b) DC-795, wood

(c) B&Q, PCSS (d) B&Q, wood

Figure 4 The load-displacement curves of the in-plane loading tests

The failures of the silicone gluing runs after the tests between different interfaces are shown in Fig. 5. Some of the tests failed with silicone gluing runs completely detaching from the concrete wall, as shown in

Figs. 5(a) and 5(d); some with silicone runs remaining attached to the concrete finish after testing, as shown in Fig. 5(b). The most severe damage occurred in the case of B&Q silicone applied on PCSS vs. concrete interface. The silicone was fractured; some remained attached to the concrete wall and some to the PCSS finish of the specimen, as shown in Fig. 5(c). This observation confirmed that the DC-795 silicone has a better ductility than the B&Q silicone, which tended to have a fracture failure mode.



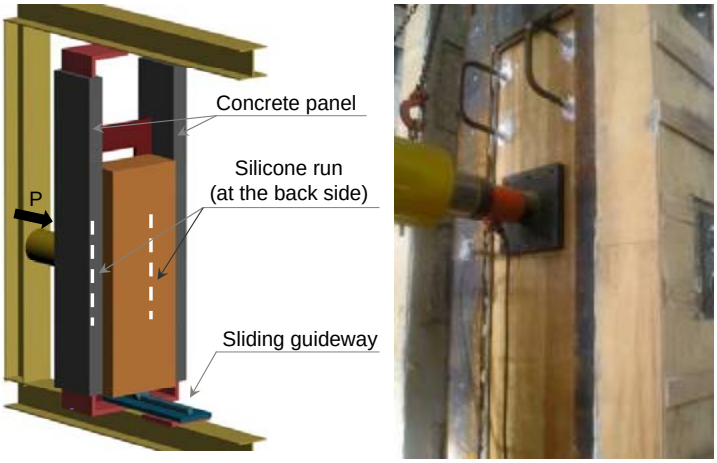
(a) DC-795, PCSS (b) DC-795, wood

(c) B&Q, PCSS (d) B&Q, wood

Figure 5 Failure modes of the silicone gluing runs for in-plane loading

3.2 Out-of-plane static push tests

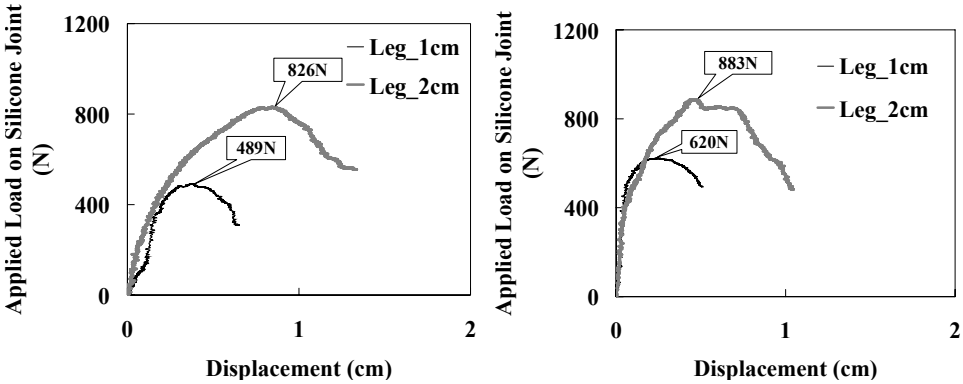
In the out-of-plane loading tests, the experimental setup was altered and the specimen was rotated perpendicular to the sliding guideway, as shown in Fig. 6. A concrete finished steel plate with an opening was fixed between the two concrete panels so that the specimen could be glued to the steel plate with silicone. The actuator end plate could then transfer the out-of-plane loading to the specimen, as shown in Fig. 6(b). Other experimental parameters, such as lengths of silicone runs, leg sizes, and the interface conditions were kept the same as those in the in-plane loading tests.



(a) Experimental equipment (b) During the test

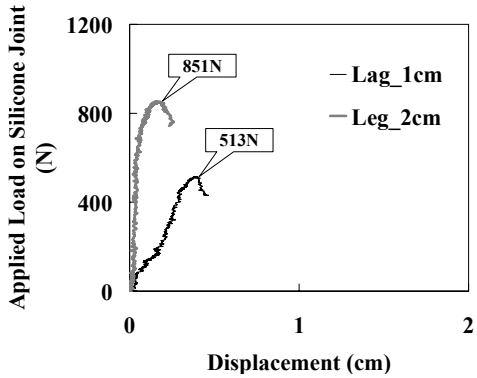
Figure 6 The out-of-plane loading testing setup

Testing results are shown in Fig. 7, in the form of Applied load vs. Displacement curves. Similar to the results for in-plane loading, the B&Q silicone has a slightly larger strength, in the same proportions observed earlier on wood (15-17%) and PCSS (3-5%) finishing. The DC-795 silicone is also more ductile than the B&Q silicone. Doubling the leg size from 1cm to 2cm did not double the strength of the silicone runs, and the size effects are in the same proportions as observed for the in-plane tests. The most striking finding is that the out-of-plane strength of silicone gluing is significantly reduced (by more than 60%) compared to the in-plane strength: this reduction is practically identical for all the configurations tested. This behaviour, as mentioned previously, differs from the metal fillet welding, which has larger strength in perpendicular direction than in the parallel direction because its failure is governed by shear stresses, while silicone is stronger in shear than in tension. To account for this strength difference according to loading direction, both of the in-plane reduction factor ρ_i and the out-of-plane reduction factor ρ_o were extracted from the experimental data, so that the strengths of the silicone gluing could be adequately estimated by Eqn 1 in both directions.

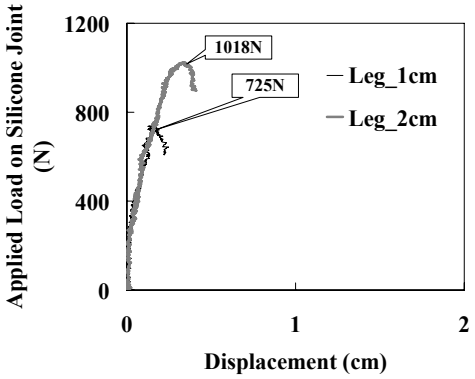


(a) DC-795, PCSS

(b) DC-795, wood



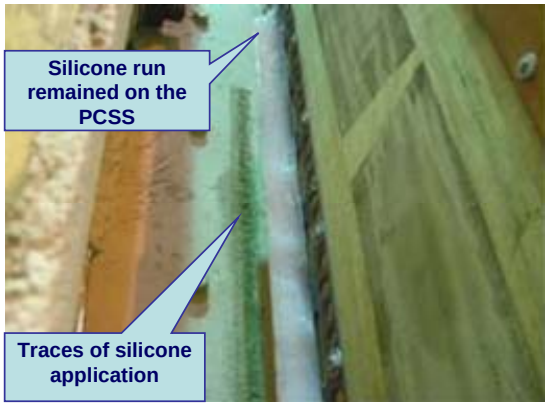
(c) B&Q, PCSS



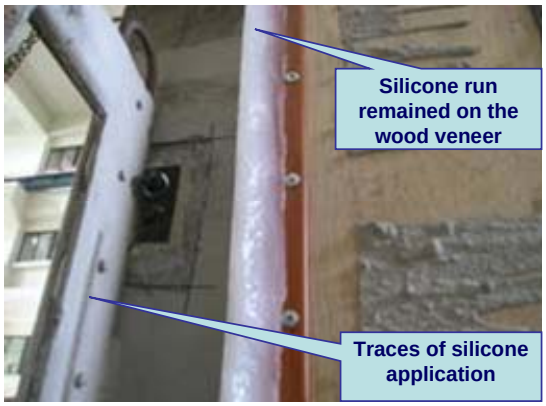
(d) B&Q, wood

Figure 7 The load-displacement curves of out-of-plane loading tests

The failures of silicone gluing runs in the out-of-plane loading tests are shown in Fig. 8. Irrespective of using DC-795 or the B&Q silicone, both interfaces of PCSS vs. concrete and wood vs. concrete failed with silicone completely detaching from the concrete wall.



(a) PCSS vs. concrete



(b) wood vs. concrete

Figure 8 The failures of the silicone gluing runs in the out-of-plane loading tests

3.3 Determination of ρ_i and ρ_o

By rearranging Eqn 1, the reduction factors ρ_i and ρ_o of silicone gluing runs can be calculated as follows:

$$\rho_i = \frac{P_{si}}{F_u \times 0.707 \cdot a \times L} \quad , for \quad in-plane \quad loading$$
$$\rho_o = \frac{P_{so}}{F_u \times 0.707 \cdot a \times L} \quad , for \quad out-of\text{-}plane \quad loading \tag{2}$$

where P_{si} and P_{so} are the in-plane and out-of-plane loading strengths of the silicone gluing runs determined from the tests, respectively. For example, if the silicone DC-795 with $F_u = 0.55MPa$ is applied with leg size $a = 1cm$, length of gluing runs $L = 80cm$ on each side ($160cm$ on two sides), and $P_{si} = 1315\ N$ and $P_{so} = 489\ N$ are obtained from the experiments, then ρ_i and ρ_o are determined by:

$$\rho_i = \frac{1315N}{0.55MPa \times 0.707 \cdot 10mm \times 1600mm} = 0.21, for \quad in-plane \quad loading$$

$$\rho_o = \frac{489N}{0.55MPa \times 0.707 \cdot 10mm \times 1600mm} = 0.08, for \quad out-of-plane \quad loading$$

Other reduction factors obtained for various experimental conditions in this study are shown in Table 1. Obviously, the out-of-plane reduction factor ρ_o (from 0.07 to 0.12) is much smaller than the in-plane ρ_i (from 0.18 to 0.31). The seismic capacity of silicone gluing is therefore controlled by out-of-plane loading under multiple-direction earthquake forces. For engineering applications, we recommend using $\rho_o = 0.05$ as a conservative design value in both directions. Besides, comparing the results of the *1cm* leg length silicone gluing runs with different lengths increasing from 160cm to 190cm (about 18%), the strengths increased in the same proportion. The strength per unit length values of the different silicone gluing runs varied from *8.2 N/cm* to *17.0 N/cm* for the in-plane loading direction, and from *3.1 N/cm* to *6.4 N/cm* in the out-of-plane loading direction.

Table 1 Strength reduction factor ρ of various types of silicone, interfacing materials and loading directions

Type of silicone	F_u (MPa)	Interface	a (cm)	L (cm)	P_{si} (N)	ρ_i	P_{so} (N)	ρ_o
DC-795	0.55	PCSS	1	160	1315	**0.21**	489	**0.08**
			1	190	1558	**0.21**	-	**-**
			2	160	2211	**0.18**	826	**0.07**
		Wood	1	160	1660	**0.27**	620	**0.10**
			1	190	1968	**0.27**	-	**-**
			2	160	2355	**0.19**	883	**0.07**
B&Q,	0.55	PCSS	1	160	1367	**0.22**	513	**0.08**
			1	190	1614	**0.22**	-	**-**
			2	160	2268	**0.18**	851	**0.07**
		Wood	1	160	1949	**0.31**	725	**0.12**
			1	190	2322	**0.31**	-	**-**
			2	160	2719	**0.22**	1018	**0.08**

Note:

-: no testing data available

a: leg size of silicone runs

L: total gluing length of silicone runs

F_u : ultimate tensile strength of the silicone

P_{si} : the in-plane strength of the silicone runs from the test

P_{so} : the out-of-plane strength of the silicone runs from the test

ρ_i : the in-plane reduction factor

P_o : the out-of-plane reduction factor

4 SHAKE TABLE TEST USING REQUIRED RESPONSE SPECTRA (RRS) SPECIFIED IN AC156

In this study, the Required Response Spectra (RRS) specified by AC156 are utilized as the excitation input for the shake table test on a cabinet glued by silicone to the back wall. AC156 was issued by ICC-ES (ICC-ES, 2006) and has been adopted in the United States in the IBC 2006 and ASCE 7-05 documents. AC 156 stipulates the acceptance criteria for seismic qualification of acceleration-sensitive OFCs/NCs by shake table testing. The RRS specified by AC156 at 5% damping are shown in Fig. 9(a).

They are defined by two parameters: A_{FLX}, the horizontal spectral acceleration calculated for flexible equipment using Eqn 3 and A_{RIG}, the horizontal spectral acceleration calculated for rigid equipment using Eqn 4.

$$A_{FLX} = S_{DS}\left(1+2\frac{z}{h}\right) \text{ and } A_{FLX} \le 1.6S_{DS} \tag{3}$$

$$A_{RIG} = 0.4S_{DS}\left(1+2\frac{z}{h}\right) \tag{4}$$

where

S_{DS} : Design spectral response acceleration at short period
z : Equipment attachment elevation with respect to grade
h : Average building/structure roof elevation with respect to grade

The underlying assumption of the AC156 RRS is that most of the building OFCs/NCs that can be affected by earthquakes will have a natural frequency between 1.3Hz and 33.3Hz. Their seismic capacity can be obtained by determining A_{FLX} and A_{RIG} from the appropriate S_{DS} required for building design in different seismic zones and usually prescribed in national building codes for 5% modal damping in the building structure. However, the S_{DS} value to apply to OFCs/NCs is that for rigid structures and does not correspond to the actual or expected fundamental frequency of the building. It should also be noticed that, from Eqn 3, although A_{FLX} increases linearly with the height of the attachment of the equipment up to a maximum of 3 at roof level, it is limited to a maximum value of 1.6 times S_{DS}. This limitation is imposed to account for the response of structural elements that may yield and undergo inelastic deformation under the extreme earthquake forces so that the floor response acceleration is saturating with height (Miranda and Taghavi, 2005; Reinoso and Miranda, 2005). The vertical RRS is calculated as two-thirds of the horizontal RRS at grade level, i.e. it does not vary with attachment height and z may be taken as zero. In this paper, the maximum seismic demand prescribed by the Taiwan Building Code (TBC) with S_{DS} = 0.8g (firm ground condition and neglecting the near fault area) is considered, and the AC156 RRS parameters for this TBC seismicity level are determined as follows (Fig. 9(b)):

Horizontal RRS

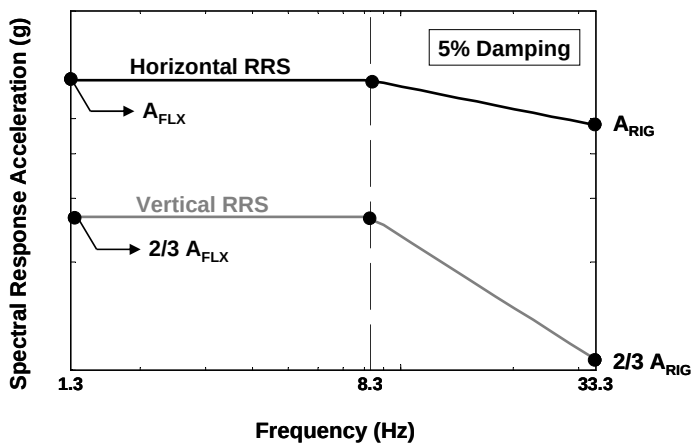
$$A_{FLX} = 1.6S_{DS} = 1.6 \cdot 0.8 = 1.28g$$

$$A_{RIG} = 0.4S_{DS}\left(1+2\frac{z}{h}\right) = 0.4 \cdot 0.8 \cdot 3 = 0.96g$$

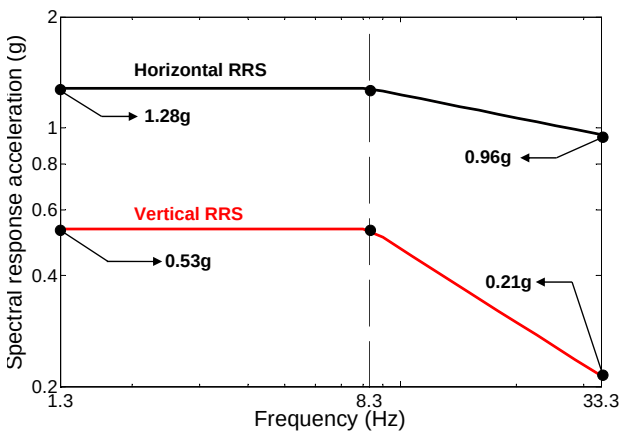
Vertical RRS (taking z = 0)

$$A_{FLX} = \frac{2}{3} S_{DS}\left(1 + 2\frac{z}{h}\right) = \frac{2}{3} \cdot 0.8 = 0.53g$$

$$A_{RIG} = \frac{2}{3} 0.4 S_{DS}\left(1 + 2\frac{z}{h}\right) = \frac{2}{3} 0.4 \cdot 0.8 = 0.21g$$



(a)



(b)

Figure 9 The AC156 Required Response Spectra (RRS) at 5% damping (a) Generic Graph (b) The RRS required in TBC

The dynamic shake table test in this study was performed utilizing a 5m × 8m × 3m (width × length × height) model house structure composed of steel frames, as shown in Fig. 10. This model structure, built by the National Center for Research on Earthquake Engineering (NCREE), is convenient to study the response

of OFCs/NCs with various attachment modes and floor acceleration inputs. The model house was mounted on a 5.1m × 5.1m shake table in the NCREE laboratory in Taipei. A cabinet with PCSS finishing was used as the specimen, and five 20-kg steel plates (total mass of 100 kg) were placed on the cabinet shelves as shown in Fig. 11(a). From the static testing results, we learned that the B&Q silicone had slightly more strength but less ductility than the DC-795 silicone. Therefore, in the seismic qualification test, we used the B&Q silicone, which will presumably has less seismic capacity than the DC-795 under reversed cyclic loading, to have conservative results. In Figs. 11(b) and (c), two B&Q silicone runs with leg size *2cm* and total length *240cm* were applied on the two sides of the cabinet against the wall. Using the strength reduction factors determined in Table 1, the total strength of the silicone runs were calculated as *3360N* and *1306N* in the in-plane and out-of-plane loading directions, respectively. The metal angles in Fig. 11(b) were used to secure the cabinet until the silicone was solidified for a week, and they were removed before the test, making the specimen sitting freely on the floor and restrained only by the silicone run to the wall. Fig. 12 shows the picture during the testing running.

Figure 10 The model house steel frame structure mounted on the shake table

(a) (b) (c)

Figure 11 Installation of the cabinet in the model house for shake table test

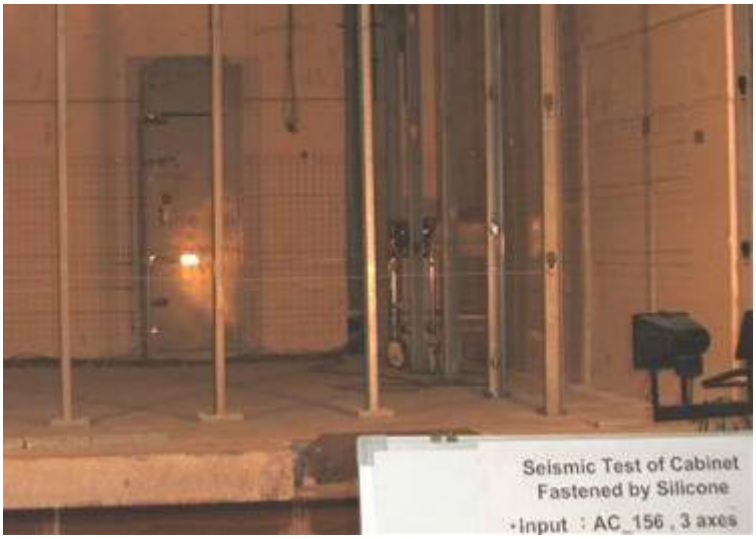


Figure 12 The experimental setup of the shake table tests on the silicone glued cabinet

The shake table test is a typical seismic qualification test on OFCs/NCs. Three orthogonal synthetic seismic input accelerations have been generated in the NCREE laboratory: their time histories are shown in Fig. 13, and their corresponding response spectra are shown in Fig. 14 (Lin, et al., 2008). The peaks of the input acceleration are *1.32g* and *0.30g* in the horizontal and vertical directions, respectively.

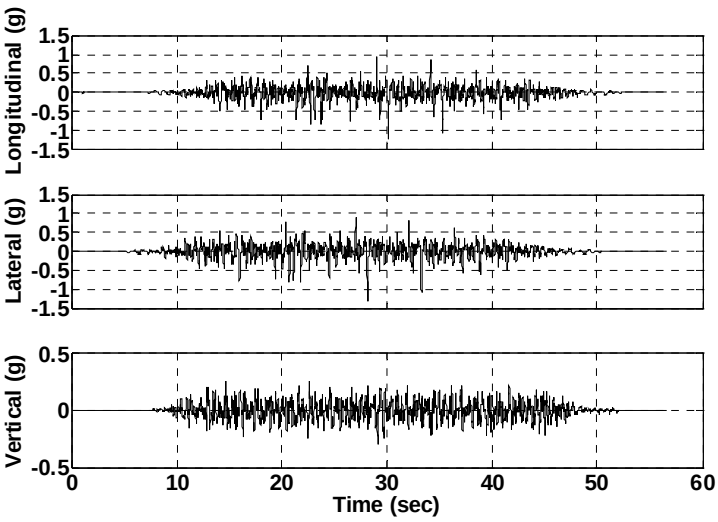


Figure 13 Synthetic input accelerations prescribed in shake table test for seismic qualification of nonstructural components for Taiwan Building Code

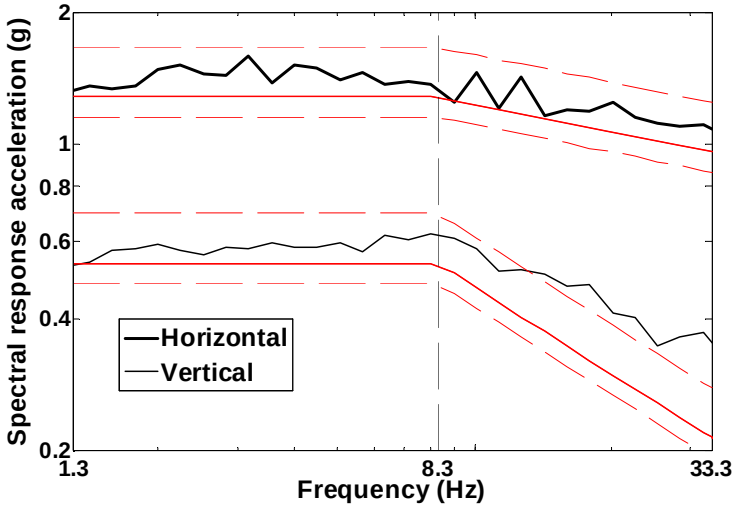


Figure 14 Comparison between the response spectra of the input acceleration of the shake table tests and the RRS specified by AC156 (dashed lines indicate bounds at 130% and 90% of the code RRS shown in solid straight lines).

The shake table testing results were conclusive and showed that the silicone runs as installed can safely restrain the cabinet with 100-kg added mass without any apparent damage.

5 CONCLUSIONS

In this paper, a new non-intrusive jointing technique is proposed and evaluated for the restraint of wall-supported OFCs/NCs using silicone gluing runs. A simple approach used to evaluate the joint strength in metal fillet welding design is adapted here to silicon gluing with similar geometric layouts. Static push tests were performed to identify the load-displacement curves and strength of the silicone gluing runs. Finally, a dynamic shake table test was conducted to verify the effectiveness of the proposed jointing technique in securing cabinets or other OFCs/NCs of similar shape during earthquakes. The salient observations and findings of this investigation are summarized as follows:

1. A simple method was proposed to determine the strength of silicone gluing runs using the metal fillet welding design equation, in which the strength reduction factors ρ were determined by static push tests on cabinets with silicone joints to a supporting concrete wall. For convenience and conservative design considerations, a lower bound value of ρ = 0.05 is suggested in any loading direction. This value was obtained considering wood and PCSS cabinet finishing surfaces glued to

normal finished concrete walls. The gluing runs had a maximum leg size of 2cm and a maximum total length of 240 cm, displayed vertically in two symmetric lines.

2. The two types of silicone (B&Q and DC-795) exhibited similar strength, with the B&Q joint having slightly more strength: 2-4 % with PCSS and 15-17% with wood finishing, independently of the loading direction and run leg size.
3. The DC-795 silicone joint exhibited more ductility than B&Q after the maximum strength point was reached. In the in-plane loading tests; the B&Q had a brittle failure mode.
4. The out-of-plane strength of the silicone gluing joint is about 37% of the in-plane strength, and is governed by a pull-out failure at the silicone/concrete interface.
5. There is a significant size effect for the leg size of the gluing runs, and it is more pronounced for the wood/concrete interface than for the PCSS/concrete. Doubling the leg size from 1 cm to 2 cm increased the strength by a factor of 1.40 and 1.68 for the two interfaces, respectively, in both the in-plane and out-of-plane loading tests.
6. The proposed jointing method using silicone gluing runs to secure the cabinet to its back wall against earthquake effects has been qualified by shake table testing using AC156 RRS protocol based on the seismic requirements of the Taiwan Building Code. The silicone-glued cabinet sustained without apparent damage under the simultaneous excitation of 0.96 g horizontally and 0.23 g vertically, with frequency contents from 1.3Hz to 33.3Hz.

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以矽力康固定靠牆櫃體之耐震性能研究

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摘 要

本研究主要探討以矽力康來固定靠牆之儀器櫃或展示櫃時，整體系統所能承受之耐震性能。以矽力康將櫃子固定在牆壁上，除可有效防止櫃子在地震中發生傾倒破壞外，且不會破壞櫃子表面，爲一可兼顧美觀與安全之新型耐震工法。其基本原理爲：將流體狀態的矽力康以類似塡角焊接之幾何構造方式，施打於櫃子邊緣與牆壁接觸的交界地方，待其固化後，利用矽力康和牆面材質的黏著力及矽力康本身的強度，達到耐震的效果。爲驗證矽力康之耐震效能，本研究首先進行了靜態側推試驗探討以矽力康固定櫃子系統之耐震能力。實驗結果顯示矽力康材料之耐震強度約與施打長度成正比，在面內與面外方向分別爲 8N/cm 以及 3N/cm，意即其強度由面外方向控制。接著，本研究亦假國家地震工程研究中心之振動台，進行矽力康固定櫃子系統之三軸向 AC156 設備物耐震反應譜測試。實驗結果顯示，以肢長 2cm，兩側各施打長度 120cm 之矽力康(總長度 240cm)來固定質量 100kg 之櫃子，可保護櫃子通過測試而無任何損壞。其中輸入震波之峰值大小：水平爲 1.32g、垂直爲 0.30g，滿足台灣建築物耐震設計規範之需求。

關鍵字：功能性設施，非結構物，櫃子，矽力康，AC156 耐震測試反應譜