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A NEW TECHNIQUE FOR WALL-SUPPORTED OFC IN BUILDINGS

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ABSTRACT

Because traditional techniques in securing Operational and Functional Components (OFC) to neighboring walls may damage the wall and the OFC, this paper tries to explore a non-intrusive fixture method for OFC on walls. Two different brands of silicone were tested to provide insight into the force-displacement relationship of a simulated cabinet adhered to a wall with silicone. A simplified equation to calculate the silicone strength by simulating the welding design concept is derived. Test results were compared to the derived equation to find a close relationship between them. Recommendation for using silicone as a non-intrusive fixture technique is made at the conclusion of the paper.

Introduction

A traditional approach in securing Operational and Functional Components (OFC), such as cabinets on neighboring walls, requires the use of metal angles for a rigid connection. This approach causes damage to both the OFC and the supporting walls. It is understood that intrusive fixture methods may be particularly unacceptable in situations such as expensive or sensitive equipment that demands manufacturer warranty. This research intends to develop a new fixture technique to avoid the above said problems by adhering cabinets to a neighboring wall. Silicone, traditionally used for glass sealants or wash basins for waterproofing, is chosen to be the glue for this study.

Usually, silicone is not considered as a structural material for its low tensile strength. Instead, it is mostly used as water-proofing filler. However, from seismic reconnaissance experience, the first author found that items attached to walls with silicone remained unmoved in many major earthquakes. This observation implies that silicone may be useful in supporting light weight OFC against earthquake forces. The advantage of using silicone to resist earthquake force is its easy application/removal and low expense, in addition to its non-intrusive fixture strength. Recently, some of the structural silicone has allowable tensile strengths of up to 0.55 N/mm^2. This strength can provide adequate adhesive force for many OFC cabinets supported on a wall.

This research developed a simplified equation for silicone strengthening based on the welding design concept for fillet welds. Experimental study, to calibrate the calculated strength, is also performed. Large

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scale testing of long gluing lines is conducted to investigate the macroscopic behavior of silicone gluing lines.

Gluing Strength Estimate

Fillet weld strength is generally calculated by the multiplication of allowable stress (F_a) and effective throat area (A_e). A_e is calculated from:

$$A_e = t_e \times L \quad (1)$$

where t_e is the effective throat, and L is the total length of the fillet weld as shown in Fig. 1. However, t_e can be different based on the direction of the force with respect to the run direction of the welds. If it is a transverse loading, shown in Fig. 2(a), t_e will be different from that of the longitudinal loading in Fig. 2(b) as: [Blodgett, 1996]

$$t_e = 0.707\,a\text{, for transverse loading;} \quad (2)$$

$$t_e = 0.766\,a\text{, for longitudinal loading.}$$

where a is the leg size of weld section assuming both legs are equal.

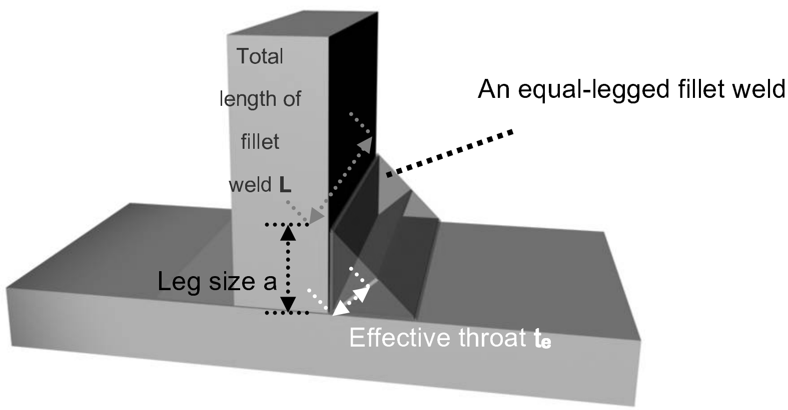
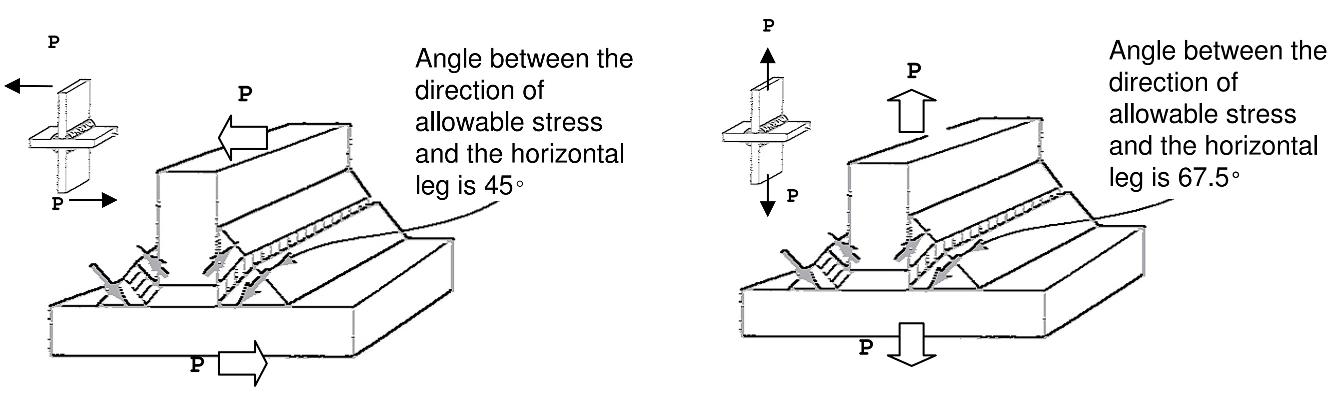


Figure. 1. Terminology in welding.



(a)Transverse loading

(b) Longitudinal loading

Figure 2. Different loading directions with respect to the weld.

To simplify the calculation for silicone application, we propose only to use the conservative Eq. 2 to account for all silicone runs, irrespective of the loading direction. Therefore, the strength of the silicone runs (***P***) shown in Fig. 3 can be estimated as:

$$\begin{aligned} P &= F_a \times A_e \\ &= F_a \times 0.707a \times L \end{aligned} \tag{3}$$

There are many types of silicone for different applications. In this study, the DC-795 [Dow Corning, 2002] from the Dow Corning is chosen for study. In comparison, a generic brand from a local hardware store, B&Q, is also tested. DC-795 is recommended by the Dow Corning as a structural sealant to be used for curtain wall application to secure glass on the curtain wall frame. It has certain advantage over other products:

1. It has a high tensile strength value (F_u) up to 0.55MPa after a week from application,
2. It is weather resistant and produce no unpleasant scent during and after application,
3. It has good bonding strength for many types of building material such as wood, Paint Coating Steel Sheets (PCSC), concrete surface, glass, etc.

The recommended allowable strength for DC-795 can be calculated as:

$$F_a = \rho \times F_u \tag{4}$$

where ρ is recommended to use 0.3 in the welding design [Limbrunner and Spiegel, 1993], and F_u is 0.55 *MPa*.

An example to illustrate the strength calculation can be made on Fig. 3 assuming that an office cabinet is placed against a wall. The silicone can be placed on both side of the cabinet to adhere to the wall. Each run of the silicone has a length of ***L*** as shown in Fig. 3.

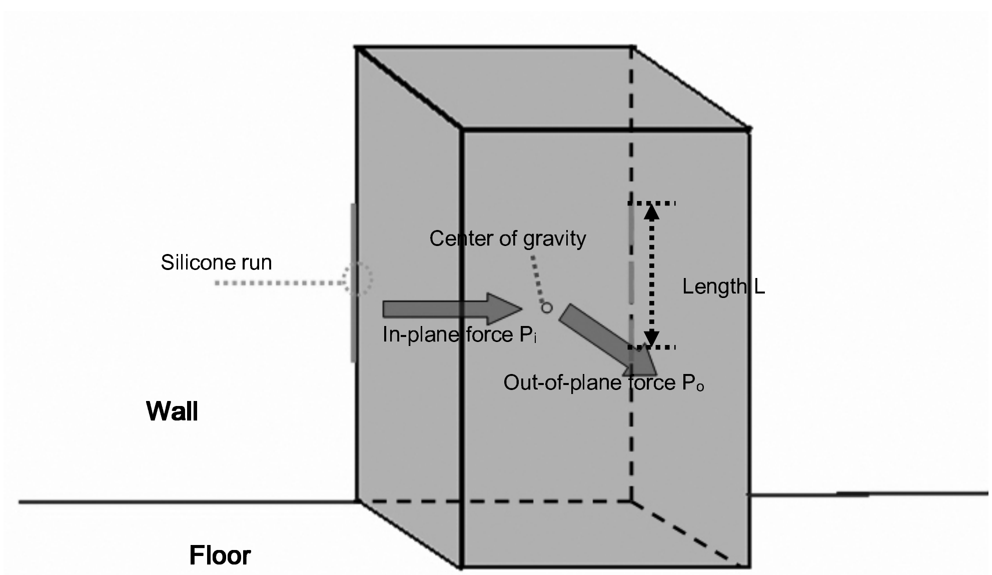


Figure 3. Schematic drawing of a cabinet adhered to the back wall under earthquake excitation.

In Taiwan, the seismic code formula to estimate the inertia force from acceleration (A_x) at the X floor for design earthquake is based on Eq. 5.

$$A_x = C_a\ (1+2\ H_x/H_r) \tag{5}$$

where C_a is the design ground acceleration, H_x is the floor height of the X floor from ground**,** and H_r is the floor height at roof from ground.

Under the design earthquake excitation, a cabinet will experience inertia force in two directions: In-plane force (P_i) and out-of-plane force (P_o) at the center of gravity as shown in Fig. 3. If this cabinet is located on the roof of a building situated in the highest seismic zone with C_a equals to 0.33 g and the cabinet's mass is 200 kg, the inertia force, P_o and P_i**,** will be about 2000 N each. A vector sum of both forces will yield a total force equals to 2820 N acting on the silicone runs.

If silicone on both sides of the cabinet each has a length of L, the total length of the silicone run will be $2L$. If the silicone leg size is 2 cm, and L equals to 80 cm, the calculated F_a based on Eq. 3 and Eq. 4 is equal to 3733 N. Comparing to the force demand of 2820 N from the last paragraph, this silicone design will provide sufficient strength against the earthquake force anticipated.

It is shown in the above calculation that it is possible for light-weight OFC be secured to the neighboring walls with the application of silicone on the peripheral of the OFC to withstand the design seismic forces. In the next section, experiments to verify the proposed design equation were performed by static tests.

Experimental Testing

Two types of silicone, DC-795 and a generic brand B&Q, were tested in full-scale to identify silicone strength. Test setup is shown in Fig. 4. Two vertical planks with finished concrete surface were to simulate a concrete wall in a building. These two planks were fixed at top and bottom to a rigid steel frame. Only the left-had side column is shown, the right-hand side column on the rigid steel frame is not shown in Fig. 4 for clarity of the figure. Both planks remain stationary during the tests. A concrete block was used to simulate cabinets or any OFC alike. Two edges of the block were adhered to the planks at the back by silicone to simulate actual silicone run on cabinets against a wall. Two runs of silicone each with a length of 80 cm were placed to join the block and the planks.

Two different types of surface finish to simulate OFC exterior were attached on the edges of the concrete block where silicone was placed. They were wood finish and PCSC. Therefore the adhesive strength between different interfaces of wood vs. concrete and PCSC vs. concrete can be compared. Two leg sizes, a = 1 cm and a = 2 cm, of the silicone run were chosen for each surface finishes in order to verify the strength of different silicone sizes.

Static tests were performed by providing an incremental horizontal force to push the concrete block in Fig. 4 until the silicone runs can no longer provide any strength. In order to reduce the friction force at the bottom of the concrete block, a sliding guide rail was placed under the concrete block. The frictional forces provided by the guide rail were measured and adjusted in the final data. The summarized test result is shown in Table 1.

Table 1. Ultimate strength of the full scale silicone glues between different interfaces (N).

Interfaces / Brand	Wood/Finished Concrete		PCSC /Finished Concrete	
	a = 1 cm	a = 2 cm	a = 1 cm	a = 2 cm
DC-795	1660*	2355*	-	2211
B&Q	1949**	2719**	1367	2268

* Figure 5 shows the force-deformation drawing

** Figure 6 shows the force-deformation drawing

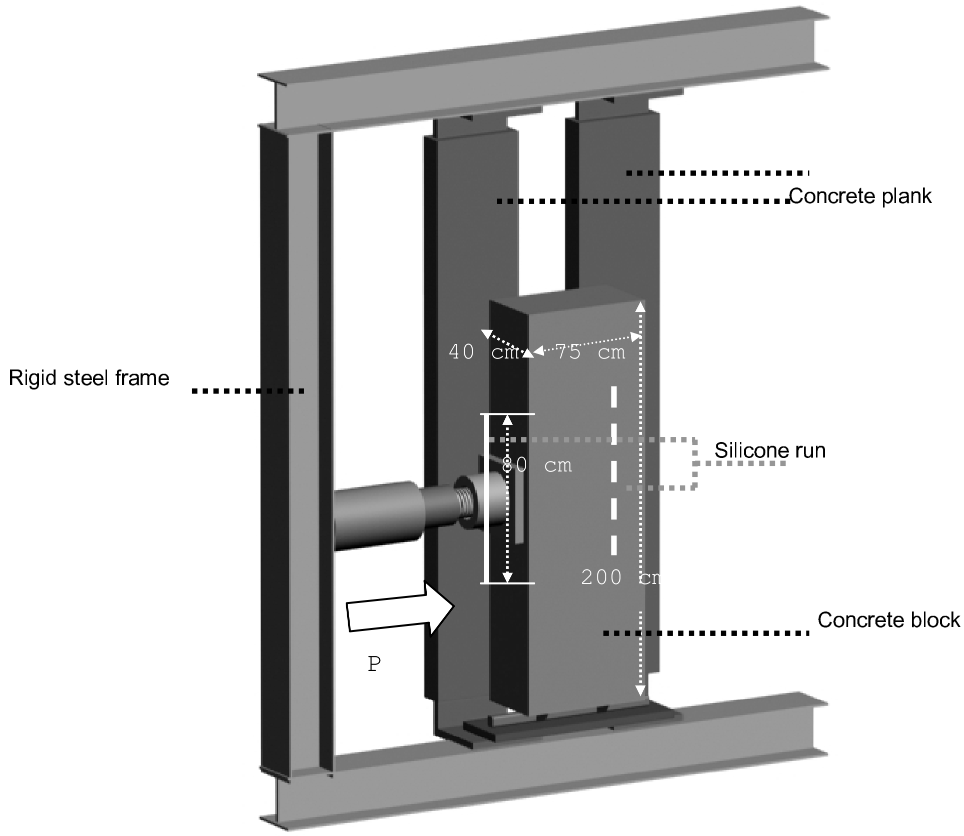
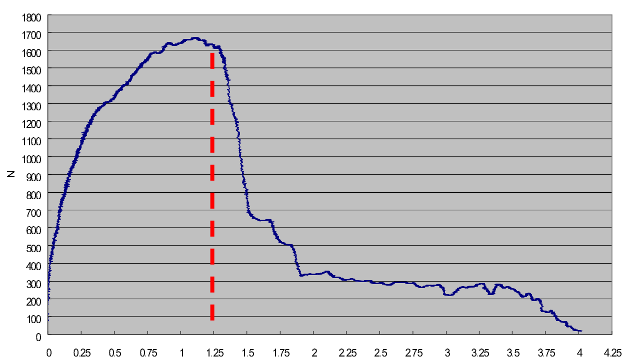
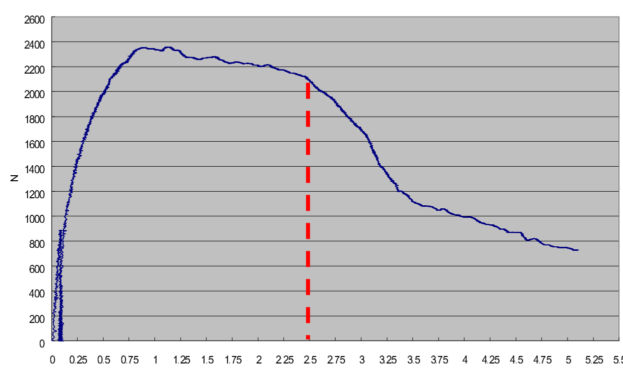


Figure 4. Test set-up of the silicone strength.

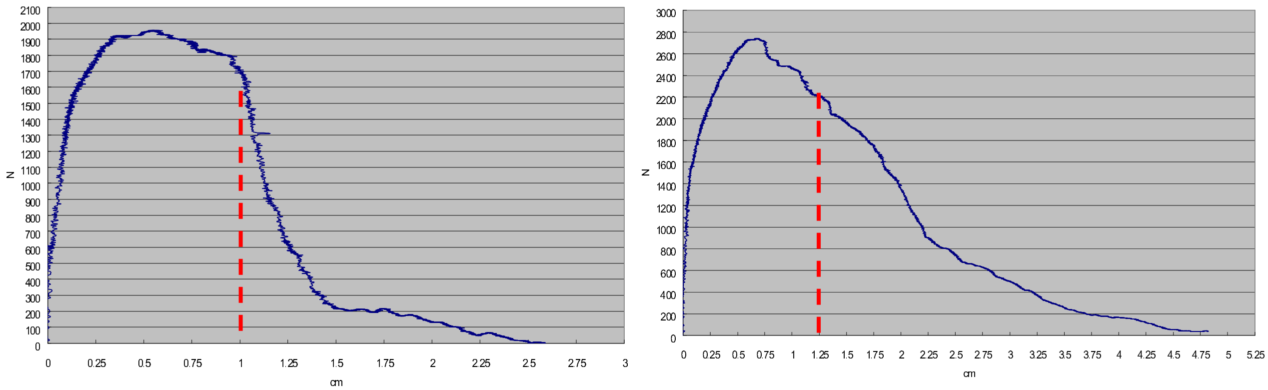


(a) 1 cm leg



(b) 2 cm leg

Figure 5. Force-Displacement curve of DC-795 on wood.



(a) 1 cm leg (b) 2 cm leg

Figure 6. Force-Displacement curve of B&Q on wood.

Test results shown in Table 1 and Figs. 5,6 indicate several interesting observation:

1) The B&Q brand performs just as well as the DC-795 even with a slightly higher strength.
2) Comparing deformation capacity at the beginning of sharp strength degradation after ultimate stress suggests that DC 795, 1.25 cm for the 1 cm leg and 2.5 cm for the 2 cm leg, tends to have a larger deformation capacity than that of the B&Q which is 1 cm and 1.25 cm correspondingly.
3) Increasing the leg size by 100% from 1 cm to 2 cm, the ultimate strength increased about 150% in most of the tests.
4) The failure pattern between different interfaces was observed. Some of the tests failed with complete detachment from the concrete finish and some with silicone remains still attached to the concrete finish after testing.

Conclusions

In this paper, a new connection technique for wall-supported OFC is proposed. The behavior of a non-intrusive approach by applying silicone as the adhesive material is investigated. A simple equation derived from the fillet weld design is proposed for the silicone application, since both of them have a similar geometric layout. Static push tests of a real-size model of two different surface finishes were performed to compare the actual ultimate strength with the calculated value.

Test results indicated that the ultimate strength from the tests for a leg size of 2 cm silicone is about 60% of that from the proposed equation irrespective of surface finish. To correct this variation, it is suggested that the ρ value in Eq. 4 could be adjusted to 0.2 to account for the differences. It is also found that the silicone specimen from the test exhibited some ductility after the initial yielding. The two types of silicone used in the tests exhibited similar strength.

From this study, the authors have found that for light-weight OFC placed next to a wall, silicone connection is a convenient glue for seismic protection. It is inexpensive and causes no surface damage to the wall and OFC. The strength of silicone is demonstrated in the paper with experimental results and a simple equation is derived for application.

Acknowledgments

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