

A preliminary comparison of the strength of two waxes for securing objects against earthquake damage

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ABSTRACT: Two types of wax were tested for earthquake mitigation use for an exhibition of large, heavy, cast-glass vessels by New Zealand glass artist Ann Robinson, at the Museum of New Zealand Te Papa Tongarewa (Te Papa). Informal testing was carried out using a mechanical tilt test. Consultation with an engineer enabled the tilt test to be related to earthquake conditions expected in the museum building. Results indicate that dental Utility Wax is stronger than Museum Wax™, but greater care is needed in its use.

KEYWORDS: Securing fragile objects, exhibitions, earthquake mitigation, Museum Wax™, test.

Fig. 1 Ann Robinson *Large Wide Bowl* (photo by Norm Heke).
Fig. 2 Ann Robinson *Cactus Vessel – blue* (photo by Norm Heke).

Introduction

In 2002–2003, the Museum of New Zealand Te Papa Tongarewa (Te Papa) held an exhibition of works by cast-glass artist Ann Robinson, titled *Pacific Rim: Ann Robinson's glass*. Robinson has been working with cast glass since the 1980s and has pioneered techniques that allow her to produce massive cast-glass vessels. Her bowls measure up to 645 mm in diameter and her vases up to 887 mm high.

Robinson uses a number of basic forms, modifying the size, shape, colour or surface decoration for each casting. Two recurring forms are the wide-rimmed bowl with a small pedestal foot, such as *Pacific Bowl* or *Large Wide Bowl* (Fig. 1), and the tall narrow 'vase' form, such as *Cactus Vessel – blue* (Fig. 2) or *Nikau Vase*. Both these forms present challenges for exhibition in New Zealand, as both are susceptible to toppling in an earthquake.

New Zealand is located in an area of high seismic activity. In New Zealand as a whole, a magnitude 7 earthquake can be expected every 10 years and several magnitude 6 earthquakes can be expected every year (Institute of Geological and Nuclear Sciences n.d.). Although the exhibition period was relatively short (12 months), the instability and vulnerability of the works meant that earthquake mitigation measures were an important consideration. Finding a suitable solution was problematic. External mounting systems would have been effective, but there was considerable opposition to the use of external mounts for these items. As artworks, the visual appearance of the pieces is of primary importance. The works are somewhat translucent, and were to be viewed in the round, so it was felt that external mounting systems would be highly visible and visually intrusive.

Museum Wax™ (see Note 1) can be effective for securing smaller glass items. It is a sticky wax that is applied to the underside of the item to secure it inconspicuously to the display surface. The Materials Safety Data Sheet (MSDS) provided by the manufacturer (Crompton Corporation 2003: 1) states that Museum Wax™ is a microcrystalline wax with a very small amount of 2,6 di-tert-butyl-p-cresol added (<10 ppm). Microcrystalline waxes are a type of paraffin wax that have very small crystals. Paraffin waxes are composed of saturated hydrocarbons that are refined from petroleum, or they can be synthesised (Kuhn 1986: 234). Paraffin waxes are described as 'highly inert' (Rivers & Umney 2003: 167); saturated hydrocarbons in general are highly unreactive (Zumdahl 1993: 1042). Werner (1957: 5) describes microcrystalline waxes as 'neutral and stable … no free acids are present and none can be formed by oxidation or hydrolysis …'. An examination of the possible negative effect of the additive was outside the scope of this project.

There are some negative aspects to the use of wax for earthquake mitigation. Waxes will stain porous surfaces such as unglazed ceramics. Waxes should therefore be applied only to non-porous surfaces such as glass and glazed ceramics. On a non-porous surface the visible wax can be removed mechanically using wooden sticks, or by using aliphatic hydrocarbon solvents such as mineral spirits (white spirit) (Cornu & Bone 1991:19).

After wax removal, a microscopic residue remains. A simple test of applying Museum Wax™ to a clean sheet of glass shows that even when all visible traces of wax have been removed, fibrous cellulose powder sprinkled on the surface will be retained in the areas where wax has been applied, indicating the presence of a microscopic residue. Therefore, waxes should not be used for earthquake mitigation on artefacts where contamination with even tiny residues is inappropriate, or where dust retention would be problematic.

Using waxes for earthquake mitigation can result in mechanical damage to the surface or structure of fragile objects. Objects that have been secured with wax are typically removed in ways that cause mechanical stress, such as by 'twisting and lifting' the object, or by using dental floss to saw through the wax. In the event of an earthquake, the movement will also apply mechanical stresses to a restrained object. In intentional removal or during an earthquake, stress is exerted on the surface where the wax has been applied, and fragile surfaces or surface decoration can be pulled away.

Furthermore, stress is also applied to the structure of the object and could cause it to break, particularly in weak areas such as old mends. Each object should be assessed carefully to ensure that it is strong enough to withstand the type of handling required for de-installation, and also that it is strong enough to remain undamaged in an earthquake if secured only at the base (Agbabian et al. 1991:115).

In the case of the Ann Robinson glass works, the objects were structurally strong and the surfaces were robust. However, given the massive weights of some of the items (up to 35 kg), it was felt that Museum Wax™ would not be strong enough to hold down the works in an earthquake. An alternative solution was proposed by the then Art and

Visual Culture collection manager, Charlotte Davey. She had previously used a different type of wax – dental Utility Wax (see Note 2), which she believed was stronger and would hold the works more securely. Use of this type of wax for earthquake mitigation has been described by Cornu & Bone (1991: 19).

This paper describes the informal testing that was carried out on dental Utility Wax to determine whether it would be sufficient to prevent the Ann Robinson glass works from toppling in the earthquake conditions that could be expected in the exhibition gallery.

Materials and methods

A test method was developed based on a model described by Agbabian et al. (1991: 115) at the University of Southern California, in association with the J. Paul Getty Museum and the Getty Conservation Institute. The paper describes a method for estimating whether a rigid object (e.g. a thin-stemmed vase) fixed at the base is strong enough to withstand the force applied by an earthquake of a specific acceleration. They addressed issues such as 'if a tall thin-stemmed glass is secured only at the base, will it break during an earthquake?'

According to the model, this can be assessed by asking the question 'would the object break if it were tilted at [e.g. 45°] from the vertical?' (Agbabian et al. 1991: 115). This is a valid approach because '… the horizontal force due to earthquake excitation can be simulated by tilting the object from the vertical and inducing the loading force by gravity' (Agbabian et al. 1991: 115). Although the model is not specifically intended for testing the strength of the method of securing objects at the base, the concept that tilting an object produces forces similar to that of a given earthquake seemed useful. Agbabian et al. (1991: 115) provide an equation that can be used to calculate the tilt angle that correlates to the force of a given earthquake so that the model can be adapted to local conditions. Te Papa consulted with Stephen Hogg (pers. comm. 2002) to adapt the Getty model to the conditions expected at Te Papa.

Due to the high risk of earthquakes in Wellington, considerable analysis had been carried out regarding the effect of earthquakes on the Te Papa building. The museum building was purpose-designed and -built for the redevelopment of the Museum of New Zealand, which opened as Te Papa on 14 February 1998. It incorporates sophisticated earthquake engineering, designed to ensure that the building will not collapse in a once-in-a-2000-year earthquake (Stephen Hogg, pers. comm. 2002). The building is supported by layered rubber and steel base isolators with lead cores, which damp the transfer of earthquake movement to the building (Merv Harvey, pers. comm. 2002). Although these measures will prevent the building from collapsing, in the event of a major earthquake they will not completely prevent toppling of artefacts within the building (Merv Harvey, pers. comm. 2002).

From the analysis carried out during the design of the building, quantitative data predicting the forces generated at each floor of Te Papa were available for a 1-in-2000-year return period earthquake, and a 1-in-250-year return period earthquake (Stephen Hogg, pers. comm. 2002). For the purposes of testing the Utility Wax, the 1-in-250-year dataset was selected. This is the same criterion used for engineering the building fit-out for permanent exhibition areas. Therefore the test applied to the Utility Wax was very conservative, as the wax was being tested for a short-term (two-year) exhibition (Stephen Hogg, pers. comm. 2002).

Pacific Rim was to be held on the sixth floor of the Te Papa building. Increasing height within a building increases the level of force exerted by an earthquake. Using the Getty model, Stephen Hogg (pers. comm. 2002) calculated that the mount bond provided by the Utility Wax would need to survive being tilted to 35° to ensure that the wax would be effective for securing a given item in a 1-in-250-year earthquake on levels 4–6 of the building. For levels 1–3, survival of a 25° tilt would be required.

The test subject chosen was a flawed casting of a *Cactus Vessel*-type vase, a duplicate of one of the works in the exhibition. Ann Robinson generously provided the duplicate for use in our tests. *Cactus Vessel* is a form that has been used repeatedly by Ann Robinson with some variations. It is a tall, narrow, thick-walled vase that flares outwards towards the top. The test vase measures 560 mm high x 160 mm in diameter at the widest point. The diameter at the base is 115 mm. It weighs 18.5 kg. The underside of the vase was relatively rough, unpolished cast glass (Fig. 3), which was expected to be similar to the surfaces of the other vases being borrowed for the exhibition.

Dental Utility Wax was sourced from a local dental supply company. The MSDS provided by the company states that 'all wax products contain mixtures of natural and synthetic parafinic [sic] waxes and oils along with non-hazardous stabilizers and food grade colourants'

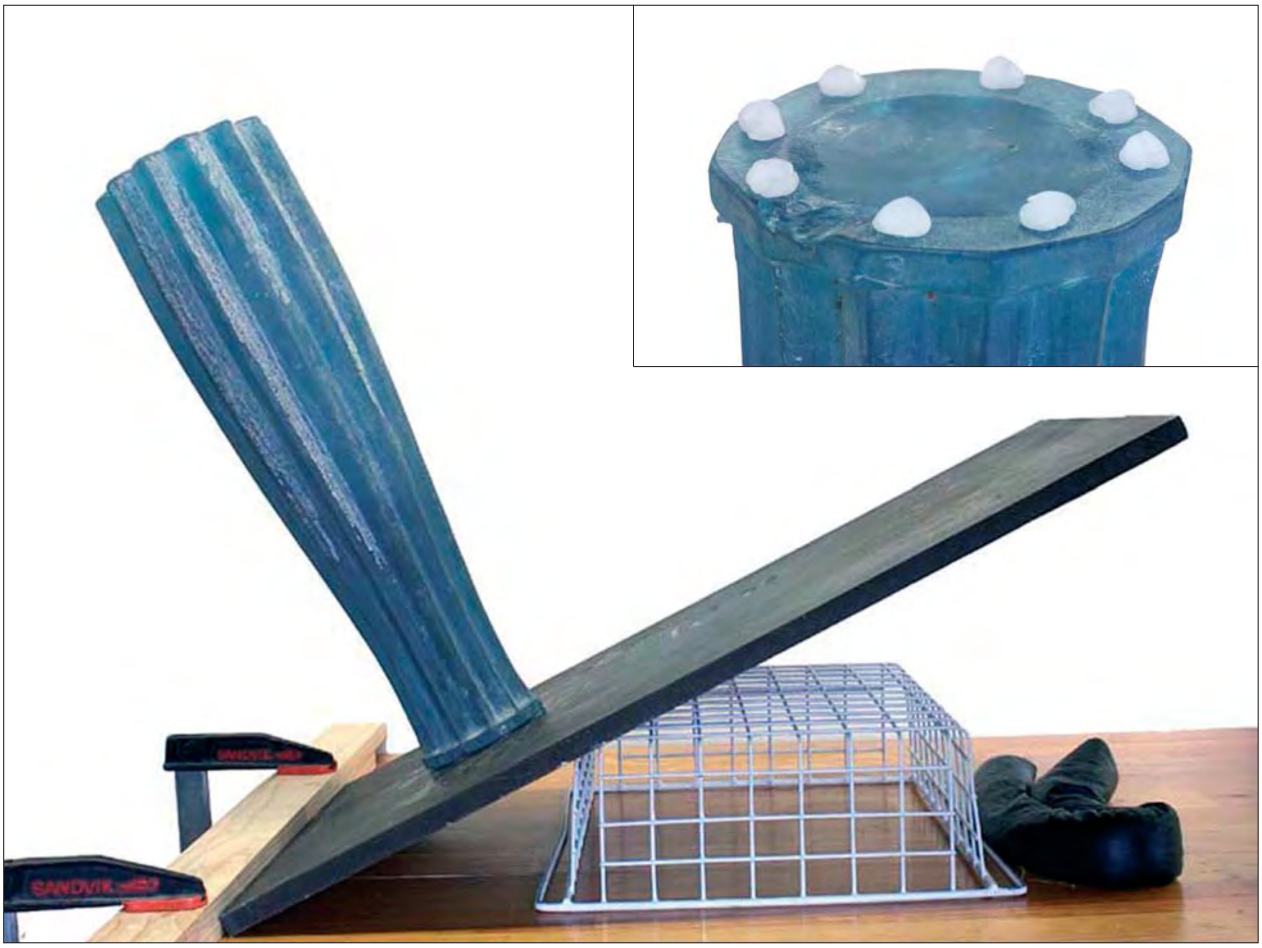

Fig. 3 (inset) Utility Wax applied to the base of a test vase (photo by Norm Heke).
Fig. 4 Set-up of vase for test (photo by Norm Heke).

(Anonymous 2001: 1). The Utility Wax used was white. An investigation into the identity and possible negative effects of the stabilisers was outside the scope of this project.

The Utility Wax was warmed with a hairdryer until it was pliable and the surface was slightly melted and glossy. Pieces were rolled into balls approximately 10 mm in diameter and applied to the underside of the vase. The wax and base of the vase were warmed gently with a hairdryer until the wax surface was again slightly glossy. The vase base was then quickly placed on the test board, pressing straight down to compress the wax evenly and improve adhesion. To maximise bond strength, wax was applied to cover the largest possible surface area around the outer edge of the base. In practice, this meant applying eight balls at even intervals around the edge of the base (Fig. 3). When pressed against the test board, the warmed wax balls would spread out to almost meet with each other.

Fourteen replicate tests were carried out using Utility Wax on the test vase. After the first four replicates, the vase-wax-board assemblage was left to cool for approximately 15 minutes before each test to allow the wax to re-harden. Between tests, the wax was mechanically scraped off the board and the vase.

The board was an old, painted wood-composite board. The area to be used was prepared by scoring with a craft knife to give additional tooth for adhesion of the wax. One side of the board was placed against a fixed edge to hold it in place, and the other side raised onto a tub support (Fig. 4). The tub was then slid towards the fixed edge, raising the angle of the board until the wax failed and the test vase broke off. The vase was caught by a second person as it detached. The angle of the board was then measured using a protractor.

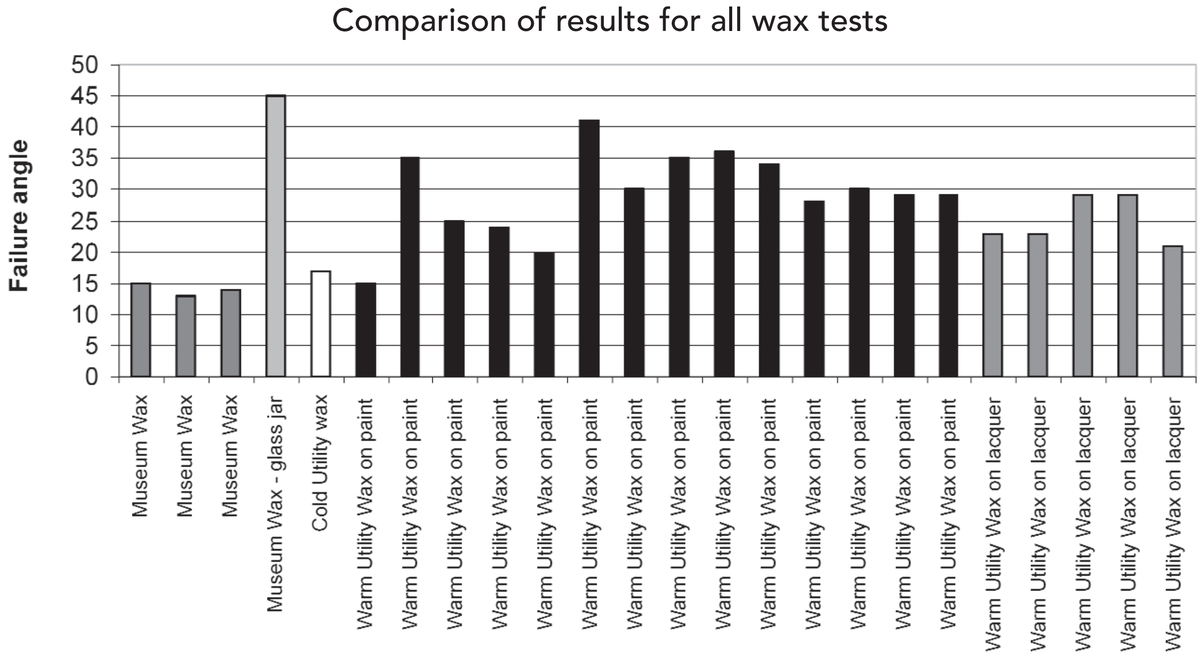

Fig. 5 Adhesion bond failure angle for all wax tests.

Several comparative tests were also made:

1. The test vase was placed on the board with no wax, and the angle at which toppling occurred measured.
2. Museum Wax™ was used to secure the test vase, and the failure angle measured.
3. A smaller, lighter glass jar was secured with Museum Wax™ and the failure angle measured. The jar was 230 mm high x 110 mm in diameter, and weighed 800 g.
4. The Utility Wax was applied cold to the test vase and the failure angle measured

In the course of the tests, it became clear that the nature of the board's surface was critical to the effectiveness of the Utility Wax. The proposed display surface was to be highly finished – medium-density fibreboard coated with cellulose nitrate lacquer. A sample of the display surface was therefore prepared and further replicates of the tests carried out as described above. To improve adhesion, the board was increasingly heavily scored as the tests were repeated.

Results

With no wax, the test vase toppled at 10°. The results for all tests using wax are presented in Fig.5. For the tests on the lacquered board, the maximum tilt angle that was achieved varied with the level of scoring, indicated in the table below.

Failure angle	Level of scoring
23°	no scoring of board
23°	light scoring
29°	heavy scoring
29°	heavy scoring
21°	heavy scoring

Discussion

The only way to understand precisely how objects will respond to an expected earthquake is to test them on a quake table that mimics the predicted movement. The cost of using a quake table was prohibitive for this project. Instead, the method chosen is a simple and inexpensive way to get a useful indication of the effectiveness of an earthquake mitigation measure.

The Utility Wax is clearly tougher and stronger than the Museum Wax™. With the exception of two results, one of which involved applying the wax cold, the Utility Wax achieved a failure angle of at least 20° in every test (Fig. 5).

In comparison, the Museum Wax™ did not secure the test vase when the tilt was more than 15°. Museum Wax™, however, appears to be highly effective for smaller, lighter objects, as shown by the 45° result for the 800-g glass jar. Failure of the Museum Wax™ was due to cohesive failure (i.e. the wax pulled apart), indicating that it is a weak wax but has good adhesion (Stephen Hogg, pers. comm. 2002).

Most of the test results for the Utility Wax used with the test vase on the painted board fall in the 25–35° range (Fig. 5). The mean failure angle was 29.3°. On the lacquered board, a failure angle of up to 29° was achieved with heavy scoring of the board. This did not quite meet the chosen criteria, but given the very conservative nature of those criteria, it indicates that the Utility Wax could be effective at securing large, heavy objects in a serious earthquake.

In addition, there is considerable variability in the test results, with failure angles ranging from 15° to 41°. Owing to the relatively informal nature of the tests, not all variables were controlled. Most notably, the speed with which the board was raised was not controlled and varied greatly. This is suspected to be the cause of much of the variability in the results. Most of the outlier results were produced during the first few tests of a session, and more consistent results tended to be achieved once a comfortable rhythm for the test process had been achieved.

The preparation of the board surface was also not closely controlled. Different parts of the painted board, which may have been scored to a different degree, were used for different tests and may have contributed to the variability of the results.

However, the level of variation of the results also suggests that small variations in wax preparation and use will result in quite different bond strengths. Some caution is therefore necessary in deciding to use Utility Wax to secure large and heavy objects. Care must also be exercised in the manner the wax is used to achieve the best possible results.

Most of the bond failures observed with the Utility Wax were due to adhesive rather than cohesive failure. The surfaces involved, and their preparation, are therefore critical to the effectiveness of the Utility Wax. Heavy scoring of smooth and/or glossy display surfaces is essential. Potential bond failure of the paint on painted display surfaces should also be considered. It should be expected that the Utility Wax would be less effective on smooth, polished glass or glazed ceramic surfaces. At this point, Utility Wax should not be expected to secure objects that are as tall and heavy as the test vase if they have smooth (polished) undersides until further testing is done.

As demonstrated by the very low failure angle (17°) produced by cold Utility Wax, the wax must be warmed with a hairdryer, or similar device, immediately prior to application to achieve adequate adhesion. Caution must be exercised when applying heat to glass objects, owing to the potential for cracking caused by thermal shock.

One significant drawback of using dental Utility Wax is that it is difficult to remove objects that have been secured with it, owing to the strength of the bond. In practice, the most effective technique was found to be twisting and then lifting the object. Re-warming the object can also be useful. Attempts at sawing through the wax with wire were unsuccessful. The thick-walled, relatively robust Ann Robinson glass works could be de-installed without damage, but the force required should be considered carefully before dental Utility Wax is used for more fragile objects.

Conclusions

Utility Wax was found to be adequate for securing Ann Robinson's cast-glass works that were similar to, or smaller than, the test vase, for a short-term exhibition on level 6 at Te Papa. The wax did not fully meet the test criteria that had been chosen; however, given the aesthetic drawbacks of alternative methods of earthquake mitigation, and the very conservative nature of the test criteria, it was felt to be an acceptable solution.

Various mechanical systems were used to secure works that were larger or more top-heavy. Fig. 6 shows the final appearance of one of the display cases in *Pacific Rim*. Overall, the results indicate that dental Utility Wax has potential for securing heavier objects than those secured with Museum Wax™. However, some caveats must be observed. There were a number of limitations to the informal testing carried out, so a more formal investigation would be needed to confirm this result. These initial results also indicate that variations in the surfaces involved and how the wax is applied greatly alter the resulting bond strength, so care is needed in its use. For small, light objects, Museum Wax™ is likely to be more reliable owing to its adhesive properties. It is also quicker and easier to work with.

One significant drawback of achieving a stronger bond is the force needed to remove objects that have been secured with dental Utility Wax. Therefore, objects need to be more robust if dental Utility Wax is going to be used

Fig. 6 *Cactus Vessel – blue* and *Cactus Vessel – neodymium* as displayed alongside other works in *Pacific Rim: Ann Robinson's glass* (photo by Norm Heke).

compared to Museum Wax™. The decision to use any wax for earthquake mitigation needs to be made after careful consideration of the strength, porosity and suitability of the object to be secured. It must be remembered that for effective protection from earthquake damage, consideration must also be given to the design and stability of the furniture used in the exhibition.

Acknowledgements

Many thanks are due to Charlotte Davey for initiating this project by suggesting that Utility Wax be tested, and to Ann Robinson for providing the test vase. Thanks are also due to Stephen Hogg (Romulus Consulting Group Ltd, Structural and Civil Engineers) for recalculating the tilt angles as related to Te Papa, as well as providing advice regarding the effect of earthquakes and the interpretation of the test results; to Merv Harvey (General Manager Building Operations, Te Papa) for providing useful information about the Te Papa building; and to Phil Sirvid (Te Papa) and two anonymous reviewers for many helpful comments on the minitial draft of this manuscript.

Notes

1 Museum Wax™ was previously manufactured by Conservation Materials Ltd, under the trade name Quake Wax™. The wax tested was trademarked Quake Wax™ and supplied by Conservation Materials Ltd, 1385 Greg St., Sparks, NV 89431, United States of America. Conservation Materials Ltd sold the Quake Wax patent to Trevco in 2000 (Trevco 2000). The composition of Museum Wax™ is the same as Quake Wax™ (Trevco pers. comm. 2004). The replacement product Museum Wax™ is now manufactured and distributed by Trevco, 445 Production St., San Marco, CA 92069, United States of America.

2 The Utility Wax rods round (white) tested were supplied by Shalfoon Dental NZ, 59–61 Marsden St., Lower Hutt, New Zealand. It is manufactured by KerrLab, 1717 West Collins Ave, Orange, CA 92867, United States of America.

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