Shake 'Em Don't Break 'Em:

Seismic Housing for Glass and Other Fragile Library and Archival Media

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Introduction

Seismic activity in certain regions of the world is a certainty. Whether or not a cultural institution has previously experienced a seismic event, if it is located within an earthquake zone it is just a matter of time. While geological time advances slowly and predicting the next seismic event with certainty is improbable, the likelihood is strong that physical breakage will occur in glass-based and other fragile library media if it is not protected. However, making a priority to implement seismic housing strategies is difficult for collections of glass plate negatives, lanternslides, papyrus sandwiched in traditional glass housings, or sound recordings on wax, celluloid, hard rubber, shellac, or acetate.

Many fragile library collections are likely to break if a temblor is large enough and close enough and the collections are unprotected. And most fragile media are constructed from materials that cannot be repaired well; the damage will be serious and in some cases irreparable. Why is the issue of safeguarding these media types from shock and vibration so foreign to library curatorial and preservation practice?

Reasons for ignoring this particular risk are legion despite a growing familiarity with the concept of preventive conservation include a lack of clear information about the extent and significance of the losses that have occurred historically to cultural property as a result of earthquakes.[1] Risk managers do not generally mandate institutions to implement specific preemptive steps to reduce the risk of collection damage from seismic activity, and the benefits of doing *anything* tactical and preemptive have not yet attracted much attention.

The result of the habitual lack of resources that hobbles nearly every cultural institution can express itself in a variety of ways: as stoicism ("we'll get by"), passive resignation ("this problem is so big we can't really do anything about it") or pessimistic defeatism ("what's the use of trying?"). Worse, institutional complacency can set in like dry rot and subvert the struggle for proactivity into lethargic apathy. However, it is comes down to a choice of priorities. Other problems can always take precedence because the specter of an impending but undefined cataclysm completes weakly with an immediate deadline. Still, whether it is asked overtly or merely waits to be realized, institutions situated in seismic zones must decide which collections they can it write off. Jerry Podany (Senior Conservator of Antiquities, J. Paul Getty Museum) poses this question as a mathematical equation: *acceptable risk = acceptable damage*.[2] If we are unwilling or unable to act, someday that deficiency will lead to forfeiture as surely as leaving the doors to special collections open will lead to loss. Given the extenuating circumstances, which losses are tolerable?

Ignoring the inevitable threat of damage or loss to specifically susceptible media residing in a defined seismic zone is clearly unrealistic. While the solutions may not be self-evident and will likely require some resources, they need not be complicated or expensive to significantly improve the odds of survival. Podany suggests reevaluating the risk is as simple as asking two questions. First, "After the shaking stops what do you expect to see?" and second, "What do you want to see?"[3]

Prioritizing mitigation strategies within a seismic zone to safeguard glass and other fragile library and archives collections will reduce the probability of physical breakage or loss occurring due to ground shaking. Doing nothing to mitigate the threat is essentially accepting a high probability of collection damage to material that is often irreplaceable and essentially impossible to repair. Even rudimentary improvements in collection storage conditions can dramatically reduce vulnerabilities. Basic upgrades turn out to be neither difficult to achieve nor expensive to implement. This place to begin is to explore strategies that use existing facilities and can be implemented within the institution's normal fiscal constraints. Waiting to implement optimal protections is tempting fate – earthquakes occur unexpectedly and any improvement implemented in advance of the event is preferable to none.

You Can Learn a Lot from an Egg

Addressing earthquake risk when it jeopardizes an institution's ability to shepherd its fragile collections through time is analogous to the historical challenge of physically shipping eggs. Until the early 20th century eggs were moved from farm to market in a basket or, as transportation options evolved, layered within the folds of an egg blanket in back of a horse drawn wagon. As can be imagined, moving eggs even short distances over rutted, unpaved roads often resulted in breakage, and what constituted "an acceptable loss" was open to discussion. A strong disagreement over who was responsible for paying for the broken eggs occurred in rural western Canada in 1911 between the owner of the Aldermere Hotel and a nearby farmer who supplied the hotel's eggs. Joseph L. Coyle, founder and operator of the *Interior News*, the newspaper in nearby Smithers, British Columbia, stepped in to resolve the dispute which necessitated his inventing what came to be called the Coyle Egg-Safety Carton.

For many years Coyle handcrafted his egg cartons from chipboard, providing each of six or twelve eggs with a discrete compartment to isolate it from external stresses.[4] By 1919, Coyle was able to mechanize the manufacturing process for his two-piece paperboard egg cartons, a development that lead to his abandoning the publishing world to join forces with United Paper Products in Vancouver. While that partnership proved short lived, it motivated him to relocate his fledgling company to Los Angeles. There he continued simplifying methods for shipping, storing and assembling egg-separating inserts,[5] and in time licensed the technology to manufacturing firms in Chicago, New York, Pittsburgh and London Ontario for international distribution.

No longer an anomaly, the egg carton became big business. By 1945, Ruth M. Schilling morphed Coyle's concept into a durable, pulp-molded container designed to coddle each of a dozen eggs in its own organically shaped individual hollow. Schilling's one-piece carton introduced the interlocking fastener on the front of the box that joined the lid to the tray.[6] Not to be outdone, in 1966 Arthur J. Weiss refined the design to open like a pair of French doors laterally down the middle of the carton with each flap covering six eggs and pressing closed in the carton's center.[7] That same year, David C. Trimble conceived the one-piece polystyrene egg carton "molded from a sheet of foamed or expanded plastic material," thus enhancing each egg's protection by padded it with foam.[8]

The lesson here is that going to any length to protect eggs in transit from the farm to the market in 1900 would have been unimaginable. Yet today, the cost benefits realized by reducing this form of loss makes the concept of designing, printing, manufacturing, shipping, and disposing of egg crates a universally accepted cost associated with doing business. While losses still occur, and improvements in shipping containers continue to evolve, the idea of walking home from the store with a basket of eggs is passé. Library preservation needs to follow suit.

Principles of Seismically Resistant Housing

Seismically resistant housing builds on well-established guidelines for collection storage as outlined in publications such as the U.S. National Park Service's *Museum Handbook*.[9] The principle of containing the collection within as many layers of protective buffering as possible – boxes stored within boxes – is known as a means to stabilize the physical and chemical catalysts of deterioration. This is analogous to the model of the Russian nesting matryoshka dolls – hollow dolls of decreasing size nested one within the other – but the origin of this theory is rooted in antiquity. The tomb of Pharaoh Tutankhamun (c. 1332-1322 BCE), for example, provides an interesting parallel with the U.S. National Park Service's five layers of protective housing intended to buffer the collection from the elements. The multi-layered components of this universally accepted sheltering model include the following:

1) **Building/facility envelope**: the exterior walls of the structure housing the collection (U.S. National Park Service), analogous to the outside walls of the King Tut's pyramid situated in the Valley of the Kings.
2) **Room/space envelope**: the interior walls of the room immediately enclosing the collection (USNPS), equivalent to the walls of the King's chamber located deep within the pyramid's stone berm.
3) **Equipment/storage furniture**: storage apparatus such as gasketed cabinets, flat map files, or powder coated steel shelving units (USNPS), comparable to the outermost pall frame and three nested inner shrines, each wrapped in linen.
4) **Container/housing**: a casing housing the object such as a box, tray, or other fully enclosed container (USNPS), similar to the quartzite sarcophagus, supported off the ground by a block of alabaster, and covered with a red granite lid, that

contained the King's three nested coffins, the outer two made of wood and the inner one of gold.

5) **Packaging/wrapping materials**: museum-quality materials that cover and/or support the object proper such as tissue, muslin, or polyethylene foam (USNPS), equivalent in the case of King Tut to the linen used to wrap the mummy.[10]

Principles for developing seismically resistant housing rely on these archetypal principles with the addition of concessions made to render fragile collections impervious breakage from vibrations and falling caused by earthquakes. Seismically resistant housing continues to rely on chemically inert materials for containing objects but also incorporates concessions to addressing building integrity, furniture stability, and object fragility.

1) **Building-level modifications:** As possible, design a new or reinforce an existing building structure to incorporate earthquake-resistant bracing or isolation to prevent structural collapse.[11]
2) **Room-level modifications:** Stabilize nonstructural objects to prevent secondary collection damage from falling objects or from broken pipes.[12]
3) **Storage furniture modifications:** Anchor shelving and other storage furniture to the floor of the building so it can sway but not fall over; install closure mechanisms (doors; netting) to prevent or inhibit housing containers from falling or being thrown from the shelves; secure paintings firmly to the wall with earthquake-resistant hangers.[13]
4) **Housing-level Packaging**: As a priority, package the most fragile collection media (glass; ceramics; brittle plastics) in chemically stable housing (boxes; trays) that mechanically insulate these media from shock and vibration and prevent vertical as well as horizontal movement.
5) **Item-level Packing**: Surround individual collection items with chemically stable padding to prevent contact with other materials and pack these individually padded objects snuggly within boxes or trays to eliminate movement or rattling.

Origins of Preemptive Collection Care Strategies

Museum conservators have taken the lead in identifying strategic approaches to protecting collections from earthquakes[14] with many innovative ideas arising from the philosophy of preventive conservation. Defined as, “any measure that prevents damage or reduces the potential for it,”[15] preventive conservation is now almost universally celebrated as a cost-effective museum management strategy, but the concept actually originated with library conservator Peter Waters, who defined “phased conservation” at its inception as an approach to addressing huge preservation problems in phases beginning with stabilization of gross, collection-wide issues to protect the greatest number of significant materials as the priority rather than lavishing conservation treatment on single items at the expense of the whole. As he noted, “[t]he *term* phased conservation was first introduced by the Conservation Office of the Library of Congress during the mid-seventies,"[16] but the idea developed from Mr. Waters' involvement in the Florence flood recovery of 1966 and the need to prioritize recovery in stages due to the vastness of the problem. In practice, this idea evolved into ways of minimizing potential future risks and is interchangeable with museum preservation concerns as the ways to do this spread over very large collections have to be strategic, applied incrementally, and be affordable.

Overcoming resistance to the idea of implementing strategies to safeguarding the collection from seismic risk includes a process of identifying the magnitude of the risk, e.g., how large is the event anticipated to be? How resistant to seismic activity is the library, archive or museum building?[17] What anticipated building and collection losses are likely to occur? The U.S. the National Earthquake Hazards Reduction Program under the auspices of the Federal Emergency Management Agency has developed a modeling program called HAZUS that can be used to estimate earthquake damage to individual buildings and their contents. This allows cultural institutions to better understand the way the building they occupy is likely to perform in earthquakes of various magnitudes as well as to estimate the damage and fiscal loss to the building and to the collection associated with each event.[18]

Approaches for improving building performance during earthquakes[19] can be found in the museum conservation literature where it is also possible to locate descriptions of seismic reinforcement approaches applied to specific monumental sculpture.[20] More rare but beginning to appear are methodologies for protecting extremely valuable antiquities collections.[21] While these technical solutions are illustrative of the exciting new possibilities developed during the past three decades, they can also be intimidating because of the large cost and sophisticated technical requirements required for their implementation. Inexpensive approaches to museum seismic housing options tend to be very scarce[22] and for libraries, nonexistent, yet this is the area of greatest promise to impact vast numbers of vulnerable collections. And there are practical similarities because library collections contain three-dimensional artifacts, paintings, and other objects traditionally associated with museum collections, and museums house fragile glass plate negatives, papyrus, and other fragile media more commonly related to libraries. In either case, minor housing improvements can make a significant impact on the likelihood of certain media to survive even minor ground tremors.

Send in the Foam

A recent example of a quick, cost effective intervention adapted to protecting an anthropology collection was designed by summer interns Stephanie Johnson and Ida Pohoriljakova and presented as a poster at the 2014 Annual Meeting of the American Institute for Conservation (AIC).[23] Their approach was to reorganize a large Chinese ceramics collection by size and shape to maximize storage efficiency within the museum's existing commercially manufactured open-face drawer-style storage cabinets. Each sliding storage cabinet drawer was fitted with several commercially available open-face trays, or the mounts used previously for displaying the objects, to subdivide the drawer space into sectors. With adequate distance allocated between objects to ensure their physical safety, each Chinese ceramic was separated with partitions termed “Blueboard Sandwiches” by their creators. Blueboard Sandwiches were made with a central layer of stiffener (corrugated archival board) padded on both sides with low-density polyethylene foam and used as custom-fitting separators between objects.

What is notable about this project is it established a simple protocol that can be carried out by future interns or volunteers that will help prevent fragile Chinese ceramics from banging together during even minor earthquakes, thereby reducing the collection’s risk of widespread physical damage. Utilized existing resources (the museum’s museum objects storage cabinets) and minimal raw materials (corrugated alkaline cardboard stiffener and Plastazote® LD45 polyethylene foam), the collection was both better organized and better protected for these interns’ efforts. A design flaw I discussed with Johnson and Ida is that earthquake forces are capable of lifting objects vertically out of open-face drawers as well as causing them to bash together within the drawer. Their response was they had considered “making seat belts for each tray,” but felt the close proximity of each tray’s contents to the bottom of the tray above would limit vertical liftoff. I sincerely love the simplicity of their approach, but suggested that one or more layers of polyethylene foam cut to fit the space above each open drawer would prevent vertical acceleration leaving the project easily accessible and simple to replicate.[24]

Following the identification of vulnerable, fragile collections stored over fault lines, a realization is that a combination of snug compression between objects to abate acceleration, separated by layers of foam padding to minimalize vibration is likely to do more to protect collections than doing nothing. When applicable, a cheap and effective preemptive collection care strategy is to send in the foam.

Case Studies in Seismic Housing Solutions for Library Collections

Seismic engineers who provided input on this project are Walter Arabasz and Barry H. Welliver. They suggested our solutions were in line with strategies being explored internationally for non-structural earthquake mitigation and encouraged our developing prototypes that work and are affordable.[25]

Example 1: Glass Plate Negatives

Environmental Scan

The University of Utah’s J. Willard Marriott Library is situated in an arid region of the western United State less than one mile (<1.6 kilometers) from an active segment of the Wasatch fault. During the past 6,000 years, the Wasatch fault has produced magnitude 6.5 to 7.5 earthquakes approximately every 400 years, and about 500 minor earthquakes occur in this region each year. The Wasatch fault is called a ‘normal fault,’ slipping primarily in a vertical direction meaning the that mountains adjoining Salt Lake City to the east will rise relative to the valley floor. Estimates by local seismographers forecast a 1 in 4 chance the region will experience a large earthquake (designated locally as "the Big One") during the next 50 years.[26]

The J. Willard Marriott Library building underwent a retrofit (June 1, 2005-June 30, 2009) that brought the 500,000 square foot (46,000 m2) building up to seismic code. The $US 80,000,000 building renovation project included installing inverted V-braced seismic steel frames around the perimeter of each floor above grade for human life safety, as well as improving the inadequate column to floor connections that would otherwise likely cause the five-story structure to pancake during an earthquake. The library's four-post freestanding steel shelving was anchored to the concrete pad of each floor and reinforced with sway braces attached between each double-faced section, improving housing conditions for the library's three-million volumes valued at approximately $US 330,000,000.[27]

As possible, the building in which the glass plate negatives or other fragile collections are housed should itself be seismically reinforced, either through new construction that meets or exceeds the International Building Code,[28] or by retrofitting the existing facility.[29] While this step may seem prohibitively expensive at the outset, collection protection and human life safety are both served by these types of improvements. Opportunities for progress in this area may prove possible if collection care can be tied to the institution's goals for improving human life safety and so prove achievable if pursued with limitless persistence, boundless patience, and a modicum of creativity. At the end of the Environmental Scan it remains the goal of this paper to encourage active steps to improve storage conditions for the collection, beginning with the most fragile items and starting with the most basic item-level packaging. In certain quarters of the globe earthquakes are a certainty. Any improvement in collection storage is likely to improve the survival rate of fragile collections where inactivity due to misplaced priorities is simply to a precursor to nature's inevitable destruction.

Packing Glass Plate Negatives and Lanternslides

The raw sheets of glass used to make glass plate negatives originally came to market in unprotected wooden boxes, so it remains possible even now to come across groups of developed negatives kept in those same boxes, or stored glass-to-glass in metal file drawers or similar crude containers. It is not uncommon to still find large collections of glass plates separated by nothing at all, or at best by buffered paper sleeves or four flap envelopes. So to begin, each plate should be protected within a loose-fitting, alkaline paper sleeve or four flap envelope that conforms to the International Standards Organization's (ISO) Photographic Activity Test (PAT) (ISO 18916:2007).[30] The seam of the paper sleeve should occur on its edges rather than in the center and the negative inserted so its emulsion side faces away from the seam to prevent potential abrasion or damage from direct contact with the adhesive. Four flap envelopes avoid this issue completely.

The U.S. National Archives and Records Administration (NARA) recommends packing warped glass plates prior to moving them within inert, extruded, closed-cell polyethylene foam envelopes.[31] For purposes of seismic mitigation, it is advisable to apply this same standard of care to all glass plates such that each rests within an inert polyethylene foam L-sleeve. L-sleeves are easily made from commercially available 1/8-inch thick (0.125 in = 0.31750 cm) polyethylene foam envelopes sealed on three sides.[32] By trimming the open end and one sealed edge of the foam envelope an L-sleeve is produced. These L-sleeves must be sized to enclose the glass plate completely and conform precisely to the interior dimensions of the storage box.

Once protected within polyethylene foam envelopes, the glass plates can be stored within commercially manufactured, buffered, paperboard boxes positioned vertically on a long edge. Plates measuring less than 4 x 5 in (10.16 x 12.70 cm) can be housed in archival top loading 'shoeboxes,' while plates measuring less than 8 x 10 in (20.32 x 25.40 cm) can be packed into standard, flip-top 'document' boxes.[33] The foam envelopes should be packed snuggly to isolate each piece of glass and prevent potential rattling. The addition of foam to separate each plate reduces the box's weight considerably from what it would be packed solid with glass, thereby reducing future handling risks in what is otherwise an exceedingly heavy box. Partially filled boxes should be padded out with inert foam to completely eliminate unfilled space, and finished boxes labeled to indicate they contain 'Glass' and are 'Fragile.'

With the glass housed at the item- and container-levels, next the storage furniture is modified. A rectangular, shelf-sized tube made from Coroplast, an inert polyolefin copolymer extruded in corrugated sheets,[34] is constructed to occupy each shelf of the (preferably) over-wide powder coated steel library shelving used for storing the glass plate negatives. One rectangular Coroplast tube will accommodate five shoebox-sized or document-sized archival storage box. These boxes are padded out with a bed of Ethafoam,® and inert polyethylene foam, within the rectangular Coroplast tube. Coroplast is an extremely durable material, and unlike corrugated paperboard, is malleable enough to hold creases (assisted by softening with a commercial electric hairdryer) yet able to withstand the stress required to force the snug-fitting housing into an existing shelf space.

Coroplast blanks to make each rectangular shelf housing are cut to fit precisely within the shelving's steel frame to constrain the Coroplast tube from sliding forward in the same manner the steel shelf is held in place. After trimming, each Coroplast housing is folded to produce a four-sided rectangular tube with the fifth side serving as an overlapping flap for closure. Two Coroplast housings fit back-to-back in pairs on each (3-foot deep) double-faced unit, so that each shelf accommodates 10 archival storage boxes.

The interior of the Coroplast housing is padded with strips of Ethafoam® (formerly manufactured by Dow Chemical) cut from dense, chemically inert polyethylene planks or rolls.[35] Ethafoam® comes in various thicknesses (1/8 in, 1 in, 2 in, and 4 in / 0.31750 cm, 2.54 cm, 5.08 cm, 10.16 cm) and that can be cut to snugly surround, separate and pad archival boxes used to house the glass plates.

Velcro hook and loop straps are attached to the front of the rectangular Coroplast tube to simplify closure but are not intended to be seismic restraints. The Velcro is mechanically attached to one side and five-sided Coroplast housing with nylon pop rivets. Greater closure strength could be achieved by lacing cotton ties through the Coroplast that wrap around the tube and are tied in front of the housing, a useful consideration were the addition of steel doors (as described below) is not included in the design.

Modifying Existing Shelving

Shelving is a major cost in developing a seismic housing solution for glass plate negatives and other fragile collections. New shelving designed to withstand an earthquake's vertical and lateral forces can be purchased, but existing shelving is often where one starts and its can also be effectively modified with reinforcing components. In either instance the design must be engineered to address locally anticipated seismic stresses.[36] Standard reinforcements to steel four-post shelving include sway braces attached between each double-faced section or for cantilevered shelving, pyramidal-shaped earthquake gussets between each cantilevered section. Most critically, freestanding, double-faced library shelving – cantilevered or four-post – must be anchored to the concrete pad of the building's floor with heavy-duty hardware that facilitates swaying but will prevent shelving collapse during an earthquake.

As mentioned above, each 1 yard (0.9144 m) wide section of shelving must be 'closed' on the front to prevent its Coroplast tube and glass-filled contents from being rocked from the shelf to the floor during an earthquake. In our own case working with four-post shelving this was achieved by attaching matched pairs of steel doors to either side of each section's frame, thereby simultaneously enclosing the contents of all six shelves from the front and the back behind closed doors. When not in use these doors must remain locked to mechanically engage a pair of steel rods that structurally insert into the top and the bottom of the shelving unit to prevent opening during a seismic event. Alternatively, some manufacturers of cantilevered shelving produce steel restraining bars that can be attached to the front of each shelf that are easily removed to enable access.[37] As mentioned previously, it is imperative with either shelving type that the frame is anchoring to the floor with durable hardware as specified by a seismic engineer.[38]

Costs

The expenses associated with implementing the seismic housing solution for glass plates described above is not prohibitive. Raw materials to rehouse 18,000 individual glass plate negatives and lanternslides in 2013 cost $US 0.50 for 4 x 5 in (10.16 x 12.7 cm) glass negative and $US 1.30 for each 8 x 10 in (20.32 x 25.4 cm) negative.[39] The project required approximately two-hours labor per shelf to prepare and rehouse the collection, and a total of 66 single-faced shelves were treated in the project (132 total hours of labor). Closure for the face of the four-post shelving system required purchase of 22 pairs of steel doors at a cost $US 682 per pair, installed ($US 15,004 total).

Example 2: Papyrus Sandwiched in Traditional Glass Mounts

Glass sandwich mounts have been used since the late-nineteenth century to house papyrus due to the ready availability of glass, its structural rigidity, and the unimpaired visual access it provides to papyrus.[40] In the case of ground shaking, however, the fragility of the mounts put the papyrus at risk as a shattered mount could easily damage its fragile contents.

The smaller glass mounts (≥ 8 x 10 in / 20.32 x 25.40 cm) in the Marriott Library's papyrus collection had long been stored in traditional steel file cabinets suspended within hanging files for ease of access. The larger mounts were housed in a small, steel horizontal map cabinet. Both scenarios left the glass susceptible to breakage but a design feature that needed to be factored into the question of improving seismic stability was the original storage cabinets had to be retained due to space and fiscal constraints.

Packing Papyrus Sandwiched in Traditional Glass Mounts

Each of the smaller papyrus glass mounts were housed in an inert polyethylene foam envelope trimmed to form an L-sleeve, as described above. With this padding in place, the hanging files were packed very snugly within each file drawer, essentially eliminating the risk of moving during ground shaking yet still retaining their accessibility.

The larger papyrus glass mounts stored in a horizontal map cabinet were vulnerable to breaking during ground shaking simply by being able to bang together in the drawers. As in the example of the anthropology collection described above, this papyrus collection was first organized by size and shape to maximize storage efficiency within the drawers of the existing map cabinet. Each papyrus glass sandwich mount in its polyethylene foam sleeve was measured for a four-flap binder. The binders were made from archival corrugated E-flute 1/16 in (1.587 mm) thick board and designed to fill the drawer -- stacked two-deep -- as tightly as possible. The four-flap binders were designed with full-length horizontal flaps and with vertical half flaps meeting in the center. All the flaps were creased to fold in the corrugated board's grain direction. Remaining voids in the drawer were filled with layers of Coroplast adhered together with 3M™ 415 double-sided tape to improve compression.

The principle for this rehousing project was to pad each papyrus glass mount, house it snugly in a protective corrugated E-flute four-flap binder, and measure the binders to fit each drawer like puzzle pieces to eliminate potential rattling between objects.

Modifying Existing Cabinet Storage

Nonstructural seismic mitigation for the file cabinet housing papyrus glass mounts in hanging folders and the metal map cabinet was accomplished by bolting them to wall studs using metal "L" brackets.

Example 3: Transcription Discs and Other Fragile Sound Recordings

While numerous sound recording media are fragile (e.g., Edison Blue Amberol cylinders; 78 rpm shellac and mineral-filled records) acetate transcription discs, most commonly manufactured with an aluminum core coated with nitrocellulose lacquer plasticized with castor oil, are so physically fragile that in the words of Gilles St-Laurent (Head Audio Conservator, Library and Archives Canada) they represent "the least stable type of sound recording."[41] Following digitization, a large collection of original acetate transcription discs intended for permanent retention was evaluated for seismic housing. Due to their projected future low-use, it was determined the collection would be best stored in the library's three-story, two million volume automated storage and retrieval system (AS/RS).

Evidence of an AS/RS system's performance following the 6.7 magnitude 1994 Northridge Earthquake at Oviatt Library, California State University, Northridge indicates the racks remained undamaged and the elevated bins did not fall from the shelves. While Oviatt Library's open stacks required approximately 600,000 books be re-shelved, according to the library's website, its then-new HK Systems "Automated Storage and Retrieval System was undamaged" by the event.[42]

The University of Utah's Marriott Library installed a similar system also manufactured by HK Systems 15-years later referred to locally as the Automated Storage Center (ARC). Situated in a standalone, seismically resistant 3.5-story building, the structure is environmentally controlled with its own standalone heating, ventilating, and air conditioning (HVAC) system.[43] Containing 19,181 open-topped metal storage bins, the ARC employs automated 'shuttles' to retrieve bins that collectively hold roughly one million collection items. The shuttles move horizontally on a track in an aisle between three-story-tall racks and can elevate to the appropriate height to pull or return bins to their fixed locations. Movement of the bins is effortless and provides the contents no significant vibration as the shuttle transports the bins from the racks to human workstations where the contents are retrieved.

The 16-inch (40.64 centimeter) diameter transcription discs retained their original acidic craft paper sleeves and these were preserved as part of the object's historic packaging. A folded sheet of 5.4-mil DuPont™ Tyvek® (a spunbonded olefin perforated with a surface pattern to soften it) was inserted between the disc and the acidic paper sleeve to provide a soft, flexible, chemically inert liner. The sleeved disc was enclosed in a 1/8-inch (0.3175 centimeter) thick polyethylene foam L-sleeve[44] cut to snugly fill the interior of a commercially manufactured top-loading phonograph record box.[45] The record boxes were loaded into the top-loading metal ARC bins prepared by padding the base with two layers of 1/8-in (0.3175 cm) thick polyethylene foam and from 4- to 6-in

(10.16-15.24 cm) of Dow Ethafoam (polyethylene) around the surrounding four edges. The goal was to completely pad out the bin to prevent any movement of the fragile acetate discs within the boxes or the boxes within the bin before returning the loaded bin to its slot in the ARC's three-story tall. Seismically reinforced rack storage.

Example 4: NASA Rocket Models

James Chipman Fletcher was the president of the University of Utah from 1964 to 1971, and went on to serve two terms as the Administrator of NASA (April 27, 1971, to May 1, 1977, and again from May 12, 1986, to April 8, 1989). A model of each space probe launched during Dr. Fletcher's tenure was presented to him as a commemorative gift, and upon his death (December 22, 1991) these models along with the rest of his archive were donated to the Marriott Library. Each model was a unique handcrafted scale-model rocket or satellite replica mounted on a wooden base, and these ranged in height from 12-inches (30.48 cm) to 7.5-feet (2.286-meters). Seismically stabilizing the 7.5-foot tall (2.286-meter) Saturn V moon rocket was the greatest challenge posed by these unique models, its greatest source of potential damage simply being the risk of falling over during an earthquake.

To provide a structural base, a rectangular foundation support covered in grey book-cloth was constructed into which the rocket's wooden stand was placed. Two opposing rigid sidewalls taller than the rocket were constructed from Coroplast[46] and permanently affixed to the rectangular foundation support with nylon snap rivets.[47] Attached to each wall were five Ethafoam half-collars covered in grey book-cloth. These aligned at strategic points along the rocket's fuselage to surround the rocket and provide structural support. The five half-collars attached to their opposing counterpart to form full collars and were connected with quick-release Velcro fabric hook and loop fasteners.

The two remaining sidewalls were added to enclose the open sides of the rocket. These wrapped around and attached to the first sidewalls with nylon snap rivets. A snug-fitting lid made of Coroplast and finished with nylon snap rivets was fitted over the top of the four sidewalls. The result was a lightweight but rigid, water resistant tubular enclosure. Nylon strap webbing was threaded through the walls of the box and fastened around the building's earthquake-resistant structural columns with a two-part buckle when in storage. The aesthetic of the design has proved so successful the library has chosen to exhibit the Saturn V rocket in its Coroplast storage box with one wall removed and the Ethafoam collars still in place , the nylon strap webbing firmly attached to a concrete column.

Conclusion

Roiling, heaving, and undulating library steel shelving containing thousands of glass plate negatives and other unique, fragile material may seem problematic, but with the application of preventive (or phased) conservation approaches, the situation need not turn out badly. Beginning with the premise that any improvement is likely to result in benefits, mitigation strategies for cultural property begin by determining the most vulnerable collections due to their fragility and prioritizing their rehousing based on value to the institution. Determining how best to protect each object or group of objects from the intense dynamism of the next earthquake is like designing an egg carton for eggs to be shipped over extremely rocky roads in an open wagon and should encompass five levels of analysis.

Beginning at the building-level, 1) if possible it makes sense to design a new or to reinforce an existing building structure so it incorporates earthquake-resistant bracing or isolation. Ensuring the structure does not collapse is essential as this is the first layer of protection or potential risk to which the collection is exposed. Potentially an expensive and complicated problem, structural mitigation may appear unfeasible. However, by identifying the risk and persisting in the need for stabilization for human life safety as well as loss reduction, change is possible over time. 2) At the room-level, stabilize nonstructural threats to prevent secondary collection damage from falling objects or broken pipes. 3) Storage furniture must be earthquake braced internally and secured to the building's floor so it can sway but not fall over. As possible, install closure mechanisms (doors; netting) to prevent or inhibit (hopefully boxed) collections from falling or being thrown from the shelves. Secure paintings to the wall with earthquake-resistant hangers. 4) As a priority, package the most breakable collection media (glass; ceramics; brittle plastics) in chemically stable housing (boxes; trays) that mechanically insulate fragile collections from shock and vibration, and prevent vertical as well as horizontal movement. And, 5) surround individual collection items with chemically stable padding to prevent contact with other materials, and pack these individually padded objects snuggly within boxes or trays to eliminate movement or rattling.

For institutions located within seismic zones, post-earthquake proof of concept for any step taken is assured -- and inevitable. Not acting will also net a predictable result and many fragile media are very expensive to repair. Simply packing the most delicate and valuable collections with well reasoned-care may prove sufficient that things survive. Eggs did not always travel to market in egg cartons, but once the option existed it seemed a shame not to put a good preemptive strategy to use.

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[24] Email communication with Ida Pohoriljakova and Stephanie G Johnson Wednesday, 25 June 2014.

[25] Walter Arabasz, Research Professor Emeritus, Geology & Geophysics, University of Utah, is the recipient of the Lifetime Achievement Award in Earthquake Risk Reduction, Western States Seismic Policy Council (04/2008); John Wesley Powell Award (for significant contributions in advancing national earthquake monitoring and earthquake safety), U.S. Geological Survey (03/2007); Alumni Award of Excellence for Science, Boston College (10/2006); and the Outstanding Service Award, Utah Seismic Safety Commission (07/2001).
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[30] The International Standard: Imaging Materials — Processed Imaging Materials — Photographic Activity Test for Enclosure Materials (ISO 18916:2007) can be found at the following link, retrieved from the World Wide Web 28 June 2014: http://211.67.52.20:8088/xitong/bz%5CISO-18916-2007.pdf The Photographic Activity Test (or PAT) is described by the Image Permanence Institute at the following link, retrieved from the World Wide Web 4 May 2013: https://www.imagepermanenceinstitute.org/testing/pat
[31] "Interleave warped plates with thin polyethylene foam (Ethafoam or Volara) to avoid cracking the plates when they are compressed against each other or adjacent flat plates." The current specification applies this recommendation more broadly to encompass all glass plate negatives; lantern slides; papyrus glass plate sandwich housings; fragile early sound recordings, etc. See, How do I move glass plate negatives? Approaches to Moving Glass Plate Negatives at the National Archives and Records Administration, retrieved from the World Wide Web 4 May 2013: http://www.archives.gov/preservation/holdings-maintenance/moving-glass-plate.html See also: Conservation Center for Art and Historic Artifacts, "Enclosure for Broken Glass Plate Negatives," 1992, recovered from the Storage Techniques for Art, Science and History website 6 June 2014, http://stashc.com/the-publication/containers-2/folders-envelopes-enclosures/enclosure-for-broken-glass-plate-negatives/ and, Sarah S. Wagner, "Enclosures for Glass and Film Negatives and Lantern Slides," 1992, retrieved from the Storage Techniques for Art, Science and History website 6 June 2014, http://stashc.com/the-publication/containers-2/folders-envelopes-enclosures/enclosures-for-glass-and-film-negatives-and-lantern-slides/
[32] Janet Pasiuk, "Safe Plastics And Fabrics For Exhibit And Storage," National Park Service Conserve-O-Gram 18/2 (August 2004), retrieved from the World Wide Web 4 May 2013: http://www.nps.gov/museum/publications/conserveogram/18-02.pdf ; Paul S. Storch, Exhibits and Storage Materials Handbook: Test Results Index Materials Glossary (St. Paul, MN: Minnesota Historical Society 2007, retrieved from the World Wide Web 4 May 2013:

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[33] Larger glass plate negatives, e.g., 18-inch x 22-inch (45.72 x 55.88 cm), require housing within polyethylene foam envelopes in 'flats,' (horizontal storage boxes) in limited quantity if the dimensions are similar, or individually if not. Added separation between each plate using sheets of corrugated Coroplast or alkaline paperboard is recommended.

[34] Annabelle F. Shrieve, Vauna Gross, Jeff Hunt, Tomomi Nakashima, and Randy Silverman, "Boxing the 'Big Huge': A Preventive Conservation Conundrum," *International Preservation News* 57 (August): 31-34.

[35] In the U.S., Ethafoam® is available from suppliers such as Masterpak: http://www.masterpak-usa.com/cat_203_ethafoam.htm

[36] Shelving and its installation of must comply with seismic requirements defined in the Uniform Building Code, Chapter 23, and the California Building Code (California Code of Regulations, Title 24, Part 2). For further information, see: Earl Siems and Linda Demmers, Library Stacks and Shelving (Cerritos, CA: Libris Design Project, 2004), retrieved from the World Wide Web 8 June 2013: http://www.librisdesign.org/docs/ShelvingforLibraries.pdf

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[39] Raw materials for this rehousing project included: alkaline paper sleeves, polyethylene foam envelopes, archival shoeboxes, archival document boxes; Ethafoam® planks; and, sheet Coroplast.

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[45] Prefabricated top-loading phonograph record boxes sized to accommodate 16-inch discs measuring 17 x 17 x 6 inches (43.18 x 43.18 x 15.24 centimeters) are available from Hollinger Metal Edge, catalog number PDT16, http://www.hollingermetaledge.com/

[46] Coroplast is manufactured in full 8-ft tall (2.4384 m) sheets.

[47] Scott Williams has seen "boxes bonded with mechanical fasteners like rivets, Chicago screws, hot melt glue squeezed into channels, ribbons, and tabs; and adhesives like double sided pressure sensitive adhesive (PSA) tapes and glues, including hot melts on intact surfaces (not squeezed into channels). The only failures of load bearing bonds have been with the adhesive methods. Double-sided tapes and hot melts do not adhere well to low-surface energy surfaces such as polypropylene. Only adhesives recommended by the suppliers should be used. PSA tapes and adhesive should never be used for load-bearing bonds because the PSA generally has low shear strength and flows or creeps when stressed." Email communication with Scott Williams, Senior Conservation Scientist (Chemist), Canadian Conservation Institute, 11 October 2011.