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SEISMIC RISK MITIGATION OF OPERATIONAL AND FUNCTIONAL COMPONENTS IN HOSPITALS – THE BRITISH COLUMBIA EXPERIENCE

Jay LEWIS, MBA,[1] Micky WANG, PEng. [2]

SUMMARY

The National Building Code of Canada requires a higher level of seismic performance for hospitals than for most other buildings. These facilities contain many patients who require medical services for both acute and chronic health problems. They also must provide emergency treatment for those injured in an earthquake. In 1999, the government of British Columbia launched a pilot Seismic Mitigation Program for schools, hospitals and other critical provincial buildings. It was funded at $133 million. This paper will describe the challenges and results of the seismic risk mitigation work done on the operational and functional components (OFCs) in thirty-two hospitals in Southwest British Columbia by M. WANG Engineering Ltd. and Terra Firm Earthquake Preparedness Inc. over a four year period.

There are many challenges associated with conducting a seismic risk mitigation program in a hospital. These include the very high density of OFCs; the continuous nature of their operations; the requirement for the maintenance of sterile conditions; the need to minimize noise levels during installation work; high security requirements; and extensive project management control. The lessons learned from hospital seismic risk mitigation work are applicable to any other facilities, as they represent the most difficult scenario in the industry.

This paper will examine the main stages of seismic risk mitigation: the initial risk assessment using the Canadian Standards Association's new CSA S832 format; the selection of components to be restrained; seismic engineering; installation and documentation. The challenges faced and solutions used in each of these areas will be described. The results of this effort, the largest of its type in the world to date, will assist in the evolution toward improved performance in this rapidly growing and highly specialized field.

INTRODUCTION

The Importance Of Hospitals

In the aftermath of a significant earthquake, citizens in every country turn to their hospitals. They expect to receive treatment for whatever injuries are sustained during the event. Yet, too often, when they arrive

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[1] President, Terra Firm Earthquake Preparedness Inc., Canada. J.lewis@terrafirm.ca
[2] Principal, M. WANG Engineering Ltd., Canada, m.wang.engineering@telus.net

at the hospital, it is being evacuated due to the damage incurred and services are severely restricted or non-existent. Occasionally, there is structural damage and in extreme cases, structural failure. The facility may have experienced damage to its operational and functional (nonstructural) components (OFCs), resulting in its closure.

A hospital facility is a brittle entity. Ironically, modern hospitals with the most advanced technology are the most seismically vulnerable. The high densities of sophisticated equipment, heavily dependent on computer controls and telecommunications, are susceptible to complete failure, often triggering evacuation of the building. A large hospital also has hundreds of kilometers of pipes containing water, fuel, medical gases, medical waste, and other substances. The rupture of these pipes within the structure can cause fire, flooding, contamination and the loss of life-sustaining systems.

Both structural and non-structural damage to hospitals may result in their closure. Administrators are understandably reluctant to evacuate their facilities. The evacuation of a hospital is a risky business, effectively terminating the support of current patients and shutting down medical services to the public at a time of emergency. Furthermore, patients are being released into an earthquake-damaged environment. Inevitably, under these circumstances, there is a risk of further medical complications and deaths.

Hospitals contain a massive investment in OFCs, which can be heavily damaged or destroyed during an earthquake. Figure 1 indicates that the vast majority of the investment in a hospital is in operational and functional components (92%) Miranda [1]. While life safety and facility functionality remain the paramount consideration in installing seismic risk mitigation systems, the protection of the considerable assets, whether publicly funded or private sector owned, cannot be ignored. Hospitals are vital elements in every community's post disaster plan and require special attention in any seismic risk mitigation effort.

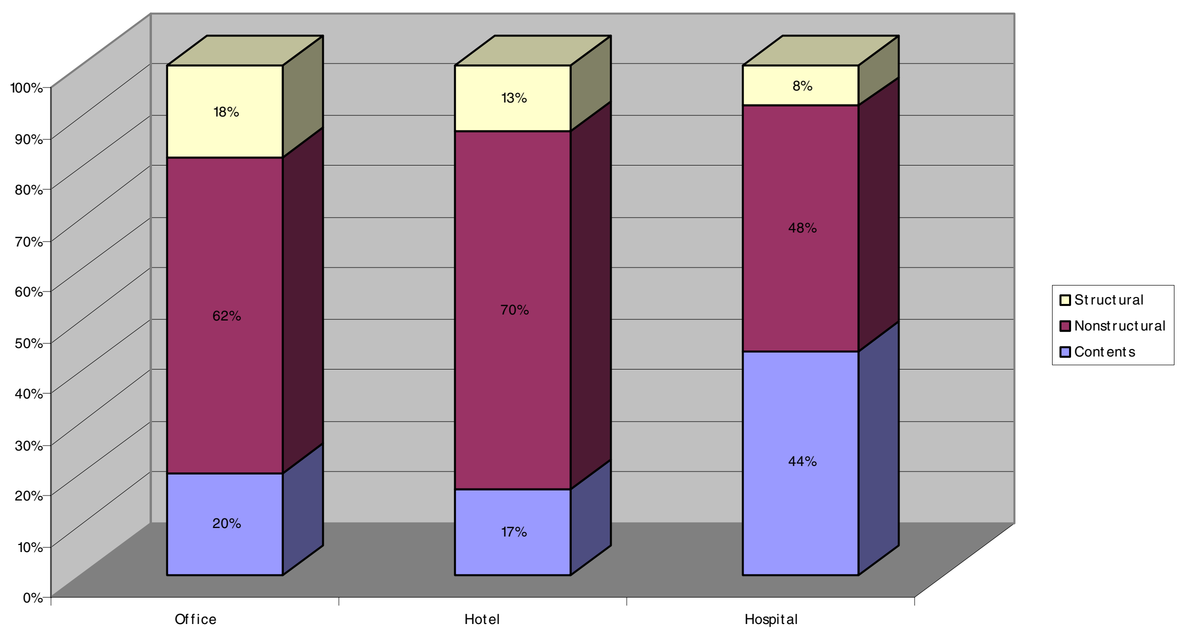

Figure 1. Typical Investments In Building Construction

Seismic Performance And The National Building Code Of Canada

A recent overview of the seismic design issues relating to the National Building Code of Canada (NBCC) reveals a long history of neglect in that area. The earthquake engineering requirements for OFCs first entered the NBCC in 1953 Assi [2]. With each succeeding edition, engineering elements have become more sophisticated and defined. Until recently, the construction industry has ignored, the seismic requirements relating to “parts and portions,” architectural, electrical and mechanical components. As a result, the OFCs in most buildings built over the past fifty years are largely unrestrained, in spite of NBCC requirements.

There are a number of reasons for this significant omission. They include:

1. Inadequate regulatory standards: A rather nebulous definition in the NBCC as to exactly which components require restraint;
2. Poor directives for implementation: A performance code rather than a prescriptive one; no visual guidelines;
3. Inadequately written seismic specifications: The construction industry is forced to exploit omissions in order to deliver competitive bids;
4. Lack of industry expertise: Poor understanding of seismic restraint design and installation practice until recently;
5. Inadequate Code enforcement: Lack of training and awareness of building code officials concerning requirements and installation of nonstructural seismic mitigation systems;
6. Fiscal constraints: Reluctance on the part of building owners to add cost to buildings when the requirement is not clearly defined and enforced.

The end result of this situation is that most buildings in British Columbia have little or nothing in the way of seismic risk mitigations systems for their OFCs. Furthermore, even new buildings currently under construction are only reaching a level where about 50% of required OFC seismic risk mitigation work is completed. While this is an improvement from a decade ago, there is still much work to be done before we regularly produce earthquake resilient buildings as required by the NBCC.

The British Columbia Seismic Mitigation Program

In November of 1997, George Morfitt, the Auditor General of British Columbia, issued a report on “Earthquake Preparedness” in this province Morfitt [3]. His position was charged with ensuring the appropriate financial performance of the provincial government. He found that “governments in British Columbia were not yet prepared for a major earthquake.” This report was followed in 1999 by another entitled “Earthquake Preparedness; Performance Audit”, produced by a Select Standing Committee on Accounts of the Provincial Legislature Gingell [4]. It “encourages the provincial government to make the seismic upgrading of provincial infrastructure a priority in British Columbia.” It further recommended, “that provincial infrastructure seismic upgrading projects include a consideration of nonstructural damage mitigation measures, such as seismic restraint systems.”

As a result of this activity, the British Columbia Ministry of Finance and Corporate Relations created a Seismic Mitigation Branch in 1999 with $133 million in funding, to run a pilot Seismic Mitigation Program over a three-year period. The time frame was later changed to five years when it became apparent that a program of that nature could not be ramped up at such a rapid pace. The Program funded seismic retrofit work in schools, hospitals and critical infrastructure buildings. The Branch was lightly staffed with four full time employees and occasional support staff.

In the first year of activity, the greater emphasis was placed on OFC seismic upgrading work which was considered to produce the greatest risk reduction per dollar. In later years structural upgrading received greater emphasis. For a comparatively short period, the Seismic Mitigation Program was a world leader, generating significant and innovative activity in this field. The Program resulted in the rapid development of OFC seismic risk assessment guidelines and supporting software. Engineering design methodologies were advanced. Fabrication and construction techniques were refined. An array of project and program management tools was brought into play. As a result, a new level of awareness was fostered among consultants, facility managers and healthcare administrators throughout the region.

In spite of its success, the Program fell victim to provincial government fiscal belt tightening. After four years of operation and with ten to fifteen percent of the work complete, the Seismic Mitigation Branch was closed and the remaining upgrade funds were distributed to the schools, hospitals and other facilities. The government's announced plan is to continue the seismic upgrading work "within the established annual operating and capital budgets of each agency" British Columbia Ministry of Finance [5]. Although the Program has been discontinued, its high volume of activity yielded substantial knowledge discussed in this paper.

SEISMIC RISK MITIGATION ELEMENTS

The OFC seismic risk mitigation process has a number of defined elements. Each element and its sequencing in the process is important if the work is to be done efficiently and cost effectively. These elements include: seismic risk assessment; project definition; engineering; project management; fitting fabrication and system installation.

Seismic Risk Assessment

The CSA S832 Approach To Risk Assessment

The seismic risk assessment of a hospital is a complex process. Hospitals contain thousands of OFCs, and large hospitals may have tens of thousands. Deciding how to approach this array of equipment logically requires an engineering based risk assessment process in order to maximize the efficiency of the mitigation investments and reduce liability. Fortunately, at the same time as the British Columbia Seismic Mitigation Branch was launched, the Canadian Standards Association was making available to Technical Committee members the early versions of "CSA S832-01 Guideline for Seismic Risk Reduction of Operational and Functional Components (OFCs) of Buildings" Canadian Standards Association [6]. Using the risk assessment methodologies included in the guideline, a data acquisition, calculation and risk reporting software was developed.

By assessing soil, building and component characteristics, an OFC vulnerability risk score is attained. Then life safety and performance requirements are considered to yield a consequence risk score. The total CSA risk rating score of an OFC is the product of the vulnerability risk score and the consequence risk score. As an optional enhancement of the standard CSA risk rating, a final factor can be added to incorporate Property Protection values provided by facility personnel. The property protection value is intended to reflect the replacement cost of an OFC and impacts of that expenditure on the facility. The total final risk rating is a product of the CSA risk score and the Property Protection factor. It is important to seek the input of facility personnel and users of specialized equipment for both the Functionality and Property Protection values as the assessor necessarily may not be fully aware of the function or cost of some OFCs. At the end of the seismic risk assessment process, every OFC within the project is assigned a total risk rating score. The resulting risk number is not meant to be an absolute value for the risk level, but is designed to yield a relational value, which can be compared with those of the other components assessed.

An example of a typical risk report is portrayed below de Koning [7].

Table 1 - Typical seismic risk assessment output table

Operational Functional Components	Risk Parameter Scores	Seismic Risk Score	Photograph
Floor: **Parkade** Room: **Plaza Level Generator Room** OFC: **Genset A** Tag: **001**	Restraint Gap Overturning Location Vulnerability **10 1 1 1 4.6** Life Safety Functionality Consequence **5 5 10** Comments: **250KW/312KVA, Generator only weighs 825 Kg. Spring mounts not seismically rated. Motor 6 cylinder Iveco Aito**	**46.0**	
Floor: **Parkade** Room: **Plaza Level Generator Room** OFC: **Silencer** Tag: **002**	Restraint Gap Overturning Location Vulnerability **10 1 1 1 4.6** Life Safety Functionality Consequence **5 5 10** Comments: **Silencer 572mm diam. X 1498 mm long. Inside piping runs 1752mm turns 90 deg. Runs 1448mm and exits through wall.**	**46.0**	
Floor: **Parkade** Room: **Parkade Entrance** OFC: **Exhaust Pipe** Tag: **003**	Restraint Gap Overturning Location Vulnerability **1 1 0 1 0.8** Life Safety Functionality Consequence **1 5 6** Comments: **Piping is hung with short rods and penetrates walls at either end.**	**4.8**	

The Assessment Team

The assessment team usually consists of two people experienced in earthquake engineering and trained in the assessment format. It is not essential to have an engineer in the two-person team format. It is highly desirable however to include an engineer in the assessment process for accurate and objective results. The other advantage with an engineer on the assessment team is the ability to assess ambiguous problematic OFC installation situations. A two-person assessment team has proven to be safer and more efficient. An engineer with experience in nonstructural seismic restraint system design must be available for consultation with the assessment team during evaluation of OFCs.

Assessment Project Definition
Hospitals are increasingly getting larger to achieve economies in scale. As hospitals are packed with OFCs the number of components to be assessed is significant. In many cases, budgetary and/or time restrictions, will dictate that not all of the OFCs in a facility will be part of the initial risk assessment. An existing business continuity plan may point to critical functions and areas, which must be maintained. A resource path to those identified functions carrying lifelines of water, electricity, fuel, medical gas, etc., may be of particular interest in forming the initial assessment scope of work. Scoping the assessment requires substantial preliminary discussions with facility staff, often in a number of departments. Better business continuity plans require less lengthy meetings. It is at this stage that a buy-in begins to develop by the various stakeholders as their opinions and expertise are solicited.

The Mitigation Project Definition
Financial resources are always limited. Seismic mitigation work in hospitals almost always results in a multi-year program, so budgetary decisions must be made. The risk assessment work is an essential element of that process, but other factors come into play as well. Once the highest risk components are identified, systems and/or zones provide a further way to group them.

Most systems operate in series, so they are inoperable if any of the elements fail. Many of the systems in hospitals fall into this category. With this in mind, it is necessary to tackle a system from start to finish even though some components may have significantly lower risk ratings. Any system is only as resilient as its weakest link. With an emergency generation system, the main fuel tanks, pumps, fuel lines, day tank, starter batteries, generator, silencer, electrical equipment and conduit must all be restrained. A weak link will result in system failure. Even if the silencer had a lower risk rating, every component in the system requires attention.

Similarly, utilities and providers of off site resources must be consulted to establish expectations for continuing service post disaster. Restraining a system to the property line without thought for whether the third party supply network will be operable is not desirable. Mitigation work may include ensuring on site backup for services required for post disaster operations that may not be available from off site supplies. The most obvious and common example of this is on site emergency power generation but may also include water for domestic, fire suppression, and HVAC system use, communications links (such as two-way satellite internet connections), and specialty medical gases.

A zone or room in a hospital may house many different OFCs with a wide range of risk values. In some cases low risk components can threaten higher risk items. A water line running over the top of a transformer is a case in point. It may make sense to restrain everything in a room rather than just the high-risk components. This also results in greater efficiency for installation work and project management as the focus is maintained in one physical location.

The project definition process sets the tone for a high value seismic risk mitigation program. Done correctly, it will result in the maximum effective risk reduction at the lowest cost, and reduce the highest risks early in the program.

Engineering Seismic Risk Mitigation
Locating and documenting OFCs
The engineering of seismic restraint systems starts with documenting the OFC locations and surroundings. This is more difficult than it might sound. Thousands of components are packed and often difficult to find in a complex structure without the benefit of detailed equipment location information. Items are digitally photo documented with location descriptions. Where available, use of facility tagging information is also

recorded, providing a meaningful record for maintenance staff. The general image is supplemented with detail shots to portray engineering issues such as conflicting components or other surrounding environment situations. These photos provide the information needed to produce an appropriate preliminary design. Preliminary engineering plans must be submitted for review by both the facility and the installation crew. The quality of the initial documentation and the expertise of the engineer will determine the efficiency with which the project reaches the construction stage.

While individual pieces of equipment are photo documented, large array or lineal systems must be placed on a floor plan. An example of this is a piping system. All individual pipe restraint points are identified with corresponding restraint detail number on a floor plan. Location specific situations are accompanied with photographs to identify potential installation difficulties. A pipe run with one hundred restraint points may have ten to twenty different restraint details. It is essential for the installers to have adequate engineering instructions to locate and select the correct restraint detail. Many lineal systems can have restraint locations marked in the field with flagging ribbon, complete with preliminary detail drawing number.

Final documentation is important from both the facility owner's and the engineer's point of view. As only portions of the total number of OFCs in a facility are mitigated at any one time, the owners must know which things have been done. From the engineer's point of view, the Letter of Assurance in British Columbia is a document, which generates considerable liability. Taken with the engineering calculations and plans, the Letter represents a performance guarantee, which remains in place over many years. It must be clear as to which OFCs have been signed off and which have not. Further complicating matters is the standard form used by most municipalities for the Letter of Assurance. It has been designed to accommodate all forms of construction engineering EXCEPT nonstructural seismic risk mitigation. The end result of the completion process is a document with numerous initialed strikeouts and detailed attachments. Great care must be taken at this point as substantial long-term liability is generated. Hopefully, municipal governments and engineering associations will see fit to recognize OFC seismic risk mitigation in their future document designs.

Generic versus custom engineering plans

As mentioned previously, there is a great deal of custom engineering required in order to achieve an effective seismic risk mitigation result that is installable and perform when the time comes. Prescriptive standards generally accepted in the industry are merely a starting point for the design process. These standards, such as those produced by SMACNA [8] and ASTM [9] portray a generic solution which must be modified to suit the demands of the structure or obstructions. In some cases, the standard solutions will not work at all and a whole new approach must be used.

Simply directing field installers to follow prescriptive standards will result in a totally inadequate restraint system or grossly over restraining a system. The importance of preliminary engineering and a proper field review process cannot be over emphasized.

Automating the engineering process

The large numbers of OFCs requiring seismic mitigation in hospitals make the automation of the engineering process important. Access to a large database of past designs can help to streamline the preliminary design process. Without these time saving techniques, the improved engineering economics required to achieve high volumes of mitigation is difficult.

Integrating engineering into project management, fabrication and installation

The engineering process is woven throughout the entire seismic risk mitigation effort. Project management of mitigation construction requires the insertion of engineering at precisely designated points with sufficient time allowances for the activity. Failure to adhere to the management plan will result in lost time, money and performance. There is always time pressure on a construction project, but the schedule cannot be sacrificed. Some common mistakes found in this area include: the failure to effectively field check preliminary designs; rushed shop drawings resulting in fabrication errors; mistakes in "for production" drawings due to short lead times; and late interim inspections failing to catch errors which have then been replicated.

Design challenges for strength, space and economy
The first engineering design criteria are usually to provide the simplest restraint system that has the strength to resist the expected seismic forces. This ideal is then often modified by the space available around a restraint point where the fittings must be installed. Traditional cable restraints present some considerable difficulty in high-density linear access routes. Other issues such as the ability to install fasteners come into play at this point. Finally, it is necessary to look at the design from an economic point of view. Is the restraint system one with the least cost labour and material mix?

The Importance of Project Management

Sequencing
Carefully defining each step of the OFC seismic risk mitigation process is the first step toward effective project management. While this sounds obvious, few, if any, organizations working in this field have done it well. Most seismic restraint work to date in new construction has been an "afterthought" and many seismic retrofit projects are poorly planned.

The project management process begins with a list of tasks. Whether the project is big or small, the tasks remain the same, but will require more or less attention. Getting the tasks in the right order may seem simple, but as mentioned earlier, it is where many organizations doing this work stumble. Failure to determine proper sequencing can result in cost overruns, delays and diminished quality. At last count, we noted some fifty tasks, which must be executed on each project.

Scheduling
Once the tasks for the OFC seismic risk mitigation project have been defined and ordered, they must be scheduled. This involves standard project management procedures to define time frames and run critical path analysis where appropriate. The biggest failure we have experienced and observed to date is the failure to allow enough time for the various tasks. Production bottlenecks can be managed by applying more resources, but usually at a greater cost. The construction industry is plagued with tasks out of sequence where expensive fixes are required, often yielding substandard results. Proper scheduling of seismic risk mitigation tasks should keep the process on track and on budget.

Facility staff buy-in
Proper project management of a hospital seismic mitigation project identifies all the stakeholders within the facility. It must be determined who requires design input, who must approve the final design and installation plan and who simply requires information. Failure to properly identify these stakeholders can result in significant project delays. A good understanding of facility politics can be useful in this process. Asking a lot of questions and being forthright in describing the likely impacts of the project on facility operations can be an important aspect in getting buy-in for the mitigation work.

The buy-in process requires time. This is why it needs to be launched early in the project schedule. Key people can go on extended holidays without leaving a decision making process in place which will allow the mitigation work to proceed. Some departments have many staff members whose response to the plan must be considered. Success in this area requires the allotment of sufficient time to allow for all key staff to take ownership of the project. The mitigation effort is being implemented for patient and employee health and safety, but if it negatively affects their workplace, they will object – strongly. Properly handled, the buy-in process can speed the project resulting in better economics and fewer headaches for everyone involved.

Fabrication of Seismic Restraint Devices

Integrating fabrication considerations into design

Most seismic risk mitigation projects require a significant number of restraint fittings, devices and fasteners. In hospitals, additional attention to these items is necessary due to the requirements for clean and sterile conditions. The use of stainless steel and sophisticated industrial finishes such as hot dip galvanizing and powder coating is common. There are significant numbers of mass-produced, manufactured seismic restraint assemblies available on the market. Cable restraints for piping, conduit and wire runs are a good example of this. Riser clamps, fittings, cables and fasteners are brought together without the need for custom fabrication.

It is still the case, however, that many required restraint devices must be custom fabricated. The location of the restraint point may be such that it requires a special design. This can be an expensive and time-consuming process. To speed the fabrication and produce the best possible product, we have employed a technique we call the “design roundtable.” This involves bringing to that table (often virtual on the Net or the phone) the main actors in a project. This generally includes the project manager (with an eye to requirements of the customer), the project seismic engineer, the fitting fabricator and the system installer. By making a few circles of the “table,” the restraint design evolves into one which: meets the needs of the facility, will perform during a seismic event, can be fabricated at a reasonable cost and installed with a minimum of aggravation.

Fitting versatility – opportunities for mass production

In spite of the fact that there is currently a great deal of custom restraint fitting fabrication required, there are many opportunities for versatile designs which can be mass produced. An example of this is the moment post. With the high density of equipment in hospitals, space is at a premium. Restraint systems, which require angle braces encroach on adjacent equipment, the structure and the space required for other services in the future.

The moment post restraint system from the floor, ceiling or wall requires far less space with its spare design. By adding articulating and multiple attachment points, a few basic designs can be made to suit a wide variety of applications. This will allow for mass production and a considerable fitting cost reduction while cutting installation time and difficulty. While steel is still the fabrication material of choice, plastics and composites offer opportunities in this field in the future.

Installation of OFC Seismic Risk Mitigation Systems

Building construction challenges

There are a number of challenges for the OFC seismic risk mitigation practitioner associated with modern construction trends. First among them is the use of post-tension based structural designs. While this practice allows for lighter and cheaper construction with greater floor-plate options, it presents a real risk for the restraint system installer. The exact location of the tensioned cables in the slab is not known. The restraint fasteners will often be required to penetrate 100mm to 150mm into the slab, which can bring the drill into the zone of the tensioned cable conduit.

This situation presents a substantial safety risk to the mitigation system installer and to people in surrounding buildings. The cost of repair of a severed cable is large. To avoid this type of accident, slab investigation is required. The main options available for this type of work are magnetic, x-ray and radar based equipment. The magnetic systems search for steel. Because many holes must be drilled next to steel objects, this tool will often be inappropriate due to interference from the surrounding environment. X-ray technology requires that everyone be cleared from the vicinity of the area being irradiated. This is often difficult in a hospital, which is occupied and active on a continual basis. As a result, ground-penetrating radar (GPR) remains the most attractive tool for performing slab investigation. No special safety precautions are required and a profile of the area is developed immediately showing the location of cables or structural steel, including the depth of the runs.

With the trend toward post tension buildings, we are also seeing thinner floor slabs. This can present a problem where the required fasteners would penetrate completely through a floor. The problem can be somewhat avoided by using higher performance fasteners and/or increasing the number of anchors and shortening their length in order to achieve the required anchor strength without penetrating through the concrete.

Roof membranes present a significant challenge for rooftop-based equipment and for fasteners placed on the bottom side of the roof deck. Much of this equipment is simply sitting on sleepers on the roof membrane without any direct attachment to the primary structure. Seismic mitigation almost always requires penetration of the membrane. This presents a risk of water leakage through the flat decks usually found on hospitals. A membrane-consulting engineer with some knowledge of the particular facility is very helpful when making these connections. When drilling into the bottom side of a roof deck to mount restraint fasteners, care must be taken not to inadvertently penetrate the membrane.

Raised access floors are commonly found in the computer rooms of modern hospitals. These structures are generally not capable of withstanding seismic forces. Compounding the problem is the large amount of heavy equipment placed on those flooring systems. If a modern hospital loses its computing capacity, its post disaster functions are seriously compromised. Server racks, computer cabinets, air conditioners and uninterruptible power systems (UPS) must be secured to the slab below the access floor. This can be done with long rods and angle braces for existing facilities. For new installations, a steel frame is used just below the floor to mount the equipment directly to the floor slab, independent of the raised floor.

Noise abatement

Hospitals attempt to maintain low levels of noise, usually with limited success. Noise is a significant stressor for both patients and staff. Impact drilling into concrete structures produces significant sound of the most irritating sort. That sound often travels throughout the building and is akin to a dentist drilling. As there is no specific time where no one in the facility will be affect by noise, the only solution is to reduce the decibel levels of the process and alter the quality of the sound. To do this, we have switched almost exclusively to core drilling from impact drilling. This cuts the decibel levels by up to 70% and improves the quality of the sound. We have discovered that we can core drill small diameter holes in close proximity to people without causing major irritation. Because of the low levels of vibration, the transmission of the sound through the structure is also kept to a minimum.

Security issues

There are a number of issues with respect to security that are of critical importance when working in a hospital. Security photo ID badges are generally worn when in a facility. A background check of mitigation company staff is also required for some hospitals. Installers may be working around women and children in vulnerable situations. Crewmembers are in pharmacies around large amounts of prescription drugs. These situations require personnel with clean personal histories. Security is required at access points to restricted areas. While working in those areas, the installers need to be sure that the access points are not breached and that potentially unauthorized people are challenged. It is possible that someone in the advanced stages of dementia can enter an interstitial floor or remote area and not be located until it is too late. Finally, tens of thousands of dollars of mitigation tools, fittings and supplies are often located on a site. Unless they are locked away and accounted for when not immediately in use, they have a tendency to disappear.

The right tools for the job
Every contractor knows that having the right tool for the job can greatly reduce the time to do the job, reducing irritation levels, improving safety and increasing profit margins. In most cases, we have been able to find the right tool on the market and in some instances, we have had to modify existing equipment or make our own.

Seismic risk mitigation work almost always takes place in confined places. Small tools are better than big ones as long as they have the power to do the job. Hand held tools are usually preferable to those requiring mechanical support. Right angle drills are very useful as long as the design minimizes heat build-up at the transfer gear. Core drills not only reduce noise levels, but the wet units eliminate dust as well. The Hilti DDEC-1s are hand held (by a strong person) and have a self-contained water recycling system, which has very little escapement. This is the only core drill that can do wet overhead coring and is our drill of choice in hospitals. We have worked closely with Hilti to enhance the performance of this excellent drill.

A LOOK INTO THE FUTURE

New Construction and the Building Code
While there are a vast number of buildings worldwide with most of their operation and functional components unrestrained, it is even more disconcerting to see new buildings being completed on a daily basis with the same seismic risk problems. We know most of the contributing factors to this situation as previously stated and it remains a significant problem for society. It is clear, through the long history we have on adherence to the seismic provisions of the National Building Code of Canada, that fundamental changes to construction practice are required in this area.

The process must start with a better description of exactly which OFCs require seismic restraint, such as in CSA S832. Referencing of the standard in the Code may accomplish this. The engineering performance levels in the Code are adequate, but a body of standard practice in the area needs to be built over time. At this point, advancing construction performance levels in this area is a “catch twenty-two” situation. The body of engineering work will not grow until there is substantial activity in the field. That activity will not happen until there is solid technical support.

At this point, the municipality based building officials become a critical element in advancing the Code adherence levels for the seismic performance levels of OFCs. It is with the municipalities that the responsibility rests for assuring building purchasers that new buildings with occupancy permits meet the current requirements of the Code. They carry a substantial liability should they fail in this function. The recent problems with water leakage due to endemic building envelope failure in this region are a case in point.

Once it becomes clear what needs to be done in the way of OFC seismic risk mitigation and that the Code will be enforced, the construction industry will conform. Such an approach creates a level playing field where bidding can take place in a fair manner. As the seismic restraint work builds in volume, greater expertise will develop in pricing and installation. While this process would likely take the better part of a decade to become firmly entrenched in the construction industry, it is a critical step if we are to stop the growing inventory of seismically “at risk” buildings in the province’s seismic regions.

Keeping Buildings Seismically Resilient - Purchasing and Maintenance Issues

From the day a new building come online, even if it meets all the seismic aspects of the Code, its earthquake resilience usually begins to degrade. Hospitals have a very high rate of equipment turnover and acquisition. As new equipment is added, there is currently a high likelihood that properly engineered seismic restraint systems will not be put in place. The project is usually small in scale, there are no building official inspections required, and it is not yet standard practice for the equipment installers to add seismic restraint.

Maintaining OFC seismic resilience over the long haul takes place at the building level and involves facility management and purchasing. Facility managers need to develop a policy that all equipment entering the hospital must be seismically restrained and signed off by an engineer. When the purchasing department goes to tender for new equipment, the tender specifications must include a seismic performance and installation requirement. If a supplier is making a claim for the seismic capacity of a product, supporting engineering documentation must be submitted.

It is only by having a seismic policy which is applied on a day to day basis that new buildings can maintain their level of performance, while older buildings are gradually upgraded.

The Cost of Seismic Hazard Reduction

Seismic risk mitigation of operational and functional components in hospitals and all other buildings is not taking place at a significant rate. We know that the consequences of not doing this work will be catastrophic and that the cost of undertaking retrofit work is substantial.

The good news is that there are opportunities to considerably reduce the cost of seismic risk mitigation. Sophisticated engineering designs coupled with larger scale manufacturing techniques are now bringing costs down significantly. With new specialized tools, additional highly trained installers and modified building construction and maintenance practices, seismic resilience can be achieved at an even more reasonable cost in the near future.

CONCLUSION

The task of making our hospitals and other buildings earthquake resilient is daunting. The buildings are complex and packed with expensive equipment. The British Columbia Seismic Mitigation Program allowed us to complete a significant volume of seismic risk mitigation work. Few other locations have had a program of this scale and impact. This activity triggered investment in, and the development of, a variety of methods and practices for performing risk assessments, engineering, project management, fitting fabrication and restraint installation in this field.

The procedures developed to date are largely intuitive and not particularly capital intensive, which should make them accessible and attractive. While there are still plenty of opportunities for innovation in this field, the groundwork is now reasonably well established. Each country has developed or adopted a building code to provide for the life safety of its population and increasingly to reduce economic losses associated with an earthquake. It is unlikely we will see another government supported seismic risk mitigation program in British Columbia in the near future. However, even greater amounts of work would be done if our current Building Code were enforced. We are currently past the point where more discussion or expensive research is required, before the necessary work can begin. It is time to get on with the massive seismic risk mitigation effort for operational and functional components in buildings and reap the benefits of increased seismic resilience in our vulnerable cities.

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