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AUTOMATING OFC INVENTORY, RISK ANALYSIS AND CONSTRUCTION SUPPORT

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ABSTRACT: Each building operational and functional component (OFC) examined for seismic risk, starts accumulating data from the beginning. Canada's standard in this field is CSA S832-14, ***Seismic Risk Reduction of Operational and Functional Components (OFCs) of Buildings*.** To generate a risk rating under the standard, there are roughly twelve inputs for each OFC to be logged - one of which is an image. Then, if mitigation is required, a strategy and concept detail design is required. At that point an estimated mitigation construction cost can be generated for budgeting purposes. A typical mid-sized hospital might have 2,500 OFC line items with multiple units of many of those. At the end of the data acquisition process, the engineering team may have had to input 30,000 data points for the project. Then there is construction support, final reviews and documentation, followed by ongoing assistance with a continuing maintenance program. This paper will explore the development work we have done in this field during the past twenty years and will look into future innovation opportunities, which will hopefully lead to a safer building stock for seismic zones.

1. Introduction

We are in the Age of Big Numbers. There are billions of people on earth with centillions of things. When the earth moves, those things fly about. As seismic risk mitigation engineers and managers, our job is to make sure that the operational and functional components (OFCs) of our buildings remain in their designated locations and do not injure or kill people nearby, compromise the structure or create business interruption losses. This process is not rocket science, but for the most part, fairly basic engineering. And yet, in spite of the fact that this work is mandated by building codes and occupational health and safety regulations, much of it is still not getting done.

One reason is, that we are being overwhelmed by a big number tsunami of OFC data. The issue throws up roadblocks for action. This paper explores the nature of this data blizzard and how to avoid being overcome by inertia under the circumstances.

We will explore the methods that we have developed in this specialized field over the past two decades, to manage the challenges of the big numbers. These include the extensive use of image mapping to visually document the OFCs in a facility. The higher resolution of images allows for better post collection review of the OFCs, but at the same time presents issues with moving large data files. Increasingly, video is being used for some facets of the work. Audio files and in-office dictation is also being used through voice recognition software to speed text inputs that flow through software to final reports. The development of powerful data bases with effective search and sorting capabilities also add to the mix for extensive automation of the seismic risk mitigation process.

2. Building the Data Base

2.1. Where Are They?

Developing an OFC inventory for a building is a rather choreographed procedure. The floor plan of the area to be studied is obtained in advance. A route through the rooms indicated on the plan is determined. Our routine is to work clockwise around the floor plate of the building and also clockwise around each individual room. The exterior is done first and then the interior portions also clockwise. Each OFC is photographed and a marker placed in the view indicating whether the component is restrained, partially restrained or unrestrained. As hundreds of OFC's may be examined in a single work day and the analysis of those units may not be done for a few days afterward, it is important not to rely on memory for the degree of restraint present.

To begin the organizing process of the data, we have been using standard spreadsheet software along with a custom macro component. The macro takes the JPEG files of the various OFC's and inserts them as thumbnails into the spreadsheet. We call this process image mapping. At this point the names and locations of the component are inserted. On large projects, drop-down menus are inserted in some cells to speed the data entry process. Further, the spreadsheet auto inserts text by column for repeated items. As well, to speed the data entry process, voice recognition software and hardware is used for entries in appropriate cells. Full automation is necessary in order to save time, cut costs and avoid the errors due to the monotony of making thousands of entries. While this work might be subcontracted to large numbers of data entry personnel, a thorough knowledge of the seismic mitigation process would be necessary to get accurate results. It is unlikely that a dedicated data entry centre would, in most cases, provide the level of accuracy necessary, at least with the present volume of work.

2.2. The Big Numbers OFC Risk Assessment

Risk assessment is done using software generated from CSA Standard S832-14, ***Seismic Risk Reduction of Operational and Functional Components (OFCs) of Buildings***. Each OFC is rated on six parameters as detailed in the standard and shown in Fig. 1. Vulnerability and consequence scores are developed, which when are placed in an algorithm to produce a risk index value. This number indicates the relative risk associated with that specific OFC as compared with other OFC's. While there are a variety of risk scores for various components, there are many with similar characteristics and risk scores, which offer opportunities for cut and paste inputs. Every shortcut must be used to speed the data input process in order to move the analysis along and keep costs reasonable.

With 12 data inputs for each OFC line item and upwards of 2500 OFC's, some 30,000 data entries may be required. Without significant automation of this process, the big numbers generated can quickly overwhelm the people doing the work, as well as those who have to interpret the output reports. By using the variety of techniques described above, the time required to do the work and produce useful results can be reduced dramatically. This reduces the so-called Tyranny of Big Numbers and allows for the process to move forward, while at the same time, applying rigorous engineering standards.

The use of a sophisticated spreadsheet allows for the creation of a central database relating to hospitals, schools, or other government facilities. Our colleagues, Bush Bohlman & Partners, have started this process with the creation of a database for the British Columbia provincial government. The transfer of data from the spreadsheet to the database uses relatively simple programming and allows for searching on an array of parameters. The aim of the entire data acquisition process is to minimize the number of visits to a facility, and keep all data inputs to a single entry procedure.

The gold standard for this process would be a system where data acquisition and input is simultaneous and takes place in the facility. While we have experimented with this process using a number of different approaches, there is still work to be done in this area, before it enters regular use. One avenue, which shows some promise, is the use of high definition video with voice recognition. This would allow for a three-dimensional view of each OFC, along a route and the input of key parameters on site at the facility. Then, using voice recognition software, the information could be added to the database without anything more than some technical editing oversight. While the use of video is of great interest, there are some challenges to overcome, such as the privacy of staff working in the facilities, very large data files and levels of noise in some parts of the buildings, reducing the accuracy of voice to text translation.

Seismic Risk Assessment of OFCs

Project Name:	Area:	Pathology Lab	Project Number:		15-Mar-15
Client:			Client Rep.:		
Consulting Engineer:			Consulting Eng. Rep.:		
Sub Consultants :			Sub Consultant Rep.:		

Location of the project: Province: "BC" $S_a(0.2)$= 0.95 Soil Class= D F_a = 1.1

OFC								Vulnerability Index					Consequence Index			Risk Index	Retrofit Index
No	DE	Photo	Qty	Rm.	Flr.	Tag	Name	Restraint	Impact	Overturning	Flexibility	V	Life Safety	Functionality	C	R	RI
117	710		1	2J15/2J15	2	Pathology Lab	Freezer	40	30	20	10	10.87	10	10	20	217.4	100
118	720		1	2J15/2J15	2	Pathology Lab	CPU	40	30	20	10	10.87	10	10	20	217.4	100
119	729		1	2J15/2J15	2	Pathology Lab	Freezer	40	30	20	10	10.87	10	10	20	217.4	100
120	731		1	2J15/2J15	2	Pathology Lab	Freezer	40	30	20	10	10.87	10	10	20	217.4	100

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Fig. 1 - OFC Inventory and Risk Assessment

3. Cost Estimating

Cost estimating is something that contractors do every day, with greater or lesser levels of success, depending on the complexity of the project and the business environment. It is important for an organization contemplating an OFC seismic risk mitigation program, to have good cost details in order to develop a project budget. In the reverse of that, they have a budget and must determine the amount of work that can be done within that. Generally, consultants will generate this kind of information based on a floor area rule of thumb. This does not work well with this type of construction work. Facilities such as hospitals and schools, because of the varied nature of the activities, which take place within the structure, do not lend themselves to the use of costs per square metre.

As the OFC inventory and risk assessment process produces a detailed list of the components to be costed, it is another short step to assign a cost of construction values to each of those items. At this stage, an engineering design detail has not been typically developed or funded. Experience in this field will generally suggest the restraint detail required for each OFC. Cost estimating without a design detail can be difficult. However, by simplifying restraint details to a number of standard approaches and a few custom options, cost figures can quickly be developed by selecting from a menu, which then yields a cost of mitigation construction for each OFC. Fig. 2 shows a typical cost report using the above process. At this point, the building owner can develop a program based on the resources available. The more detailed estimation process also allows for better management of bidding or tender processes in order to make the best decisions on contractor selection.

To date, significant amounts of seismic restraint work has required custom design, fabrication and construction work. This slows seismic risk mitigation activity and substantially increases the cost. The manufacturing of more standardized seismic restraint products is one solution to the challenges we face in this area. We have done that in the past and have recently developed a system for restraining large free-standing cabinets. However, we face a "chicken or egg" situation. Volume of some mitigation work is restricted due to initially higher costs, and then demand does not support a mass manufacturing process.

No		Loc.	Qty	Name	Cost	Details
49		160	1	Shelving unit	$ 158	Attach shelving unit to walls studs
50		105	144	Fire suppression system	$ 12,931	Brace fire suppression, piping to meet requirements of NFPA 13.
51		105	11	Lighting modules	$ 1,185	Brace first row of lighting modules to avoid wall the impact.
52		105	5	Ductwork	$ 1,018	Brace large round duct at each beam/column intersection.
				TOTAL	$ 41,741	

Fig. 2 - Costing of OFC Risk Mitigation Construct

4. Engineering Detail Design

Though a facility may have hundreds of discrete OFC's in an array of different environments, there are ways to reduce the number of detailed drawings required and the amount of time spent generating each of them. Many make the mistake of assuming that if you have a restraint detail for a blood analyzer, that detail will work for all blood analyzers. Such is not the case, even for the same model. Seismic forces applied to an OFC can vary significantly depending on its location in the building, the soil classification on the site and other factors. Sometimes this will influence the design characteristics, but not always. One must decide where to draw the line between using detailed drawings for all OFC's and when to simply modify a more generic detail with an attached additional specification.

The automation options available to the engineer in this field are many and new techniques are coming along each day. The calculations, which lead to design details, can be automated through standard Mathcad type applications, where the OFC site parameters are loaded and outputs include applied seismic forces, leading to restraint fitting designs along with attachment and anchor selections. This process not only speeds the calculations, but also yields a readily verifiable record of the approach used. Examples of the force calculation inputs are shown in Fig. 4. A typical anchor design format is shown in Fig. 5.

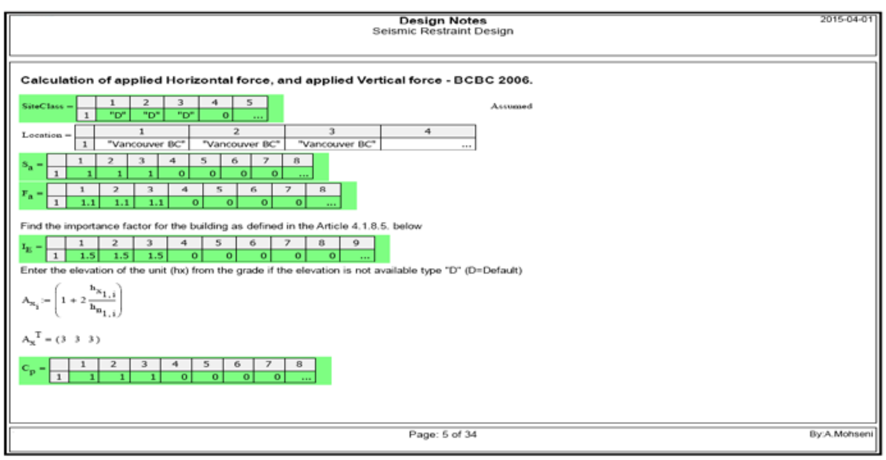
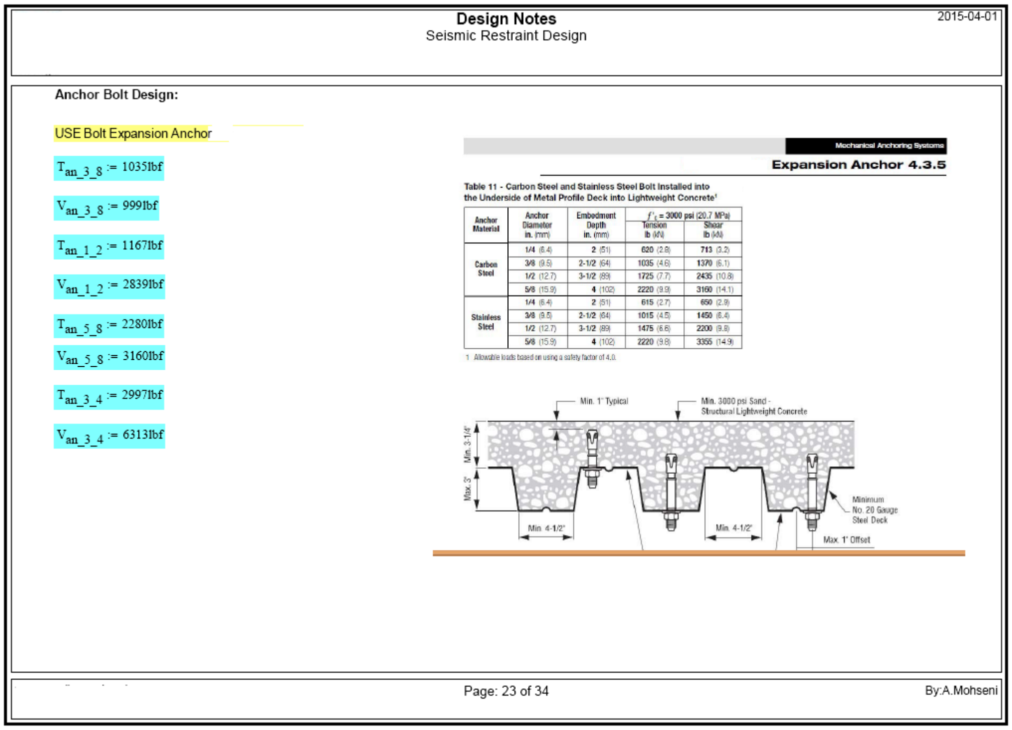


Fig. 3 - Mathcad Force Calculations



Design Notes
Seismic Restraint Design
2015-04-01

Anchor Bolt Design:

USE Bolt Expansion Anchor

$T_{an\_3\_8} := 1035lbf$

$V_{an\_3\_8} := 999lbf$

$T_{an\_1\_2} := 1167lbf$

$V_{an\_1\_2} := 2839lbf$

$T_{an\_5\_8} := 2280lbf$

$V_{an\_5\_8} := 3160lbf$

$T_{an\_3\_4} := 2997lbf$

$V_{an\_3\_4} := 6313lbf$

Mechanical Anchoring Systems

Expansion Anchor 4.3.5

Table 11 - Carbon Steel and Stainless Steel Bolt Installed into the Underside of Metal Profile Deck into Lightweight Concrete[1]

Anchor Material	Anchor Diameter in. (mm)	Embedment Depth in. (mm)	f'_c = 3000 psi (20.7 MPa) Tension lb (kN)	Shear lb (kN)
Carbon Steel	1/4 (6.4)	2 (51)	620 (2.8)	713 (3.2)
	3/8 (9.5)	2-1/2 (64)	1035 (4.6)	1370 (6.1)
	1/2 (12.7)	3-1/2 (89)	1725 (7.7)	2435 (10.8)
	5/8 (15.9)	4 (102)	2220 (9.9)	3160 (14.1)
Stainless Steel	1/4 (6.4)	2 (51)	615 (2.7)	650 (2.9)
	3/8 (9.5)	2-1/2 (64)	1015 (4.5)	1450 (6.4)
	1/2 (12.7)	3-1/2 (89)	1475 (6.6)	2200 (9.8)
	5/8 (15.9)	4 (102)	2220 (9.8)	3355 (14.9)

1 Allowable loads based on using a safety factor of 4.0.

Min. 1" Typical
Min. 3000 psi Sand - Structural Lightweight Concrete
Min. 3-1/4"
Max. 3"
Min. 4-1/2"
Min. 4-1/2"
Minimum No. 20 Gauge Steel Deck
Max. 1" Offset

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Fig. 4 - Mathcad Anchor Design

Detailed drawings for OFC's are typically produced for installers, who are often not trained in reading traditional engineering drawings. With that in mind, it is often productive to use a mix of images and 3-D drawing as well as techniques that are more traditional. This approach appears to be less intimidating and more effective in translating from engineering requirements to installed systems. By using project drafting frames, and an array of drag-and-drop tools, the design details can be produced relatively quickly. Methods used for structural engineering work are often cumbersome when dealing with hundreds and sometimes thousands of details. Each building has hundreds of small structures within it, all of which require engineering attention, to a greater or lesser degree. Fig. 5 below shows a typical approach to this part of the seismic risk mitigation process.

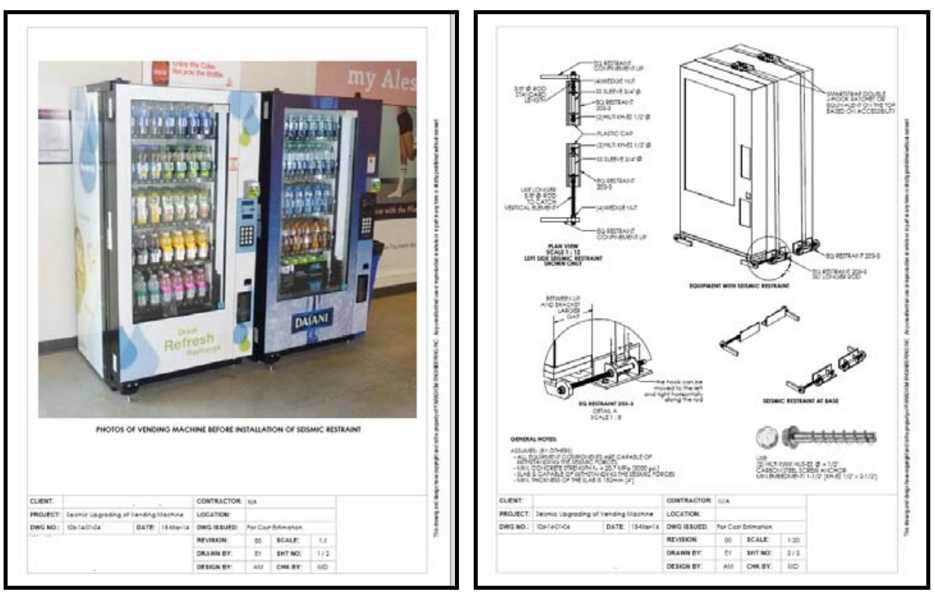

Fig. 5 - Typical Seismic Restraint Details

5. Conclusion

If we are to make headway in preparing the operational and functional components of our buildings for a seismic event, we must deal with the overwhelming task of restraining billions of units to their structures. This can only be done by taking advantage of the latest methods for automating the risk mitigation process. We have the tools at hand and more are arriving on the scene each day. Advances in image capture and mobile computing, if used effectively, can make the daunting task far more efficient. With advanced software, traditional ways of communicating structural engineering requirements can be enhanced for the OFC environment. There is no need to be intimidated by the Big Numbers, if you have the right tools.

6. Acknowledgements

Many of us in this relatively new and specialized field of OFC seismic risk mitigation were mentored by or had the privilege of working with Micky Wang, PEng. We will always be grateful for the time he spent with us sharing his expertise and experience. We will miss his cheerful presence at 11CCEE.

7. References

CANADIAN STANDARDS ASSOCIATION, "CSA - S832-14 - Seismic Risk Reduction of Operational and Functional Components (OFCs) of Buildings," 2014.