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CLASSIFICATION OF OPERATIONAL AND FUNCTIONAL COMPONENTS (OFCs) OF BUILDINGS IN TERMS OF THEIR SHAPE, FUNCTION, RESTRAINT, AND DETAIL OF CONNECTION IN ORDER TO FACILITATE HIGH VOLUME SEISMIC RISK MITIGATION ENGINEERING

Amir MOHSENI[1] and Carlos E. VENTURA[2],

SUMMARY

Seismic risk mitigation programs for operational and functional components (OFCs) of buildings generally consist of such key elements as a seismic risk assessment, mitigation cost estimating, component selection, seismic engineering, seismic installation of restraint systems, quality assurance, and mitigation tracking and documentation.

In order to reduce the amount of required calculations for design and analysis for generic situations, and to define a system that works for unique situations, an innovative analytical and design methodology has been developed. The proposed methodology is discussed in this paper and illustrative examples to demonstrate its advantages are presented.

INTRODUCTION

The principles and techniques for seismic risk mitigation of structures, which have been developed and refined for structural engineering, can be utilized in the non-structural discipline. However, the high volumes of OFCs in a project present significant challenges to the implementation of cost effective engineering solutions for their seismic risk reduction..

A recent industry/academic partnership has produced a system of classification of OFCs, which allows for an efficient data base search resulting in preliminary or final designs. This paper describes the methodology developed and shows how can it be applied it to typical OFCs included in the various categories defined by the Canadian Standards Association's S832-01 Guideline for Seismic Risk Reduction of Operational and Functional Components (OFCs) of Buildings [2].

In the proposed methodology the OFCs can be divided into four main categories: cylindrical, prismatic, architectural, and structurally similar non-structural. Each main category has related classifications

[1] Manager, Engineering Division, Terra Firm Inc., Canada, amir@terrafirm.ca

[2] Professor of Civil Engineering, University of British Columbia, Canada, ventura@civil.ubc.ca

according to: the position of the equipment with respect to the structural elements; the function of the equipment; the type of restraint; the equipment to restraint connection and the restraint to structural element attachment. An archive is described, which includes examples from mechanical, electrical, telecommunication, architectural, and specialized categories as defined in CSA S832-01[2]. Actual field data is used to illustrate the range of examples analyzed.

There are ten stages in a typical non-structural seismic risk mitigation project:

1. Identification of OFC
2. Risk assessment (seismic evaluation) of OFCs.
3. Analysis for upgrading of existing restraints or design of new restraints and generation of drawings with details.
4. Contract award.
5. Cost estimation.
6. Project management and planning
7. Fabrication and installation of the restraints.
8. Quality control.
9. Quality assurance.
10. Providing as-built plans and documentation.

The methodology defined in this paper can be employed either directly or indirectly in each of the above stages to increase efficiency. But in order to see how this methodology can be implemented at each stage of the mitigation process, first a philosophy of classification should be introduced. Then by defining each category in this methodology, the application of the classification on mitigation stages will be explained. Because there is such a vast array of operational and functional components in a building, (particularly in a hospital), the engineering activities, as the core of the seismic risk mitigation process, must be automated. If each item in the building were to receive custom engineering attention, the process would take too much time and would be too expensive. With tens of thousands of restraint points to be considered in many large facilities, an automated engineering system is essential.

The seismic restraint designer should be a structural engineer. Considering that the engineer may not necessarily be familiar with all of the OFC's technical specifications (e.g. weight, dimensions, function and behavior), the data acquisition and sorting process provided by the automated engineering process should help the engineer to perform the risk assessment and the design more efficiently.

PHILOSPHY OF CODING FOR OFCS FOR MITIGATION

The coding methodology incorporates parameters such as: shape, type, function, restraint element, location, connection type, and weight of the OFC. Each parameter includes a set of sub-categories. These categories are derived from an archive of as-built restraint designs and digital images, which includes almost two thousand different restraint situations. This database avoids the repetitive procedure of designing each seismic restraint system from scratch.

As the body of work grows, it is clear that no one person can possibly remember where to find a particular previous solution. So, it is likely that many people and organizations working over a wide geographical area would be redesigning the same restraint system without the benefit of a central database containing information that could be of significant value to all the parties involved. As a consequence, this would slow the mitigation effort and increase the cost. A central resource database avoids these problems.

To further increase efficiency, this coding process is linked to a design database with the capacity to generate preliminary CAD blocks. The CAD blocks carry-costing information linked to current fabrication and installation pricing formats in order to speed the project estimation process.

The list below defines briefly the different potential products of this methodology:

- A catalog of organized information of historical restraint of OFCs. This information can be as simple as electronic albums of digital photographs from different equipment before and after installation of seismic restraint, with an archive of related as built drawings. This can be used as a base for the structure of a database.
- A set of computer programs for various types of OFC. These programs are designed to analyze nonstructural equipment in relation to horizontal and vertical forces generated during an earthquake. By inputting the appropriate seismic parameters, and physical and geometrical properties of the OFC, the program is able to calculate the size and type of restraint and connections required.
- A CAD block-generating program that uses the output of the above mentioned restraint designer to produce CAD drawings by using either newly generated CAD blocks or existing archive details.
- An estimating program that calculates the required fabrication time and material as well as the required installation time and material for the seismic restraints and related attachments.
- A faster and more efficient recording system for documentation purposes.

The advantages of the implementation of the coding methodology in these potential products will become evident following a further definition of the coding process.

Coding For Shape.

OFCs can be divided to three main categories with respect to their geometric shape regardless of their function. These include:

1. Cylindrical or with a circular cross section. (e.g. hot water tank, boiler, generator silencer, piping, heat exchanger, etc.). (See Table 1)
2. Prismatic shape or rectangular cross section.(e.g. MCC, A/C unit, incubator, duct, UPS, etc.). (See Table 2)
3. Structurally similar or frame-based shape. (e.g. shelving unit, server rack, telecommunication tower, etc.). (See Table 3)

There is a fourth category in this set, which is an exception from the general definition. This is the group including architectural components of a building (e.g. suspended ceilings, windows, art work, non-bearing partition walls, etc.). The main idea behind this category is to narrow down the classification of OFCs to as small a number as possible and to make the equipment distinguishing step simple. (See Table 4)

Coding For OFC Type.

The second coding parameter is the type of the equipment. This parameter defines the existing situation of the equipment with respect to its support by the structure and/or the material inside the equipment. Each of the four categories defined under the shape parameter are divided according to their type (e.g. a cylindrical OFC can be horizontal or vertical, suspended from the ceiling or sitting on a housekeeping pad, and it can be an electrical cable or a pipe, etc.). There are 9 categories for the cylindrical shape and 7 categories for the prismatic shape**.**

Table 1. Different types of cylindrical OFCs

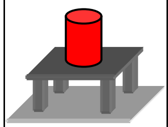
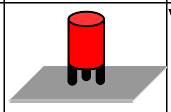
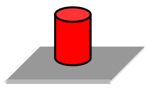
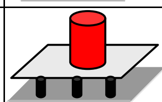
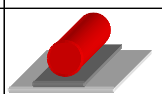
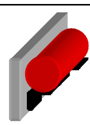
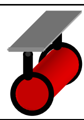
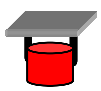
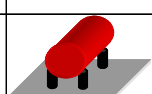
Code	Type	Definition	Example
101		Vertical cylinder on desk top	Chemical tank in laboratory
102		Vertical cylinder on legs	Hot water tank, fuel tank
103		Vertical cylinder on base	Medical gas tanks
104		Vertical cylinder on false ceiling	Vertical tank on raised accessed floor
105		Horizontal cylinder on base	Boiler on house keeping pad
106		Horizontal cylinder supported by wall	Expansion tank
107		Suspended horizontal cylinder	Pipe lines and ducts
108		Suspended vertical cylinder	Generators silencer
109		Horizontal cylinder on legs	Chemical tanks

Table 2. Different types of prismatic OFCs

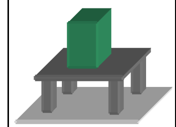
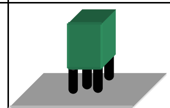
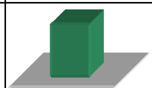
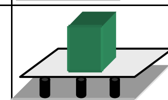
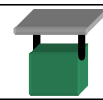
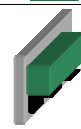
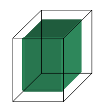
Code	Type	Definition	Example
201		Prism on desk top	Desk top equipments
202		Prism on legs	Generator's day tank
203		Prism on base	Electrical cabinets
204		Prism on false floor	Servers on raised accesses floor
205		Suspended prism	Exhaust fan
206		Prism supported by wall	Electrical panel
207		Moving prism	Elevators

Table 3. Different types of structurally similar OFCs

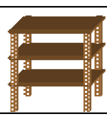
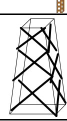
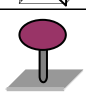
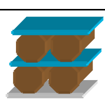
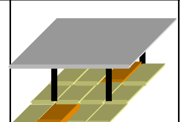
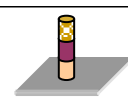
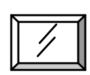
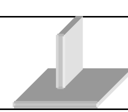
Code	Type	Definition	Example
301		Racks or shelving	Server rack, bookshelves, display racks
302		Truss	Telecommunication tower
303		Cantilever	Supply water tank
304		Stack rack	Wine rack

Table 4. Different types of architectural OFCs

Code	Type	Definition	Example
401		False ceiling	Acoustical Suspension Ceiling and Fixtures
402		Art works	Totem pole
403		Glass	Building claddings
404		Divider	Partition walls
405		Exhaust ducts	Chimneys

Coding For Function.
This coding parameter defines the OFC based on its function. The simplest way to define the function of the component is to name it according to its productive function. Currently, the index of OFCs includes more than 100 different types of components. This index can be categorized based on CSA S832 guideline [2] (See Table 5 for details).

Table 5. Different categories of OFCs based on their function.

<table>
<tr><th colspan="8">Architectural</th></tr>
<tr><th colspan="2">Code</th><th colspan="2">Category</th><th colspan="2">Code</th><th colspan="2">Category</th></tr>
<tr><th colspan="2">001-120</th><th colspan="2">External</th><th colspan="2">121-240</th><th colspan="2">Internal</th></tr>
<tr><td colspan="4">– Canopies, porches, balconies
– Parapets, walkways, signs
– Corbels, exterior infill walls
– Glazing, cladding
– Veneer attachments (wood, masonry, stone)
– Ornamentation
– Roofing, louvers
– Etc.</td><td colspan="4">– Partitions, stairways, shafts
– Ceilings, doors, glazing
– Atrium spaces, skylights
– Glass elevator enclosures
– Etc.</td></tr>
<tr><th colspan="8">Building Services</th></tr>
<tr><th>Code</th><th>Category</th><th>Code</th><th>Category</th><th>Code</th><th>Category</th><th>Code</th><th>Category</th></tr>
<tr><th>241-360</th><th>Mechanical</th><th>361-480</th><th>Plumbing</th><th>481-600</th><th>Electrical</th><th>601-720</th><th>Telecommunications</th></tr>
<tr><td colspan="2">-Heating, ventilation, A/C equipment
– Elevators
– Chillers, ducts, diffusers
– Tanks, boilers, furnaces
– Fire extinguishers
– Pressure vessels, pumps
– Gas piping
– Etc.</td><td colspan="2">– Piping
– Sprinkler systems
– Fire suppression systems
– Faucets
– Etc.</td><td colspan="2">– Electrical panel boards
– Emergency lighting
– Light fixtures
– Electric generators
– Transformers
– Electric bus ducts
– Motors, power control systems
– Uninterrupted power systems
– Battery racks
– Etc.</td><td colspan="2">– Telephone systems
– Communications systems
– Cable trays
– Etc.</td></tr>
<tr><th colspan="8">Building Contents</th></tr>
<tr><th colspan="2">Code</th><th colspan="2">Category</th><th colspan="2">Code</th><th colspan="2">Category</th></tr>
<tr><th colspan="2">721-840</th><th colspan="2">Common</th><th colspan="2">841-960</th><th colspan="2">Specialized</th></tr>
<tr><td colspan="4">– Moveable partitions
– Filing cabinets
– Office equipment
– Vending machines
– Kitchen equipment
– Shelves, storage racks
– Computer equipment
– Etc.</td><td colspan="4">– Antiques, fine art
– Hazardous materials
– Medical supplies
– High-tech equipment
– Life-support equipment
– Etc.</td></tr>
</table>

Coding By Restraint Element.

The fourth coding parameter is the restraint element. The restraint element can be as simple as a length of flat bar, a custom made steel frame, or a set of snubbers. The database contains 75 different types of restraint. This parameter does not define the type of the connection between the restraint and the structure or the connection between the equipment and the restraint (See Table 6 for details).

Table 6. Main categories of seismic restraint components or seismic restraint

Code	Seismic restraint or components of seismic restraint	Definition
001-020	Adhesive	Industrial adhesive that can be used for some attachment applications (e.g. connecting a steel section to neoprene pad)
021-040	Aircraft cable	High strength steel cables which should be used with thimbles.
041-060	Base isolation system	An energy dissipation based seismic restraint which can be installed between equipment and the supporting structure.
061-080	Bending	Steel bending
081-100	Channel struts	Galvanized steel section with C shape in cross section
101-120	Coating	Galvanization of steel sections (does not include painting or powder coating?)
121-140	Cutting	Any required steel cutting during fabrication stage
141-160	Desk top restraint	Seismic restraint with flexibility of adjustment that can be used for desktop equipment (e.g. Thumblocks, stud plates, etc.)
161-180	Drilling	Any required drilling during fabrication stage
181-200	Existing element	If the strength of the existing element (supporting equipment) is sufficient it can be used as restraint element
201-220	Finishing	Rounding the edge of cut steel during fabrication stage
221-240	Fitting	Angles with predrilled holes
241-260	HSS	Hollow Structural Steel with cylindrical or prismatic shape, various sizes.
261-280	Machine work	Machine work required to build a custom made restraint or restraint component (e.g. millwork, or metal lathe)
281-300	Neoprene pad	Bridge bearing neoprene pad
301-320	Neoprene washer bushing	Neoprene washer (grommet) for vibration isolation.
321-340	Nylon strap	High strength nylon strap with quick release buckle.
341-360	Painting	Painting surface of restraint element
361-380	Pipe clamp	Pipe clamp (e.g. U clamp , long ear clamp,…)
381-400	Seat belt	Car seat belt with high tensile resistance and heavy duty buckle used to restrain various equipment
401-420	Snubber	All directional snubber
421-440	Stainless steel section	Stainless Steel sections which can be used for laboratory applications
441-460	Steel angle	Structural steel angles with different sizes and X-sections
461-480	Steel Pipe	High strength steel pipes
481-500	Steel plate	Steel plates or flat bar from 6mm to 25 mm in thickness
501-520	Steel strap	Steel straps up to 4 mm in thickness
521-540	Steel wire	Steel wire (e.g. 12 gauge steel wire) which can be used for bracing a suspended ceiling system
541-560	Welding	Required welding for connecting steel section to fabricate a seismic restraint or restraint components.
561-580	Wood	

Coding By Connection.
The fifth coding parameter is the type of connection. Two different types of connection are defined at the same time. These are: the connection between the restraint and the structure, and the connection between the component and the restraint (see Table 7). This parameter defines more than 60 different categories of connections. (e.g. welding, anchor bolts, fasteners, adhesive and/or a combination of two to four different attachment materials).

Table 7. Main categories of connection elements

Code	Connection elements	Definition
001-020	Adhesive	Industrial adhesive that can be used for connecting seismic restraint to the OFC or OFC to the support member.
021-040	Asbestos removal	Required asbestos removal before attachment to structure or equipment
041-060	Bolt, nut, and washer	Assorted fasteners of different capacities.
061-080	Chemical anchor	Anchors which can be used for connecting seismic restraint to the structural element (e.g. steel rods with epoxy)
081-100	Cutting	Any required steel cutting during installation stage
101-120	Drilling	Any required drilling during installation stage
121-140	Epoxy	Different types of epoxy that can be used with the chemical anchor
141-160	Filler	Steel filler plate or shim
161-180	Finishing	Rounding the edges of cut steel during installation stage
181-200	Fire retarding foam	A fire retarding foam that can be used in some applications. (e.g. between a pipe line and structural element when the line passes through a hole from two separated areas
201-220	Grout	Grouting between seismic restraint and connecting concrete surface.
221-240	Insulation removal, and renewal.	Removing insulation before restraint installation and replacement of insulation after restraint installation (e.g. Pipe insulation)
241-260	Mechanical anchor	Anchors with tensile and shear resistance due to mechanical connection to concrete (e.g. Wedge anchors)
261-280	Painting	Any required painting in installation phase
281-300	Rivet	
301-320	Screw	Assorted screws to connect the restraint to OFC or restraint to the structural element
321-340	Welding	Any field welding

Coding By Weight.
The sixth coding parameter is the weight of the equipment. There are 10 different ranges of weight from extremely light to extremely heavy. (e.g. a duct is in the first 3 light weight ranges and a boiler is in the last 4 heavy weight ranges, each in their specified weight categories).

Coding By Design code
Before designing a new restraint, the existing condition of the equipment in a structure (i.e. the existing connection, or if available, restraint) must be reviewed and analyzed. This requires investigating the capability of the existing attachments and restraint elements; specifically, the structural – nonstructural interaction. Each attachment should be studied with respect to the potential for uplift and displacement, as well as taking into account: horizontal forces, and the supporting structure's behavior. If there is no restraint and/or attachment to the structure, or there are questionable restraints and/or attachments, new restraints should be designed. For any OFC with given physical properties and technical specifications,

different applied forces can be obtained depending upon the applicable building code. Therefore, for one OFC a range of seismic details with respect to different codes can be obtained. With this methodology an identification code can be defined to meet the requirements of any existing design code in the world. Table 8 shows three different North American design codes with associated identification codes.

Table 8- Horizontal force requirements from different North American design codes.

Design code	**1995 NBCC** [1]	**2000 IBC** [4]	**1997 UBC** [3]
Identification code	**01**	**02**	**03**
Applied horizontal force to OFC during an earthquake	$V_P = vIS_PW_P$	$F_p = \frac{0.4a_pS_{DS}I_p}{R_p}\left(1+2\frac{z}{h}\right)W_p$ $F_{p\max} = 1.6S_{DS}I_PW_P$ $F_{P\min} = 0.3S_{DS}I_PW_P$	$F_p = \frac{a_pC_aI_p}{R_p}\left(1+3\frac{h_x}{h_r}\right)W_p$ $F_{p\max} = 4.0C_aI_PW_P$ $F_{P\min} = 0.7C_aI_PW_P$

Coding by alternative

For a given OFC and specific design code, the designer may provide alternative details for the seismic restraint in order to accommodate:

- Site limitations.
- Required seismic performance objectives.
- Special circumstances for retrofit or new installation scenarios.

Each one of these requirements has a significant effect on the design of seismic restraint details. However, a discussion of these effects is beyond the scope of this paper. The need for a code that defines different alternatives is specified in this paper but not expressly defined. The last character in the code for a seismic restraint detail refers to the alternative parameter. (See example 2 for more details).

AUTOMATING THE ENGINEERING PROCESS

Restraint design procedure.

There are three stages for restraint design.

1. The structure of the equipment should be modeled. This model can be a SDOF system (Single Degree of Freedom) or a MDOF system (Multiple Degree of Freedom). For structurally similar nonstructural equipment one can use commercially available finite element computer programs to model the structure - three-dimensionally where appropriate.
2. Quantify horizontal force and uplift applied to the OFC during an earthquake. In order to find the horizontal force (i.e. the base shear for structural analysis) the following parameters are required by most of the available codes:
    - The seismic zone where the supporting structure is located, and attenuation parameters.
    - The component's elevation or its position with respect to the structure's height.
    - The flexibility of the equipment and existing attachments (i.e., in NBCC 1995 [1] equipment with a natural time period less than 0.06 sec is considered rigid).
    - The type of material the equipment contains (i.e. whether it is considered to be a toxic or explosive material).
3. After finding the applied horizontal and vertical forces the restraints and the required connections can be designed. In order to design the restraint system, sometimes one needs to use manufacturers directions (e.g. specification given for seismic snubbers in the manufacturer's catalog). On occasion, one needs to design a custom restraint. Wherever possible existing

standards and guidelines are used for design (e.g., for some types of pipe runs and ducts SMACNA [6] can be referenced; and for acoustic suspended ceilings one can use the ASTM E-580 standard [5].

Often one can find physical restrictions such as structural elements (e.g. pre stressed RC slab) or space limitations (e.g. not enough room to install the designed restraint) that result in modifications being made to the standard restraint design. In this case, a conceptual sketch is prepared at the preliminary phase of the project. For the best results, the design engineer should work closely with the fitting fabricator and installer to come up with the optimum plan. A good example of a typical situation is the use of a moment post as an alternative to a forty-five degree brace, due to lack of space or potential interference.

Engineering Software Design.
The process of automating all the stages of the seismic risk mitigation engineering process can be achieved through the development of a software interface for a SQL database. The software includes analysis and design programs for each class of OFC as outlined previously. The result of that design process can be linked to a CAD block-generating program that produces the cost estimated engineering drawings immediately after the design phase.

A typical seismic restraint design package consists of four main elements.

1. A photo or a sketch showing a plan or an elevation view of the equipment.
2. A detail drawing showing the restraint elements.
3. A detail showing the connection between the unit and the structural element.
4. A detail showing the connection between the equipment and the restraint element.

This satisfies the requirements of good engineering practice and is of great assistance to the fabricator and the installer.

EXAMPLES

In order to understand the application of this methodology a few typical examples of seismic restraint for nonstructural equipment are presented.

Example 1
Figure 1 shows the seismically capable mounting of a microscope installed in a hospital operating room. As can be seen in the figure, there are several difficulties in this location, such as: existing obstacles like duct and pipe and drilling into pre-stressed concrete. Further complicating matters is the sensitivity and importance of the environment (Lewis [7]). If the database happens to have an existing drawing for this situation it can be used following confirmation of applicability. If not, the classification system leads the designer to come up with a number of alternatives using the restraint designer program. Each alternative is designed considering different site limitations or other difficulties.

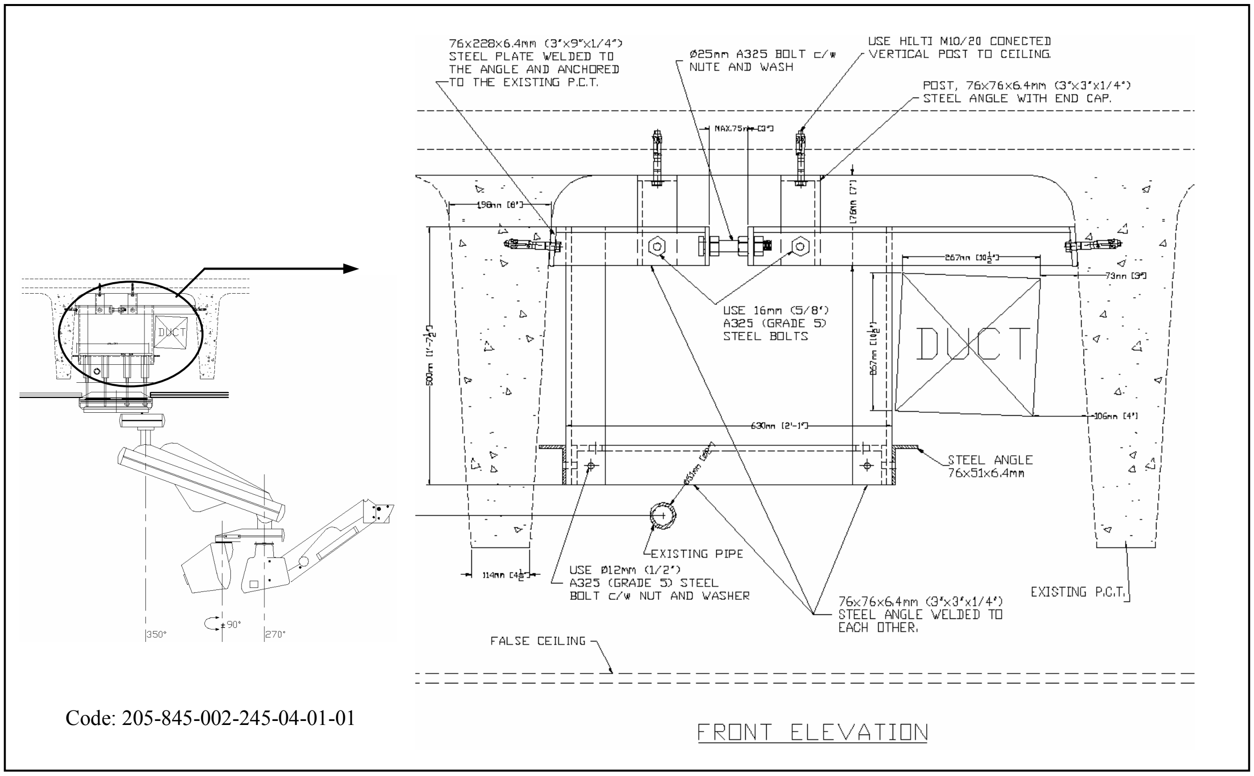


Figure 1.Detail of a seismically capable mount for a microscope in a hospital operating room

In terms of coding for this detail one can use Table 1 trough Table 7 to come up with the restraint code. Table 8 shows briefly each individual code and related definition for the OFC

Table 8.Code for the seismic restraint detail shown in Figure 1

205	845	0022	245	04	01	02	Classification	Definition
							Detail	The second detail created in this category
							Design code	NBCC 1995 [1]
							Weight	6400N
							Connection	Mechanical anchor from table 7
		441,481,541,161,≡ 0022					Restraint	Steel angle, steel plate cutting, welding, and drilling from table 6
							Function	Medical supply/ Specialized OFC. (Microscope) from table 5
							Shape and type	Suspended prism from Table 2

Inputting the complete restraint code (205-845-0022-245-04-01-02) into the software system would enable the following to happen:

1. The entire code is used to perform a search of existing designs to find the closest match (if available).
2. Initial design parameters are established using the design code (NBCC) and the weight code (6400N).
3. Restraint type code and data from step two are combined to specify steel angle thicknesses and sizes.

4. Data from step two above is used in combination with the connection code (mechanical anchor) to specify anchor size.
5. The operator can review search results (if any) to determine if any are suitable for the current situation. If an existing design is suitable for the current circumstances (such as clearance, availability and type of attachment to the primary structure) the results from steps 3 and 4 (anchor and steel angle specifications) can be applied to the existing drawing.
6. In situations where existing drawings are not suitable, elements of the individual code can combine relevant CAD blocks into a rudimentary starting point for a detail drawing, which can be manually modified and annotated to meet the demands of the circumstance, and added to the database for future use.
7. Cost estimates are generated by compiling cost information for labour and materials associated with each CAD block used in the preliminary drawing generated. Where a suitable existing drawing was found, cost information associated with that drawing might have been updated to include real recorded costs based upon prior installations. Maintenance of the cost database can be automated using an external database generated by commercially available estimation and project management software.

The above steps will be very similar for the following two examples.

Example 2

In this example the seismic restraint and coding for a typical suspended acoustic ceiling is shown. As can be seen in the figure 2 there are at least to different types of connections to structural elements, however the restraint can be designed as steel wire [5]. Therefore for this system we define two codes in relation to two different details (See Table 9).

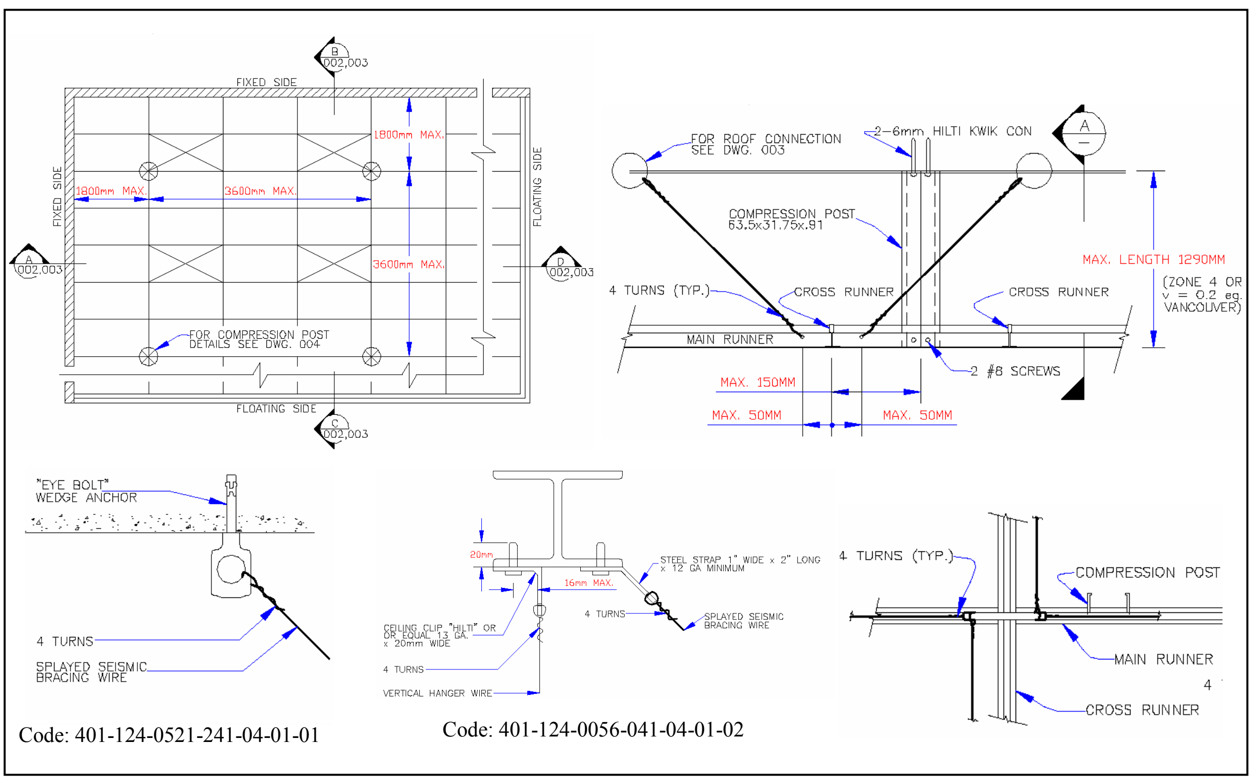


Figure 2.Details of seismic restraint and connections for suspended acoustic ceiling

Table 9. Codes for the seismic restraint detail shown in Figure 2

401	124	0521	241	04	01	01	Classification	Definition
401	124	0056	041	04	01	02		
							Detail	Detail number two in this category
							Design code	NBCC 1995 [2]
							Weight	0.19 KPa
							Connection	Mechanical anchor or steel bolt from table 7
			521,221≡ 0056				Restraint	Steel wire or Steel wire and fitting from table 6
							Function	Ceiling from table 5
							Shape and type	Acoustical Suspension Ceiling from table 4

Both variations of the code can be input to compare cost and suitability for the given circumstance. In this case, cost information would have been provided in units of square feet. Both options can be presented to the client as needed.

Example 3

In this example the seismic restraints for a set of liquid nitrogen tanks are shown in figure 3. As can be seen in table 10 the code related to the restraint element is comprised of different components (see Table 6). Each restraint element can be defined by combining a number of different components and using the specific code that results from each combination.

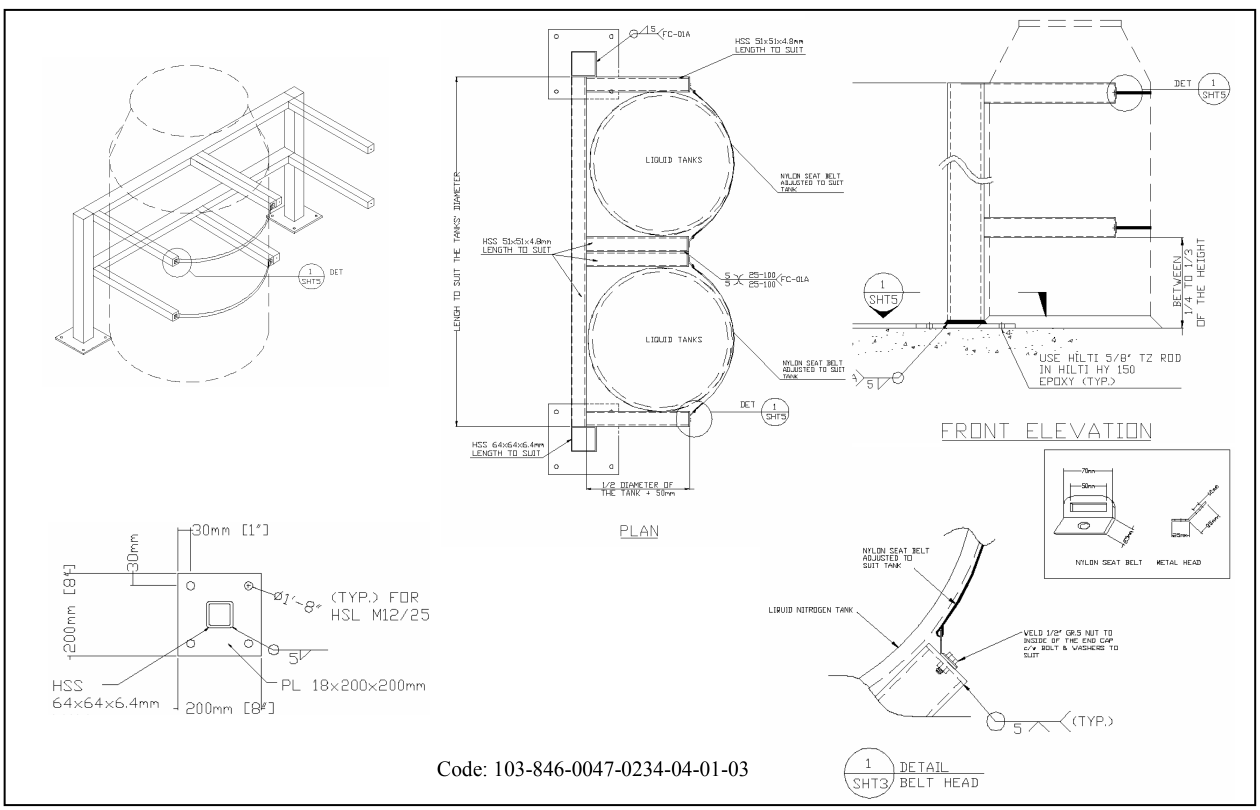


Figure 3. Details of seismic restraint and connections for liquid nitrogen tanks

Table 10. Codes for the seismic restraint detail shown in Figure 3

103	846	0047	0234	04	01	03	Classification	Definition
							Detail	Detail number two in this category
							Design code	NBCC 1995 [1]
							Weight	1928N/tank
			241,041≡ 0234				Connection	Mechanical anchor and steel bolt from table 7
		241,541,481,161,381≡ 0047					Restraint	HSS, welding, steel plate, drilling, seat belt table 6
							Function	Medical supply/Specialized OFC (Nitrogen tank) From table 5
							Shape and type	Vertical cylinder on base table 1

Example 4

The figure given below shows the detail of seismic restraint and connections for a display rack system. As can be seen in the figure, each leg is retrofitted and secured by a specific restraint. The code for the detail is explained in Table 11.

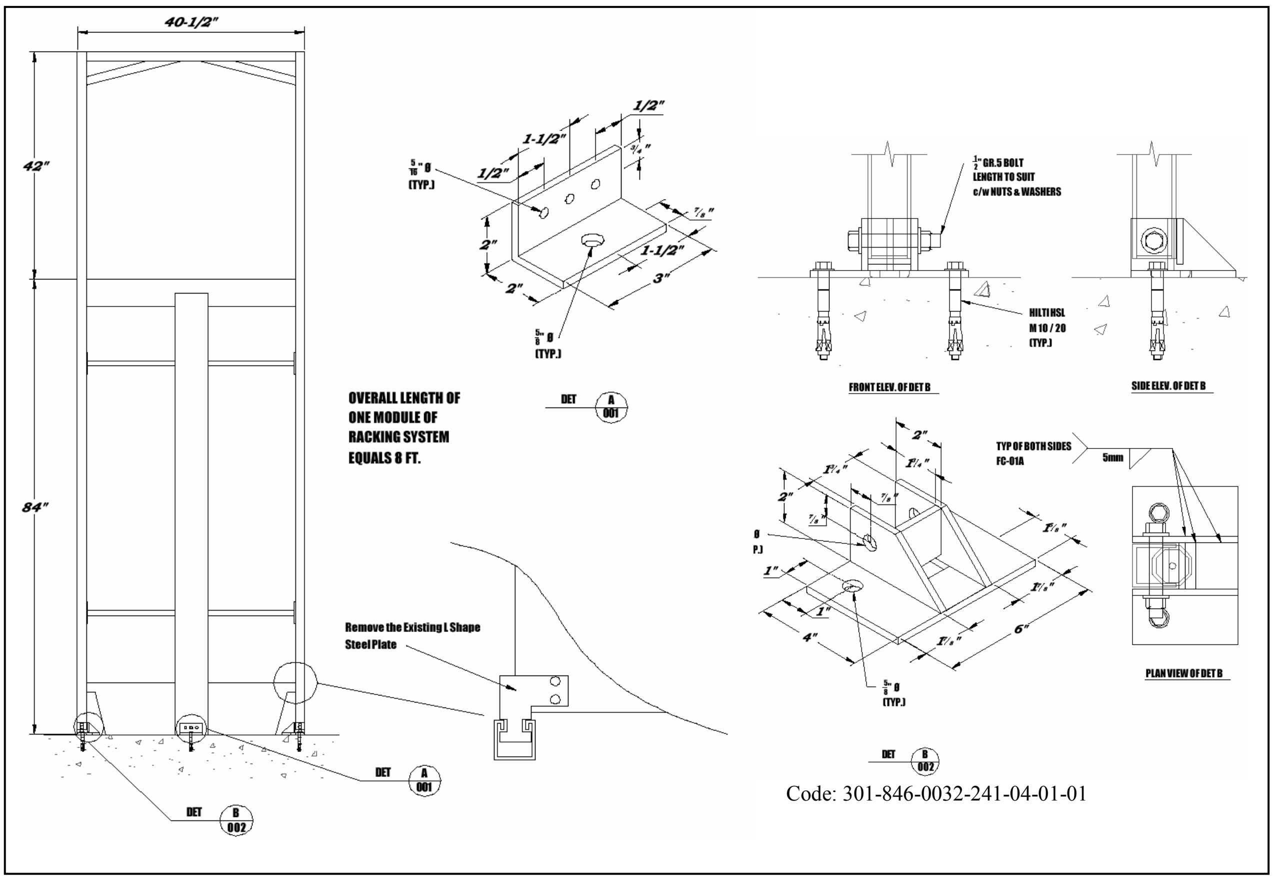


Figure 4. Details of seismic restraint and connections for a display rack

Table 11. Codes for the seismic restraint detail shown in Figure 4?

301	846	0032	241	04	01	01	Classification	Definition
							Detail	Detail number one in this category
							Design code	NBCC 1995 [1]
							Weight	4500N / module
							Connection	Mechanical anchor from table 7
			441,481,121,161,541≡ 0032				Restraint	Steel angle, steel plate, cutting, drilling, and, welding from table 6
							Function	Display (Storage) rack From table 5
							Shape and type	Racks or shelving from Table 3

CONCLUSIONS

The amount of engineering work required making even a small inroad on the necessary and often required seismic risk mitigation work for operational and functional components of buildings is daunting. Given the lack of institutional support for this process, it is only through the design of highly automated and relatively easy to deploy systems that we will make any progress toward reducing the massive seismic hazard facing many urban regions around the world. The flow chart given in the figure 5 briefly shows the application of methodology in potential software, which is explained in the above-mentioned examples.

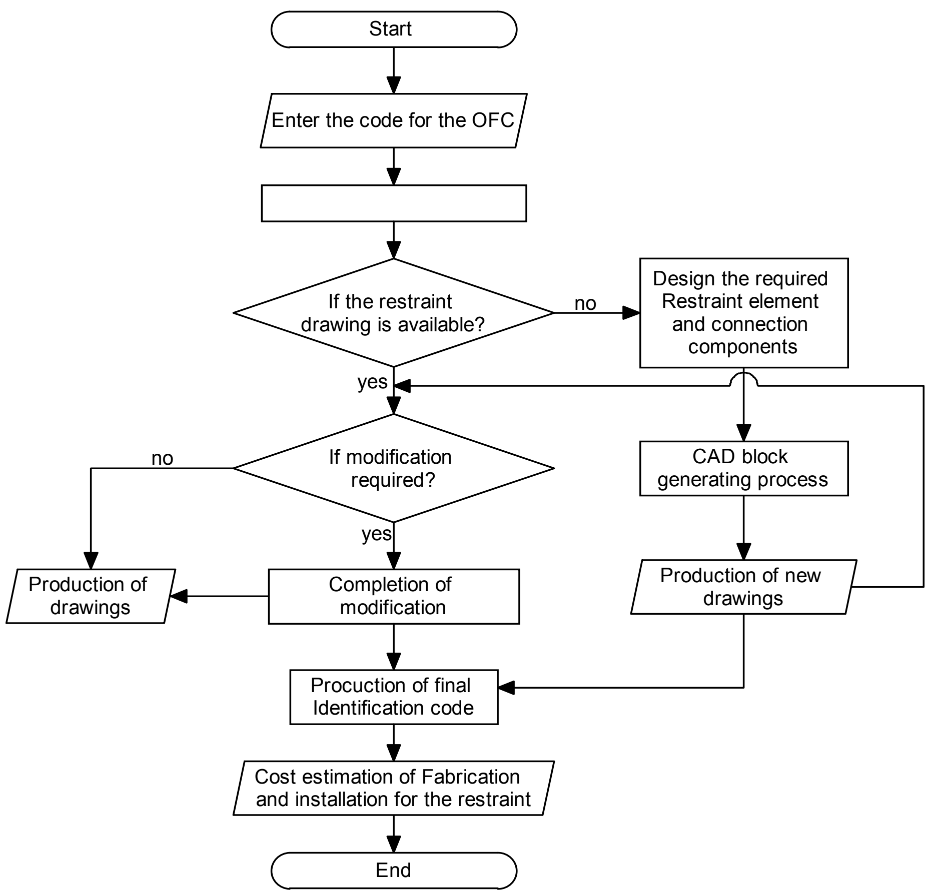


Figure 5. A flowchart for the application of the methodology in potential design software

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