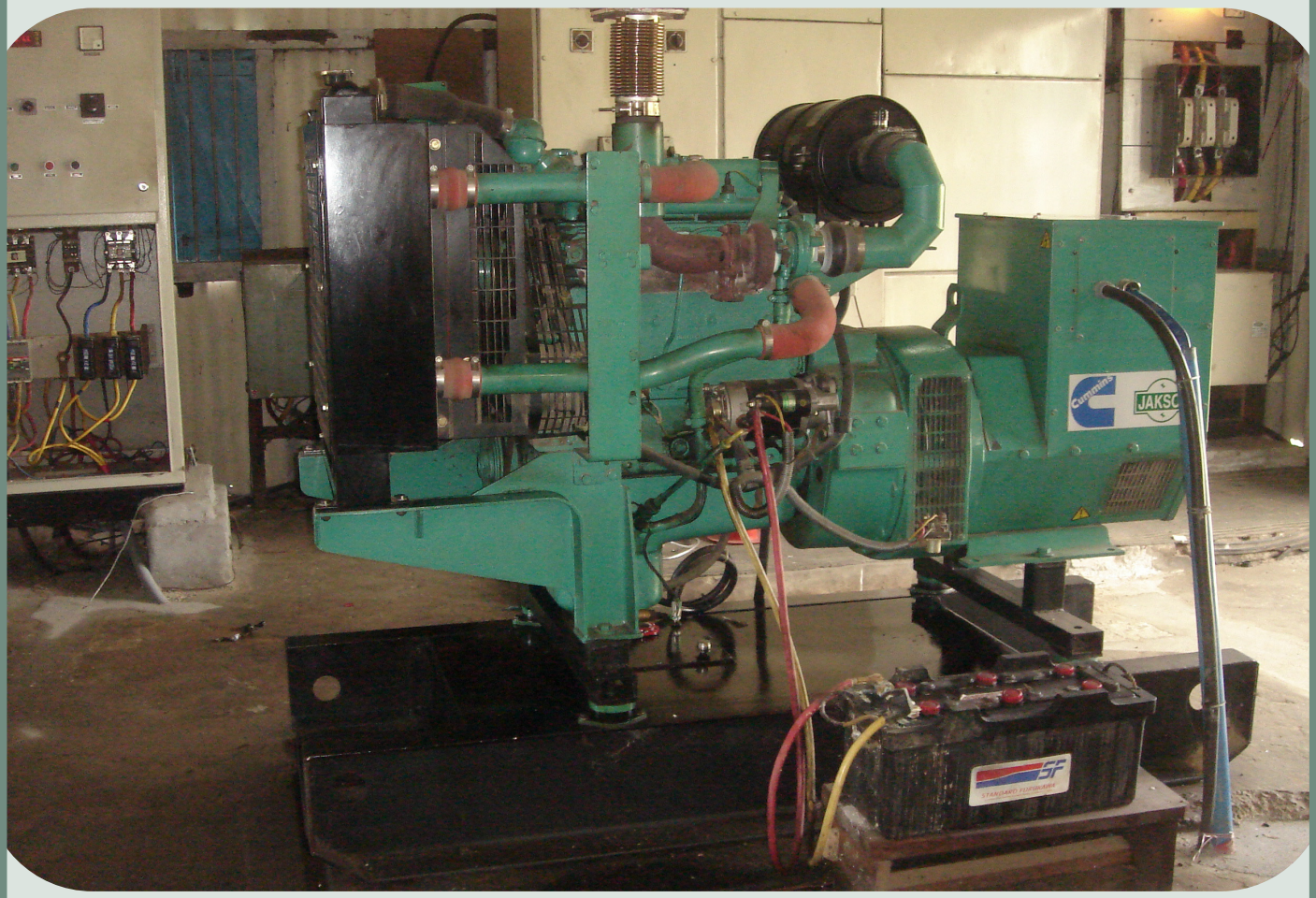
Instructor Guide



Reducing Earthquake Risk in Hospitals

from Equipment, Contents, Architectural Elements and Building Utility Systems

A Training Course for Hospital Maintenance and Facilities Personnel

GeoHazards International
A Nonprofit Working Toward Global Earthquake Safety

GeoHazards Society
I N D I A

Swiss Re

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from Equipment, Contents, Architectural Elements and Building Utility Systems

A Training Course for Hospital Maintenance and Facilities Personnel

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Purpose

Hospitals provide life-saving medical care on a daily basis to the communities that they serve. Communities expect the hospital staff to save lives in an emergency and to care for community members that have been severely injured or have become seriously ill. Earthquakes threaten your hospital's ability to carry out its responsibilities to care for the ill and injured. Past earthquakes around the world have destroyed hospitals or damaged them so that they could not function. These hospitals failed their communities in their hour of greatest need.

Reasonable measures can reduce the risk of earthquake damage and losses, and to keep hospitals functioning after an earthquake. This two-day training course will help you empower the facilities department to reduce one of the major sources of earthquake-related damage and losses: a hospital's medical equipment and supplies, contents, architectural elements, and building utility systems. Damage to these items has caused deaths, injuries, building functional loss, and economic loss in past earthquakes, even in cases in which the building structure itself was essentially undamaged. The course also provides an introduction to the other components necessary for keeping a hospital functional and safe: structural safety of hospital buildings, hospital emergency preparedness, and personal preparedness for the staff.

This set of training materials provides content and instructions for a two-day training course for hospital facilities personnel. These training materials are based on GeoHazards International's manual entitled *Reducing Earthquake Risk in Hospitals from Equipment, Contents, Architectural Elements and Building Utility Systems*, and are meant to be used in conjunction with the manual. Each trainee should receive a copy of the manual, either electronically or in hard copy. The manual is freely downloadable from the GeoHazards International website: http://www.geohaz.org/hospitalsafetymanual.

GeoHazards International prepared this set of training materials for use in a hospital earthquake preparedness project in India, but the materials can be easily modified for use by other organizations in other locations with GeoHazards International's prior permission. The training materials include this instructor guide, which includes detailed instructions for the numerous practical exercised included in the course, presentations in Microsoft Powerpoint™, and student handouts. This instructor guide will take you through the presentation slide by slide and will identify important aspects you should highlight.

Audience

Your audience will consist of maintenance and facilities personnel, which could include engineers, tradespersons, and handymen. You will need to determine the professional backgrounds of your audience members ahead of time, so that you can tailor the practical exercises accordingly.

Training Objectives

Our objective is that trainees should be able to do the following after they complete the course:

1. Understand why earthquake safety is important:

   (a) Understand why hospitals need to function and continue to care for patients after an earthquake, and not just avoid collapse of the hospital's buildings;
   (b) Understand what might happen to the hospital and its equipment, systems, architectural elements and contents if a strong earthquake occurred; and
   (c) Understand the basics of earthquake hazard in the region (i.e., that earthquakes can affect their location, historical earthquakes that occurred in the area, etc.).

2. Understand how to reduce the damage and consequences caused by an earthquake:

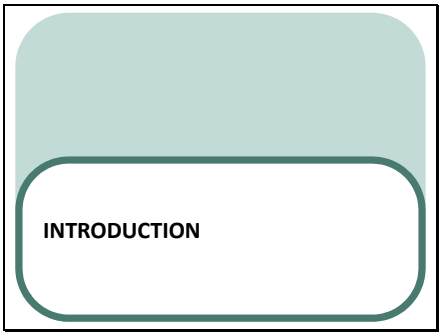
(a) Know the basic elements of a hospital earthquake risk management program: risk assessment, building safety, securing objects and systems, preparedness planning and training/ practice;
(b) Understand two different ways earthquakes cause damage to building equipment and systems: by shaking and by pulling and stretching items connected to the building(s);
(c) Recognize and understand, conceptually and practically, how to anchor or relocate items than can fall, slide, or topple and break, interrupt life support, cause injury or block exits;
(d) Recognize the need to work with the medial staff, especially nurses, to develop earthquake safety solutions that do not compromise functionality;
(e) Know the basics of the hospital emergency planning process; and
(f) Know what to do before, during, and after an earthquake.

3. Understand how they can participate in earthquake safety efforts:

(a) Know the options for their involvement: join safety committee, identify and anchor hazards, develop solutions, etc.
(b) Think about their potential role in the hospital's emergency preparedness plan; and
(c) Develop a family preparedness plan.

Step-by-step Presentation Guide

Introduce GHI, GHS and Swiss Re with a few sentences about each. Introduce yourself and welcome your audience.

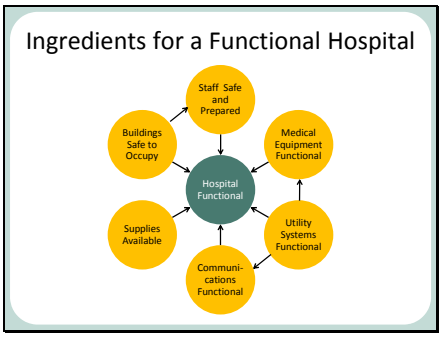


Tell the story of a hospital rendered non-functional by an earthquake. Use this slide with the story of Bhuj Civil Hospital in the manual, or tell a more recent story from another earthquake, such as Haiti or Chile. If you use a different story, replace this slide with a single slide with one or two photos of the hospital that emphasize the main points of the story.

If you talk about Bhuj, you can ask – was the doctor a hero? Yes, but he should never have had to be one. The building and its systems failed him, and we want to prevent that from happening to other doctors in other hospitals. He did what he could under the circumstances, but imagine what could have happened if the hospital building was functional. How many lives could have been

saved? Infections and complications prevented? Invite the participants to start thinking about what could happen in their hospital and how they can help make the hospital more resilient. Introduce them to the concept of resilience - that you plan to get back to normal operations (or as close as you can) within a certain timeframe, which for hospitals will be as soon as you can. For instance you would want to rebound to deliver critical services within pre-determined number of days, not months.

In the meantime, you plan to be able to deliver the appropriate level of care, which may be austere care if you have a mass casualty situation like in Bhuj, and your hospital building is not usable. Austere care is defined as the level of medical care, modified from the expected standard of care, which is provided when hospital resources, medical supplies and medical personnel are limited or unavailable for an extended response period. (For example, that might happen if the earthquake occurred tomorrow, before you had the chance to make any safety improvements.)



So, what do you need to keep a hospital building functional after an earthquake? Explain that keeping a hospital functional after an earthquake requires a number of interdependent actions. Keeping the buildings' structural systems safe and performing well enough to continue occupying the buildings will help keep the staff and patients safe. It will also help them perceive that they are safe in the building, so that the staff is available to provide lifesaving care to the community. (Engineers make the judgment about safety, but user perception of damage is very important – most people will not want to go back in a building that appears to have suffered significant damage.)

In order to keep medical equipment functional, the equipment must not be damaged, and the utilities that power it must be functioning as well. For example, a ventilator will need both backup emergency power and the medical gas system to

remain functional. An autoclave will require both electrical power and water. You will need building utilities functioning in order to provide services.

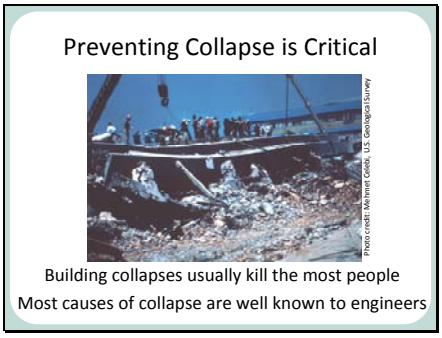
Take the time to discuss each bullet point to help trainees understand how each item contributes to hospital functionality.

Earthquake damage affects unprepared hospitals more severely than other buildings because:

- Patients may incapacitated and therefore more vulnerable: many can't take protective actions that healthy people can; some are on life support; damage that would cause minor injuries to or merely inconvenience healthy people could severely injure incapacitated patients.

- Hospitals have complex systems crucial to maintaining patient care: medical gases, electricity, climate control, suction/vacuum, water, electrical, communications; these systems can also create hazards when damaged by an earthquake: flammable gases, spilled laboratory chemicals and medicines, broken glass, fallen suspended ceiling panels (common in rooms with climate control) and dust creating unsanitary conditions. Loss of a sterile or sanitary environment due to earthquake damage and functional loss can have drastic effects on the health of patients already vulnerable to infection.

- Hospitals contain expensive medical equipment: it can be very costly and time-consuming to replace.



Explain that preventing the hospital buildings from collapsing is the first and most important way to save lives. In most earthquakes, building collapses cause the vast majority of deaths. (The most notable exceptions are large undersea earthquakes that generate tsunamis, such as the 2004 Sumatra, Indonesia earthquake that generated a tsunami that affected the whole Indian Ocean.) The hospital building shown collapsed during the 1985 Mexico City earthquake. More than 900 hospital staff and patients died in two major hospital building

collapses in the 1985 earthquake.

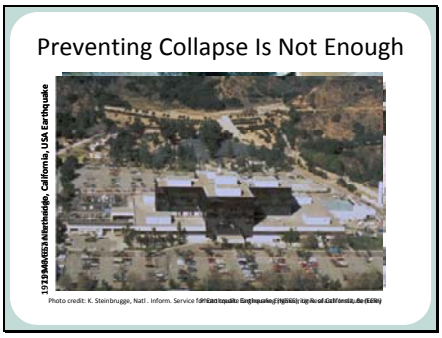
Preventing collapse should be your hospital's top priority, though it may take time and funding. There are a lot of things you can do in the meantime to make your hospital safer and more likely to be functional, but we'll get to that in a minute. The good news is that the types of severe damage that leads to collapse don't have to happen. Almost all building collapses are caused by the types of deficiencies in the building's design, construction, or maintenance that are well-known to structural engineers.

Three Steps to Prevent Collapse

1. Design and construct all new buildings to code
2. Have a structural engineer assess buildings
3. Act on recommendations: simple retrofit measures can prevent collapse in many cases

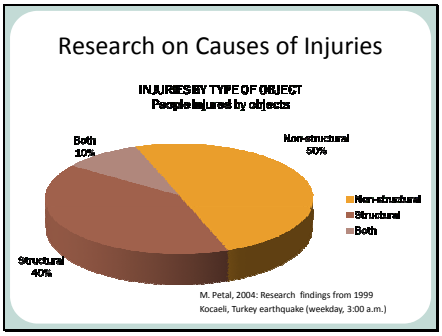
There are three simple steps your hospital can take to prevent any of the hospital's buildings from collapsing. The first step is to ensure that all new buildings on the hospital campus are designed and constructed in accordance with India's building code for earthquake-resistant design, Indian Standard 1893, put out by the Bureau of Indian Standards. A knowledgeable structural engineer should do the design and supervise the construction. Second, have a structural engineer with experience in the earthquake vulnerability assessment of buildings evaluate your hospital's buildings unless they were recently built to comply with the 2002 version of the IS 1893 building code – this is the first step to improve the safety of your current buildings. The third step is to act on the engineer's recommendations. In many cases, simple retrofit measures can prevent collapse.

You can and should advocate for all these things and support your administrators as they pursue structural safety. However, structural assessments and designs require a qualified structural engineer and may require larger expenditures. Today we are going to talk about what you can do meanwhile to reduce risks and improve the hospital's ability to remain functional, especially in more frequent smaller earthquakes. Or, if your building is already earthquake-resistant, how you can greatly improve the chances that the hospital will remain functional.



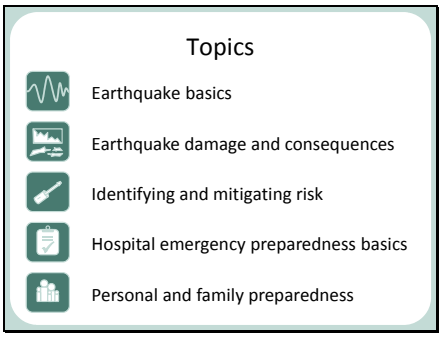
In order to keep the staff and patients safe, you must prevent the building from collapsing. However, earthquake safety isn't just about the building standing up. Use the story of the old and new Olive View Medical Center buildings in the Los Angeles area of California to make this point.

The original hospital was new when it suffered structural damage in the 1971 San Fernando California earthquake that was so severe the hospital had to be demolished and rebuilt. The new hospital was built to be very strong, with large steel walls to resist earthquake forces. The new hospital was tested by the 1994 Northridge earthquake, and the building itself suffered no structural damage despite the shaking being very strong. However, a fire sprinkler pipe broke and caused water to leak (the 6th floor was flooded), the oxygen tank toppled, disrupting medical gas supply, and staff had difficulty getting to work because of a collapsed flyover. The hospital was evacuated for several days as a result mostly of the water damage. The new hospital should have been able to take in patients, rather than evacuating them.

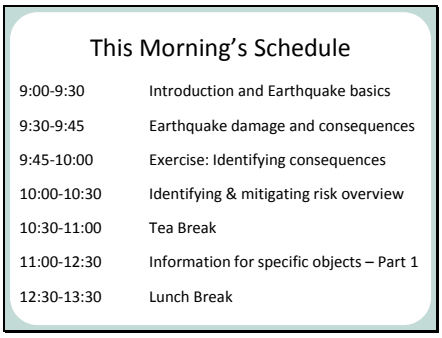


A survey of people following the 1999 Kocaeli (Izmit) Turkey earthquake showed that many people – fifty percent – were injured by non-structural objects. Securing or relocating these objects can prevent many injuries and reduce the demands placed on the health system immediately after the earthquake.

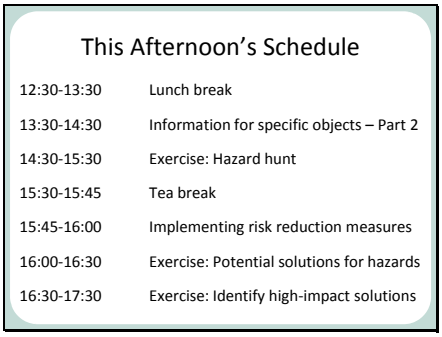
Emphasize the importance of simple, often inexpensive actions that maintenance personnel can take. Over time, such actions can make a big difference. Example: anchoring cupboards to prevent exits from being blocked, putting snubbers on the emergency generators. The photos show how easy it can be to take steps toward safety.



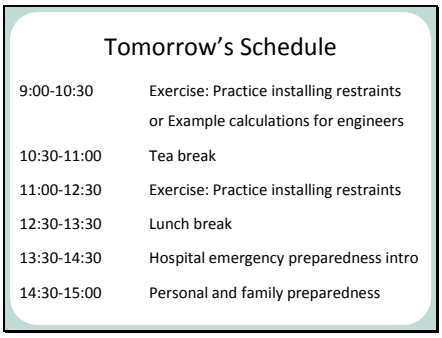
Introduce the topics we will cover during the course: earthquake basics, earthquake damage and consequences, identifying and mitigating risk, hospital emergency preparedness basics, and personal and family preparedness.



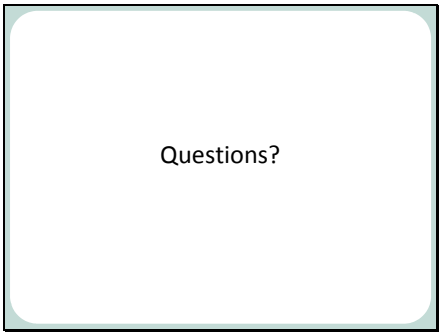
Go over the schedule. This is a suggested schedule for the morning. You can modify the start and end times and the length of the breaks as needed. Part 1 of Information for specific objects will cover mechanical and electrical equipment, medical equipment, furnishings and hospital administrative systems, and supplies.



Continue with the afternoon schedule. Coverage in Part 2 of Information for Specific Objects is pipes, ducts and conduits; tanks and medical gases; architectural elements; and lifts. The time for the hazard hunt may vary with the size of you're your hospital and the number of trainees. You will not need to conduct a thorough hazard hunt, but you will need to visit enough locations to gain material for the upcoming practical exercises. To avoid disrupting hospital operations, focus your hazard hunt on mechanical equipment, building utility systems, and architectural elements on the exterior and in administrative or office areas. If any medical service areas happen to be closed for maintenance or repairs, you could add them to the hazard hunt. The final two exercises of the day can be compressed or expanded depending on the situation at the hospital. You will need to do some work in advance to get a sense of the possibilities, and to have some options on hand in the event that your audience is having difficulty proposing potential solutions (if you have engineers in the audience this is unlikely to be a problem).

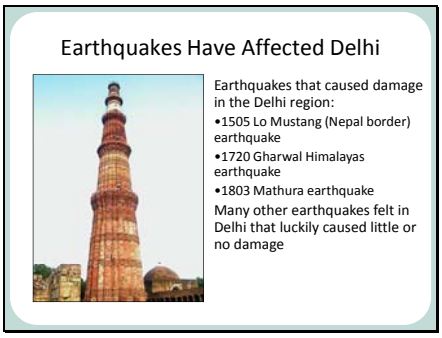


Briefly review the schedule for the second day. If you have engineers (as opposed to tradespeople) and you are going to do some example calculations, do that at the start of the day, and adjust the schedule as needed by taking some time from the practice installing restraints exercise. If not, proceed to practice installing restraints. The afternoon session on hospital emergency preparedness basics includes a short exercise. You can expand this exercise if you would like to make the second day a full one.



Answer any questions on the schedule before you begin with the first technical section, which is on earthquake basics.

Earthquake Basics – in this section we will cover not only some basics of earthquake shaking, but also some of the basics of how earthquakes affect buildings.

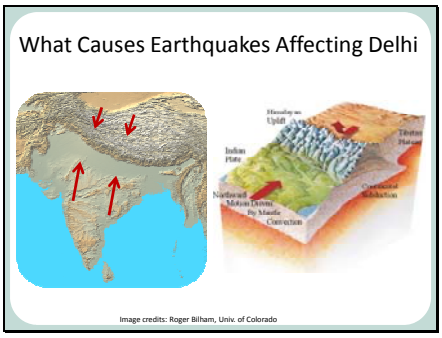


The earthquake hazard information in this slide and the next 3 slides is specific to Delhi. You will need to substitute hazard and historical earthquake information for the location of your training session. If you are in an area that had a major historical earthquake, add a slide for that earthquake that summarizes its effects: deaths, injuries, number of people homeless to the extent known. If you can find a relevant first-hand account of that earthquake, tell it briefly (1-2 minutes) to help the audience start thinking about what happens during earthquakes.

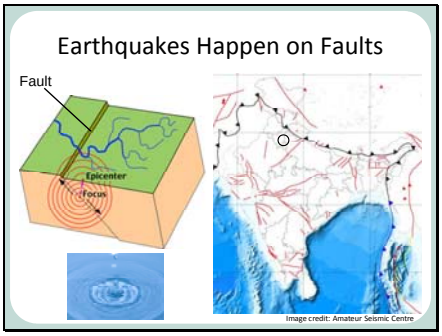
You can also ask the audience if they have felt earthquakes. You will need to keep an eye on the time, so call on only two or three people that said they felt and earthquake and ask which earthquake and how it felt. Try to keep them to less than a minute each, unless someone was working in a hospital when there was an earthquake that caused strong shaking at the hospital – that will be an interesting story that is worth taking time for! Part of the job will be convincing people that earthquakes can happen to them, and if someone in the room did have it happen to them, it can be very compelling. (If you do have someone like this with experience in a hospital in a major earthquake, please be sure to talk to them at the coffee break to get additional information from them, and determine how you might weave their experience into other parts of the training session.)

Some details on earthquakes affecting Delhi:

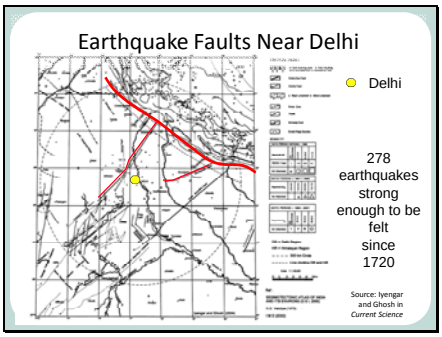
- 1505 Lo Mustang was a very large earthquake that damaged Agra, Delhi, Dholpur and Gwailor.
- 1720 Gharwal Himalayas earthquake which damaged Old Delhi
- 1803 Mathura earthquake is the last large earthquake to cause damage in Delhi – this is the earthquake that is thought to have damaged the Qutub Minar



The portion of the earth's crust that India sits on, called the Indian tectonic plate, is colliding with the portion of the earth's crust that China sits on, called the Eurasian plate, as the graphic at left shows (ask if they remember plate tectonics from their school days). The Indian plate is actually going underneath the Eurasian plate. Tremendous forces are involved in this activity. This process has built (and is still building) the Himalayas, and it causes many earthquakes not only in the Himalayas but also near Delhi and in peninsular India as the Indian plate buckles and bends under the stress.

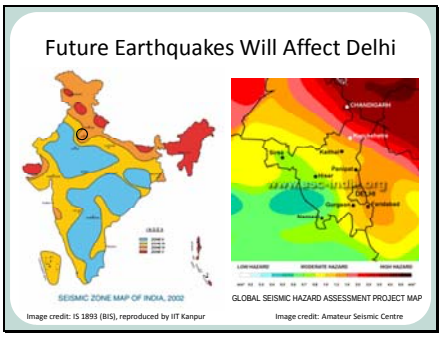


Earthquakes happen when the rocks that are locked together along the tectonic plate boundary or within the plates themselves are unable to take any more deformation, and they break and slip past each other. This releases a huge amount of energy, some of which races through the earth as *seismic waves*, similar to the way ripples go out when you throw a rock into a pond. When the seismic waves reach the surface of the earth, we feel them as an earthquake. Next, explain that earthquakes occur on *faults*, which are weak places where the earth's crust has broken before. The big fault zone where the two plates come together is shown in black with triangles that point in the direction India is moving. Other major faults in India are shown in red on the map. If you know where the faults are, you know where earthquakes are likely to happen. And of course, there are faults near Delhi ….



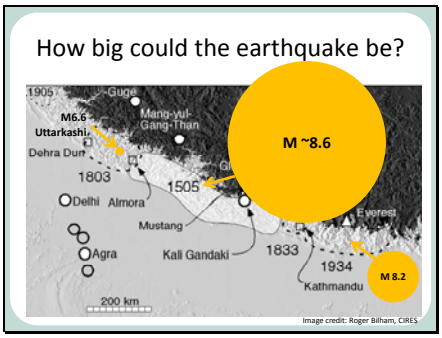
There are several active faults near Delhi that cause earthquakes. The largest earthquakes occur along the main plate boundary fault that we showed in the previous slide, called the Main Boundary Thrust (MBT). (This is the long, thick red line.) Delhi is indicated by the yellow dot.

You can mention that in the area around Delhi, there have been at least 278 earthquakes since 1720 that have been strong enough to be felt.



Explain that because of the ongoing collision shown previously, future earthquakes will affect Delhi. The Seismic Zone Map of India, at left, shows an estimate of how strong engineers and scientists think the shaking will be in various parts of India, based on past earthquakes. You can mention that the map is a work in progress, and is updated as new information becomes available. Despite India's very long history, we have complete earthquake information for only about 200 years.

The seismic hazard in India has also been estimated as part of the Global Seismic Hazard Assessment Project. This seismic hazard map was made by earth scientists and shows slightly more detail than the zone map. (If needed you can explain that the zone map is what is used in the building code, and it is simpler primarily for that reason.)

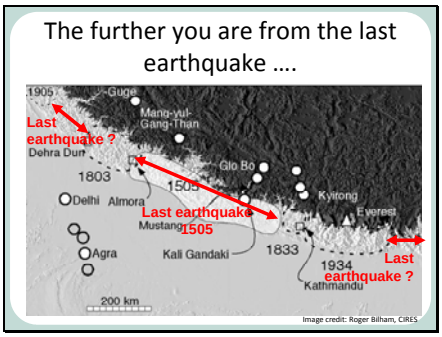


The size of an earthquake is described by a scientific term called *magnitude*. You may have heard the term, "Richter Scale" – today scientists use a different type of magnitude measurement based on the amount of energy released when the fault breaks. Magnitude is measured on a logarithmic scale of 1 to 10. The logarithmic scale means that a magnitude 7 is MUCH bigger than a magnitude 6 earthquake – the energy release is about 32 times greater. And, a magnitude 8 earthquake would release 32 times 32 (~1000) times the energy that a magnitude 6 earthquake would.

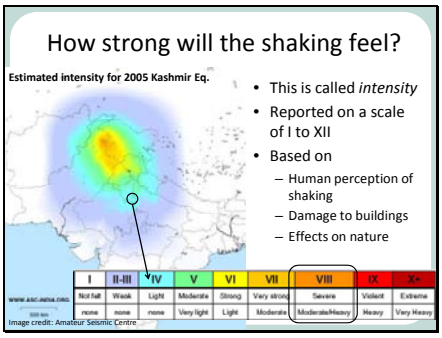
Some earthquakes in the Himalayas help us understand how the magnitude scale works. The biggest earthquake in this graphic is the 1505 Lo Mustang earthquake, which damaged Delhi. Because there were no *seismographs* (instruments that measure earthquake shaking) at that time, we don't really know how big it was, but scientists estimate it was about M8.6. The 1934 Bihar-Nepal earthquake was magnitude 8.2. Notice that the gold ball with the magnitude printed on it is MUCH bigger for the M8.6

earthquake than the M8.2 earthquake. Ask audience if they are surprised. Then mention that the 1991 Uttarkashi earthquake with M6.6 is much, much smaller still – it's the smallest gold dot.

Mention that the central Himalaya near Delhi can experience earthquakes of all the sizes shown, and in between as well. In addition, local earthquakes in the M6 to 7 range can occur on the local faults near Delhi that we showed in an earlier slide.

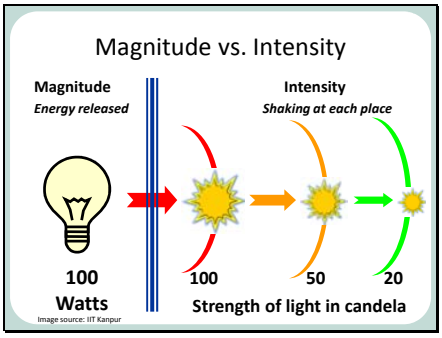


Explain how the plate boundary builds up stresses that need to be released once in a while, through major earthquakes. The major earthquakes that have occurred recently at the Plate boundary near Delhi are the 1905 Kangra earthquake (more than 105 years back!!) and the Bihar Nepal earthquake of 1934. There was also a large earthquake in 1803 in Mathura. Scientists call the portions of the plate boundary between recent, large earthquakes 'Seismic Gaps' and expect the next big event to occur in such gaps. For instance, there has not been a large earthquake in the central seismic gap since 1505, and there are portions of the plate boundary such as Sikkim where we have no records of historical events not because there have been no earthquakes but because the records have been lost or destroyed.

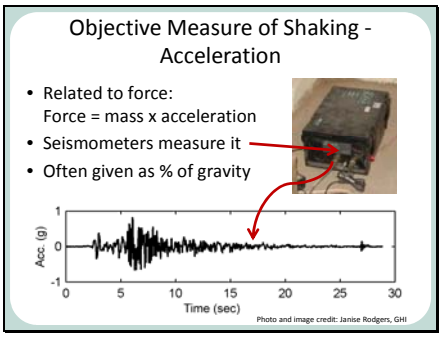


How strong the shaking feels at your location is described by a scientific term called *intensity*. Intensity is described on a scale of Roman numerals from I to XII (first row of table), and it is based on human perception of shaking (second row), damage to buildings (third row), and effects on nature. The map shows that the estimated intensity for the last big earthquake in north India, the 2005 Kashmir earthquake, was IV in Delhi – explain that this meant light shaking and no damage. Ask if anyone felt the earthquake. Note that the maximum expected intensity based on the Seismic Zoning Map is VIII. You should change the circle and arrow to fit the location of the training, as well as the box around VIII if your

location is in a different seismic zone. Also, you can substitute an earthquake that occurred near the location of the training. The Amateur Seismic Centre website (www.asc-india.org) has many historical intensity maps for South Asia earthquakes.



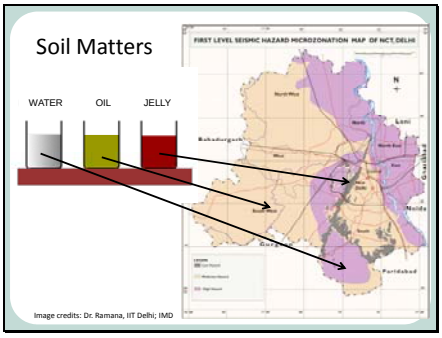
Explain that the difference between magnitude and intensity can be explained with a simple example. The magnitude of the earthquake is like the watts in a light bulb. No matter where you are, the light bulb is still a 100-watt light bulb. It is a 100 watt bulb if you are standing next to it, or in the next room, or even down the next street. Intensity is like strength of the light as measured by the number of candle lights (candela). If you are next to the light bulb, the light will be stronger than if you are further away.



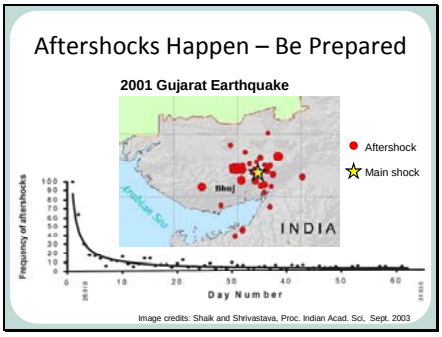
Acceleration is a measure of how fast the ground speeds up and slows down as it shakes back and forth. Think of driving in a car. You press the accelerator pedal, and the car goes faster. Accelerations are important because they are related to forces (through Newton's Second Law of Motion that you may remember from school; force equals mass times acceleration), and you need to know forces to be able to anchor objects so they don't fall. Accelerations can also be measured by instruments called seismometers or accelerographs (point to the one shown in the picture) that make a "picture" of how hard the ground shook during the earthquake (point to acceleration time history). For earthquakes, accelerations of the ground and buildings are often expressed as a percentage or decimal fraction of the acceleration due to gravity, which is something familiar. For instance, vertical earthquake accelerations of more than 1 g (which are very rare) would throw objects into the air. Earthquakes generate both horizontal and vertical accelerations, but the horizontal accelerations do the most damage. This is because most structures are well-designed for vertical loads – otherwise they would fall down just due to gravity (they are designed for 1 g plus a safety factor already) – but

not necessarily for horizontal loads.

If someone asks why don't you just measure how the ground itself moves (i.e., displacement), explain that displacement is hard to measure precisely (researchers now use GPS to measure displacements of tall buildings that move slowly) but that it is easy to measure acceleration because of Newton's second law.



Explain that the soil under the buildings affects how strong the ground shakes. Use the illustration of water, honey, and jelly shaking differently to show how the ground shaking on the soft soils deposited by the Yamuna is much higher than on the rock. This slide is specific to Delhi, but you can substitute one for your area if you have a soils map or microzonation map.



When a damaging earthquake occurs, there will be a number of smaller earthquakes afterward that are called *aftershocks*. Some of these aftershocks will be large enough to cause additional damage on their own. Aftershocks normally decrease in size and frequency with time, so the largest and most potentially damaging aftershocks typically occur in the two weeks or so after the event. There is also a small chance that a larger earthquake could occur as well, though this is quite rare. In this case the first earthquake would be what is called a *foreshock*.

After an earthquake happens, you should expect aftershocks and take appropriate safety precautions if you are inspecting buildings or equipment for damage, repairing damage, or cleaning up. You should think, "What could happen if an aftershock occurs while I'm doing this?" Don't go into buildings that are badly damaged and could collapse in an aftershock.

Questions?

Answer questions from the participants. Limit the number of questions to keep on schedule. You can invite participants to ask additional questions at the tea break or at lunch.

EARTHQUAKE DAMAGE AND ITS CONSEQUENCES

Introduce the next section on earthquake damage and its consequences.

Building Damage

Photo credit: Mehmet Celebi, USGS

The building's structure, the parts that resist gravity loads acting vertically and earthquake forces acting horizontally (laterally), can be damaged by earthquakes. Damage can range from none to complete collapse. Major damage to load-bearing elements such as columns and bearing walls usually makes the building unsafe to re-enter. Almost every earthquake has aftershocks, so don't enter badly damaged buildings because an aftershock could cause them to collapse.

Would you go in this hospital?

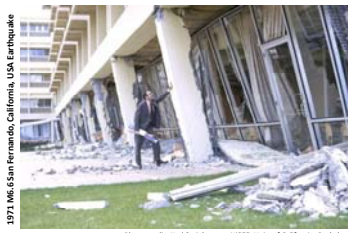
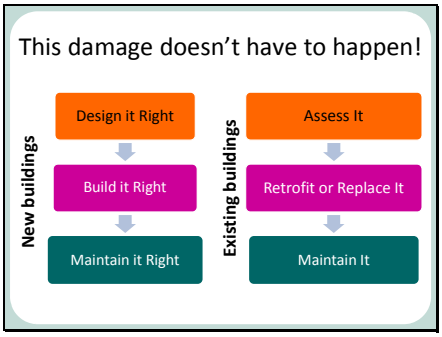


Photo credit: Karl Steinbrugge, NISEE, Univ. of California, Berkeley

This building is leaning dangerously and is at a state of what structural engineers call "imminent collapse". It is very dangerous to enter such buildings because they could collapse in an aftershock.

This building has partially collapsed – too dangerous to enter.

This hospital initially does not appear to have been as badly damaged. However, upon closer inspection we see that one corner of the first storey above ground has collapsed and there are large cracks. Portions of the wall could fall in an aftershock. This building is unsafe to use; hence the tents in front. This is a pediatrics building – would you want your child to be treated in this building?



Major structural damage that would close your hospital does not have to happen. It has discernable causes that can be identified during an evaluation by structural engineer, or avoided during design (for new buildings). Preventing collapse in the expected major earthquake must be the hospital's top priority.

Remember to:
Design it right
Build it right
Maintain it right

Or, if you have an existing building:
Assess it
Retrofit it or Replace it
Maintain it

You can take these actions by:

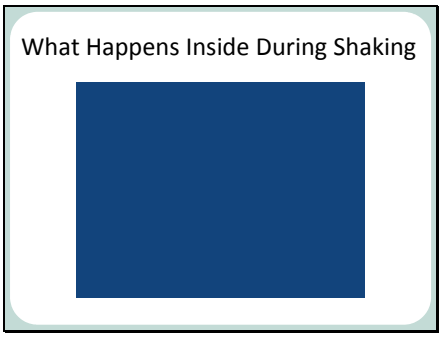
- Hiring a structural engineer with earthquake engineering experience to either assess your currently existing buildings or design proposed new ones.
- Follow his or her recommendations
- Hire good, honest contractors and make sure

they follow the design

- Maintain the building so that its earthquake resistant features are not compromised

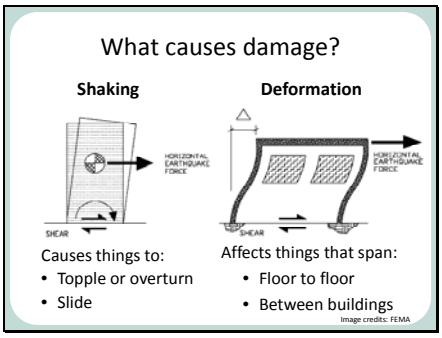
This is a photo of the inside of a hospital in Chile after the 2010 earthquake. Ask participants to spot what has been damaged. They should be able to point out the suspended ceiling, pipes, light fixtures, wiring, and wall finishes. Also, the power is out.

Ask participants whether they could work in this building. Why or why not? The power is out so it is dark, and light fixtures have fallen so even if there was power there would not be light. The suspended ceiling has collapsed, dropping accumulated dust on everything and leaving the corridor littered with debris. Objects are hanging from the ceiling. A pipe has broken and caused a water leak that created a large puddle in the corridor.



This video was taken by a camera inside a Japanese TV broadcast company office during the 1995 Kobe earthquake. Point out the employee spending the night in the office, who tries to protect himself by curling into a ball during the shaking.

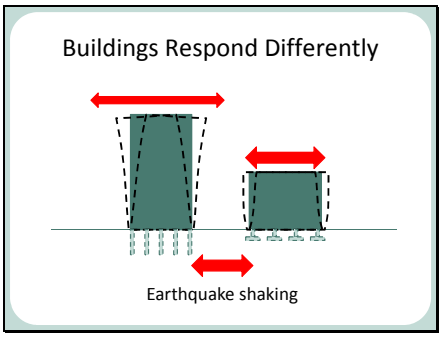
What would happen if this kind of shaking happened in your hospital? Will it be able to respond well? What will be the consequences?



Earthquakes cause damage to a building's equipment, contents, systems, and architectural elements in two major ways.

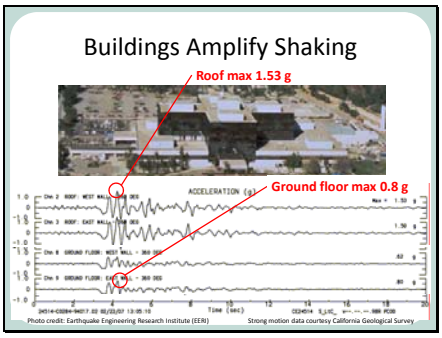
•The ground shakes the building back-and-forth, and then the building shakes everything that is in it or attached to it. Objects can tip over, slide, or break due to this back-and-forth motion. Tall, narrow objects are especially vulnerable to toppling.

•The earthquake motion causes the building to bend as it sways back and forth. Engineers call this motion deformation. Objects that are connected to two different floors get stretched or squeezed, and they can crack, bend or break. Objects like pipes that are connected to two different buildings can also get stretched or squeezed as the buildings move differently.



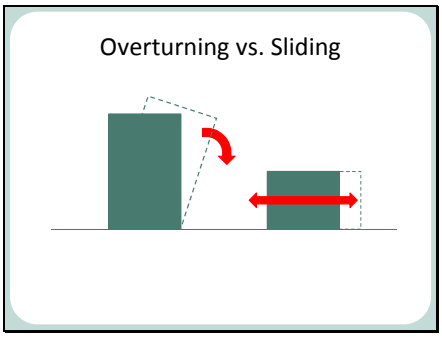
Explain that buildings of different sizes and shapes shake differently. This affects things that connect between them, like pipes. Pipes are not strong enough to tie the buildings together and make them shake in unison. Instead, the pipes will break as the buildings shake differently. If the buildings are too close together, they can pound against one another.

If someone asks why this is the case, explain the every building has what is called a fundamental period of vibration, which is the time it takes the building to sway back and forth once. Taller, more flexible buildings sway back and forth farther than shorter, stiffer buildings, so it takes more time for them to go back and forth. You can use an analogy from music if needed (marimba, xylophone) to help explain the concept. (Essentially, longer more flexible members in musical instruments vibrate more slowly and create lower pitched sounds; stiffer members vibrate faster and create higher pitched sounds.)

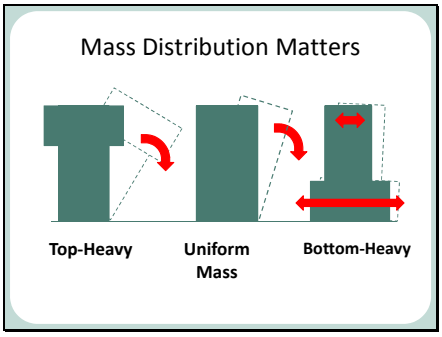


Almost all buildings amplify shaking, so the shaking can be stronger at the roof than the ground storey. The accelerations shown were recorded during the 1994 Northridge earthquake by seismographs at ground storey and roof of the new Olive View Medical Center. This is some of the strongest earthquake shaking that has been measured in a building. The rule of thumb from typical building codes is that the shaking is 2.5 times stronger at the roof of a building than at the ground storey for shorter buildings.

Tall buildings will not shake as hard but will sway back and forth much farther and bend more. This means that objects on the roof and in the upper floors will have greater demands – greater forces for stiffer buildings, and greater deformations for more flexible buildings. In stiff buildings, roof mounted equipment and objects on upper floors will be shaken harder. In the new Olive View Medical Center, pipes and equipment on the upper floors were damaged by the extremely high accelerations – some of the highest ever recorded.



How can you tell whether an object is likely to overturn (topple) rather than slide? This is an important distinction – toppling is more likely to cause damage to the object, to injure people, or to block exits than sliding is. A rule of thumb is that objects that are more than 1.5 times taller than they are wide are likely to topple, unless they are weighted at the bottom.



Bottom-heavy objects are much less likely to topple than top heavy objects with the same aspect ratio, and are also much less likely to topple than objects with a uniform mass distribution and the same aspect ratio. Top-heavy objects are the most likely to topple.

Consequences of Earthquake Damage

- Loss of life
- Loss of function
- Loss of property/money
- Loss of community confidence

List the four major categories for consequences of earthquake damage for hospitals.

Loss of Life

1987 M5.9 Whittier Narrows, California, USA

Photo credit: Degenkolb Engineers, FEMA 74

A large concrete panel (approximately 1 m x 2 m) fell from the exterior of a parking garage during the 1987 Whittier Narrows (Los Angeles area), California earthquake and killed a pedestrian on the sidewalk below – a young woman who was a university student. Whittier Narrows was not a major earthquake – magnitude 5.9.

Other large, heavy items that can fall from the outside or roof of buildings - such as unreinforced brick parapets, pieces of exterior masonry infill walls, and plastic water tanks (such as Sintex) - present a similar danger to people outside the building.

Loss of Function

2006 M6.7 Hawaii, USA Earthquake

Photo credit: William T. Holmes, Rutherford & Chekene

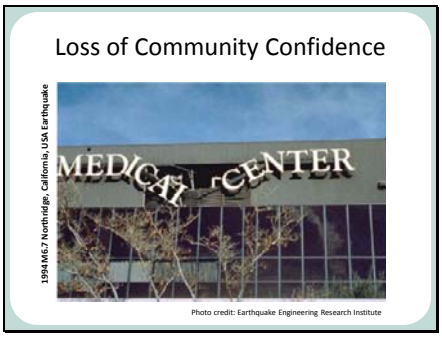
This Operation Theatre at Kona Community Hospital in Hawaii was rendered non-functional by the collapse of the suspended ceiling during the 2006 M6.7 Hawaii earthquake. Besides the danger from parts of the ceiling and light fixtures hanging down, large amounts of accumulated dust fell into the OT.

Loss of Property or Money

1971 M6.6 San Fernando, California, USA Earthquake

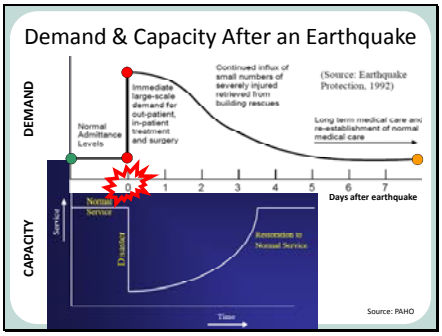
Photo credit: FEMA

This radiology equipment was damaged by the 1971 San Fernando earthquake and was not usable. Radiology and imaging equipment can be very expensive to replace.

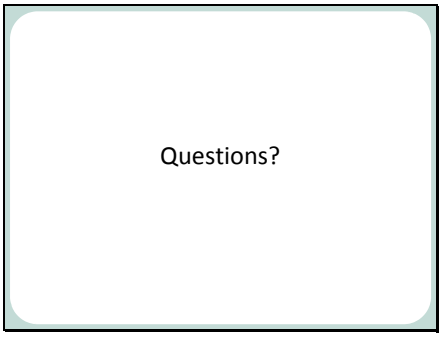


Would you want to go in this hospital?

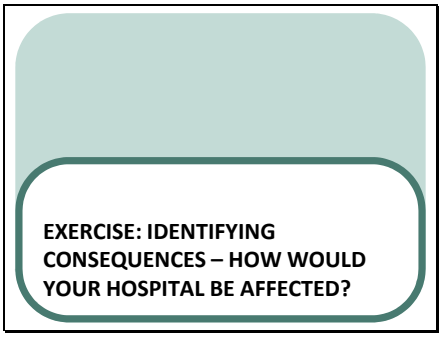
The sign was knocked askew by mechanical equipment that slid off its supports in the mechanical room behind the sign.



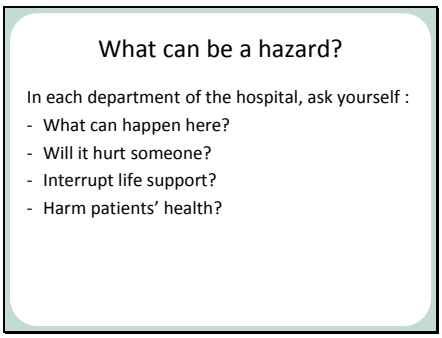
Following an earthquake, demand increases due to injuries in the surrounding community. The graph shows the medical care needs as a function of time. Ask what happens to the capacity of the hospital, and then click to bring up the capacity graph. In unprepared hospitals, capacity decreases substantially due to damage, staff not being able to come in (blocked roads, family crisis, or injured/killed themselves). The loss of function caused by the capacity decrease can also lead to a loss of community confidence.



Answer questions from the participants. Limit the number of questions to keep on schedule. You can invite participants to ask additional questions at the tea break or at lunch.



Lead the group in a discussion of how their work, and the hospital in general would be affected by earthquake damage. Use a large sheet of paper, blackboard, or whiteboard to write down the group's answers (or in a pinch you can enter them directly in a PowerPoint slide).



Questions to ask:
-What can happen here? Visualize how things will move during an earthquake, and what will happen as a result. Will something overturn? Fall? Slide?
-Will it hurt someone?
Examples: Falling cladding panel, large heavy objects that fall, slide or topple
-Interrupt life support?
Examples: Emergency generator falls from supports = no emergency power = no life support
-Harm patient or staff health?
Examples: Chemical spill in laboratory releases toxic gas; damaged radiology equipment releases radiation

Explain that even though we won't recommend that people run out of a building during an earthquake (unless there are very specific circumstances that make that response the best), the exits need to remain clear in case part or all of the building needs to be evacuated following the earthquake. There might be structural damage, a fire, or a hazardous materials release, despite your earthquake safety measures. Plus, if your hospital is still functional, people will need to be able to move around, and to get in.

Ask the trainees to find the hazards here.
The guard seen in the left-side photo is sitting in vulnerable spot where he could be injured by toppling equipment or falling glass shards. Broken glass on the floor in the doorway could cut the feet of people in sandals trying to exit the building after the earthquake. In the waiting room, the unbraced false ceiling, suspended fans, tall cabinet and equipment behind the desk and glass above the door also pose a hazard.

Ask the trainees to spot the hazards in this room. They include:
- suspended fan and lights can fall
- cupboards and items stored on top can topple
- chemicals on the shelf can spill or mix

Ask the trainees to spot the potential problems in the laboratory. They include:
- Table top equipment can slide off
- Samples can be lost
- Computers with valuable data can fall down
- Glass beakers, vials and test tubes can fall and shatter.
- Glass fronts of cabinets can shatter if something heavy slides into them. Glass shards can cut feet.
Remember, someone's life could depend on the lab equipment and results.

Ask the trainees about hazards in this medical records room. Medical records are vital for hospitals. The tall heavy shelves can topple over, putting the people in the room in danger, and the records can fall out and get mixed up.

Ask the trainees to spot the potential problem areas, which include:
-Ducts are not braced
- Large diameter pipes are not braced
- Electrical cabinets may not be anchored and can topple
- Pumps, compressors and other smaller equipment may not be braced

Options for Reducing Risk

- Relocate
- Protect:
  - Anchor, brace or restrain against shaking
    - or -
  - Accommodate deformation
- Plan for cleanup or breakage

Explain that there are several ways to reduce risk from objects and systems.

The first and simplest option is to relocate the item, if possible.

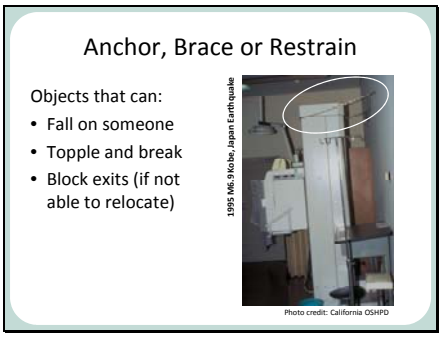
The second option is to anchor, brace, or otherwise restrain the object to keep it from falling, toppling, or sliding.

If neither of the first two options is feasible (such as for equipment that is moved often and cannot be anchored), you can assume that the object will fall or break, and plan for that. For example, if adding shelf restraints in medical records will place too much of a burden on the staff during day-to-day operations, then there will need to be a plan to sort the records when they fall to the floor during an earthquake (sorting and re-filing records can take a tremendous amount of staff time). In Chile, the hospital staff was still sorting medical records nearly a month after the 2010 Chile earthquake.

Relocate

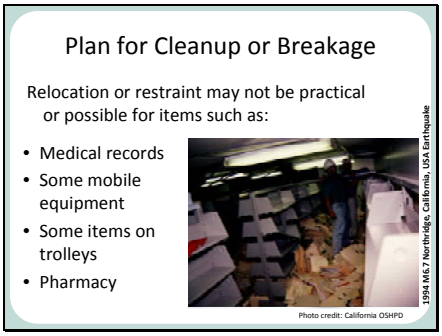
Objects that can:
- Block exits
- Fall on someone

Cupboards placed like this are common sights in hospitals. Although it saves space within rooms, this practice can result in blocking the corridor - an important exit route.

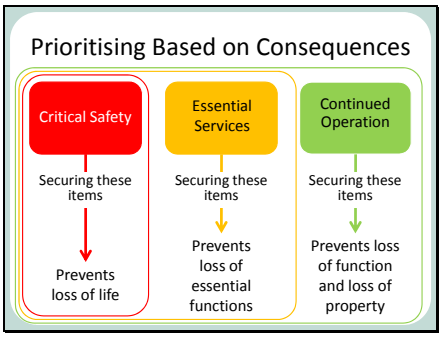


The imaging equipment shown was kept from overturning in the 1995 Kobe, Japan earthquake (a very strong event) by a simple chain restraint.

The photo shows flexible connections at the new Bhuj Civil Hospital. The flexible connectors accommodate the deformations between the building and the ground when the building moves back and forth on special sliders called base isolators, and they keep the pipes coming into the building from breaking. These connectors have to accommodate more than a half meter of displacement but the idea is the same as for other cases: determine the amount of differential displacement, and then provide a flexible connector that will accommodate that displacement.

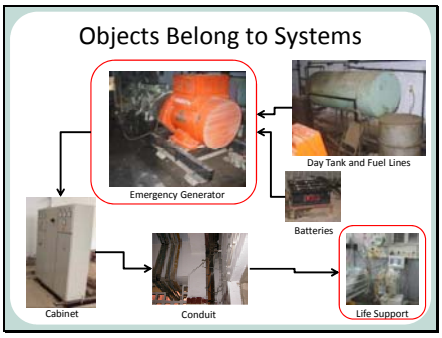


If restraints or anchoring will interfere too much with functionality, you can simply plan for cleanup and/or breakage. Some examples might be shelved items like medical records, pharmacy, or some supplies. Also items on trolleys and some overturning-prone mobile equipment may fall into this category. The photo shows a pile of medical records approximately a meter deep that fell from shelves during the 1994 Northridge, California earthquake. You can imagine how long it took to pick up all the records and sort them!



Explain the red (Critical Safety), yellow (Essential Services), and green (Continued Operation) performance goals from the manual. Securing all the red items is intended to prevent the loss of life in an earthquake (and subsequent problems like fire following the earthquake).

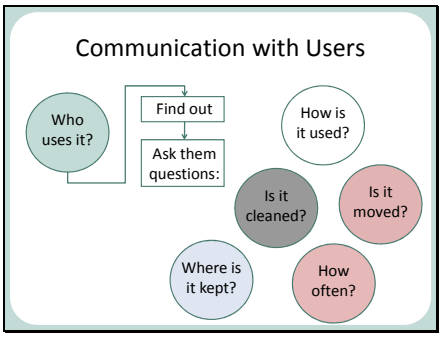
We recommend anchoring all the items needed to achieve the Critical Safety level of performance as a minimum, near-term goal. Securing all the yellow items as well as the red items is intended to keep the hospital's essential services functioning. These services will either maintain care for very ill patients (ICU, Neonatal ICU) or enable the hospital to care for those injured by the earthquake (Emergency Department, OTs). Securing the green items as well as the yellow and red items is intended to minimize the disruption to hospital operations as well as the cost of replacing equipment and repairing other items.



Look at systems and performance, not just individual objects. What do you want your hospital to be able to do? Try to prioritize according to systems. For example, what would it take to protect the emergency power system? You will need to make sure the emergency generator is anchored first. But you will also need to look at the day tank and fuel lines that supply fuel from the tank to the generator, as well as the batteries needed to start the generator. (The day tank is a local tank with a limited amount of fuel for the emergency generator. Day Tanks were originally specified as an above ground, local, source of fuel for emergency and stand-by generator sets. These tanks were sized to automatically maintain 24 hours of fuel next to the generator set. As the industry grew, however, the term "day tank" became synonymous with any above ground tank that has a pump, motor and control circuit mounted on top.)

How will the power generated get to the life support equipment in the ICU? You will need to ensure that cabinets with switchgear are anchored, and that conduits and wiring can

accommodate differential movement at building separations.

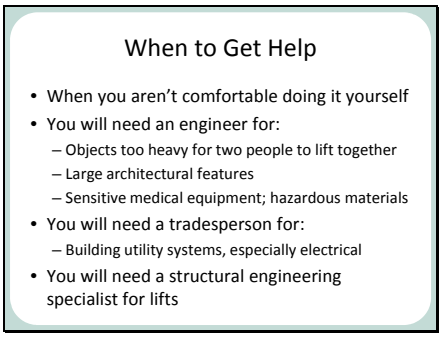


When determining whether or how to protect an item from earthquake damage, it is critical to determine things like: who uses it, how they use it, how often they use it, how it is moved or cleaned, and how often. The trainees will need to talk to the people that use the item and ask these questions. It is very, very important to work with the users to come up with a protection solution that will work. If it interferes with their work, they will likely remove the solution. If it requires them to do an extra task, it is likely that it may not work, unless there will be training and the task is incorporated into standard procedures. The best protection solutions will either go unnoticed or will also serve another purpose.

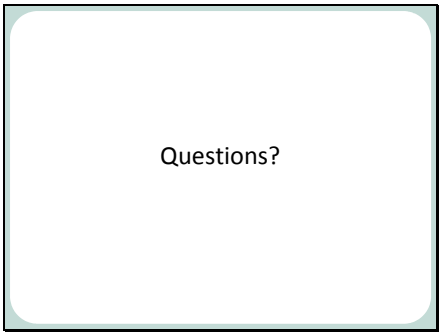
A potential example: ask how many in the audience are parents. Ask them to recall the period when their children were very small and wanting to climb everything (I assume children everywhere go through this phase). Anchoring shelving, cupboards, or almiras (free-standing wardrobes or closets) at home (or perhaps in the pediatrics ward) would both keep the children from pulling the furniture over onto them, and would keep it from toppling during an earthquake.

In addition to communicating with and working with users, you should have program of staff training that educates staff members on earthquake safety measures. Mitigation will not be effective if the staff undoes the work you do, either because they don't understand it or it interferes with their work. Good communication can help prevent the latter by helping you develop solutions that meet user needs.

It's very important to talk with colleagues on the medical and support staff to find out how work is done and how equipment is used. If you use an anchoring solution that interferes with the staff's work or their ability to use equipment, the restraints will just get undone or won't be used. You may not be able to anchor some items at all (because they are in use so much), and so you will need to have a backup plan in case the object is damaged. Work together with the staff for each area to select solutions everyone can live with. Ask questions:
Does this need to be moved? Opened? Cleaned? How often? Would a restraint affect your work?



You will need to know your audience. If they aren't engineers (or most of them aren't), they will need engineering help for many objects that need anchoring. Items that are typically too heavy include major mechanical and electrical equipment, large medical equipment (especially imaging/scanning units), large racks and shelving systems (such as for medical records), exterior architectural features (parapets, sunshades, canopies, etc.), brick partition walls, and tanks.



Answer any questions. If things are running behind, you can ask the participants to ask their questions during the tea break, which is scheduled to happen now. Also, you will have time during the break to talk to participants one by one and provide more detailed answers.

This Morning's Schedule

9:00-9:30	Introduction and Earthquake basics
9:30-9:45	Earthquake damage and consequences
9:45-10:00	Exercise: Identifying consequences
10:00-10:30	Identifying & mitigating risk overview
10:30-11:00	Tea Break
11:00-12:30	Information for specific objects – Part 1
12:30-13:30	Lunch Break

Note where we are in the schedule. Up next is Part 1 of Information for specific objects, which will cover mechanical and electrical equipment, medical equipment, furnishings and hospital administrative systems, and supplies.

INFORMATION FOR SPECIFIC OBJECTS – PART 1

Specific Categories of Objects

- Mechanical and electrical equipment
- Medical equipment
- Furnishings and hospital administrative systems
- Supplies
- Pipes, ducts and conduits
- Tanks and medical gases
- Architectural elements
- Lifts

Explain that you will present vulnerabilities and potential solutions for different categories of objects. You won't cover every object that trainees may see, but you will cover commonly encountered objects, and they can adapt the principles for these objects to other, similar objects.

Mechanical and Electrical Equipment

- Emergency power: generators, batteries
- Electrical: transformers, cabinets, switchgear
- Fire-fighting: fire water pumps, extinguishers
- Communications: cabinets, rooftop equipment
- Cooling: chillers, cooling towers, rooftop units, window ACs and coolers
- Heating/hot water: Boilers, geysers

Go over the various types of mechanical and electrical equipment. Some of this equipment, such as the emergency generator, will be Critical Safety priority level. Most other equipment will be Essential Services or Continued Operation priority level.

Slides for specific mechanical and electrical equipment, and the objects following, will have the same format:
-Existing condition showing what can happen during shaking (arrows showing motion are animated and will not appear immediately, so that trainees can guess)
-Earthquake damage
-Methods of anchoring / mitigation measures

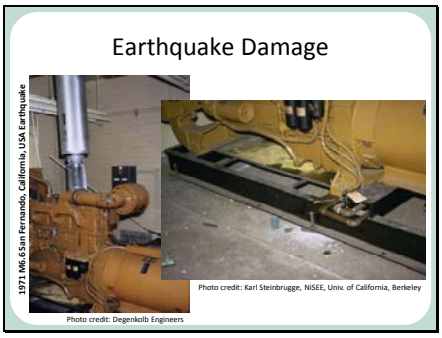
Emergency Generator & Batteries

Photo credit: Hari Kumar, GHI

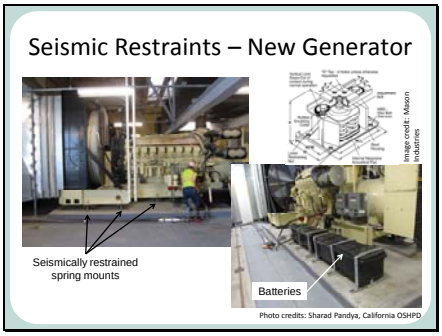
The emergency generator and batteries provide electrical power when power from the grid is lost. Grid power is almost always lost following major earthquakes. You should expect that the power will go out, and that you will need your emergency power system. The emergency generator is an important part of the emergency power system, but it is not the only part.

There are two types of batteries that are used in emergency power systems. Your hospital may have one or both. The first type is batteries that are needed to start the emergency generator. The second type provides uninterrupted power while the emergency generator is starting up, in order to keep life support systems functioning.

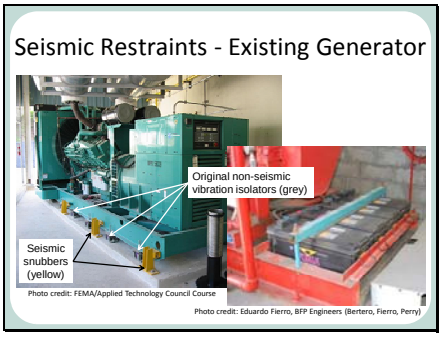
We will discuss the other elements in the emergency power system in subsequent sections: the day tank that supplies fuel to the generator, the electrical cabinets that contain controls for the emergency power system, and the conduits that distribute the electrical wires. You should also have a supply of fuel to power the generator for a minimum of 72 hours.



This emergency generator fell from its spring mounts and slid one meter during the 1971 San Fernando, California, USA earthquake. A properly engineered anchorage can prevent this type of damage.

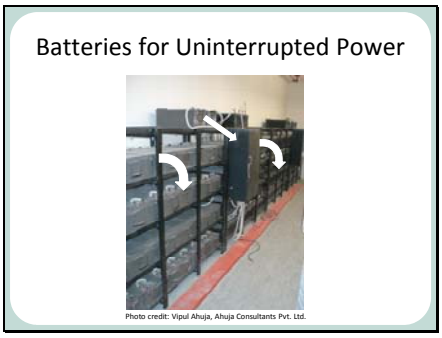


Emergency generators are very often vibration isolated. This makes them vulnerable to damage from earthquake shaking. New generators can be installed on special seismically restrained spring mounts that provide vibration isolation as well as seismic protection. An engineer should design the restraint system. Anchor batteries that start emergency generators by providing a tie-down.

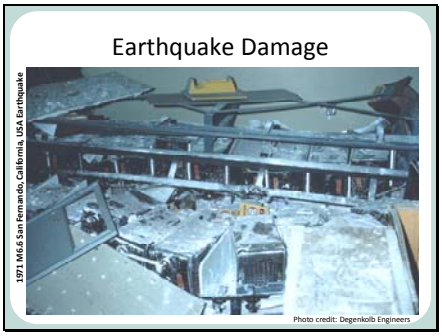


Existing generators can be protected using devices called “snubbers” that prevent the generator from sliding off its supports. Point out the snubbers in the photo. Explain that a snubber provides all direction restraint to the equipment without compromising the vibration isolation. A snubber restraint system must be designed by an engineer as well.

Anchor batteries that start emergency generators by providing a tie-down to keep them in their rack or by anchoring them within the emergency generator housing.



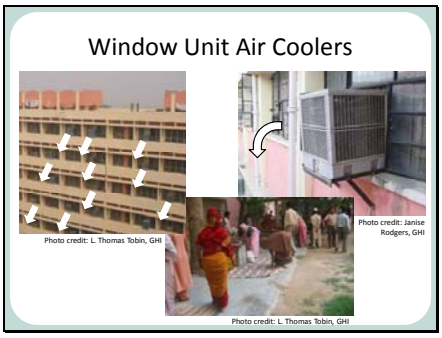
Banks of batteries stored on racks provide uninterrupted power while the emergency generator is starting up, in order to keep life support systems functioning. Unbraced, unanchored racks such as the one shown can topple or collapse under earthquake shaking.



This battery rack failed in the 1971 San Fernando California earthquake, and the batteries fell out and leaked. The white residue is from leaking battery acid.

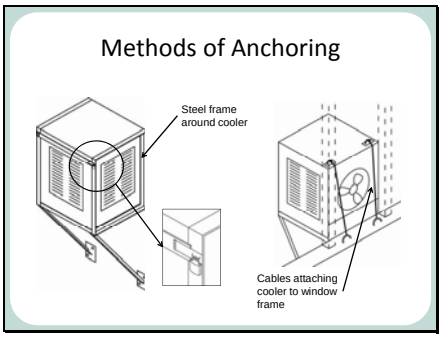
Provide a strong rack, which will not collapse, for the hospital's batteries. Anchor the rack to the floor or wall with a positive connection, so that it will not topple. Shorter racks, such as the ones shown above, are less susceptible to toppling than tall ones are. Restrain the batteries within the rack, so that they cannot topple out of it. The batteries above are secured in strong battery racks that are fixed to the floor. The side and end rails keep them from toppling out.

The existing, vulnerable rack was retrofitted with cross bracing. The rack was bolted to the floor to prevent toppling.



Window unit air coolers are a major falling hazard. They do not typically have any lateral restraints and can easily topple from the small platforms they sit on. Often, the coolers are located above areas where people congregate.

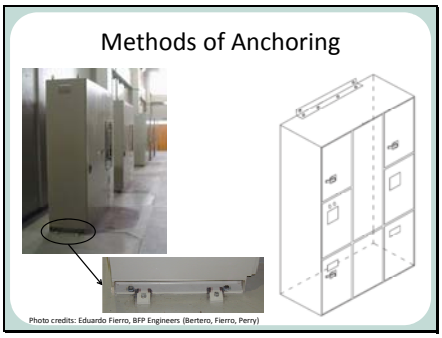
This piece of equipment with a similar support to those commonly used for air coolers toppled over during the 2010 Haiti earthquake. Only a piece of metal on the outside of the hospital kept it from falling to the ground.



There are a number of possible ways to anchor air coolers. Some solutions may serve a dual purpose: earthquake safety and theft prevention. Security measures designed to prevent the air coolers from being stolen can be adapted to provide seismic protection as well. Coolers can be supported on a special frame or fastened to the building with cables. Attach cables to the steel grill or to strong portions of the window or wall. An engineer will need to design the bracing or anchoring solution to resist the forces expected for full coolers near the top of the building. It will be more cost-effective to select or make one design and then use it for all of your hospital's air coolers.

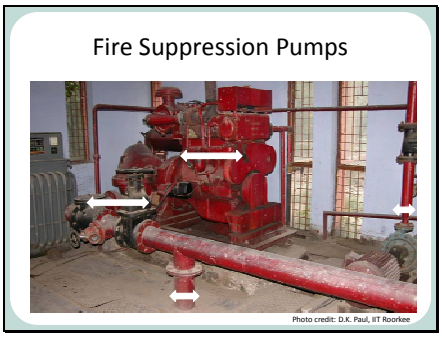
Because they are tall and narrow, electrical cabinets can topple over and damage the electrical equipment inside. This is one part of the electrical system. If any part of the system fails, your hospital will lose power, life support equipment will shut down, and patients could die as a result. A chain is only as strong as its weakest link…

Electrical cabinets toppled in the 1985 Mexico City earthquake and the 1999 Izmit, Turkey earthquake

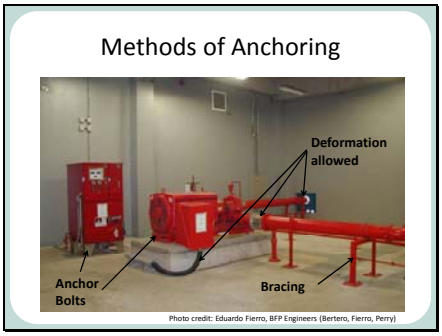


Electrical cabinets can be anchored to either the wall or floor. Cabinets should be on a reinforced concrete house keeping pad. Anchorage can be located at the base inside the units. Alternately if the adjoining units are bolted together the anchorage can be at the base on both sides.

As with any electrical installation, use caution when designing solutions for and working on electrical cabinets. Anchoring should only be done after consulting with an electrician to determine if the anchoring method is safe; the best practice is to involve the electrician in the design and installation of restraints. Ensure that the power to the cabinet is switched off before installing any restraints.

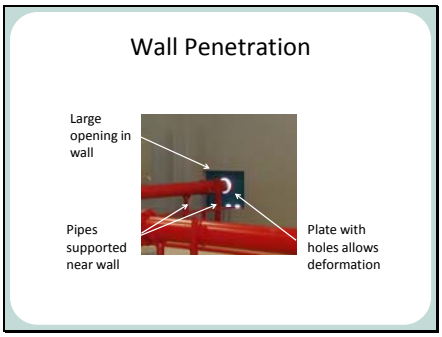


The pipes don't have flexible connectors, so they could possibly break or leak, and there would not be water pressure to fight a fire. Also, if the pump is not anchored, it could slide off its supports and break pipes as well.

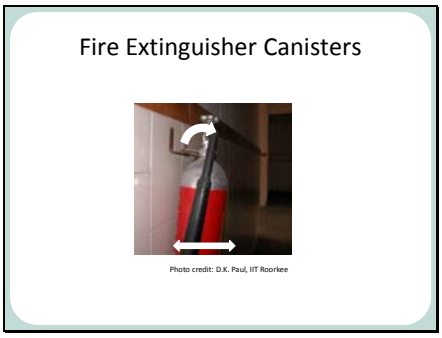


This fire pump system was properly anchored and had flexible connections. It was undamaged during the 2001 Peru earthquake.

Seismic protection of fire suppression systems requires several actions. The fire suppression pump must be properly anchored to its concrete pad or to the floor. The pump must have flexible connections, and fire water pipes must be braced. For pipes that penetrate masonry walls, the penetration must be large enough that relative motion during the earthquake won't damage the pipe or wall.



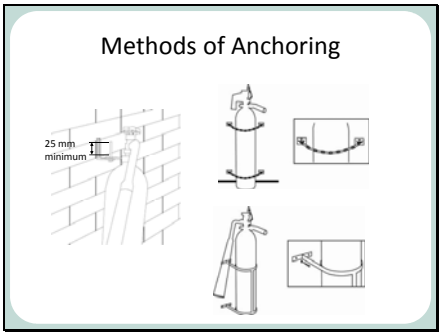
When pipes pass through walls, allow enough space for them to move without breaking either the pipe or the wall. Pipes that cross fire barriers need special consideration.



Improperly mounted fire extinguisher canisters can fall and roll.

The impact could damage the canister and prevent it from working properly. The canister could also roll under other items and not be readily available when needed. Hunting for a fire extinguisher that is not where it should be wastes valuable time. During the time that it takes to locate the extinguisher, the fire could spread from something small enough to be put out with the extinguisher to something larger and that would be more difficult and dangerous to extinguish.

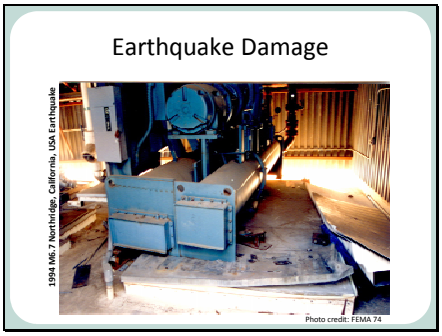
Ask whether the trainees can find the fire extinguisher in the left-hand photo, then advance the slide to add the circle showing its location. It could have easily been buried in the pile of medical records. On the other hand, the properly mounted extinguisher in the right side photo stayed mounted despite damage caused by separation at the seismic joint between buildings where it was mounted (the separation did cause the sign to fall, though this is not too important).



The canister's attachment to the wall must be strong enough to resist the lateral forces from the fire extinguisher’s movement. The canister will swing back and forth. The attachment can permit motion but must not allow the canister to fall.

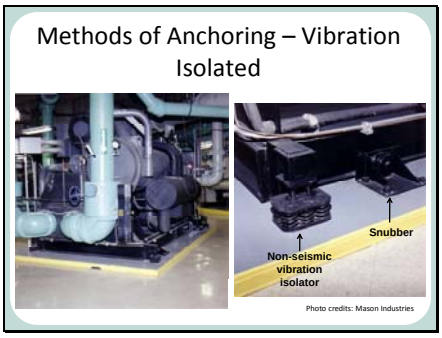
Show how the vulnerable canister a few slides back can be attached properly with a longer attachment pin that will prevent the canister from falling off even if it swings back and forth and even bounces up and down. We recommend that the attachment piece be at least 25 mm long.

Unanchored chillers can slide off of their supports, which can damage the chiller and break water pipes or other connections. Chillers on vibration isolators are particularly at risk.

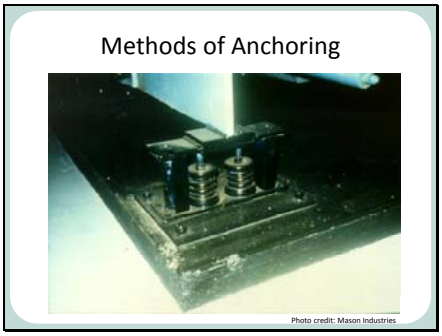


Damaged chillers prevent central air conditioning systems from working. Broken water pipes could cause local water damage or flooding, depending on the location of the chiller.

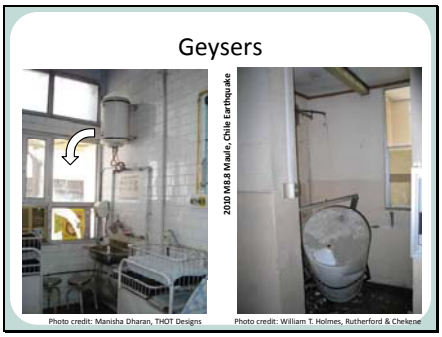
If chillers do not require vibration isolation, a rigid anchorage to a concrete pad is safest. This chiller is bolted to the concrete pad.



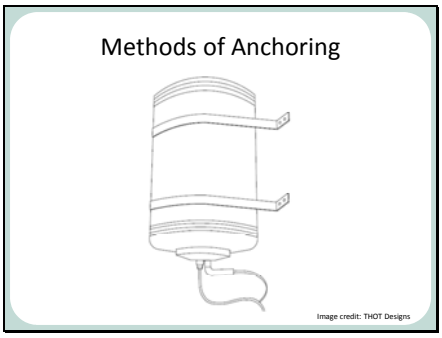
Vibration-isolated chillers should be restrained with special seismic restraint devices called snubbers or with seismically restrained spring mounts. Explain that a snubber provides all direction restraint to the equipment without compromising the vibration isolation. Using spring isolators without snubbers or without seismically restrained housing will actually increase earthquake forces and cause the springs to fail. This chiller has spring isolators plus snubbers (show which is which – spring is on the left hand side of the right photo, while the snubber is on the right).



This is a seismically restrained spring mount.

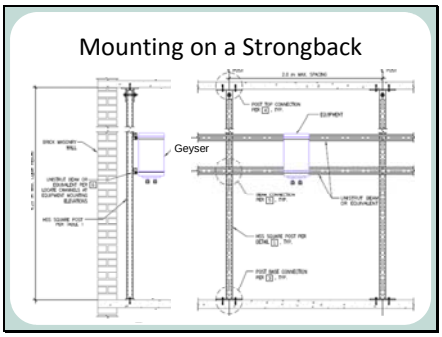


Existing geyser in a Neonatal ICU. Geysers that are not well-anchored could fall and break the water connections. This water tank fell at Talca Hospital during the 2010 Maule, Chile earthquake. Note the leaking water.

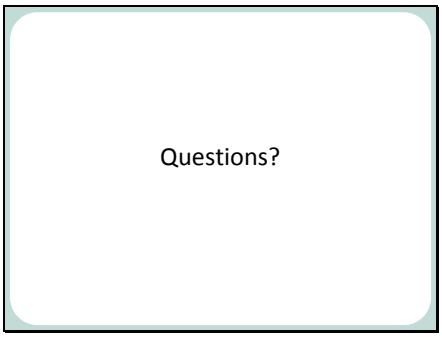


Geysers should be anchored to the wall with bolts that are sized to resist the horizontal forces caused by the expected level of earthquake shaking. The geysers should have straps around the top and bottom that attach to the bolts, or bolts should be rigidly attached to the frame. These bolts must be properly installed, so that they will not pull out, and the wall must be strong enough to resist the forces from the geyser without failing. An engineer may need to determine whether a geyser is well anchored or not.

You can add straps as shown above to restrain geysers that are not well-anchored.



Geysers can also be mounted on a strongback. A strongback is a floor-to-ceiling support system to which objects can be anchored in cases where the wall is not strong enough. Larger geysers may need to be anchored to a strongback if the wall is weak or too tall and slender to support itself during earthquake shaking.



Take any questions before moving on to Medical Equipment.

Medical Equipment

- Large floor- mounted: Imaging/scanning, blood bank refrigerators
- Autoclaves and sterilizers
- Operation theatre lights
- Wheeled or trolley-mounted: radiant warmers, anaesthesia machines, ventilators
- Monitors and small wall-mounted equipment
- Laboratory bench-mounted
- Clinical use computers covered in next section

Explain that we will not attempt to cover all the specific medical equipment in a hospital. We will go over common or particularly vulnerable items, as well as equipment that is particularly important in the post-earthquake period. You should be able to find a solution for most equipment based on what we cover here.

Note that some equipment cannot be anchored for functional reasons, and that all anchorage solutions must be developed and discussed with user input – otherwise they may be removed by users.

Imaging and Scanning Units

Photo credit: Kanchan Sabnis, GHS

Photo credit: Janise Rodgers, GHI

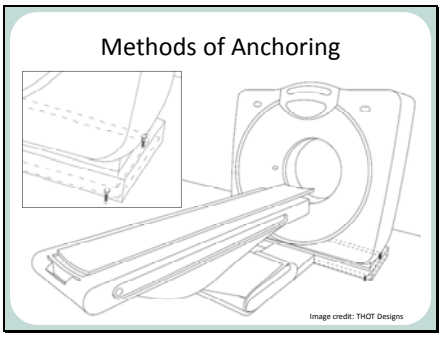
Some of the largest and most expensive equipment in the hospital is imaging and scanning units. If not properly anchored, these units can slide or topple and become damaged and potentially unusable. Imaging equipment is very important in the post-earthquake period because fractures are one of the most common types of injuries people suffer during an earthquake.

Earthquake Damage

Photo credit: FEMA

Photo credit: California OSHPD

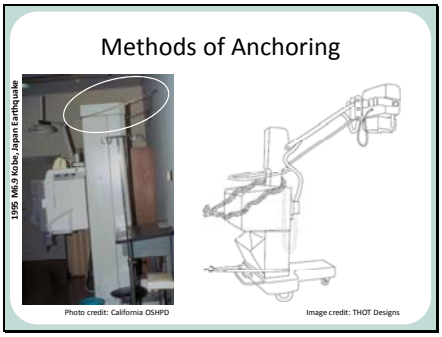
Earthquake damage to imaging equipment. If equipment suffers enough damage, there could be a dangerous radiation leak.



All fixed units should be anchored to the floor with bolts per the manufacturer's instructions, and most are. You should check to ensure that the machine is in fact bolted to the floor properly, though. Manufacturers that sell these machines in areas such as California and Japan (i.e., most major manufacturers) should be able to provide you with guidance for how to anchor their equipment to resist earthquake shaking. (The type of bolts, and how they should be installed.)

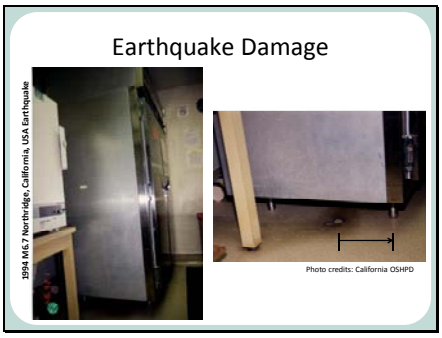
Also, all stationary patient tables should be anchored.

Mobile units should not be anchored. If the equipment is prone to toppling, you can park it in a "garage" or attach a tether when it is not in use. Mobile equipment that is not prone to toppling can be allowed to roll around, except in special circumstances (like very heavy equipment that could crush nearby vulnerable patients – this will be rare).

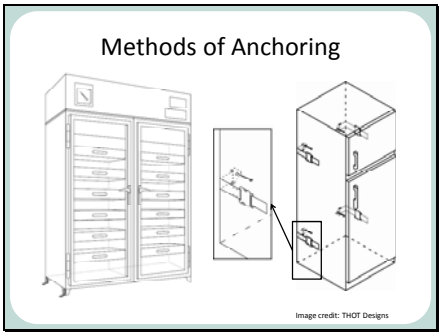


The equipment above was prevented from toppling during the 1995 Kobe, Japan earthquake by a simple chain restraint. Such simple restraints can be a good option for equipment that has to be moved infrequently.

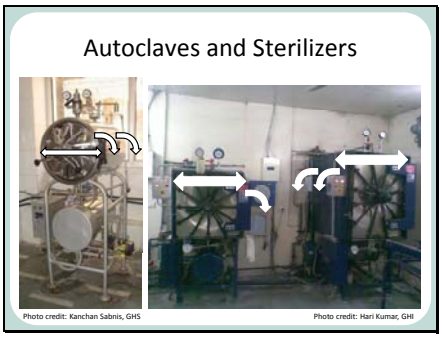
Blood bank refrigerators can topple, or if the door does not have a proper latch it can come open. If it comes open the blood bags can fall out, or the door may not close properly and the blood may spoil.



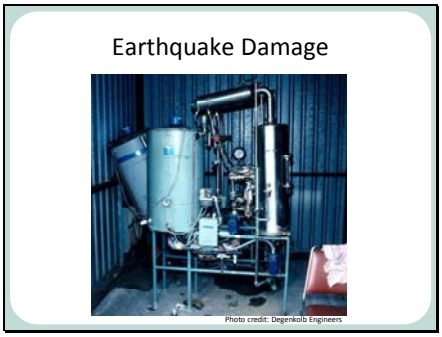
This blood bank refrigerator slid approximately 100 cm during the 1994 Northridge, California earthquake. Refrigerators that slide far enough can become disconnected from their electrical power source. Refrigerators can also topple and cause loss of blood when it is needed most.



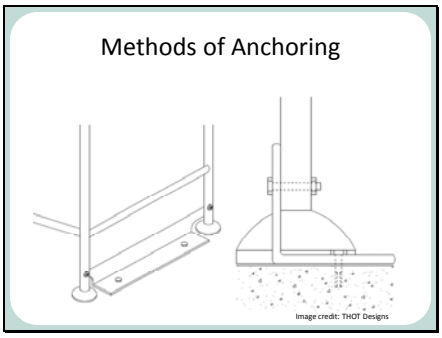
Anchor large blood bank refrigerators to the floor to prevent them from toppling. Smaller refrigerators can be anchored using straps or L-clamps at the top. (Such L-clamps are anchored to the wall but touch the top of the refrigerator rather than being screwed into it.) Ensure that there is a door latch installed if you are using an ordinary refrigerator designed for home use. (Most commercial blood bank refrigerators have latches.)



Autoclaves that are tall and narrow can topple. These autoclaves have a large aspect ratio, meaning that their height divided by their width is greater than one and a half.



Equipment with a similar aspect ratio and complexity to autoclaves and some other sterilization equipment was damaged in a California earthquake.

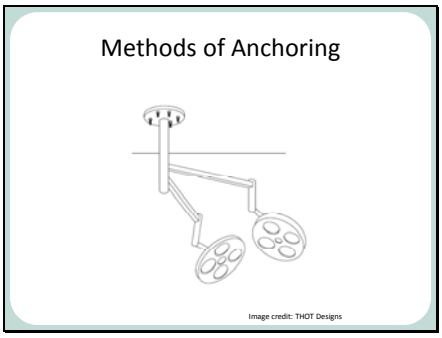


Fixed equipment, such as autoclaves, needs to be anchored. Anchor the legs of standalone autoclaves to the floor using an angle iron. Chest-type autoclaves can be anchored to the floor or can be built into the wall. Ensure that there are flexible connections to water pipes.

OT lights can swing, become damaged, and fall.

An OT light broke and fell during an earthquake simulation experiment. This type of failure has not been observed in the field after earthquakes, but it could happen.

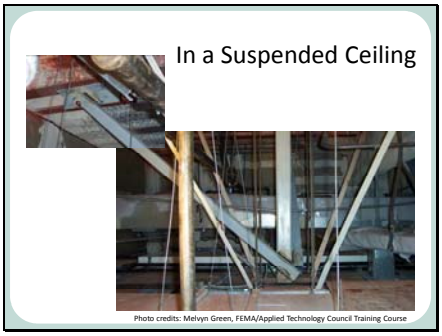
If anyone asks “what is an earthquake simulation experiment?” explain that researchers use a piece of equipment called a *shaking table* to simulate earthquakes and their effects on buildings, bridges, and equipment. A shaking table has a platform with large jacks underneath that move it back and forth to simulate an earthquake. Researchers attach the items they wish to test to the platform, and then they shake them with a simulated earthquake and observe what happens.



OT lights need to bolted directly into the structural ceiling, or braced back to the ceiling if there is a suspended ceiling. Suspended ceilings are not strong enough to keep the lights from swinging and falling.

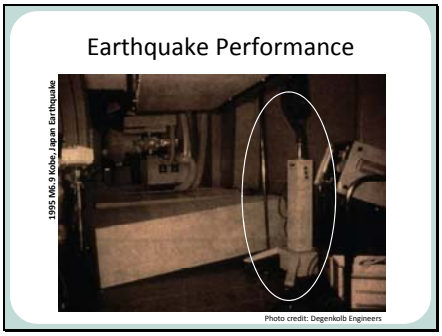
Most lights, especially those with long booms/arms, will need to have a very substantial anchorage just to function in everyday use. This is

because the long arms generate very large forces at the anchorage, and the lights must not bounce much when they are moved during surgery. Seismic forces can be a little bit different than normal service forces, but a good anchorage will greatly help for seismic purposes. The anchorage should be checked for seismic forces, however.

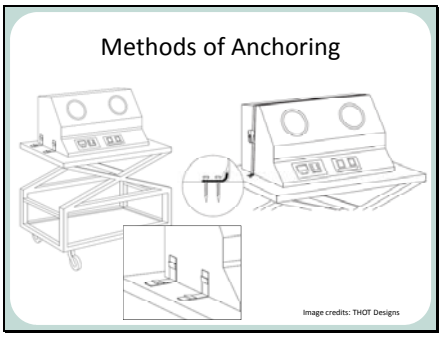


These photos show the complexity of installing OT light bracing above a suspended ceiling in an interstitial space with many systems. It must be carefully thought through by the engineer and workers. The main point is that you need to resist all the forces that the light will impose, both during regular service and during an earthquake. Buildings with wood or metal truss roofs would require bracing such as this; in concrete buildings you can bolt the OT light directly to the slab above (you will need a longer, stiffer arm to get down below the suspended ceiling, however).

Equipment mounted on trolleys can slide off if it is not anchored. Tall and narrow wheeled equipment may be prone to toppling unless it is bottom-heavy.

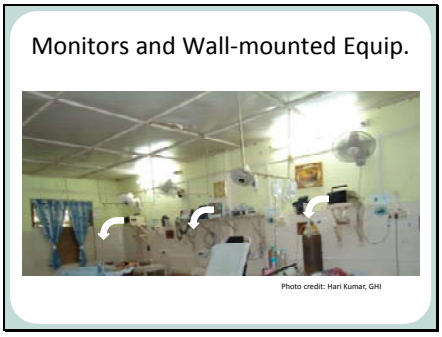


Bottom-heavy wheeled equipment did not topple during the 1995 Kobe, Japan earthquake. Cabinets and other equipment toppled.

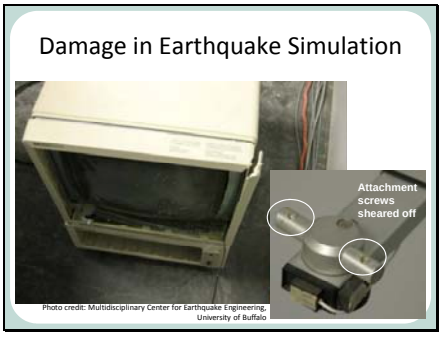


Equipment on trolleys can be anchored with clips or straps. If using straps of the type shown at left, ensure that you take great care during the installation process, as the double-backed tape used is VERY susceptible to improper installation (not cleaning surface and not applying enough uniform pressure to gain good surface adhesion.) If possible, choose anchoring clips that do not rely on double-backed tape, such as the option at right.

Large wheeled equipment and carts can be parked in a “docking station” with easily removable restraints when not in use.

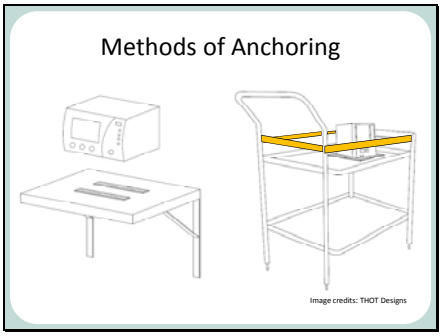


Monitors placed on shelves or other surfaces without a positive connection could topple. Those directly above beds of vulnerable patients are the most hazardous.

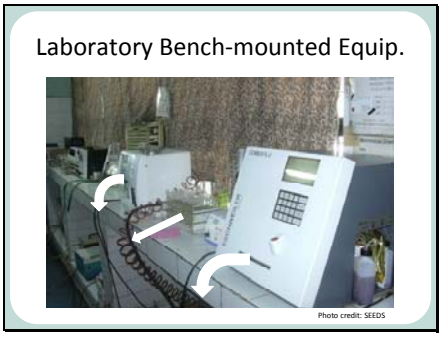


The screws attaching this monitor to the bracket that supported it sheared off during an earthquake simulation experiment. The sheared-off screws are indicated by the white ovals in the photo on the right.

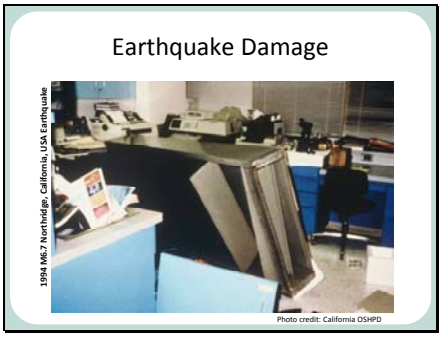
Mounting brackets can be used for both TVs and monitors. Private vendors supply mounting brackets that are earthquake resistant as well as being designed to improve ergonomics and functionality. Earthquake-resistant mounting brackets are available for monitors from all major manufacturers.



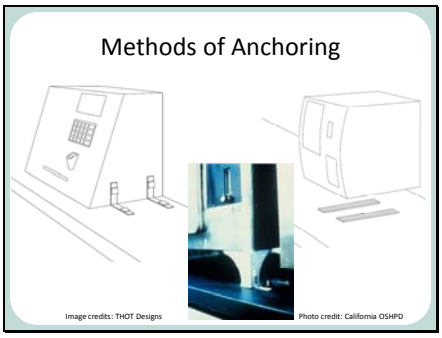
Small monitors can be secured with hook-and-loop tape or be placed on non-slip mats. Also, small shelf lips or rails on carts can help prevent equipment from sliding and falling. Wall-mounted monitors should have brackets that are designed to withstand earthquake forces.



Laboratory equipment can fall from benches.

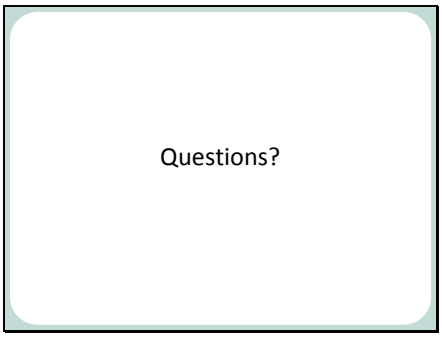


Damage to a laboratory in the 1994 Northridge, California earthquake.

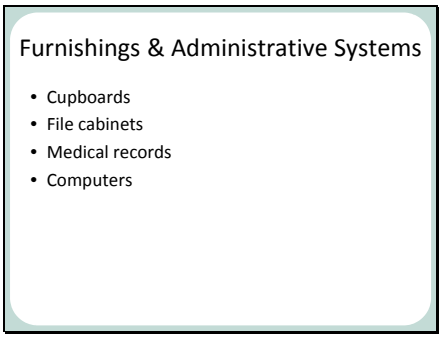


There are many restraints available for laboratory equipment. Items that do not need to be moved can be bolted to the bench-top. Other options are straps and hook-and-loop tape. If using straps of the type shown at left, ensure that you take great care during the installation process, as the double-backed tape used is is VERY susceptible to improper installation. If possible, choose other anchoring methods.

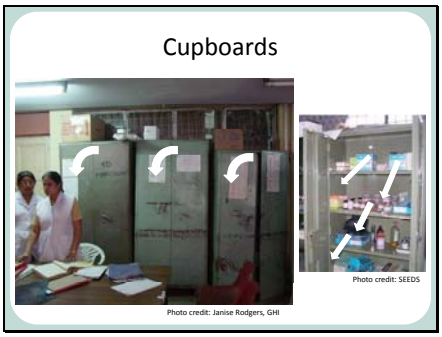
You can develop your own solutions as well using available materials.



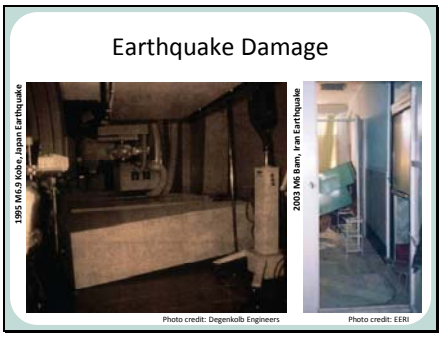
Take any questions before moving on to Furnishings and Hospital Administrative Systems.



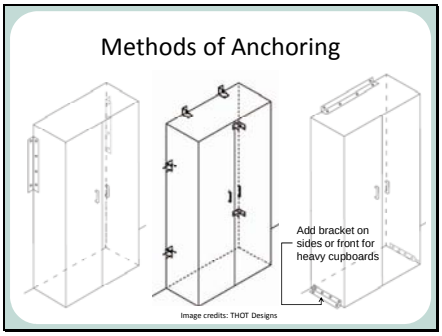
Computers can also have clinical uses, and we will discuss that as well.



Cupboards can topple, and contents can fall out, or spill inside and mix. Toppled cupboards in passages can block the medical staff's access to patients.



Toppled cupboards in hospitals in Japan and Iran.



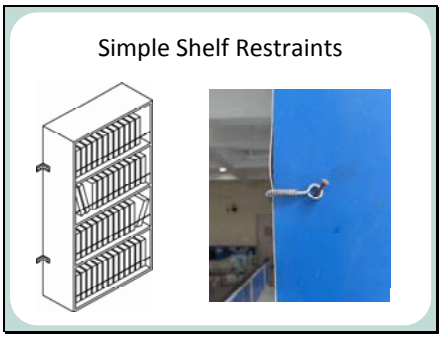
Cupboards are easy to restrain, but you will need to anchor them adequately. Heavier cupboards may need attachment at both top and base, especially if the wall strength is questionable. For cabinets attached at the base, verify the capacity of the cabinets to withstand earthquake forces without buckling.

Pass around L-bracket anchors.

Medical records can fall from shelves, and racks can topple.

Fallen records in California and Haiti.

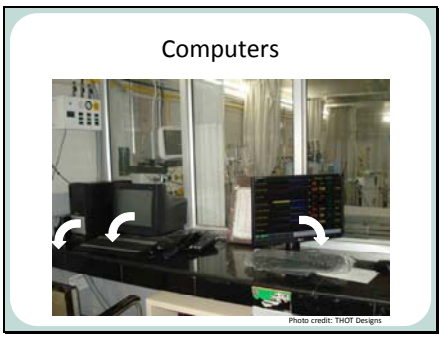
Racks containing medical records should be braced to keep them from collapsing or toppling. Records can either be held in place with shelf restraints, or you can plan to devote significant staff time to sorting and re-filing if the files fall to the ground. Re-filing went on for weeks after the 2010 Chile earthquake.



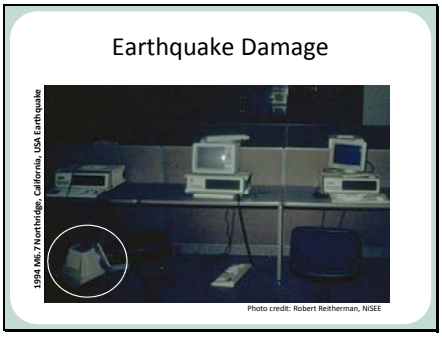
Shelf restraints can be as simple as a wire spring attached with a nail at each end.

These slides show the process for installing simple spring shelf restraints.

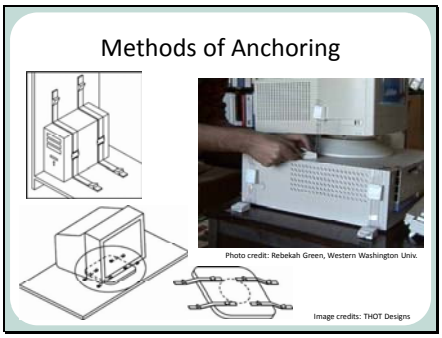
- Obtain materials: springs and nails, plus hammer and pliers
- Nail through eye at one end of spring
- Stretch spring (not too tightly) and nail other end



Computers can be present in clinical settings, such as the one above, or in administrative settings. In both cases, computers can fall from tables or benches and be damaged.



The computer monitor at left fell from the table during the 1994 Northridge earthquake.



Computers can be anchored with special clips, straps, or other hardware, mounted on kiosks or carts, or placed in special shelves. If special clips and straps use double-backed tape, ensure that you install them properly and check them annually. If the tape loses its “stick”, you can replace it with double-sided tape available in hardware shops. You can also use security devices designed to prevent theft, which may be more attractive due to their dual purpose. Anchoring solutions for computers used in clinical applications must be suitable for the medical environment and address functionality and infection control requirements.

Questions?

Take any questions before moving on to Supplies.

Supplies

- On trolleys
- On racks
- Pharmacy
- Sterile storage

On Trolleys

Photo credit: Manisha Dharan, THOT Designs

Supplies can fall from trolleys. Glass bottles can break and their contents can spill or mix.

Earthquake Damage

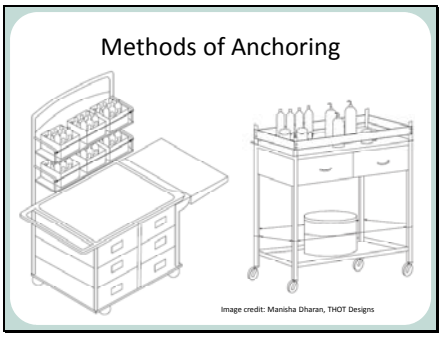
1991 M7.6 Costa Rica Earthquake

Photo credit: Degenkolb Engineers, FEMA 74

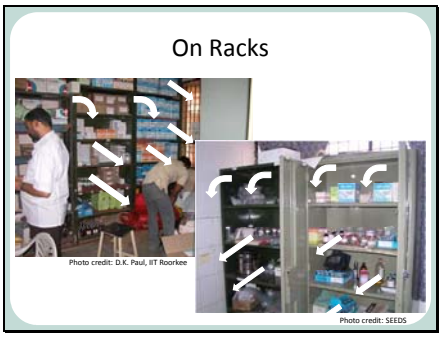
2009 M6.3 L'Aquila, Italy Earthquake

Photo credit: Khalid Mosalam, Univ. of California, Berkeley

Chemical spill in Costa Rica; medical gas cylinders fell in Italy.

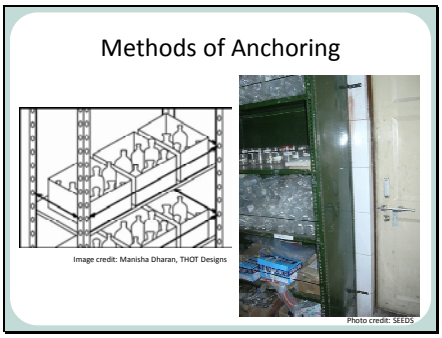


Possible solutions: bins, shelf restraints, rails, or shelf lips.

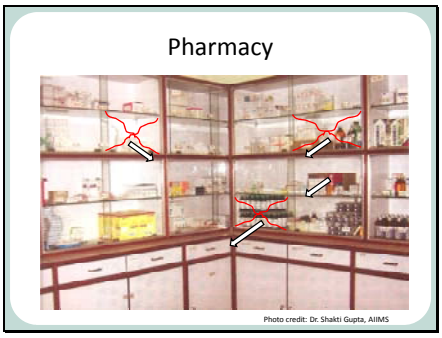


Supplies can fall from racks, or the racks themselves can topple.

Spilled contents in California and Haiti.



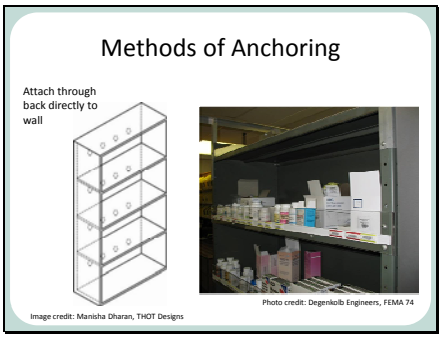
Shelf restraints can keep items from falling out. Small or breakable items can go in bins. Racks can be anchored to the wall.



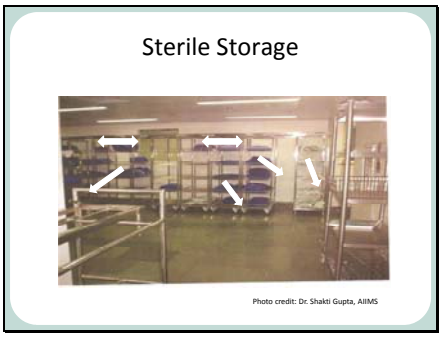
Glass in pharmacy can break, and medicines can fall down and spill. Broken glass can also injure people working in the pharmacy.

Medicines can easily fall down and spill when pharmacies have open shelves.

Spilled pharmaceuticals and chemicals.

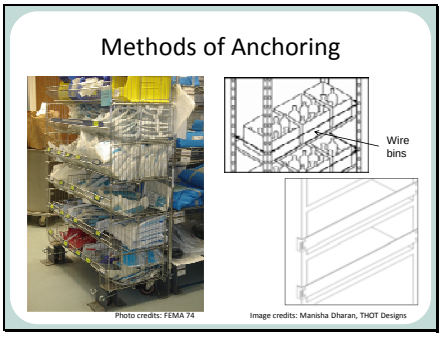


Pharmacy cupboards and racks can be attached directly to the wall by drilling through the back. The clear shelf restraints are shatterproof Plexiglas. Safety or tempered glass that does not fall from the frame when it breaks can also be used in glass-fronted pharmacy cabinets.

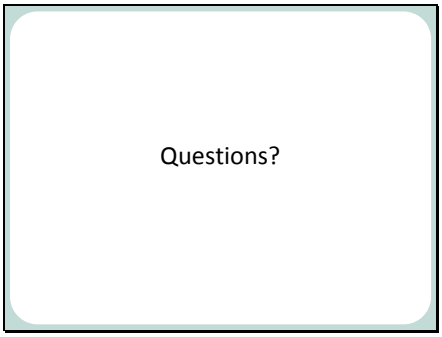


Sterile items can fall from racks, or tall and narrow racks could topple.

Light-gauge racks with similar aspect ratio to those used for sterile storage toppled in a hospital during the 1995 Kobe, Japan earthquake.



These racks are anchored at the base. An angled lip at the front of the shelf helps keep small loose items from falling out. Another option is to provide some type of easily sterilised shelf restraint, such as a wire bin that cannot fall out of the shelf.



Answer any final questions, and make yourself available during the lunch break to discuss the morning's topics with trainees.

This Afternoon's Schedule

12:30-13:30	Lunch break
13:30-14:30	Information for specific objects – Part 2
14:30-15:30	Exercise: Hazard hunt
15:30-15:45	Tea break
15:45-16:00	Implementing risk reduction measures
16:00-16:30	Exercise: Potential solutions for hazards
16:30-17:30	Exercise: Identify high-impact solutions

Review the afternoon schedule. Coverage in Part 2 of Information for Specific Objects consists of pipes, ducts and conduits; tanks and medical gases; architectural elements; and lifts.

The time for the hazard hunt may vary with the size of your hospital and the number of trainees. You will not need to conduct a thorough hazard hunt, but you will need to visit enough locations to gain material for the upcoming practical exercises. To avoid disrupting hospital operations, focus your hazard hunt on mechanical equipment, building utility systems, and architectural elements on the exterior and in administrative or office areas. If any medical service areas happen to be closed for maintenance or repairs, you could add them to the hazard hunt.

The final two exercises of the day can be compressed or expanded depending on the situation at the hospital. You will need to do some work in advance to get a sense of the possibilities, and to have some options on hand in the event that your audience is having difficulty proposing potential solutions (if you have engineers accustomed to regular design work this is unlikely to be a problem).

Questions?

Answer any questions on the schedule.

INFORMATION FOR SPECIFIC OBJECTS – PART 2

Pipes, Ducts and Conduits

- Small pipes: rigidly attached and suspended
- Flexible connectors
- Large pipes (> 50 mm nominal size)
- Conduits and electrical distribution
- Ductwork

Pipes, ducts and conduits are the arteries of your building utility systems. It is important to protect them from earthquake forces so that you can maintain function. In the case of pipes, it is also important to prevent leaks. In the 1994 Northridge, California earthquake, the biggest contributor to the new Olive View hospital being evacuated was the fact that broken pipes caused large amounts of water to leak.

Small Pipes

Photo credit: Manisha Dharan, THOT Designs

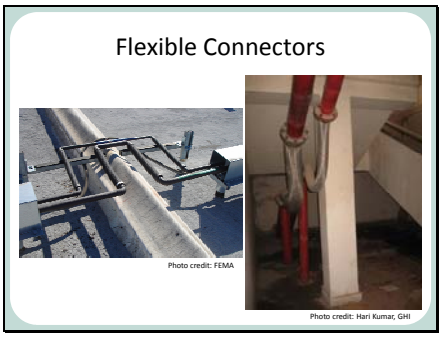
Small pipes are those less than 100 mm nominal diameter. Small rigidly attached pipes typically have problems in locations where they are stretched or bent by earthquake motion – this can break the pipes, and the contents can leak. In the photo, several small medical gas pipes are supported on a pipe bridge that spans between two different buildings. Neither the bridge and its anchorage nor the pipes are strong enough to tie the buildings together and make them respond as a unit. Rather, since one building is tall and one is short, they will tend to move differently and the pipe could break when they pull apart.

Earthquake Damage

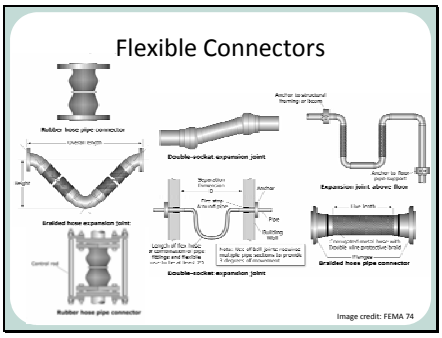
1994 M6.7Northridge, California, USA Earthquake

Photo credits: Mason Industries

Pipes that broke in the 1994 Northridge, California earthquake.

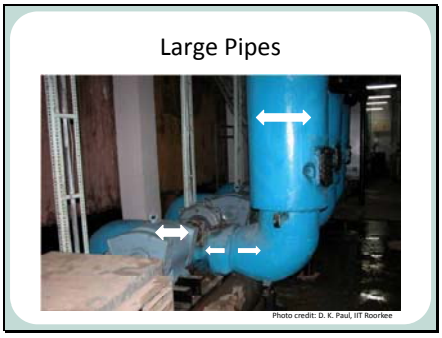


Prevent damage by providing flexible connectors anywhere you expect differential movement: at expansion or seismic joints, across the isolation plane in a base isolated building, or between buildings.



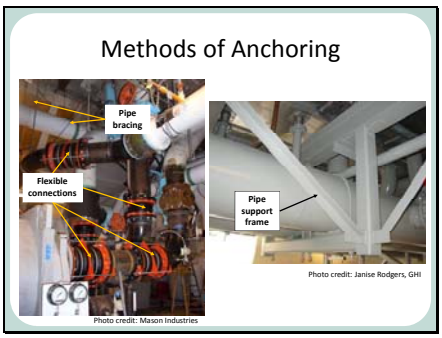
Some of the many types of flexible connectors.

Pipes that are 1 ¼ inch (32 mm) diameter or more should be seismically braced (this comes from the California Building Code and ASCE 7-05). Suspended pipes that are this size or larger should be braced at regular intervals in all three directions (transverse, longitudinal and vertical) using a detail like the ones shown, or equivalent bracing using locally available materials.

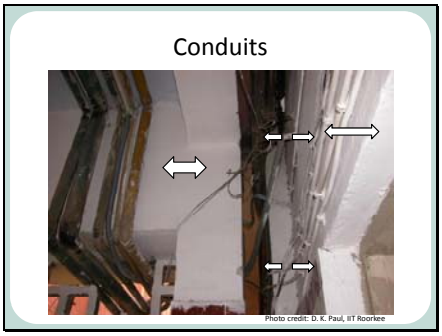


Large pipes that are not braced can vibrate excessively and break at joints or at connections with equipment. Large pipes are much heavier than small pipes and can generate large seismic forces. Many connectors used for large pipes are cast iron, which is brittle. These connectors have often broken in past earthquakes.

Many connectors used for large pipes are cast iron, which is brittle. These connectors have often broken in past earthquakes – the pictures are examples from the 1994 Northridge, California earthquake.

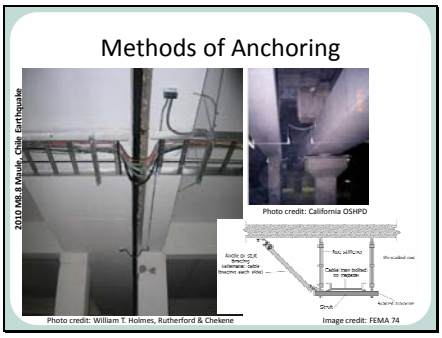


Anchor large pipes to special support members or to the structural framing. Very large pipes may need their own support frame. Provide flexible connections at those places where pipes connect to equipment or to the structure. Flexible connections are very important for large pipes, which are less flexible than smaller pipes. Large pipes connected to both the ceiling and floor-mounted equipment will experience the full relative displacement between the floor and the ceiling, which can be larger than many conventional, non-seismic flexible connectors can accommodate. Several manufacturers produce flexible connectors such as those at left that can accommodate these large relative displacements.

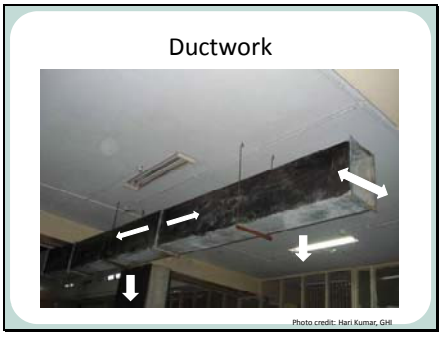


Like small pipes, conduits are typically damaged by differential displacement that pulls them apart. The conduits shown cross a separation between two buildings.

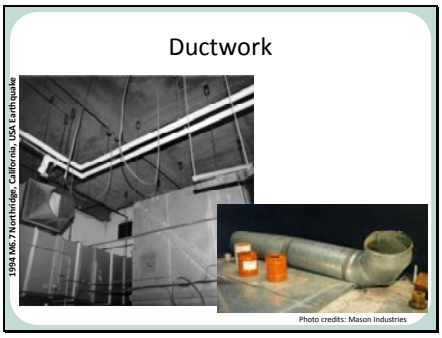
Conduit damage in two different earthquakes: on the left, the conduit separated from its supports and fell down; on the right, the conduit buckled in compression and then pulled apart.



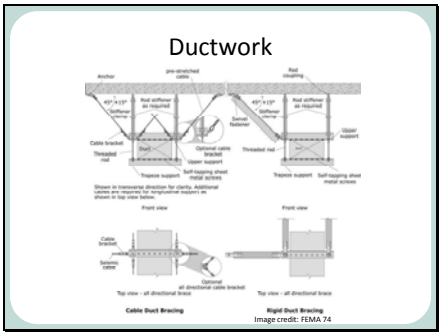
This rack for cables was specifically designed with enough "slack" in the cables to accommodate the anticipated differential displacement across the seismic joint, which prevented damage in the 2010 Maule, Chile earthquake. Note the minor earthquake damage to the columns and at the seismic joint. A similar detail accommodates deformation in a California hospital. Use flexible connectors in locations where you expect differential displacements. Cable trays can be braced against swinging by using a detail such as the one shown. Conduits larger than 75 mm (3 inches) should be braced. (If anyone asks, this recommendation comes from the California Building Code and American Society of Civil Engineers Standard 7-05).



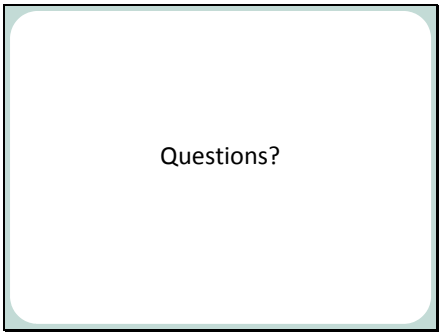
Unbraced ducts can swing, separate at joints, and fall.



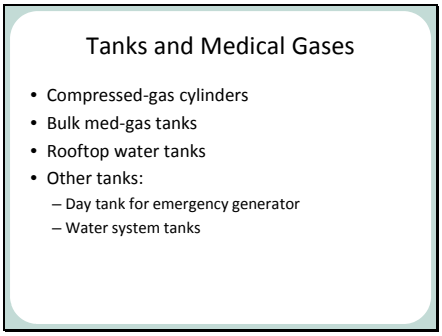
This is what happened to a large duct during the Northridge earthquake.

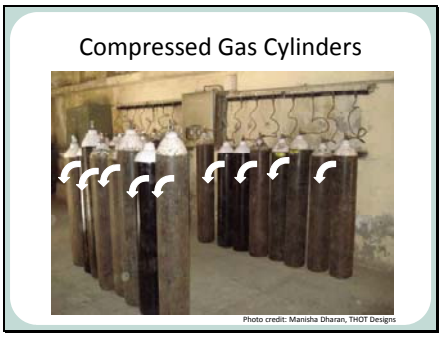


Some recommended duct bracing details are shown. Mention that ducts with cross-sectional area less than 6 ft (1.8 m) in cross-sectional area or having diameter 29 inches (735 mm) or less are exempt from bracing in seismic codes in the US. Prioritize bracing – ducts that can fall and injure someone should be braced, as well as large ducts if you are striving for the continuous service level of performance. Note that to simplify the drawing, the bracing in the longitudinal direction has been omitted from the drawings. Longitudinal bracing is necessary.



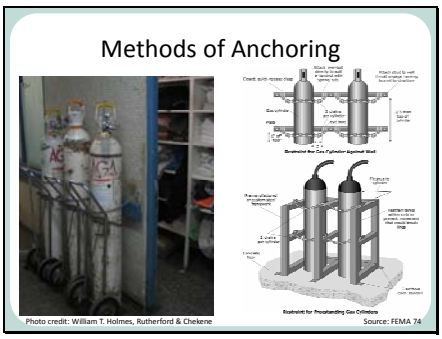
Answer any questions before moving on to the next section, Tanks and Medical Gases.





Strong shaking can cause unrestrained cylinders to topple. Cylinders connected to manifolds can break their connections.

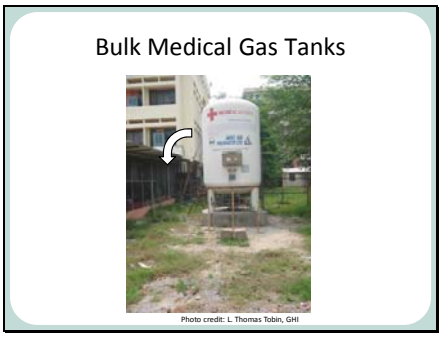
Unrestrained cylinders toppled over.



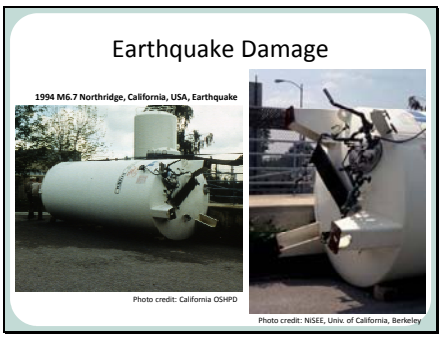
Gas cylinders can be anchored with chains to either a wall or a separate frame.

For large numbers of cylinders, you can design and build specialized racks like this one. These compressed nitrogen cylinders were undamaged in the 2001 Peru earthquake.

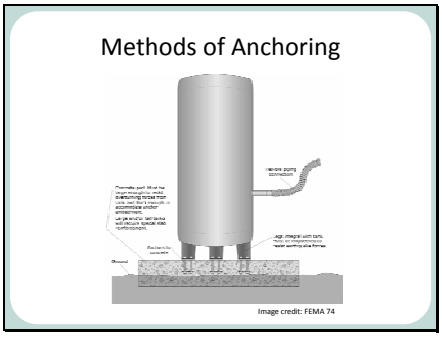
If asked how to get the cylinders out – you loosen the wing nuts and turn the piece that holds the cylinders in place ninety degrees or remove it entirely.



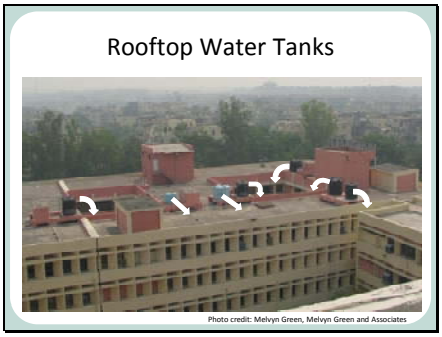
Bulk medical gas tanks that are not bolted down properly can topple over and break their connections with med gas supply pipes.



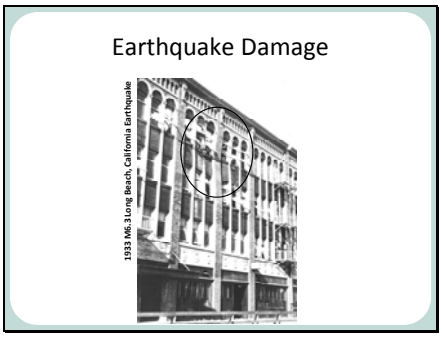
The oxygen tank at the New Olive View Medical Center toppled during the 1994 Northridge, California, USA earthquake.



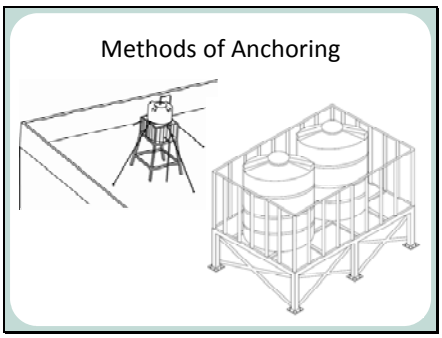
It is very important to look at all portions of the seismic load path, the route the forces take to get from the object to the ground. Failures have occurred at all these points: connection of the tank to its legs, connection of the legs to the concrete pad, and design of concrete pad.



Rooftop water tanks, especially unrestrained plastic tanks situated close to the edge of the roof, can slide or topple from the roof during strong shaking. Parapets that are not strong enough to stand up on their own cannot keep a tank from going over the edge.



A falling rooftop water tank damaged the front of this building during the 1933 Long Beach, California earthquake.

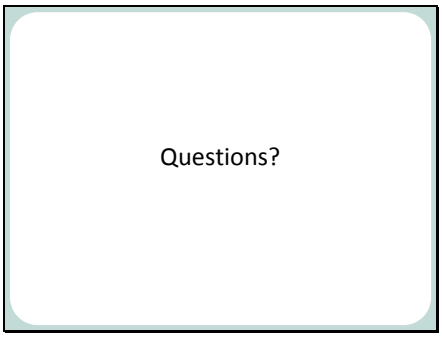


Explain that the restraint enclosure has to be engineered to resist the loads imposed by a full water tank under the expected level of shaking at the roof. Provide flexible connections to water tanks to avoid broken pipes (and leaks) if the tank slides within the enclosure or the enclosure deforms.

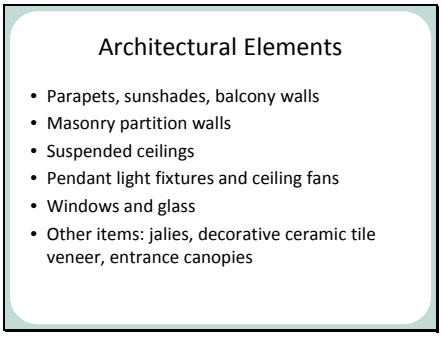
The day tank holds fuel for the emergency generator. These tanks are often unbraced and could slide or fall from their supports, and break connections with the pipes that supply the generator with fuel.

This tank slid on its supports and broke the pipes connected to it.

Anchor day tanks and other tanks by providing a structural support frame that can resist earthquake forces and is bolted to the floor or foundation. This slide shows one option for increasing the strength of an existing support system. The anchorage system should protect against both overturning and sliding. Provide flexible connections to all supply lines and pipes.

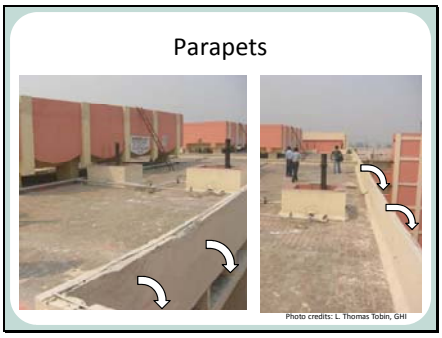


Answer any questions before moving on to Architectural Elements.



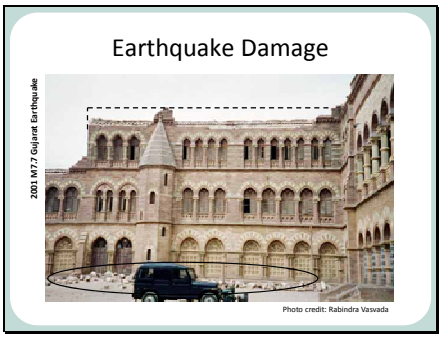
Explain what architectural elements are, by giving the examples in the list.

If someone asks, the difference between architectural elements and furnishings is that architectural elements are part of the building. However, they are not considered as “structure” that helps hold the building up or resists any loads. Furnishings are considered contents - objects that people bring into the building after it is completed.

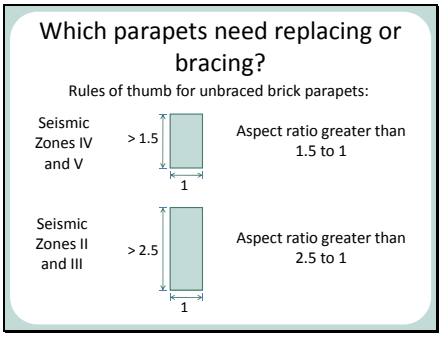


Parapets are located at rooftop level and experience higher accelerations. Unbraced brick parapets are or improperly anchored concrete parapets can topple and kill people that are outside the building near the walls. Parapets have fallen in many smaller earthquakes and killed people. People congregating outside buildings and those trying to run out during the shaking are particularly at risk.

You should mention that some buildings have poorly attached sunshades or unreinforced balcony walls that could topple as well and create a falling hazard similar to parapets. Sunshades can be retrofitted with steel brackets or replaced if they are in poor condition as well - hunks of concrete spalling and falling from deteriorated sunshades are a falling hazard even without an earthquake! Balcony walls need to be anchored or braced so that use of the balcony is preserved.



The parapet on this building used to be where the dashed line is, but it fell during the 2001 Gujarat earthquake. The fallen stones can be seen on the ground in front of the building (behind the vehicle). Note the lack of other damage to the building. Unreinforced masonry parapets are one of the most vulnerable parts of a building and often topple at levels of shaking that are not high enough to cause other structural damage.



Rule of thumb: unbraced brick parapets with aspect ratios of 1.5 to 1 (1.5 times taller than they are wide) in Seismic Zones IV and V and 2.5 to 1 in Seismic Zones II and III are likely to topple.

Note: If you happen to have engineers in the audience who want to know where these ratios come from, they come from the so-called “California procedure” in Appendix A1 of the 2006 International Existing Buildings Code (IEBC), Table A1-F. The table uses values of design spectral acceleration at one second period (Sd1): aspect ratios of 2.5 are permitted where Sd1 < 0.4g; ratios of 1.5 are permitted where Sd1 >=

0.4g. A rough equivalence has been made between these spectral values and the Seismic Zones per IS 1893:2002, the current version of the earthquake-resistant design code here in India.

Replace It

- The best solution for hospitals is to replace unreinforced masonry
- Replace with new reinforced concrete parapet
- Must be properly anchored to roof slab

The best solution for hospital buildings is to replace unreinforced masonry parapets with concrete parapets that are properly anchored to the roof slab.

If you can't replace it, brace it

Photo credit: FEMA 74

Parapets that are likely to topple need to be braced back to the roof to prevent them from toppling; bracing needs to be designed by a structural engineer. Bracing can consist of steel angle iron braces attached to an angle running longitudinally near the top of the parapet, and attached to it with through-bolts. The through-bolts connect to steel plates on the front, which can be plain or decorative to either blend in or act as decorative elements.

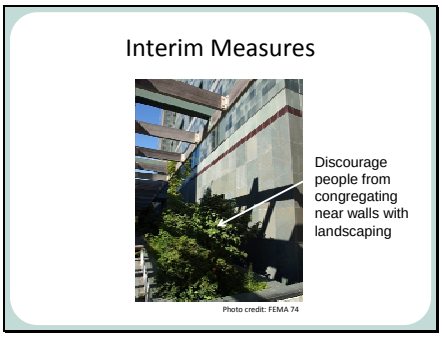
Bracing – View from Street

Photo credit: Janise Rodgers, GHI

Ask if the audience can spot how parapet bracing looks from the front of a building. The plates that attach to the front of the braces can be inconspicuous. Use the animations to show where the plates are.

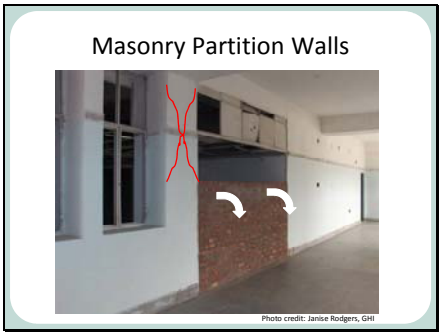
Ask if the audience can spot the parapet bracing on this building. Use the animations to show where the plates are.

This brick building in California has also had further retrofit in which the roof trusses were tied to the brick walls. The two rows of steel plates below the parapet are for this retrofit.



As an interim measure, you can plant landscaping that discourages people from congregating near walls. It will be important to maintain the landscaping and ensure that plants are not inviting – use shrubs rather than grass.

This is a measure that can be used to keep people away from any dangerous areas outside buildings. The building shown has exterior tile veneer, and tiles are likely to fall off during an earthquake. The landscaping was planted to keep people away from the walls. (The building is on the University of California, Berkeley campus.)



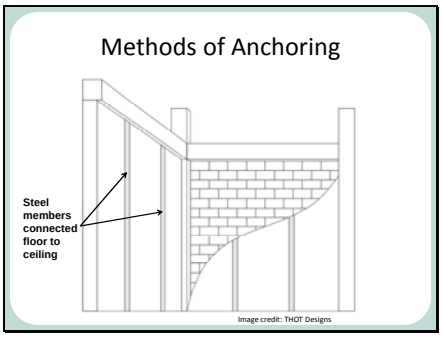
Unreinforced brick partitions that are only one brick thick can crack and fall into rooms or outward to the ground outside, as the building moves back and forth in an earthquake. Bricks, large portions of the wall, or even the whole wall can topple into rooms, if the wall is not anchored to the concrete beams and columns in some way.

Damaged infill has fallen out of the building frame.

Mention that in addition to being damaged themselves, unreinforced masonry infill walls can also cause damage to the building's concrete frame. Sometimes this damage is severe, and could even cause the building to collapse in some cases. You can see some cracks in the columns on the left side near where the infill is still in the wall.

Explain that unreinforced masonry infill walls often resist lateral forces even though they are not designed to do so. The stiff masonry is tightly fit into the frame, so it "jams" in the corners as the frame flexes and moves back and forth. This causes the infill to act like a shear wall rather than a partition. Infills that are strong enough can damage the frame, especially if they are only partial height.

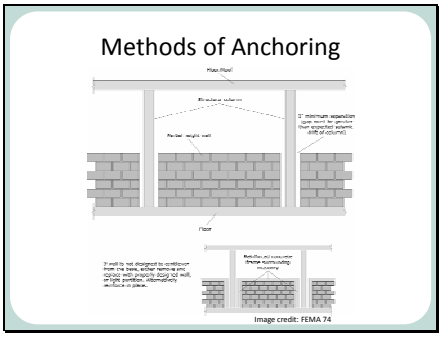
Thicker partial-height masonry walls can cause the adjacent concrete columns to fail. Column failures are considered major structural damage. Engineers refer to this type of failure as the "short column" or "captive column" effect, because the walls restrain a portion of the column from moving. As a result, all of the deformation has to occur within a short segment of the column. Most columns aren't designed for this and often fail. These columns in a Taiwan elementary school were damaged by the partial height masonry infill walls below windows during the 1999 Chi-Chi earthquake.



Anchor partition walls using steel members connected floor to ceiling, shown. Another option is to provide a fiber-reinforced polymer or microconcrete (with woven wire mesh reinforcement) overlay. Full-height partitions can also be detached from the columns, and a steel angle used to connect the top of the wall to the ceiling to prevent toppling. However, this is disruptive, and gaps in walls raise fire protection concerns that will need to be addressed.

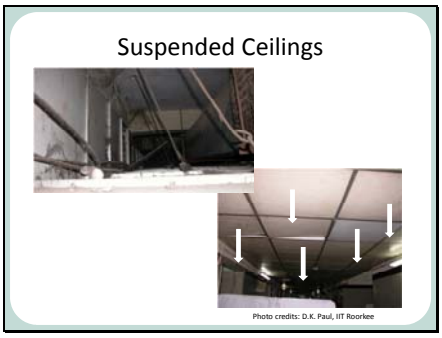
You can mention that this is an area of active research and that better solutions are needed and being sought.

Note that in the illustration the panel on the right is shown with a cutaway view to show the brick beneath the plaster and steel members.



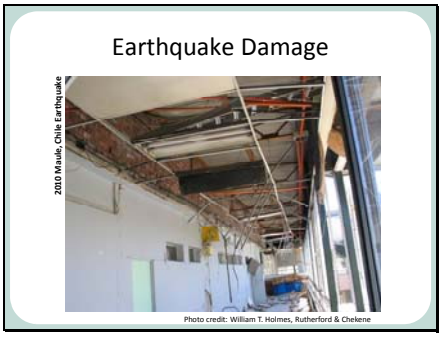
For partial height walls, leave a gap to avoid creating what is called a “captive column”. If the infill wall is stiff and strong, this phenomenon can cause severe structural damage to the columns on either side of the wall. You can use an elastomeric material in the gaps to seal them.

New partial height walls should be designed to cantilever from the base (i.e., reinforced with a connection to the floor that can resist overturning forces in the out of plane direction) If existing walls have not been designed to cantilever from the base, they can be reinforced with small confining concrete beams and columns. The columns must be properly connected to the floor slab (dowels are a common way to do this).

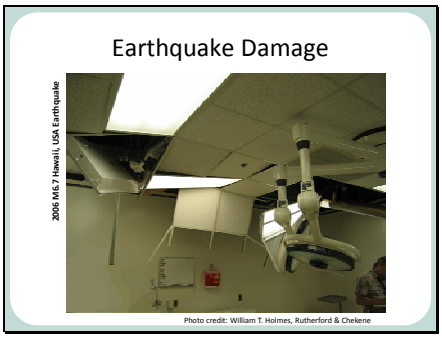


These have proven to be more of a problem in recent earthquakes than previously thought. Fallen ceiling tiles (along with accumulated dust) have led to evacuations in hospitals in Hawaii and Chile.

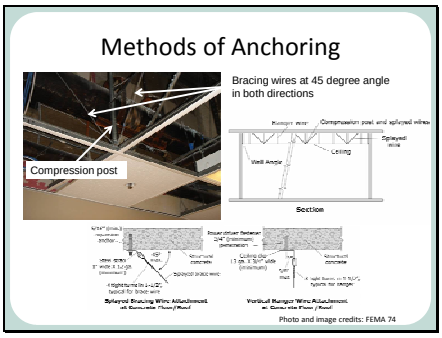
Metal panel ceilings such as the one shown don't often have panels that fall down, but this photo from a hospital in L'Aquila, Italy shows they sometimes do fall.



Panels commonly fall from suspended acoustical (lay-in) tile ceilings during earthquakes, releasing the accumulated dust on top of them into the room. Panels around the edges of a room are often the first to be dislodged. This hospital in Chile suffered major damage to its unbraced suspended ceiling systems.

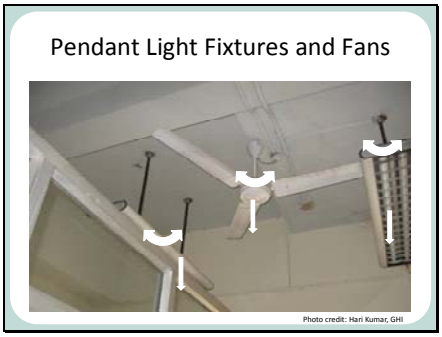


The disruption, perception of danger (the ceiling is falling!) and unsanitary conditions due to dust has contributed to the evacuation of hospitals in several recent earthquakes, despite the building structures performing well. This hospital in Hawaii was evacuated primarily because of damage to the suspended ceilings.

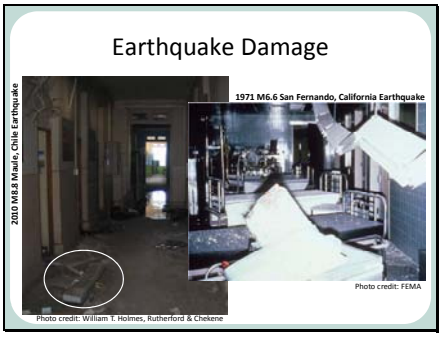


Anchor suspended grid systems in larger rooms by adding bracing wires and compression struts from the ceiling grid to the floor slab or beams above. In smaller rooms where bracing is not required, include hanger wires in the T span adjacent to the wall (T members support the tiles) so that the T will not fall when it slides off the perimeter support angle.

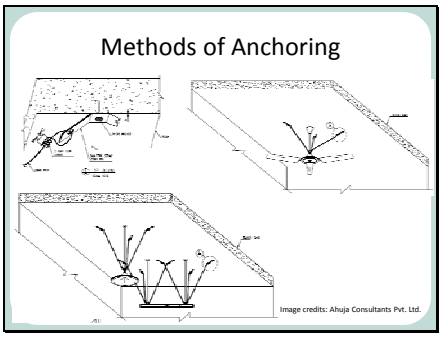
The recommended layout of the braces and struts is shown in section view. Connect the bracing wires and hanger wires to the concrete slab as shown. GHI does not recommend retrofit of suspended metal panel ceilings unless they are above a particularly critical area, because panels are unlikely to fall and attaching them to their supports would impede access to the ceiling space.



Pendant light fixtures and ceiling fans on rods will swing and can break the connection at the ceiling. Light fixtures and fans on chains, wire rope, or cables are safe, provided that the chain/rope/cable is attached securely with a closed circle hook or other device, so that it can't slip off.



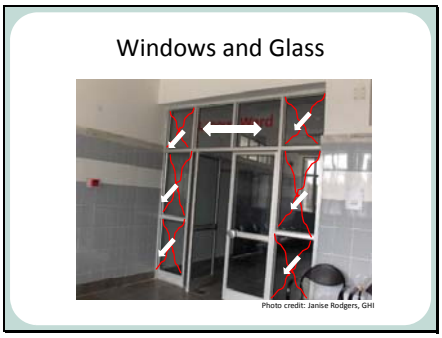
Fallen pendant lights in hospitals in Chile and California.



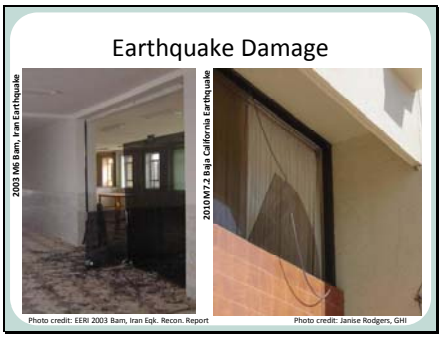
You can limit the swing of a light fixture or fan on rods by providing wires that attach the light or fan body to the ceiling. This should prevent the connection at the ceiling from failing.

Alternatively, you can replace the rod with a chain, wire rope, or cable and allow the light to swing. Swinging will not harm the light, if the fluorescent tubes have restraint devices like the wires around the fixture shown above right, to keep them from falling out. Screw-in globe bulbs do not need additional restraints.

There is at least one standard in the US that requires pendant lights and fans to be braced if the length of the suspension member is more that 24 inches. Lights and fans with longer pendant arms will generate larger forces at the anchorage. (If your audience does not consist mostly of engineers, you may need to explain that the long pendant arm acts like a lever.)



Explain that glass is mostly a hazard for those near walls (especially outside), or trying to exit. Glass can also be a problem if people aren't wearing shoes.



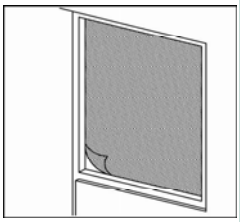
Glass doors and windows shattered in the 2003 Bam, Iran earthquake and the 2010 Baja California earthquake, respectively.

Earthquake Damage

Would you want to be on this sidewalk during an earthquake?

Methods of Anchoring

- Film is available in different thicknesses
- Can also be used for security purposes



Security or safety film can be used to prevent glass shards from coming out of the frame if the glass breaks during an earthquake. These films come in different thicknesses. The thicker security films can also serve double duty as security films to secure against breakages or even blast loading, depending on the film. Manufacturers can provide specifications. Explain that because film is relatively expensive, we recommend that it only be applied to critical areas, such as large panes of glass at or above exits. If glass breaks, take the opportunity to replace it with safety glass. Annealed, tempered, and safety glass do not create shards that can fall from the frame when they break, and are much safer than plain glass.

Questions?

Answer any questions before moving on to Lifts, the final section under Information for Specific Objects.

Lifts

- Rail systems and counterweights
- Lift equipment
  - Similar to other major equipment, similar solutions
  - If fixed, bolt it down
  - If vibration isolated use snubbers or seismically restrained spring mounts
- Control cabinets can be anchored like other electrical cabinets

Lifts are typically very vulnerable to earthquake damage, because the counterweights can swing and bend the rails. However, retrofitting them is not simple and requires experience. You will need to consult a structural engineer with special expertise with lift systems. It becomes very difficult to move patients without lifts, unless there are ramps. If your hospital has ramps, that's good.

Lift motors, generators, hoist machinery, hydraulic pumps and control cabinets can be protected using strategies similar to those found in the mechanical and electrical equipment section for similar types of equipment.

Rails and Counterweights

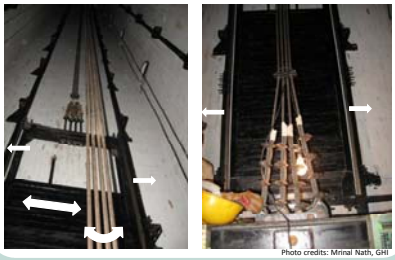


Photo credits: Mrinal Nath, GHI

Lift systems have several parts that can be particularly vulnerable to earthquake damage. If they have not been designed to resist the lateral forces imposed by the counterweights and the lift car, the guide rails for the counterweights and the lift car can move, potentially causing the counterweights and/or the lift car itself to derail. If counterweights derail, they can crash through the top of the lift car.

Earthquake Damage

1971 M6.6 San Fernando, California, USA Earthquake

Photo credit: NISEE (Ayres and Sun)

1994 M6.7 Northridge, California, USA Earthquake

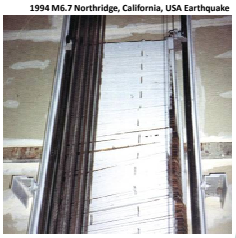
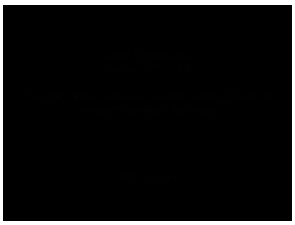


Photo credit: California OSHPD

The view at left is looking down a lift shaft. Note the counterweights that have swung out in the upper part of the photo. If the car were to come up or the counterweights go down, they would collide. The counterweights in the right photo have suffered as similar type of failure and have also swung out.

Earthquake Damage



This video from the 2010 Chile earthquake was captured by a hospital security camera. It shows what happens when counterweights hit the lift car.

Seismic Protection

- You will need a structural engineer with special experience with lift systems
- Guide rails may need added brackets to resist lateral forces from car and counterweights
- Add safety brackets or guide shoes to help prevent derailment
- Counterweight containment 'baskets' must be strong enough
- Need "go slow" option for use after earthquake

Explain that lift systems are complex and that you need a structural engineer with specialized experience. There are usually several steps that such engineers take to seismically protect lift systems.

Lift rail systems are typically retrofitted (strengthened to better resist earthquake forces) by adding new support brackets to the rails and by strengthening existing support brackets to resist earthquake forces, as well as by providing safety brackets (also called guide rail retainer plates) to keep the lift car from derailing. The counterweight containment "baskets" must also be checked and strengthened if needed. The walls in the lift shaft must be examined to determine if they can withstand the earthquake forces imposed by the lift cars and the counterweights, once anchored; if not, then the walls will need to be strengthened. A structural engineering specialist should design the retrofit measures for the lift system. This specialist will need to evaluate the strength of the lift enclosure and to properly design strengthening measures for both the shaft and lift rail system, if necessary.

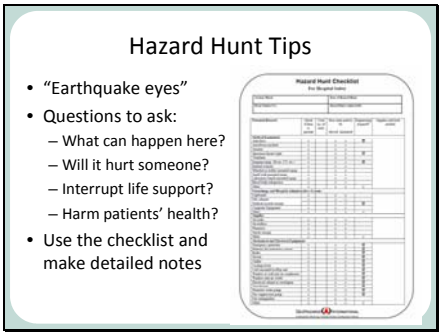
If you install a new lift or replace an old one, then you should specify that the entire system be seismically designed for the level of shaking expected in your area. New lift systems also provide useful control systems that can help maintain functionality after an earthquake, when use of the lifts will be critical for moving patients to safe areas or evacuating, or if the building performs well as you intend, handling the influx

of badly injured (many OTs are on not on the ground level). Some new lifts are equipped with a sensor system and control devices that allow the lift car to “go slow” (~150 feet per minute) after an earthquake to prevent life-threatening car-counterweight collisions. You can mention that these “go slow” systems are required for hospitals in California. (Lifts with a seismic sensor that shuts them down in the event of an earthquake will be much less useful – you will typically need someone from the lift company to restart them after a shutdown, and it may be very difficult to get that done immediately after a major earthquake, when you will still need at least one lift.)

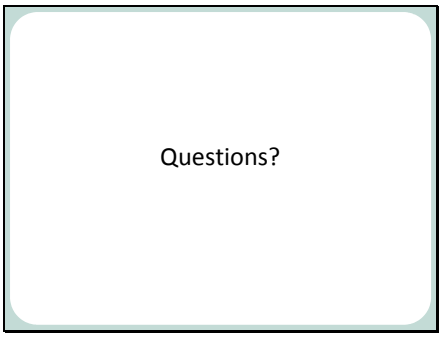
Mention that lift electrical and control panels are similar to other types of electrical cabinets and switchgear. Lift motors and hoist machinery are also similar to other large mechanical equipment. An ordinary engineer can anchor them properly. You do not need a specialist for these parts of the work.

Questions?

Divide the trainees into small teams (~4-6 people) for the hazard hunt. Have the teams visit different areas of the hospital. To avoid disrupting medical care, focus on the areas that can be visited without disturbing patients: the physical plant and mechanical rooms, roof and building façade, medico-legal records, laboratory, store rooms, administrative areas, etc. At some point, the hospital will need a full hazard hunt, but you don't have to see everything during the training exercise. You could get photos of medical areas like OTs and radiology ahead of time and perform a virtual hazard hunt as well.



You'll need to give the suggestions listed on the slide in order to help the trainees have a more successful hazard hunt.



Answer questions from the participants. Limit the number of questions to keep on schedule, but ensure that everyone knows what to do during the hazard hunt.

This Afternoon's Schedule

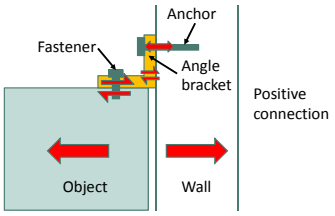
12:30-13:30	Lunch break
13:30-14:30	Information for specific objects – Part 2
14:30-15:30	Exercise: Hazard hunt
15:30-15:45	Tea break
15:45-16:00	Implementing risk reduction measures
16:00-16:30	Exercise: Potential solutions for hazards
16:30-17:30	Exercise: Identify high-impact solutions

Continue with the afternoon schedule.

REDUCING RISK, CONTINUED

Now we will continue with reducing risk, but move into more practical guidance.

Anchoring Objects



Seismic Load Path

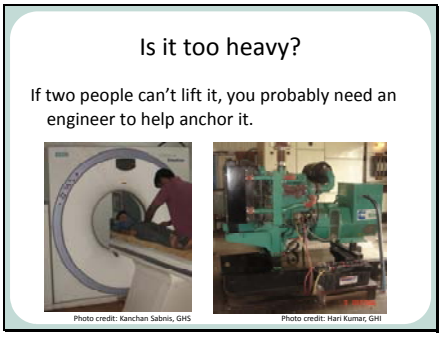
Most objects should be anchored using what is called a *positive connection*. This means that the object is physically attached to a hard attachment point, such as a wall or the floor, with hardware such as bolts, screws, L-brackets, cables, chains, or specialized devices. Positive connections can resist tensile forces and do not rely solely on friction or gravity.

The forces generated by the earthquake will need to be transferred from the object to the anchors to the supporting wall, floor or ceiling. Engineers call the path the forces follow the *seismic load path,* or *seismic force path*. Every part of the load path must be strong enough, or the restraint won't hold in an earthquake. For example, if the anchor itself is too weak, it will break. If the anchor is strong enough, but is not installed properly, the anchor will pull out of the wall. If the anchor is strong enough and installed properly, but the wall is not strong enough, the wall will fail instead. A portion of the wall could be pulled out, or the wall could topple over out-of-plane. When anchoring to walls, you must ensure that the walls are connected to the floor

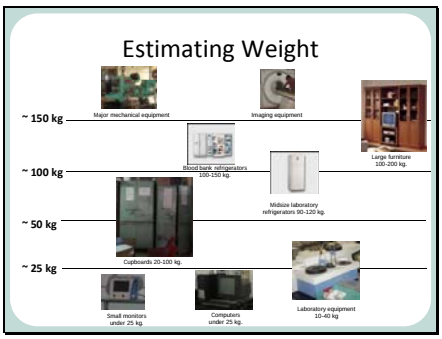
and ceiling. We will provide additional guidance on anchoring to walls a little later in the presentation. Keep in mind that it is better for the anchor to fail than for the whole wall to be pulled down.

Think through the load path when you are determining how to anchor an object, especially if it is large or heavy. If the wall is not strong enough, you may need to anchor to the floor instead.

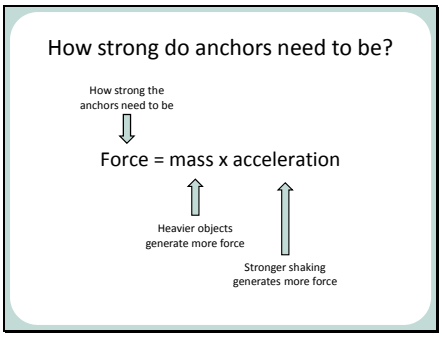
We will give you some guidance on what you can anchor yourself versus when you need help from an engineer. However, use your judgment: if you think the object is too large, oddly-shaped, or heavy for you to safely anchor yourself despite the manual's guidance, then please consult an engineer.



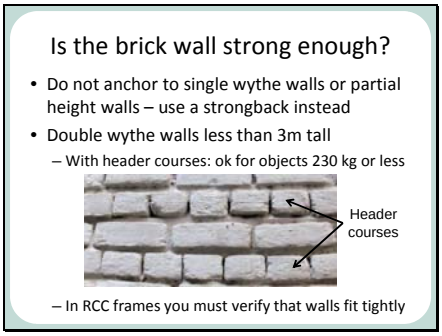
You will need an engineer to design the anchorage for very large, heavy objects – the simple prescriptive approaches used for lighter to moderately heavy objects may not be strong enough.



Before choosing your materials and hardware you need to estimate how much the item that you are mitigating weighs. This table may be helpful when estimating weight.



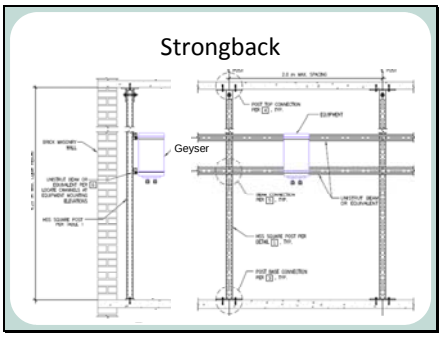
Remembering back to your school days, Newton's second law provides us some clues as to what will happen during an earthquake, and what we will need to do to keep objects secured. Force equals mass into acceleration. This means that we can find out how strong the anchors need to be, if we know how much something weighs and how strong the shaking is expected to be. This equation also shows us that heavier objects are going to generate more force and will need stronger anchors than light objects. Stronger shaking also generates more force. The shaking will be stronger at the roof because the building itself amplifies the ground motion, and that means that objects on the roof will need stronger anchors than those at the ground storey.



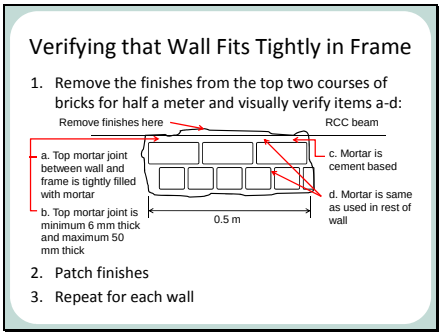
Here are some guidelines to follow when anchoring to burnt (i.e., fired clay) brick walls yourself, without consulting an engineer. First, you need to determine whether the wall is strong enough. Explain the rules of thumb. Single wythe partition walls and partial height walls cannot even support their own weight during an earthquake, so do not anchor anything important to them (lightweight pictures or signs are okay). Instead, install a floor-to-ceiling support member called a *strongback* and anchor items to the strongback.

Double wythe walls with header (bond) courses joining the two walls can support objects up to 230 kg. Header courses can be identified because the bricks are in the "short" direction when looking at the wall. If double wythe walls do not have header (bond) courses, the wythes will behave independently like single wythe walls, which are not nearly as strong. Do not anchor to walls without header courses.

If your building is an RCC frame with masonry partition walls, the walls must fit tightly or they can fall out of the frame during an earthquake.



A strongback is a floor-to-ceiling support system to which objects can be anchored in cases where the wall is not strong enough. A strongback also provides the added benefit of preventing weak walls from toppling over into the room.



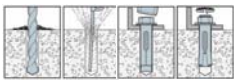
Follow this procedure to verify that the brick partition or infill walls in reinforced concrete frames fit tightly in the frame. Otherwise, the wall can topple out of the frame.

- Remove the finishes from the top two courses of brick near the ceiling for half a meter.
- Visually verify all of the following:
  a. Top mortar joint between the wall and frame is tightly filled with mortar
  b. Top mortar joint is a minimum of 6 mm thick and a maximum of 50 mm thick;
  c. Mortar is cement based; and
  d. Mortar is the same as used in the rest of the wall
- Patch finishes
- Repeat for each wall. The requirements can be relaxed if you expose 5 to 10 walls on a floor and every wall you test fits tightly. You should test at least one wall when moving to a new floor or wing as the mason may not have been the same.

These requirements can also be relaxed if you have construction photos that will allow you to verify the needed information in no. 2.

Anchoring to Brick Walls

- Only use approved anchors
- Install according to manufacturer instructions



- Insert anchors into bricks, not mortar joints
- Check mortar condition with coin or small tool such as pen knife

We have a list of approved anchors that you must use in order for the strength values to be valid. Other anchors may not be reliable. Hand out a list of approved anchors. Explain that other anchors might be okay but that an engineer will need to verify that the anchors are equivalent to the approved anchors on the list.

It is critically important to follow the manufacturer's instructions when installing the anchor. Otherwise, it might not be strong enough. You should insert anchors into bricks rather than mortar joints.

Check that the mortar is in good condition, and is strong enough by scraping it with a coin or fingernail. If it comes out when scraped, the mortar is weak and the wall may not be strong enough to anchor to.

When to Consult an Engineer

- For burnt brick walls taller than 3m
- For all other types of walls:
  - Stone masonry
  - Timber
  - Lightweight partitions
  - Dhajji-dewari
  - Hollow clay tile
- For objects heavier than 230 kg
- GHI has tabulated wall strength values that engineers can use

You will need to consult an engineer for burnt brick walls taller than 3m, for objects heavier than 230 kg, and for different types of walls. You and your trainees may encounter walls that are not constructed from brick masonry. These walls have different strengths and characteristics, and the guidance for brick masonry does not apply. Dressed stone walls can be quite strong, depending on the type of stone. If stone walls have two or more wythes, there should be through stones to connect the wythes. Otherwise, the wythes will behave independently like single wythe walls, which are not nearly as strong.

Hollow clay tile walls are not nearly as strong as brick masonry. There are special anchors that can be used to anchor to hollow clay tile walls.

Anchoring to Concrete

- Only use approved anchors
- Install according to manufacturer instructions
- Avoid rebar when drilling holes for anchors
- If you accidentally hit rebar, STOP drilling and relocate the hole – DO NOT cut thru rebar
- Clean the dust out of the hole

As with masonry walls, it is critically important to follow the manufacturer's instructions when installing the anchor. Otherwise, it might not be strong enough. There are a number of different anchors available, and the installation instructions are different for each type.

Stress the importance of avoiding rebar, especially in columns and beams, and pre-stressing or post-tensioning tendons/strands. Some buildings are built with prestressed or precast concrete, and have special high-strength steel cables called tendons inside. Damaging rebar or tendons while drilling holes could compromise the safety of the building. Never drill without first locating these with a rebar locator or similar equipment.

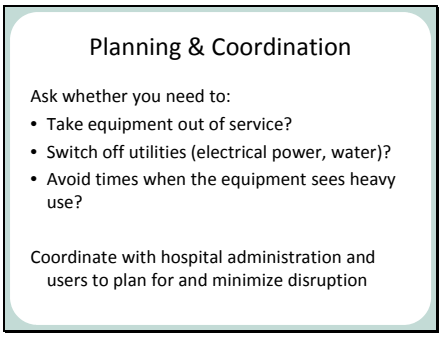
If you are drilling in a floor slab or accidentally hit rebar despite the above precautions, STOP drilling immediately. Drill a new hole in another nearby location. DO NOT cut or drill through rebar even if it small in diameter.

Safety

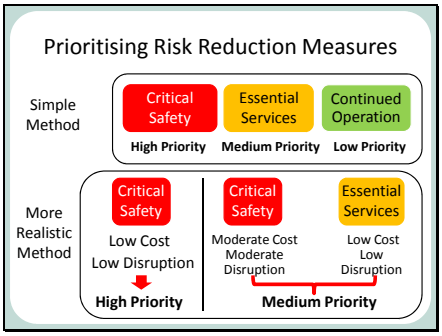
Areas of particular concern:
- Electrical power systems
- Inflammables and fuels
- Gases
- Hazardous chemicals
- Heights

- Use ONLY qualified tradespeople
- Follow safety protocols

Safety is very important when installing seismic restraints. It is inherently hazardous to work on many of the utility systems and equipment in a hospital. Some areas of particular concern are electrical power systems, inflammable fuels, gases, hazardous chemicals, and heights that expose you to a potentially deadly fall. ONLY qualified tradespeople should work with electrical, fuel, and gas systems. These persons should follow established safety protocols for their trade: turning off electrical power supply or gas to item before beginning work, using protective gear and clothing, following procedures, etc. People working in locations with exposure to falls should be trained and use appropriate safety harnesses, ropes, etc.

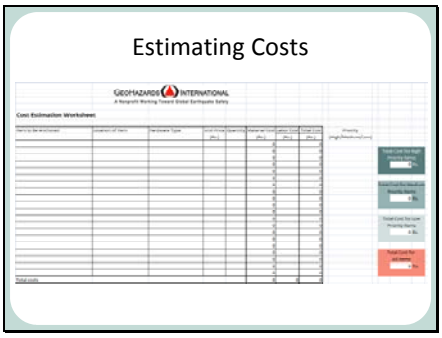


In order to perform work safely, equipment and parts of systems may need to be taken out of service for a short period of time. You will need to plan for the disruption this will cause. In some cases, the work can be scheduled to minimize disruption. For instance, the attachments for OT lights can be strengthened at night when no surgeries are scheduled. You can work on the cooling system in the cooler months, and the heating system (if there is one) in the warmer months. Work with the hospital administration and medical staff to plan for and manage disruption. You will build good rapport and support for earthquake safety efforts if you work with other hospital personnel to minimize and manage disruption.

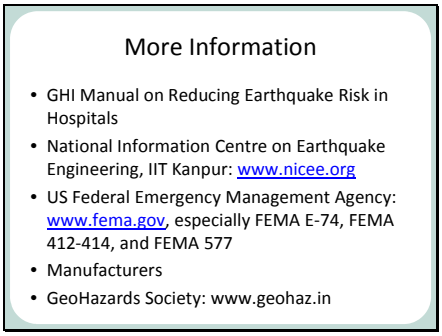


Explain that you can prioritise risk reduction measures in several ways. The simplest way would be to make all the Critical Safety items high priority, the Essential Services items medium priority, and the Continued Operation items low priority. You would fix all the high priority items, then all the medium priority items, and lastly all the low priority items. However, realistically some of the Essential Services items might be taken care of before all of the Critical Safety items are finished, because those Essential Services items are less costly and less disruptive, or because specific staff members are motivated to make their workspaces safer. We should encourage actions that improve safety and incorporate the wishes of staff members.

A more customized approach, shown on the bottom, would also consider cost and disruption. For example, Critical Safety items that are inexpensive and easy to fix would be high priority –the proverbial “low hanging fruit”. Perhaps the medium priority items would consist of Critical Safety items with moderate cost and/or level of disruption to fix, as well as Essential Services or even Continued Operation items that would be inexpensive and easy to fix. The remaining items would be low priority.



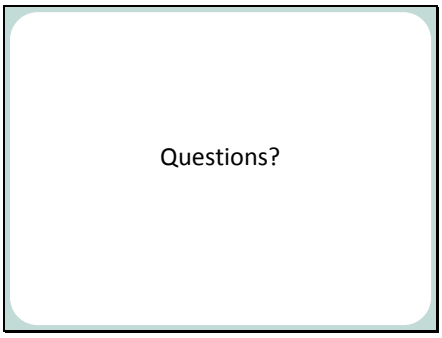
This spreadsheet can be downloaded from the GHI website.



Mention that all FEMA documents are free to download. FEMA E-74, “Reducing the Risks of Nonstructural Earthquake Damage: A Practical Guide” is an online document that contains a lot of useful information, though it is not written for hospitals.

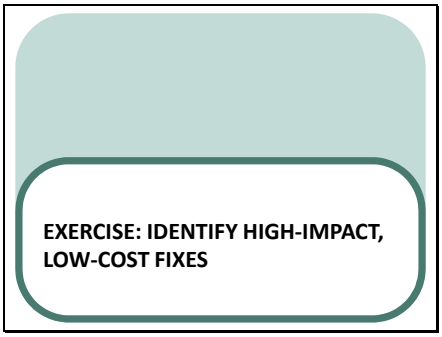
Manufacturers include:

Specialized devices: B-line, CalDyn, GS Metals, International Seismic Application Technology (ISAT), Mason Industries, Tolco, and Unistrut
Films: 3M
Concrete anchors and small hardware: Hilti and many others



Answer questions from the participants. Limit the number of questions to keep on schedule. You can invite participants to ask additional questions at the end of the day.

1. Break up trainees into groups (could be same as for the real hazard hunt, or different); consider including representatives from concerned departments of the hospital if they are willing to participate (they will be able to answer questions regarding mobility and usage of equipment in question).
2. Trainer assigns each group an item: (a) from the list of hazards that could be difficult to secure because they must be moved or used, or that require a custom solution; or (b) each group works on a part of one system, like the emergency power system, to determine what needs to be done and how: conceptual design; installation issues/planning requirements, functionality issues
3. Groups formulate list of potential consequences of fall/damage for item;
4. Groups brainstorm potential solutions or workarounds to reduce risks from these items;
5. One person from each group presents findings



Discussion with full group:
1. Lead the trainees in a discussion of the results of hazard hunt exercise and their knowledge of facility and identify one or more “low hanging fruit” hazards that can be fixed easily;
2. Discuss potential consequences vs. cost/disruption to fix
3. Cost estimation exercise – use the spreadsheet

Today We Learned

- Why hospitals are at risk from earthquakes
- About earthquake basics
- About earthquake damage and consequences
- How to identify and mitigate risks
  - General principles
  - Specific objects
  - How to conduct a hazard hunt
  - Things to consider when implementing measures

Review what we covered today (be brief!!).

Why hospitals are at risk – they contain complex systems, vulnerable people, and expensive equipment.

Earthquake basics - earthquakes have occurred and will continue to occur; how big the earthquake is and how strong the shaking might be; be prepared for aftershocks; factors like size and shape determine how an earthquake will affect a building or an object

Earthquake damage and consequences: damage to the building, systems and contents can cause loss of life, loss of function, loss of property/money, and loss of community confidence.

How to identify and mitigate risk: Identify risks with a hazard hunt; look for things that can fall, slide or topple; consider objects as part of a system; look at manual for guidance on specific objects; talk to people that use the object to help develop solutions; keep in mind safety, functionality, and load path when developing and implementing seismic protection measures.

Tomorrow's Schedule

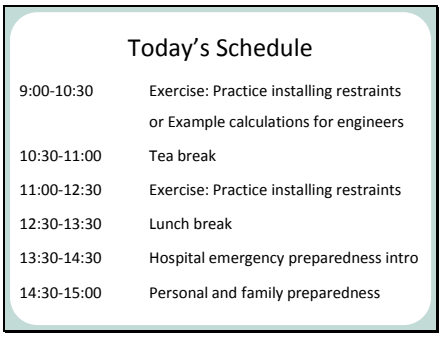
9:00-10:30	Exercise: Practice installing restraints or Example calculations for engineers
10:30-11:00	Tea break
11:00-12:30	Exercise: Practice installing restraints
12:30-13:30	Lunch break
13:30-14:30	Hospital emergency preparedness intro
14:30-15:00	Personal and family preparedness

Briefly remind participants of the start time for the next day.

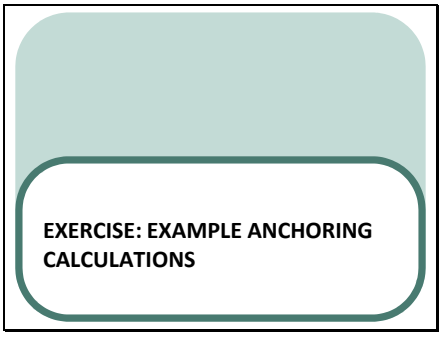
Questions?

Answer any final questions.

Welcome the trainees back for Day 2 of the training course.



Briefly review the schedule for today. If you have a group of engineers (see the note on the next slide) and you are going to do some example calculations, do that at the start of the day, and adjust the schedule as needed by taking some time from the practice installing restraints exercise. If not, proceed to practice installing restraints. The afternoon session on hospital emergency preparedness basics includes a short exercise. You can expand this exercise if you would like to make the second day a full one.



Use this exercise ONLY if your audience contains a lot of engineers who do structural calculations regularly and who will find it useful.

Go through example calculation from the manual/Jain paper, with input for a piece of equipment in the hospital. You will need to collect some information either ahead of time or during the hazard hunt, thought the second option may be a better learning exercise. Use information gathered during the hazard hunt or make a second trip back to the item to get measurements, estimate mass, etc. The item may be selected based on results of "low hanging fruit" identification exercise.

You will need to have a copy of the Mondal and Jain paper, a copy of the relevant sections of IS 1893, and a calculator. Work through the examples in the manual ahead of time so that you are familiar with the calculations and the process. Know the IS 1893 parameters for the seismic zone where you are doing the training.

EXERCISE: PRACTICE INSTALLING RESTRAINTS

In this exercise, trainees practice installing simple restraints and/or install a more complex but important restraint such as snubbers on the emergency generator. If the latter, you will need to do your homework: do the calculations for the snubbers and have another engineer check them, buy or procure the snubbers, and bring them with you to the site. Ideally, you will have a handyman or tradesperson assist with or lead this exercise.

HOSPITAL EMERGENCY PREPAREDNESS BASICS

This section provides a brief introduction to the topic of hospital emergency preparedness.

Before an Earthquake

- Form a hospital safety committee
- Understand the hazards you face
- Assess your risk and impacts on operation
- Train your staff and drill regularly
- Make the following plans:
  - Mitigation plan
  - Emergency response plan
  - Continuity of operations plan
  - Continuity of business plan
- Identify alternative sites/facilities to operate from

There are a number of actions that hospitals should take to prepare themselves before an earthquake strikes.

If you have not already done so, form a hospital safety committee that can address all the hazards (natural and manmade) the hospital faces. The safety committee will guide the hospital through the remaining activities.

The hospital safety committee will be responsible for assessing and reducing risks from earthquakes and other hazards, and for developing the hospital's emergency preparedness plans. The hospital should have one committee that will address all hazards and emergencies; subcommittees can focus on particular hazards.

Hospital Safety Committee

Representatives from all departments, including:
- Administration
- Nurses and doctors
- Medical departments: ED, Radiology, etc.
- Facilities/engineering
- Security
- Laboratory
- Housekeeping

It is very important that the committee have representation from all departments, so that everyone in the hospital will be working together and the needs and roles of every department will be understood. The problems and solutions associated with earthquake performance are interrelated and involve people with different responsibilities and areas of specialty. All of these points of view are important for proper performance and require cooperation. If the solution, anchoring something for example, creates problems for the user, then the anchor will be undone and the unsafe condition perpetuated. Cooperation leads to better understanding, better solutions and people who believe in the need to do things correctly.

The hospital safety committee will need to make several different plans, including the following: an emergency response (life safety) plan, a hazard mitigation plan, an emergency operations and continuity of operations plan, and a continuity of business plan.

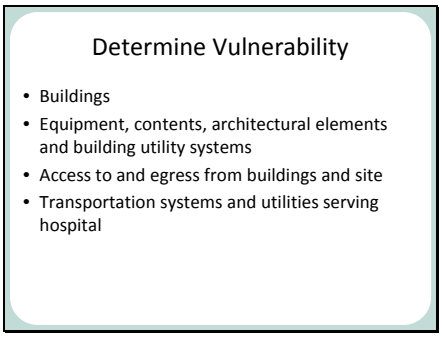
Remind participants of the concept of resilience that we introduced at the beginning of yesterday's session. Looking at the planning process from a resilience perspective means that you will set goals and timeframes for returning to normal operations as quickly as possible, and providing adequate care in the meantime.

Determine Hazards and Threats

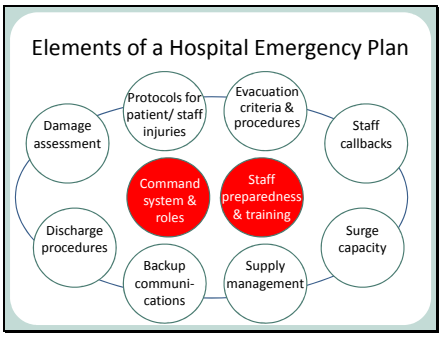
- Hazards:
  - Earthquakes: shaking & secondary hazards like fire
  - Floods
  - Fire
  - Cyclones
- Threats:
  - Epidemics
  - Terrorist acts
- Multi-hazard assessment tools available

Risk assessment is the first step in understanding the challenges you may face. Mention that the hospital safety committee should address all the potential hazards and threats the hospital faces as part of a comprehensive safety program.

Multi-hazard assessment tools are available from Pan American Health Organization (PAHO), Kaiser Permanente (a large managed-care organization in the US), and others. GHI can provide tools to help with risk assessment upon request.



As part of your risk assessment, you will need to determine the vulnerability of not only the hospital's buildings, but also of the objects and systems that keep the hospital functioning. These include all the equipment, contents, architectural elements and utility systems within the buildings, which we are discussing today. Also, you need to look at access to and egress from the buildings and site – can you get in and out of the hospital? You also need to consider the transportation systems (roads, rail lines, transit systems) that people use to get to the hospital, and the utilities serving the hospital, such as sewer, water and power.



Describe some of the elements a hospital emergency plan should contain, and hand out either an example plan or the HICS earthquake planning guide. You should mention the following areas that plans should address:

-Command system and organization: Who will have which roles, and who are the back-ups? Plans should not depend on any one person.

-Damage assessment: Assess damage to facility.

-Protocols for patient / staff injuries: What to do if people already at the hospital (staff and patients mostly) are injured?

-Evacuation criteria and procedures: What triggers and evacuation and how to conduct the evacuation. Evacuation can be dangerous for fragile patients, so only evacuate if really necessary.

-Surge capacity: How will you handle an influx of patients from the community? Have specific plans and procedures in place.

-Discharge procedures: How will you discharge existing patients that have less severe conditions in order to free up beds for those severely injured by the earthquake?

-Staff callbacks: How will you reach staff that are not on duty and have them return to work to help handle the influx of patients?

-Backup communications: How will you communicate if landline and mobile phone

service is down?

-Supply management: How will you manage your existing supplies, given that it may be difficult to get more in the short term (< 72 hours).

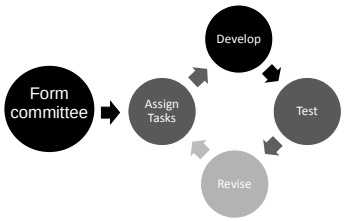
What You're Planning For

- Damaging earthquakes often:
  - Create mass casualties
  - Damage or affect the hospital directly
  - Injure staff and/or patients
- How will you handle the influx of patients?
- Where and how will you triage patients?
- Treat them?
- What will you do with the "walking wounded" and the "worried well"?

Surge capacity (the ability to handle an influx of patients) and procedures for mass casualty management are key elements of the hospital emergency plan. Plans to handle mass casualty events can be applicable to other natural and man-made hazards. Mass casualty management plans can be based on the number of casualties generated by an event; the type of event may be less important than the number of casualties. Having a plan will be important for things like bus crashes or bombings (hopefully not, but best to be prepared) as well as an earthquake.

For earthquakes, the number and severity of casualties that present at nearby hospitals depends on a number of factors. Building collapses are the main culprit in severe injuries, while falling hazards can create a large number of "walking wounded" as well as fewer severe injuries. The number of building collapses will vary greatly depending on the vulnerability of local buildings and the strength of the earthquake shaking. There will also inevitably be some "worried well" – people who are not actually injured but want reassurance that they are okay.

Process for Developing a Plan



The process for developing your hospital's emergency plan will begin with the formation of a safety committee, either at the direction of an administrator or because leaders within the staff come forward and champion the effort.

Emphasize that the process of developing, testing and revising a plan is an ongoing effort that must involve all facets of hospital operations in order to be successful.

Tasks and Plan Development

- Gather information:
  - How are things done normally?
  - What would change after a disaster?
  - How can we do things better?
- Identify needs and gaps
- Each portion of the plan will have specific tasks
- Someone will need to write each draft section

When making the hospital emergency plan, it will be important to assign specific tasks to individuals so that someone on the committee will be responsible for each item. This will help spread out the workload and will also create accountability.

Many of the initial tasks will involve gathering information: finding out what is already being done, and how that can be leveraged or modified. The committee will need to identify gaps as well as how things could be done better.

Testing the Plan

- Tabletop exercises
  - Simple
  - Enhanced
- Mock drills
- Large-scale exercises

Discuss the options for testing the plan. Many audience members will not be aware of the potential exercises and drills, or what they are called, so explain all the types of drill you are going to mention.

In all these cases you will need a scenario upon which to base the exercise. A scenario can be simple or complex.

Simple tabletop exercise (definition from US Environmental Protection Agency): A facilitated analysis of an emergency situation in an informal, stress-free environment. It is designed to elicit constructive discussion as participants examine and resolve problems based on existing operational plans and identify where those plans need to be refined. There is minimal attempt at simulation in a tabletop exercise. Equipment is not used, resources are not deployed, and time pressures are not introduced. This is the simplest type of exercise to conduct in terms of planning, preparation, and coordination.

Enhanced tabletop exercise (definition from US EPA): An enhanced tabletop exercise is a simulated interactive exercise that helps to test the capability of an organization to respond to a simulated event. The exercise tests multiple functions of an organization's emergency response plan. It is a coordinated response to a situation in a time-pressured, realistic simulation that involves several agencies. An enhanced tabletop exercise focuses on the coordination,

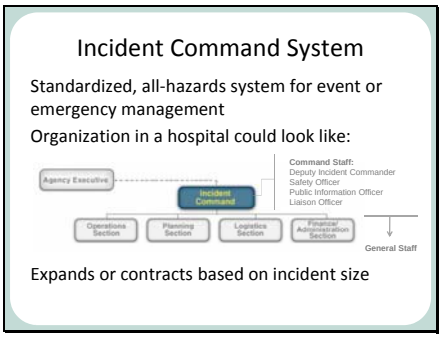
integration, and interaction of an organization's policies, procedures, roles, and responsibilities before, during, or after the simulated event. This type of exercise will require much more planning, preparation, and coordination than a simple tabletop exercise.

Mock drills: A mock drill is a simulation of an emergency event that is used to test emergency preparedness procedures and plans, and allow participants to physically practice what they would do in a real emergency. For example, participants would practice protective actions such as drop, cover and hold on during an earthquake mock drill. The mock drill can be simple or detailed, and it typically tests egments of an organization's emergency plan related to a particular hazard (for example, there can be mock drills for fire, earthquake, etc.). It can involve role players who pretend to be injured or trapped.

Large-scale exercises: A large-scale exercise is a more elaborate simulation of an emergency event that typically includes all the agencies and organizations that would be involved in a response in a particular area, such as a city, tehsil, or district. Typically, a hospital would participate in a large-scale exercise conducted by a government agency, but would not lead such an exercise. Large-scale exercises require detailed planning and coordination, but can be very effective in testing how various organizations will work together and identifying areas for improvement.

In order to stress the importance of drills, you can tell the story of Rick Rescorla, Security Chief for Morgan Stanley in the World Trade Center in New York. Because of his dedication to developing evacuation procedures and holding regular drills (every three months for everyone, even senior executives), all but a handful of Morgan Stanley's 2700 employees escaped unhurt when the World Trade Center was attacked on September 11, 2001. Mr. Rescorla ordered Morgan Stanley employees to evacuate,

following procedures, after the first tower was hit (they were in the second tower). Tragically, Mr. Rescorla and three deputies died when the building collapsed while they were still trying to evacuate others.



Explain that the Incident Command System is a standardized, all-hazards emergency/event management framework that allows multiple organizations and jurisdictions to work together. ICS is a cost-effective and efficient way to handle both small and large events.

Because hospitals need special provisions for emergency response, there are special variations of the original ICS for hospitals; Hospital Incident Command System (HICS) is one of these. ICS has been widely adopted by hospitals in the US and Canada due to a Joint Commission on Accreditation of Healthcare Organizations (JCAHO) requirement that hospitals use ICS in their emergency management programs. We recommend that you consider using IRS/ICS in your hospital.

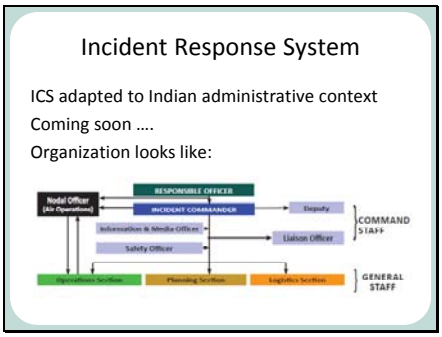
ICS was developed to help better manage emergency responses, and to rectify some problems that plagued past responses to emergencies. These problems included communication difficulties, lack of accountability resulting from unclear lines of authority, and lack of an effective management structure to keep commanders from being overloaded. ICS has been tested and refined for over 30 years in events of all sizes.

ICS has a flexible, modular structure that expands and contracts as the incident changes in size or scope. The only position that is staffed in every event is the Incident Commander. Other positions are added by the Incident Commander as needed.

Note: the Incident Commander is not always the most senior person, but should always be the most knowledgeable and experienced person.

The Safety Officer is a very important position (actually the most powerful person in the command structure): they can stop any activity if they deem it to be unsafe. The Safety Officer also monitors staff to detect fatigue, abuse and post-traumatic stress syndrome.

Tell trainees that this is only a brief introduction to ICS. The FEMA website has numerous resources for ICS training if they would like to learn more.



Explain that the Incident Response System is India's version of ICS. IRS is based on the Incident Command System (ICS), with adaptations to the Indian context (primarily the Indian administrative system). It is currently being rolled out in India; NDMA released guidelines in July 2010 and training of government officials will begin soon.

IRS has Indian administrative structures incorporated into it. Incidents will be handled through Incident Response Teams (IRTs) that are pre-designated at the state, district, and sub-district (tehsil and block) levels. Your hospital should eventually be contacted regarding its role in the appropriate IRT.

In addition to working with other agencies through IRS, the hospital will need its own emergency plan. This plan should be compatible with the IRS, though it may be simpler to start with basic ICS or HICS and adapt it directly to your hospital's needs.

IRS/ICS is designed to

- Meet the needs of events of any kind or size
- Allow personnel from a variety of organizations and agencies to meld rapidly into a common management structure
- Provide logistical and administrative support to operational staff
- Be cost effective by avoiding duplication of efforts
- Be flexible – no need to match the organizational structure for day-to-day operations

Slide credit: FEMA

IRS provides a single set of guiding priorities for your planning process.

Command and Control

- Unity of command
  - Clear
  - Creates accountability
- Transfer of command
- Span of control
  - Leader directly manages small number of resources
  - Optimal number in ICS is five; maximum is seven
  - ICS organizational structure expands and contracts as needed to maintain manageable span of control

Incident managers must consider command and control, and IRS/ICS is set up to make that simple and straightforward. ICS/IRS uses some basic concepts:
-Unity of command: There is one chain of command, with one position (Incident Commander) clearly and ultimately in charge. This creates accountability.

-Transfer of command: A transfer of command ALWAYS includes a transfer of command briefing. ICS anticipates the need to transfer command (there will be a day shift and night shift as the Incident Commanders need some sleep) and provides for it.

-Span of control: A very useful concept, span of control says that a leader can only effectively manage a finite, small number of resources directly. Based on research, the optimal number of resources is five, with the maximum being seven. A resource could be a person or a team. If the number of resources under a particular person's control exceeds the manageable span of control, ICS has procedures to add organizational structure (like branches or groups) to maintain the span of control.

Security and Crowd Control

People will converge on the hospital. Security will:

- Control access
- Provide perimeter security
- Manage vehicle traffic at emergency entrance
- Facilitate entry of patients and triage
- Designate areas outside the hospital but within secured perimeter for family members and the media

Many different people will converge on the hospital:
-The injured and their family members, whether severely injured or "walking wounded"
-The "worried well"
- Spontaneous volunteers wanting to help
- Trained medical personnel from other facilities arriving as part of mutual aid agreements or requests from the hospital

- The media
- Government officials and politicians (typically after the immediate crisis phase has passed)

In the phase immediately following the earthquake when numerous casualties are arriving, you will in all likelihood prevent almost all family members (except a parent accompanying a small child, for instance) or any other visitors from entering the hospital, to allow the medical staff to focus on treating patients. Designate an area for family members outside the hospital, but within the secured perimeter.

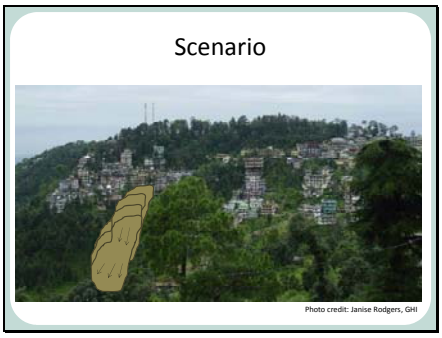
Communication and Liaison

- Communication of accurate and useful information is critical
- ICS/IRS specifically provides command staff
  - Information and Media Officer
  - Liaison Officer
- Communication with family members needs special consideration

Communication is critical during a disaster. The hospital will need to communicate effectively with outside entities such as the families of patients, government agencies involved in the response, and the media. The hospital will also need to communicate within the organization. ICS/IRS provides staff positions within the command staff to handle these duties.

Providing accurate information and repeating consistent messages at timely intervals helps to reassure people and prevent rumors. Resources for communicating messages include the media, government and the military. In a major disaster, you will need to communicate with other hospitals and provide regular status updates to the government and/or international relief agencies working in your area (UN, Red Cross/Red Crescent, etc.).

Family members will be outside the hospital building, and you should set up a communication post outside but within the family area inside the secure perimeter to provide information to family members in an orderly manner. Security will help control the crowd.



Read/describe the following scenario (or a similar one appropriate for your local conditions) to the trainees to help them understand how ICS/IRS works:

It is the middle of the monsoon. A minor, local earthquake at 4 pm causes a rain-soaked hillside in the Himalaya foothills to collapse and cause a landslide. A town sits atop the hill, and the landslide moves the soil from beneath several buildings containing houses and shops, and causes them to collapse. The earthquake also causes tall and narrow items to topple in some other buildings.

The district hospital is about 15 km from the town where the landslide occurred. Fortunately, the road between the town and the hospital had been re-built six months ago with proper drainage and was not damaged by the landslide (or the monsoon rains, for that matter). People at the hospital felt minor shaking. Power and utilities remain functioning. The medical superintendent is out of station, on her way home from a conference in Delhi. The deputy medical superintendent, who is in charge in her absence, calls facilities immediately and directs them to make a quick check for damage, even though the shaking was not strong and nothing in his office has been damaged. He and his office staff split up and do a quick walk-through of the hospital themselves to make sure no one has been injured (he leaves one person in his office to answer the phone). No one has; everyone took protective actions as they had been trained to do.

A few minutes later (at 4:05 pm), one of the emergency department doctors gets a call on his mobile from a friend in the town atop the hill, saying that there has been an landslide, several buildings have collapsed, and there are a number of people injured. The friend is just getting into a minibus taxi on his way to the hospital with some other injured people; his daughter has a badly broken ankle from a fall down the stairs while trying to run out of a

building, and he has some cuts on his head from being struck by falling objects. He asks the doctor to contact the authorities for help in freeing some people trapped in the buildings collapsed by the landslide. He says that people are digging by hand but they need equipment.

The doctor immediately notifies the deputy medical superintendent that there has been significant damage in the town due to the landslide and that casualties are headed for the hospital. The deputy medical superintendent immediately activates the hospital's emergency response plan, which utilizes IRS. He is the Incident Commander for the hospital. He directs the emergency doctor to prepare the emergency department to receive casualties, and designates him as Deputy Incident Commander. He appoints the medical superintendent's assistant as Liaison Officer, and directs him to notify local authorities of the landslide and coordinate with the search and rescue team and authorities. The next shift of nurses is arriving, and the Incident Commander (the deputy medical superintendent) directs the current shift to remain at work as well to handle the incoming patients.

Ten minutes later (at 4:25), the head of facilities reports that they did not find any damage in the initial assessment of because highly vulnerable items had been anchored before the earthquake. The Incident Commander summons the security guard, and directs him to set up a security perimeter and family waiting area with help from the facilities department now that the damage assessment is complete. The deputy medical superintendent calls the medical superintendent on her mobile and reaches her as she is nearing her home. He tells her what has happened and that he has activated the hospital's emergency response plan. She promises to be there as soon as she can.

Thirty minutes after the earthquake (4:30 pm), casualties begin to arrive from the town. The emergency department is soon filled to capacity

and beyond. An hour after the earthquake, the medical superintendent arrives at the hospital. After a transfer-of-command briefing, she takes over the role of Incident Commander from the deputy medical superintendent. Additional family members of the injured began arriving, and the medical superintendent appoints a Public Information Officer to set up an information desk outside to provide information to the families and to work with security to keep them from disrupting the work of the emergency department. Word of the earthquake has also reached hospitals in several nearby districts, who call to ask how they can help. (As the IRS rolls out in India, the process may change and become more formally routed through the Incident Response Team). The medical superintendent designates the emergency room doctor, currently the deputy incident commander, as Operations Section Chief to manage ongoing operations, the assistance arriving from these other hospitals, and potential patient transfers to other hospitals.

Ninety minutes after the earthquake, the Liaison Officer gets a call from the fire brigade requesting a medical team to assist several badly injured victims the brigade is currently trying to extract from the collapsed buildings. Since most of the patients in the ED have been stabilized, the Operations Section Chief sends an experienced trauma doctor and two nurses to the scene. The medical team assists in the extraction and arrives at the hospital an hour and a half later with three very badly injured victims, two of which had amputations in the field in order to free them. The patients are stabilized at the hospital. Three hours after the earthquake, the media begins to arrive in the area. The Information and Media Officer provides reporters with information on the number of injured and on the hospital's good seismic performance, and continues to provide family members with information.

Six hours after the earthquake (10 pm), all patients have been treated and admitted or

discharged, and arrangements have been made to transfer the two patients with amputations to hospitals in Delhi (or the nearest big city for your area) that specialize in amputee care and rehabilitation. The transfer is scheduled to occur the next morning. The Operations Section Chief works with the Liaison Officer to identify the best sources for replenishing medical supplies; several nearby hospitals agree to send supplies over in the morning.

Sixteen hours after the earthquake, the hospital continues to provide care for the patients who have been admitted, and is very full. Several truckloads of medical supplies arrive from nearby hospitals to replenish the stocks.

Seventy-two hours after the earthquake, hospital operations return to normal, save for a heavier patient load due to a few earthquake victims who remain hospitalized.

Prepare People and Provisions

- Train the staff and repeat training on a schedule
- Conduct regular drills
- Implement preparedness measures called for in the plan
- Keep enough supplies on hand for 72 hours, including for your mass casualty plan

Training is important – people need to know what to do. Staff need to be trained on life safety and response procedures, and in implementing the operational continuity/recovery plan. (There will not be time for training in the aftermath of a disaster.)

Also, “use it or lose it” applies to disaster preparedness too. If you don’t use your knowledge, you’ll forget. So, conduct regular drills and refresher courses, as well as providing training for new staff members.

We’ll talk about this more later, but the families of staff members will also need to be trained and prepared so that they can manage on their own while the staff member reports to work.

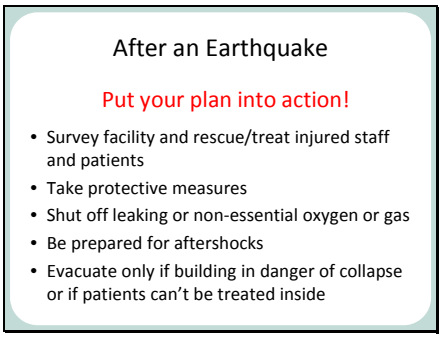
You can substitute your local jurisdiction’s recommendation for how long to remain self sufficient before help arrives for the 72 hours listed.

Mention any relevant resources for staff training.

Summarize the broad classes of risk mitigation actions.

Mitigate risk based on the established hazard and risk assessment, and priorities to reestablish operations and delivery of services. The hospital's existing policy should define the hospital's mission, from which priorities for mitigation will be derived.

People who are able should drop, cover, and hold on. People in hospital beds should remain in bed, curl into a ball lying down if possible and cover their head with a pillow. Staff should instruct patients and family members on what to do if possible, but should protect themselves so they will be able to provide care to many after the earthquake.



Put your emergency plan into action.

Survey the facility, and rescue and treat any patients or staff that have been injured

Take measures to protect yourself. You can't help if you get hurt.

Shut off any oxygen or gas that is leaking or nonessential to prevent fires and explosions.

Expect aftershocks, and avoid situations where an aftershock would put you in danger.
- Evacuate the building only if it has suffered severe damage and is obviously in danger of collapse, or if you can't treat the patients inside.

Protective Measures

- Don't put yourself in dangerous situations
- Don't use lifts
- No open flames
- Wear protective clothing: sturdy shoes, plus masks, gloves, and hard hats

You will need to take some commonsense protective measures.

- Don't put yourself in dangerous situations: if there may have been a hazardous materials release (i.e., in radiology), or simply walking across broken glass in inadequate shoes; there are many other examples you can give. You won't be able to help if you become a victim.

- Don't use the lifts until they can be checked; lift systems can be vulnerable to earthquake damage unless they have special seismic protection measures in place.

-Do not light matches, use lighters or candles, or have any open flames until all danger of gas leaks is past; otherwise there could be an explosion or fire.

- Wear protective clothing: sturdy shoes to avoid injuries from broken glass, masks to keep out dust, gloves to prevent cuts, and hard hats to protect from falling debris when inspecting or surveying buildings.

Damage Assessment

- Need a trained person on staff or available to assess the hospital within an hour of the quake
- Can be difficult for the untrained to evaluate severity of damage
- Evacuate without waiting for assessment if:
  - Building appears in danger of collapse
  - In danger from collapse of adjacent structure
  - Imminent threat of landslide
  - A fire you can't put out yourself has started

Someone on the maintenance/facilities staff should be qualified and specially trained in post-earthquake structural damage assessment, or arrangements should be made beforehand with the appropriate authorities for a damage assessment within an hour of the earthquake. Remember that local authorities may be overwhelmed, and it is prudent to have your own damage assessor unless there a government agency with specific staff on call for post-earthquake damage assessments.

As a starting point, you can tell the facilities personnel that one way to proceed will be to work with an engineer experienced in damage assessment to prepare a document and train the building engineering staff where to look at critical structural points and potential points of system failure. This can be done in conjunction with a building vulnerability assessment. If the facilities engineers know the potential trouble spots ahead of time, they can do a much quicker and more effective assessment.

The training should also include what does not present a danger (slight cracks, etc.) as sometimes hospitals get evacuated unnecessarily when there is a critical need for medical services. This happens because it can be difficult for untrained persons to assess the severity of building damage. As you've seen during this course, damage to architectural elements can look really bad even if the main structure is not badly damaged: partition walls can crack or even fall over, and suspended ceilings can fall.

Remember that an unnecessary evacuation needlessly puts fragile patients in danger, and prevents the hospital from using its facilities to save lives.

HOWEVER, if a building appears to be badly damaged and in danger of collapse, evacuate it immediately without waiting for an outside assessment. An aftershock can bring down buildings that are near collapse.

There are also other things that can make the building unsafe, and you should evacuate:

- An adjacent building or structure is on the verge of collapse and could fall on the building;

-There is an imminent threat of a landslide: there are large cracks or fissures in the ground, or slope displacement (landsliding) near the building;

- A fire has started and you or your colleagues cannot put it out yourselves; this calls for immediate, rapid evacuation because normal firefighting systems may not be operational unless you've take special seismic precautions; the fire brigade may not be able to respond immediately because there may be many fires.

Is it in Danger of Collapse?

The building could collapse in an aftershock if:

- It is visibly leaning in one direction
- Concrete frame buildings: majority of columns at any one storey have large X-shaped cracks or crushed ends
- Masonry bearing wall buildings: majority of walls on any side in any one storey have large X-cracks

While there is an entire training course on how to tell if a building is safe or dangerous after an earthquake (in the US, the ATC-20 course Postearthquake Safety Evaluation of Buildings), there are a few simple pointers. The building is in danger of collapse if:

-It is visibly leaning in one direction

-For concrete frame buildings, if the majority of columns in any one storey level have large X-shaped cracks or crushed ends

-For masonry bearing wall buildings, if the majority of walls on any side have large X-cracks

Minor cracks and damage to finishes do not make the building's structure unsafe. Toppled contents and fallen suspended ceilings do not make the building's structure unsafe. In fact, very little of the damage to all the different objects we've shown you yesterday and today would make the building unsafe to use; the damage we showed mostly causes disruption and can hurt people during the earthquake, but it won't cause the building to collapse.

This is Olive View Medical Center after 1971 San Fernando, California earthquake. Ask if they think this building is a collapse risk. Yes – both the stair tower and main building are leaning alarmingly.

This is Hospital 5 de Deciembre, Mexicali, Mexico after the 2010 El Mayor-Cucupah (Baja California) earthquake. Ask if the hospital is a collapse risk. No – the exterior damage to the cladding does not put the building at risk of structural collapse. Government engineers verified that the hospital's structure was undamaged and safe. However, the hospital had been mostly evacuated as a precaution. The precise rationale for the evacuation was unclear, because the building suffered minor damage to its contents, architectural elements and utility systems.

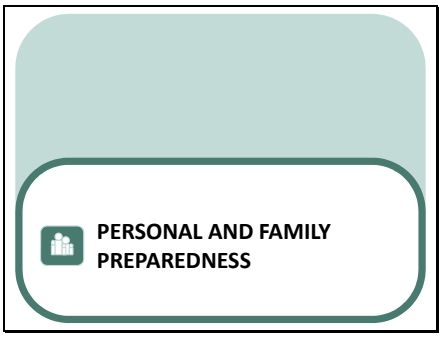
Questions?

Answer any questions on the hospital emergency preparedness section.

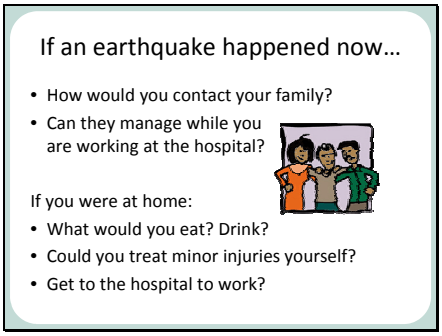
EXERCISE

Ask each participant to think about how their work would be affected by an earthquake, and about what they could do to prepare or mitigate the consequences. You may need to give suggestions – what would we do if "x" happened?

Have them break into small groups (3-5 people) and discuss their answers. Ask one person per group to give a quick summary of their group's discussion.

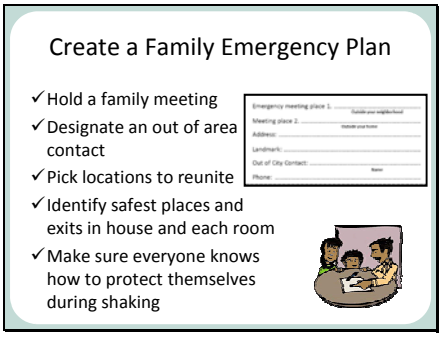


Our final topic is personal and family preparedness. Knowing your family is safe will help you do your job better.



Ask trainees to think about these questions.

A hospital is an important facility that will have a crucial role immediately following an earthquake. You will not be able to go home immediately and check on the welfare of your family. Your family should be prepared, so that they can take care of themselves and help their neighbors.



Explain each bullet point in detail, and emphasize than many small steps can make a very big impact on your family's safety. If your family is prepared to manage without you, you can have peace of mind while at the hospital helping the community.

-Hold a family meeting: Be sure all family members that live in your home attend, especially children and elders. If other family members live very close by, consider having a joint meeting with their families so you can coordinate your plans.

-Designate an out-of-area contact: Communication systems will be overwhelmed after a disaster. Do your part to lessen the load so those with true emergencies can get the help they need. Designate a person that does not live in your area and who has a mobile phone to be the one for your family and friends to call to find out about your family's well-being. Talk to that person and tell them about their role and what to expect. You will send them a short SMS to tell them that you are okay. Tell your friends and family members to call the out-of-area contact in the event of a disaster, and give them the

mobile number.

-Pick locations to reunite: If the family is not together when the earthquake happens, they will need to reunite. You will be at the hospital – they will need to manage on their own. Mobile phone networks will be overloaded so you will need to designate a location beforehand. Select locations in your house, outside your house, and outside the neighborhood (in case access to your neighborhood is blocked).

Hand out cards with space to write meeting places and out of area contact.

- Identify the safest places in the house and in each room. These will be locations away from falling hazards, glass, or fire hazards; and preferably under a sturdy piece of furniture. Also identify the exits and alternative exits in each room. It will be helpful to walk from room to room and find the safest places and exits together. Children may not realize that windows are alternative exits.

-Make sure everyone knows how to protect themselves. Everyone should know what to do when the shaking starts. If inside, Drop, Cover and Hold On. If outside, move away from trees, power lines, buildings, or anything that could fall, and drop down. If driving, pull over and stop in a safe area away from flyovers, bridges, light and power poles, etc.

Protect Your Family Physically

- Check that your home or building was built to code with earthquake resistant features
- Identify and anchor falling hazards
- Secure gas cylinder
- Have a fire extinguisher and know how to use it
- Get one family member trained in First Aid

Explain the elements of physical protection:

-Building safety is the most important. With the help of a qualified engineer, determine if your building is earthquake resistant, or whether it needs strengthening.

-Identify and anchor or relocate falling hazards. Pay particular attention to large and heavy items.

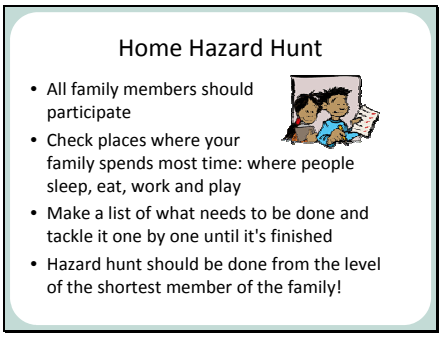
-Secure hazardous chemicals to prevent them from spilling or mixing.

-Have a fire extinguisher and make sure everyone knows where it is and how to use it.

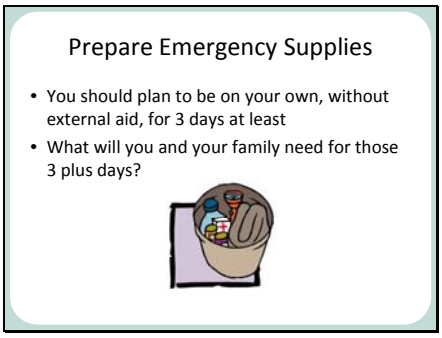
-Have one member of your family get trained in

first aid (remember, you will have to stay at the hospital so it should not be you).

Also, it's always a good idea to keep a pair of shoes and a torch (flashlight) by your bed, in case an earthquake happens during the night. The power is very likely to go out and you could injure yourself by stepping on broken objects or falling in the dark.



Ask trainees to conduct a home hazard hunt with their families. Very simple, low-cost anchoring solutions can prevent injuries and property damage.



Make sure that the time to plan to be on your own matches that for the jurisdiction where you are doing the training. The standard timeframe is 72 hours (3 days), but can be longer in rural or remote areas.

Write on a whiteboard or large pad of paper and have trainees tell you what they would need. Be sure they cover the following:
-Food
-Water
-Prescription medicines (especially those that are taken daily)
-Torch (flashlight) and battery
-Radio and batteries
-First aid kit
-Cash
-Toiletries
-Special items for elderly, disabled, small children and animals

Hand out DDMA (or other) preparedness checklists.

Sample Family Emergency Kit

- Non-perishable food to last 72 hours
- Water (10 liters/ day/person)
- First aid kit + prescription medicine+ sanitary items
- Torch +spare batteries
- Radio + batteries
- Emergency cash
- List of emergency telephones
- Copies of valuable documents (scan & email)
- Spare eye glasses etc..
- Whistle

Explain that each family's kit will be different. This list is only indicative and should be a starting point to help them think of the things they will need. Explain that they should think of individual family members' needs when preparing the kit. If you have pets you will need to plan for their food and water as well.

Here are the answers for the whiteboard exercise – make sure your trainees got all of the major items.

You may need to explain prescription medicine to your trainees because they are not medical staff. You can say something like: "There may be someone in your family who needs to take a particular medicine every day. This must also be part of your kit. Use the medicine in the kit and replace it with fresh medicine regularly to keep it from expiring."

Get Trained

- Learn basic first aid if you don't already
- Remember, you may be at home or elsewhere rather than at the hospital
- Coordinate with your hospital's disaster preparedness committee

Remind facilities personnel that they may not be at the hospital (where the medical staff know how to treat injuries) when the earthquake strikes, and that in that case they will still need this knowledge. Have the facilities/engineering department representative on the hospital disaster preparedness committee discuss the possibility of getting training beyond basic first aid with the committee. They may need facilities staff to be trained in specific aspects such as the hospital incident command system, logistical support for mass casualty management, basic search and rescue, or how to operate and maintain certain backup utility systems. They should also know what capacities the staff have, which can be called upon in an emergency if needed.

Make trainees aware of any local training programs (i.e., put on by the Disaster Management Authority or Fire Service) that can help them be better prepared.

Questions?

Answer any questions.

WRAP-UP

Yesterday We Learned

- Why hospitals are at risk from earthquakes
- About earthquake basics
- About earthquake damage and consequences
- How to identify and mitigate risks
  - General principles
  - Specific objects
  - How to conduct a hazard hunt
  - Things to consider when implementing measures

Review what we covered yesterday (be brief!!):

Why hospitals are at risk – they contain complex systems, vulnerable people, and expensive equipment.

Earthquake basics - earthquakes have occurred and will continue to occur; how big the earthquake is and how strong the shaking might be; be prepared for aftershocks; factors like size and shape determine how an earthquake will affect a building or an object;

Earthquake damage and consequences: damage to the building, systems and contents can cause loss of life, loss of function, loss of property/money, and loss of community confidence;

How to identify and mitigate risk: Identify risks with a hazard hunt; look for things that can fall, slide or topple; consider objects as part of a system; look at manual for guidance on specific objects; talk to people that use the object to help develop solutions; keep in mind safety, functionality, and load path when developing and implementing seismic protection measures.

Today We Learned

- How to install restraints
- About hospital emergency preparedness basics
- How to prepare ourselves and our families for an earthquake or other disaster

Review what we covered today (be brief!!):
How to install restraints: we practiced installing restraints (summarize in two sentences what we anchored and how it will help.)

Hospital emergency preparedness basics: a hospital safety committee; the need for a plan and to test it with drills; incident command system;

Personal and family preparedness: family emergency plan and kit; home hazard hunt.

Next Steps

- Summary of next steps for project; will vary with situation

Here, you will explain what will happen next during the project. In most cases, you will work with the hospital to begin taking the steps toward earthquake safety that we learned about today: finding an engineer to assess the building, doing a hazard hunt, estimating costs and prioritizing, forming a hospital safety/emergency preparedness committee, beginning to implement mitigation measures, etc. Some hospitals may have already decided to pursue a more in-depth earthquake risk reduction program that includes structural retrofit (strengthening). Be sure to provide accurate information about the plans your hospital's administration has, and that you have their permission to discuss the planned actions with the staff. You may wish to have a hospital administrator explain the hospital's plans during the introduction to the training course, rather than here at the end.

What YOU can do

- Think about your role
- Create a family emergency plan
- Drill, Drill, Drill

Encourage trainees to think about what they can do to improve earthquake safety and preparedness in their work space and at home.

Questions?

Answer any final questions.

Help us improve

- Please fill out the questionnaire
- Let us know how we can improve:
  - the training
  - the manual
- Email any additional feedback to info@geohaz.org

Ask that trainees fill out the evaluation questionnaire to help improve the training course, and invite them to provide additional feedback to info@geohaz.org.

Thank You

GeoHazards International — www.geohaz.org

GeoHazards Society India — www.geohaz.in

Thank everyone for coming.

This training course was made possible by generous support from:

Swiss Re

Thank Swiss Re for their support and conclude the training course.