LESSON

03

CONSTRUCTION MATERIALS, STRUCTURES AND DAMAGE TYPES

Lecture-03 periods

LESSON OBJECTIVES

Upon completion of this lesson, you will be able to:

1. Define construction materials and classify them by their composition types and uses.
2. List and describe three forces that can affect construction materials
3. List three properties of each material: concrete, steel and wood.
4. Describe two methods of construction.
5. List four types of structures.
6. List at least three characteristics of a building in each of the following four categories:
   - General
   - Architecture
   - Structural elements
   - Non-structural elements
7. List and describe two types of damage in a structure and their potential resulting failures.
8. Name and describe the four basic collapse patterns.

Instructor Activity

▶ *PPT 3-1 to 3-4*

Introduce yourself and your assistant.

Present the lesson topic, explain the relevance of the lesson to the course, state the duration, and describe scheduled activities and method of evaluation.

This lesson is important because identifying the construction materials and structure type allows the rescuer to anticipate the type of collapse (pancake, V, lean-to, or cantilever). Also, this lesson will assist in identifying material-specific tools. Identifying damage types assists the rescuer in determining the stability and hazards of the structure.

Present lesson objectives. Ask a participant to read them aloud from the workbook. Ensure that the objectives are clear to all participants.

Ask the participants to contribute from their experiences related to the lesson topic. Stress the importance of knowing construction materials, how they respond to various forces and what types of damage can be expected.

1

Construction Materials

Natural materials processed by man and used in the construction of buildings, which consist of structural and non-structural elements.

1.1 Classification by Composition

1.1.1 **Stone:** Marble, granite, slate.

1.1.2 **Organic materials:** Wood, plywood, paper, particleboard

1.1.3 **Metal:** iron, steel, aluminium.

1.1.4 **Conglomerates:** concrete, plaster, adobe, clay

1.1.5 **Ceramics:** tiles

1.1.6 **Glass:** windows, glass block

1.1.7 **Plastics:** polyurethane, polyethylene, thermosetting adhesive

Instructor Activity

▶ *FC 3-1*
Read and discuss definition

▶ *PPT 3-5*
Discuss the various classifications by composition.

Promote discussion among participants to allow them to generate results.

1 Construction Materials (Cont.)

1.2 Classification by Use in the Structure

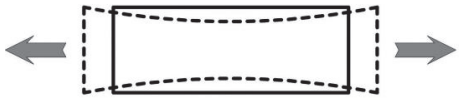
- **Structural/load-bearing** elements
- **Decorative** elements and façades or veneers
- **Non-structural** walls and partitions
- **Covering** elements (roofing)

2 Forces Acting on Construction Materials

2.1 Tension

Forces that act to **elongate** or stretch a material.

Examples: _____



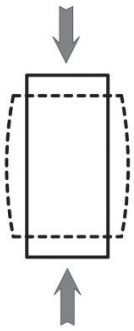
Tension

2.2 Compression

Forces that act to **crush** or compress a material.

Examples: _____

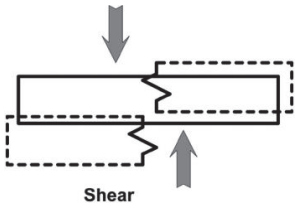
_____



2.3 Shear

Forces acting in opposite, parallel directions and on different planes so that they cut or break a material.

Examples: _____



Shear

The forces of tension, compression and shear, and combinations of these, are those that affect materials and structures, with the potential to cause damage.

Instructor Activity

▶ *PPT 3-6*

Discuss the various classifications by use.

Discuss construction materials in the typical structure shown.

▶ *PPT 3-7*

Illustrate the concept of tension using a rubber band or similar item (stretch it and allow it to return to its original position).

Ask for examples from the class.

▶ *PPT 3-8*

Illustrate the concept of compression by pushing down on the desk with your hands.

Ask for examples from the class.

▶ *PPT 3-9*

Illustrate the concept of shear by breaking a thin piece of wood, a pencil or toothpick.

Ask for examples from the class.

Apply the above three concepts to the strength and weakness of construction materials that rescuers will have to deal with when gaining access to victims.

3

Properties of Construction Materials

3.1 Concrete

A construction material consisting of a mix of cement, rock, sand and/or other inert materials, water and a small amount of air.

Characteristics

- Resistant to **fire** and **compression**
- Weak under **tension** and **shear**
- Continues to harden with time
- Very heavy: one cubic meter (m3) weighs almost **3,000 kg**

- Concrete cures by hydration, meaning that it needs water to harden. Once dry, concrete always develops cracks, which do not necessarily represent a **failure**. Concrete is strong in compression but weak in tension, which is why steel rebar is a necessary component of concrete beams, columns and floors.

- To appreciate the significance of concrete in construction and rescue operations, you must know how much it weighs: approximately 2,400–3,000 kg/m3. On a smaller scale, a piece of concrete measuring 15 cm x 30 cm x 30 cm weighs approximately **32-40 kg.**

Instructor Activity

▶ *PPT 3-10*

Ask participants to close their workbooks.

▶ Drawing from the experience of the participants, ask them to describe the properties of concrete, steel and wood.

Once the discussion is complete, ask them to open their workbooks and complete the blank spaces.

Display a piece of concrete to illustrate and discuss its properties. Make emphasis on the enormous weight of concrete.

3 Properties of Construction Materials (Cont.)

3.2 Steel

Characteristics

- Can be bent without breaking (malleable)
- Easily conducts **heat, sound** and **electricity**.
- Resistant to **fire** and **compression**. It starts to lose strength above 700 degree Fahrenheit.

Instructor Activity

▶ Discuss properties in more detail.

Ask participants to complete the blank spaces.

3.3 Wood

Characteristics

- Easy to cut
- Light
- Not fire-resistant
- Good **insulator** (will not transmit electricity)
- Provides warning — **creaks** before breaking

Instructor Activity

▶ Discuss properties in more detail.

Ask participants to complete the blank spaces.

4 Methods of Construction

The type of construction will give some indication of the way a building will collapse. Experience has shown that there are patterns in the way structures collapse. Therefore, this knowledge is useful in determining the **probable location** of voids and spaces where victims may be trapped, and in selecting the methods to employ in extricating them. Buildings can be divided into two main categories: **framed** and **unframed**.

Instructor Activity

▶ Read workbook text and discuss how it relates to the probable location of voids.

Ask participants for examples of both types of construction.

4

Methods of Construction (Cont.)

4.1 Unframed Structures

Unframed structures are those in which the weight of the floors and roof are supported by the **bearing walls**.

Examples of this type of structures are brick and joist (support pillar for ceiling or floor) buildings and wood apartment buildings. As a general rule, these do not exceed seven stories in height. Rescue operations in unframed structure collapses are usually difficult, lengthy and dangerous. To the uninitiated, an extensive collapse gives the impression that the occupants have little chance of survival. Fortunately, rescues can be made because of the formation of voids created by structural members, strong objects such as machinery and heavy furniture, or a combination of these.

NON FRAMED STRUCTURE

Instructor Activity

▶ *PPT 3-11*

Discuss description.

Make sure participants are filling in blank spaces in their workbooks.

Allow time for questions and comments.

4.2 Framed Structures

Framed structures are erected by constructing a structural steel or reinforced concrete skeleton made of **horizontal beams** and **vertical columns**.

The floors and/or roof are **not** dependent on the walls for support. Collapse can be more localized, but older concrete structures can suffer a pancake failure, and some steel structures with poor joints have overturned. The rescue teams face the same problem and seek out voids created by the collapse, as in unframed structures. Many buildings have elements of both unframed and framed structures. Most buildings have non-bearing walls. A common structure is one with exterior bearing walls with an interior framed system. A few examples would be tilt-up concrete walls with a wood roof and floors, and older brick or concrete wall warehouses with wood or concrete floors.

_____

_____

_____

Frame structure

▶ *PPT 3-12*

Discuss description.

Make sure participants are filling in blank spaces in their workbooks.

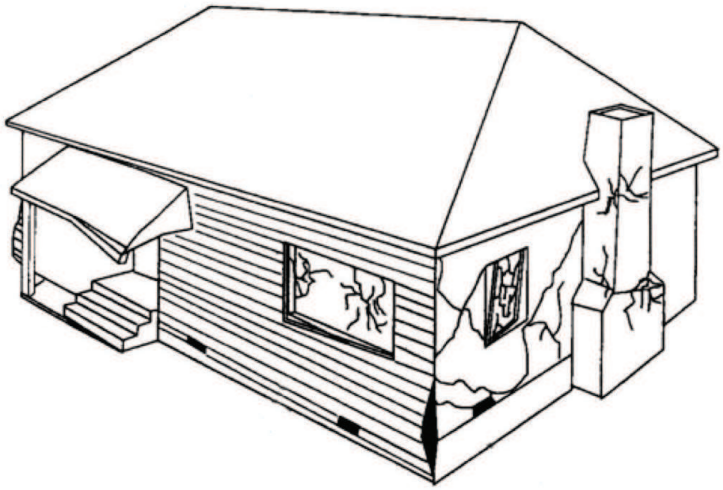
Allow time for questions and comments.

5 Structural Types

Based on experience with earthquakes and collapses, building types can be also divided into four separate groups, with each exhibiting a distinctive collapse pattern. These groups are:

5.1 Light Frame

- Residential homes and apartments of up to **four** stories, and constructed mainly of **wood**. The principal weakness is the **lateral** strength of the walls and the connections.



- Rescuers operating in a light-frame building collapse should check for stability problems by looking for badly cracked or leaning walls and offset of the structure from the foundation, or a leaning first story in multi-floor dwellings.

_____

_____

_____

Instructor Activity

▶ *PPT 3-13*

Make sure participants fill in the blank spaces in their workbooks as you go along.

▶ *PPT 3-14*

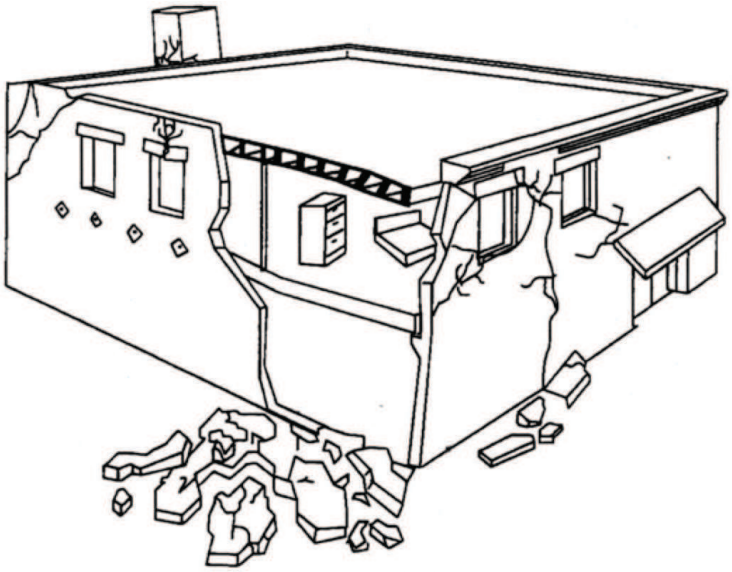
Discuss important characteristics of light frame construction and problems commonly encountered.

Make sure participants fill in the blank spaces in their workbooks as you go along.

5 Structural Types (Cont.)

5.2 Heavy Wall (URM) Unreinforced Masonry

These buildings are one to **six** stories in height, and may be residential, commercial, industrial, or institutional. They have **heavy** masonry walls and **wooden** floors. When operating in an unreinforced masonry building make sure to check for loose and broken parapet walls and ornamental masonry, broken connections between walls and floors, cracked wall corners, and unsupported and partially collapsed floors.



Instructor Activity

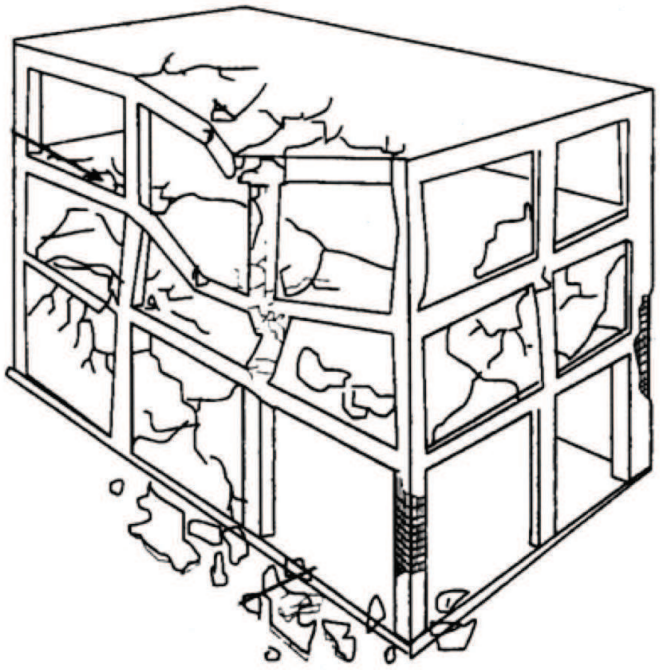
▶ *PPT 3-15*

Discuss important characteristics of heavy wall (URM) construction and problems commonly encountered.

5 Structural Types (Cont.)

5.3 Heavy Floor

Structures in this category can be residential, commercial, or industrial (concrete highway bridges). They have concrete frames and may be up to **12** stories tall.



Rescuers should evaluate the stability of the structure by checking:

- The confinement of the concrete within the reinforcement of the columns
- Cracking of columns at each floor line
- Diagonal sheer cracking in major beams adjacent to supporting columns
- Cracks in sheer walls

Instructor Activity

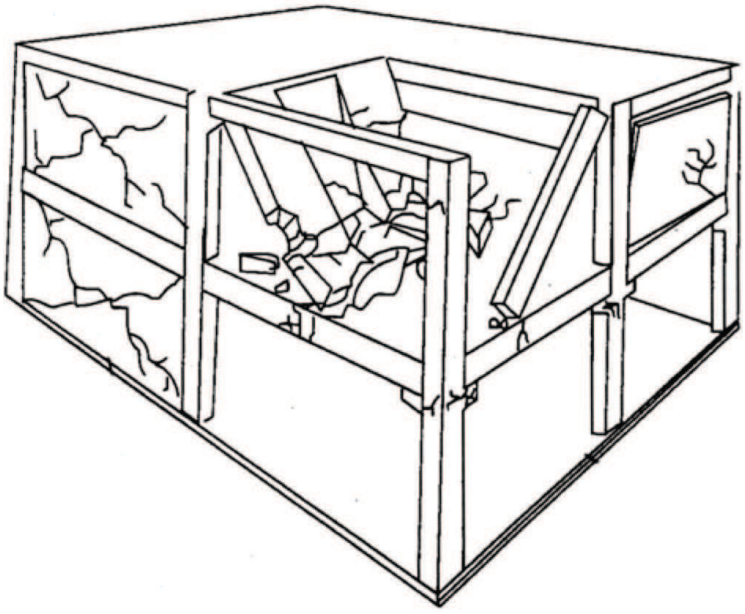
▶ *PPT 3-16*

Discuss important characteristics of heavy floor construction and problems commonly encountered.

5 Structural Types (Cont.)

5.4 Pre-Cast Concrete

Buildings with fairly **heavy** floors and some **heavy** walls. Precast structures may be commercial or residential and also include pre-cast parking facilities. These structures generally are one to **twelve** stories in height. Principal weakness is in interconnection of parts: slabs to walls/beams; beams to columns; walls to slabs, etc. Rescuers operating at a pre-cast building collapse should check for badly cracked walls, **beam-to-column** connections for broken welds and cracked corbels, column cracking at the top and the bottom of joints, and wall panel connections and shear wall connections at floor areas.



Instructor Activity

▶ *PPT 3-17*

Discuss important characteristics of pre-cast concrete construction and problems commonly encountered.

Highlight the importance of obtaining this information when arriving at a scene.

Point out that in the lesson on Search and Location Techniques the participants will be using a data collection form with which they will be gathering this type of structural information.

6

Characteristics of a Structure

After seismic activity or other force causes structural and non-structural damage, it is important to relate the characteristics of the structure to the damage it has suffered.

6.1 General

General characteristics of a structure include the following elements:

- **Occupancy** type
- Modifications to the original structure/plans (if applicable)
- Location of **utilities**
- Contents
- Number of occupants

6.2 Architecture

Architectural characteristics of a structure include the following elements:

- Shape of building and foundation
- Height and number of **floors**
- Number of **basement levels**
- Major cantilevers
- Location of **chases** (stairwells, elevator shafts and service chutes)
- Primary materials used

Instructor Activity

▶ *PPT 3-18*

▶ Review general characteristics.

▶ Review architectural characteristics.

Make sure participants are filling in the blank spaces.

6

Characteristics of a Structure (Cont.)

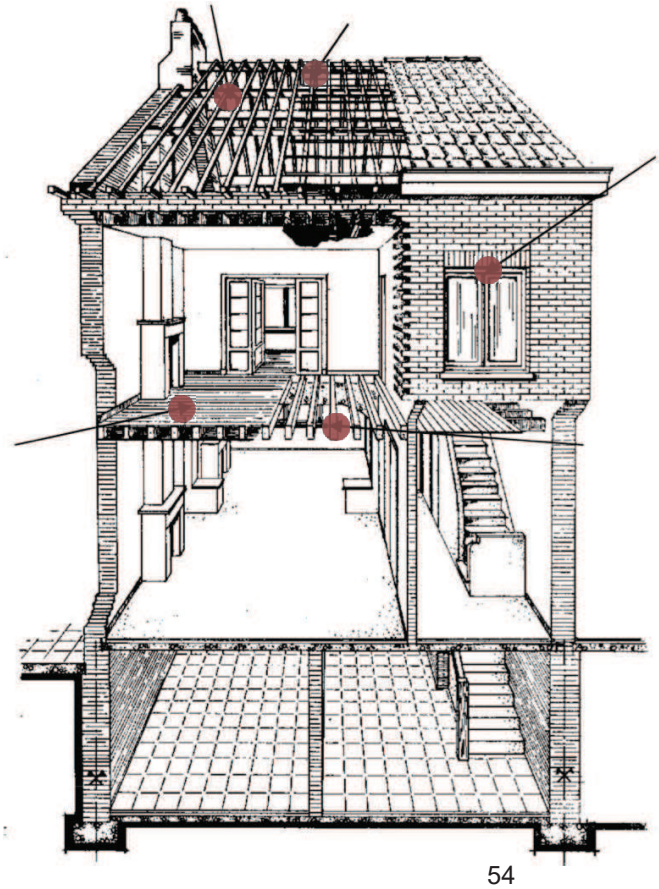
6.3 Structural Elements

The structural or load-bearing elements of a structure include the following:

- Columns
- Beams, girders, trusses, joists, rafters, purlins, studs
- Floor slabs, roof
- Load-bearing walls
- Foundations

6.4 Non-structural Elements

- Non-load-bearing walls, partitions, in-fill
- Windows, doors and other openings (fenestrations)
- Façades, veneers, parapets, and other



Instructor Activity

▶ *PPT 3-19*
Review structural elements.

▶ *PPT 3-20*
End this section by reviewing and stressing the difference between structural and non-structural elements.

This will be relevant to the upcoming discussion on damages types.

7

Damage Types and Potential Hazards

Damage to buildings can be categorized as structural and non-structural. **Structural damage** affects the **structural** elements of a building, and likewise, non-structural damage affects the **non-structural** elements of a building. However, both types of damage are capable of causing injury, death, contamination and other hazards.

7.1 Structural Damage

- Total structural collapse
- Leaning floors, roofs and walls
- **Collapsed** and **roofs**
- Collapsed columns in one or more floors
- Substantial, permanent **lateral** shift in the structure
- **Cracks in columns, floor slabs and/or bearing walls**
- Cracked foundation
- Cracked elevator shaft

7.2 Non-Structural Damage

- Generalized cracking
- Cracked or fallen **exterior façades** and **veneers**
- Fallen staircases
- Shift in the elevator shaft
- **Damaged utilities**
- Building signs and balconies

Instructor Activity

▶ *PPT 3-21*

Discuss differences between structural and non-structural damage.

Ask participants to relate what they have learned about structural and non-structural elements to the two damage types.

▶ *PPT 3-22*

Point out structural and non-structural damage in image.

7 Damage Types and Potential Hazards (Cont.)

7.3 Types of Hazards

In damaged, partially and fully collapsed structures, we can identify three types of hazards:

- **Falling:** Part of the structure or its contents are in danger of falling.
- **Collapse:** The volume of enclosed space made by the structure will be reduced, as stability is lost.
- **Other:** Electricity, water, fuels, toxic gases (carbon monoxide), hazardous materials (asbestos), biohazards (industrial, medical), etc.

Instructor Activity

Discuss various types of hazards.

8 Basic Collapse Patterns

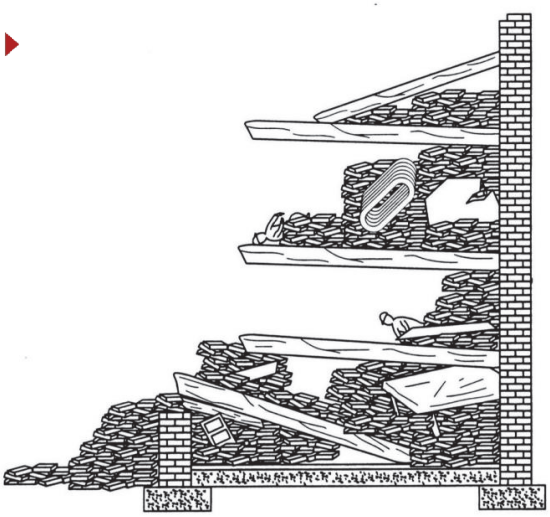
▶ *PPT 3-23*

Ask participants to indicate what types of damage might be expected in each type of collapse.

8.1 Cantilever

Results from a wall collapse which allows a floor or roof assembly to drop **partially**, but to remain **suspended** above the floor or base below on the side where the wall failed. The opposite end of the floor assembly remains **attached** to the wall and at its original connection point. This type of collapse is extremely unstable and dangerous.

Cantilever ▶



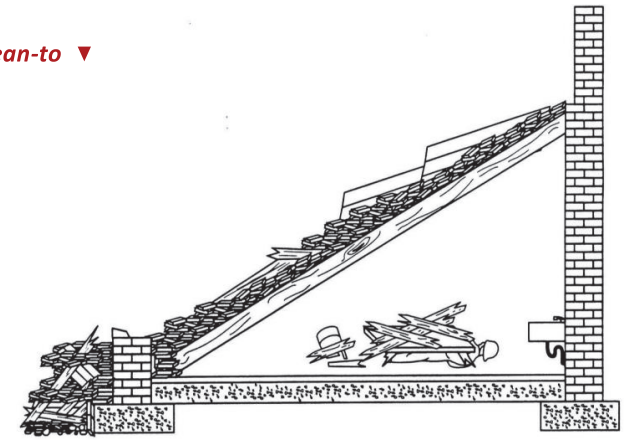
8

Basic Collapse Patterns (Cont.)

8.2 Lean-to

Found where a wall failure causes a floor or roof section to fall completely on **one side**, while the other end remains **supported** . This collapse usually results in a **triangular** void. Remember that the remaining supported end of the fallen section may be precariously supported.

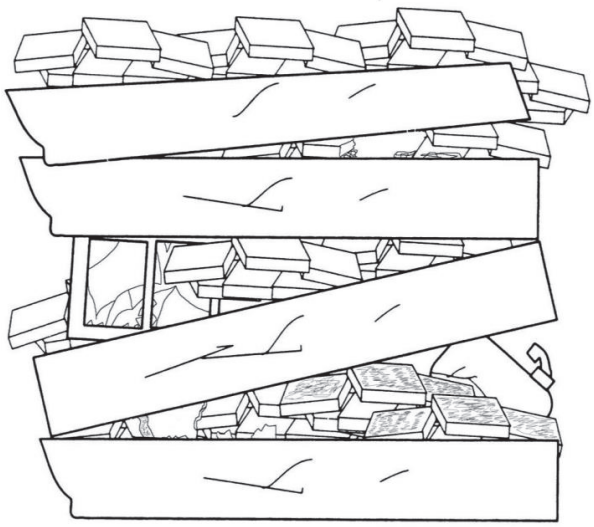
Lean-to ▼



8.3 Pancake

Refer to multi-floor collapses where several floor slabs completely fail and **stack up** on top of each other. The resulting voids are **limited** in space and are difficult to access, especially in concrete structures.

Pancake ▼



Instructor Activity

▶ *PPT 3-24*
Ask what types of damage might be expected.

▶ *PPT 3-25*
Ask what types of damage might be expected.

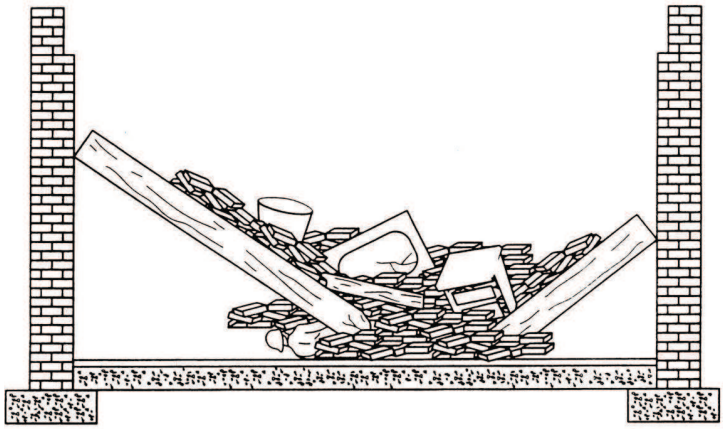
8

Basic Collapse Patterns (Cont.)

8.4 V-Shape

This collapse will be created when a floor assembly collapses in the **middle** due to failure of centre supports or overload of the floor. The result is two identifiable voids which are created on **each side** of the broken floor assembly.

V-Shape ▼

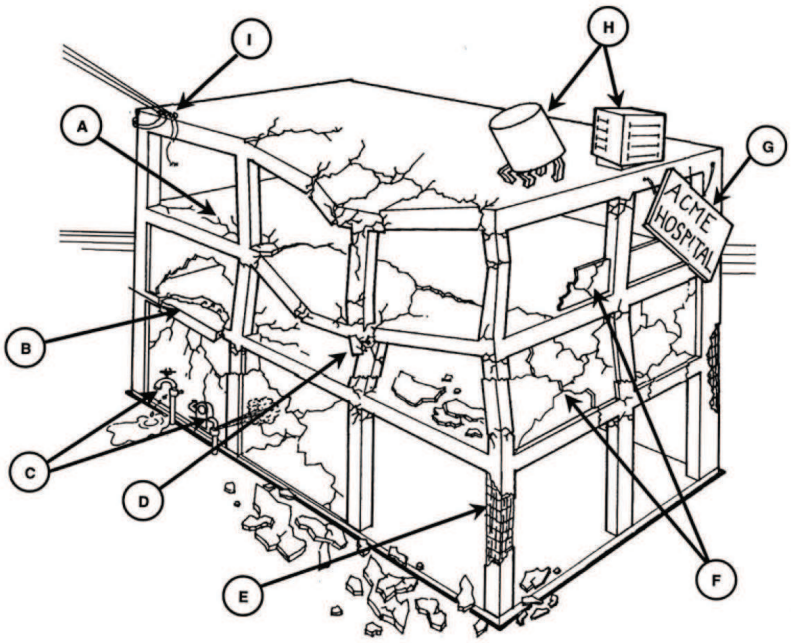


Instructor Activity

▶ *PPT 3-26*

Ask what types of damage might be expected.

Identify the Failure Types



Identify the failure types above and whether they are structural or nonstructural:

A. **Cracked floor at column (Structural)**

B. **Concrete floor or wall piece hanging by rebar (Structural)**

C. **Broken gas and water lines (Non-Structural)**

D. **Badly cracked concrete walls (Structural)**

E. **Concrete missing from inside rebar cage (empty basket) (Structural)**

F. **Badly cracked in-fill walls of un-reinforced masonry (Non-Structural)**

G. **Loose signs or wall panels and ornaments may fall (Non-Structural)**

H. **Loose H.V.A.C. equipment and/or water tank (Non-Structural)**

I. **Broken electrical lines (Non-Structural)**

Instructor Activity

PPT 3-27

Ask participants to study the diagram and identify the various failures and damage types. Allow them 5-10 minutes to complete the exercise.

Have a class discussion on the exercise.

Instructor Activity

REVIEW

Lesson objectives and other main points. Ensure that lesson objectives have been met.

EVALUATION

Remind participants to study the RM in preparation for Post-Test.

Ask participants to complete Lesson Evaluation Form.

CLOSING

Thank class for their participation and announce the next lesson.

— INSTRUCTOR'S COPY

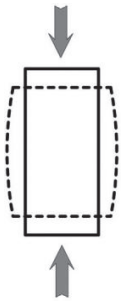
POST-TEST | LESSON 3

Construction Materials, Structures and Damage Types

1. Match the following construction materials (Column A) with their classification by composition (Column B). Write the corresponding numbers in the spaces.

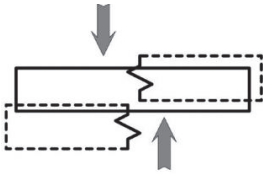
Column A		Column B
1. Aluminium	2	Ceramics
2. Tiles	3	Organic
3. Wood	5	Conglomerates
4. Marble	1	Metals
5. Cement	4	Stone

2. Identify the each type of force in the three diagrams below and describe its effect on construction materials.



Force: **Compression**

Effect: **Acts to crush or compress a material**



Force: **Sheer**

Effect: **Forces acting in opposite, parallel directions and on different planes such that they cut or break a material**

Force: **Tension**

Effect: **Forces that act to elongate or stretch a material**

3. List three characteristics for each of the following three materials:

Concrete	1. Resistant to fire and compression
	2. Weak under tension and shear
	3. Continues to harden with time
Steel	1. Malleable (bendable, flexible)
	2. Resistant to fire and compression
	3. Conducts heat, sound and electricity
Wood	1. Light
	2. Not fire-resistant
	3. Provides warning before breaking

4. **Identify the method of construction of the damaged building pictured below:**

_____✓___ **Framed**

_____ **Unframed**

5. List the four basic types of structures.

- Light frame
- Heavy wall (unreinforced masonry)
- Heavy floor
- Pre-cast concrete

6. List two structural elements and two non-structural elements of a building:

Structural: **Beam; column**

Non-Structural: **Wall; window**

7. Draw arrows and label the types of damage you note in the following two paragraphs. Classify them as structural (S) and non-structural (NS).

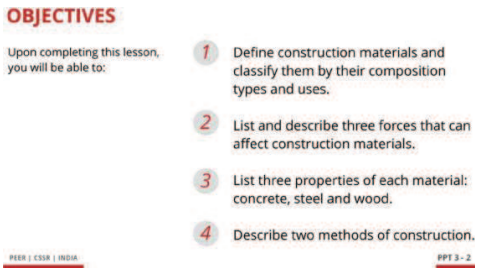
8. Name and briefly describe the four basic collapse patterns.

- **CANTILEVER –** Results from a wall collapse which allows a floor or roof assembly to drop partially, but to remain suspended above the floor or base below on the side where the wall failed
- **LEAN-TO –** Where a wall failure causes a floor or roof section to fail completely on one side, while the other end remains supported
- **PANCAKE –** Multi-floor collapses where several floor slabs completely fail and stack up on top of each other
- **V-SHAPE –** Created when a floor assembly collapses in the middle due to failure of centre supports or overload of the floor

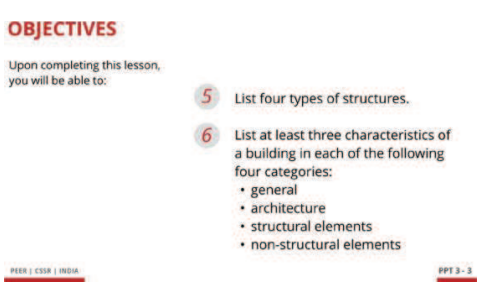
LESSON 3
— PPT's

3-1

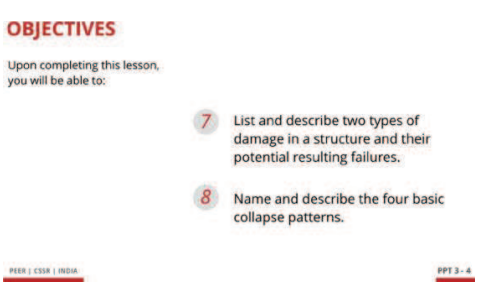
3-2



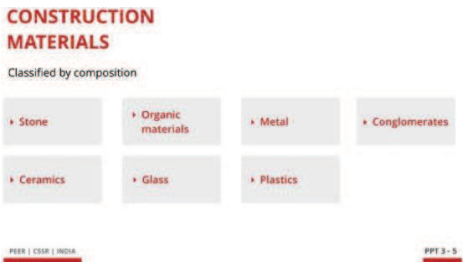
3-3



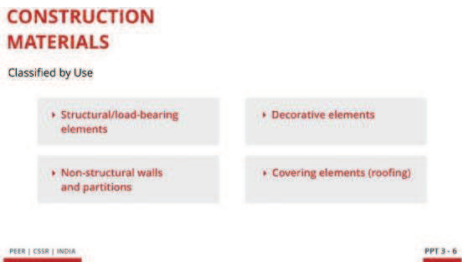
3-4



3-5

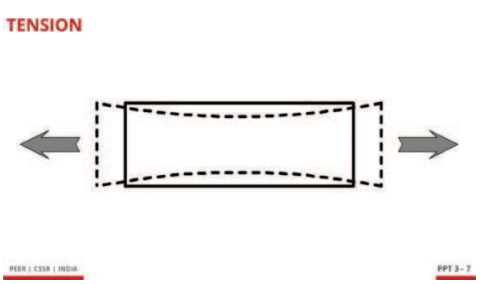


3-6

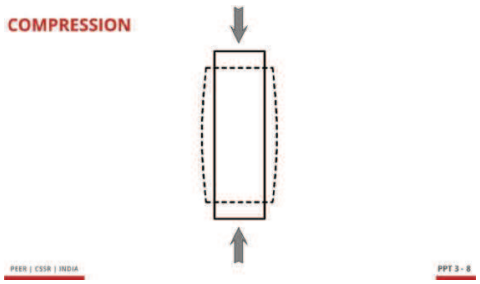


LESSON 3
— PPT's

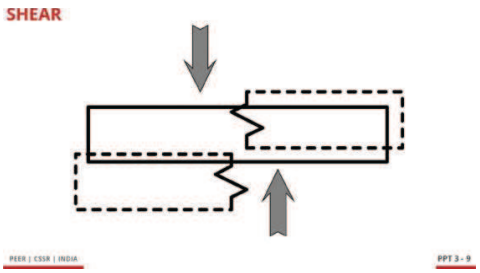
3-7



3-8

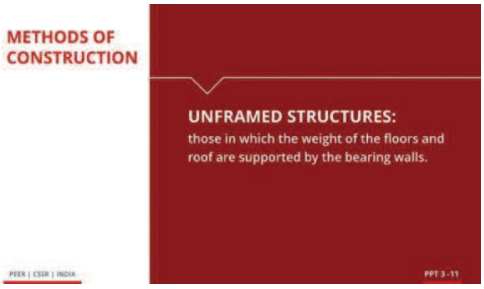


3-9

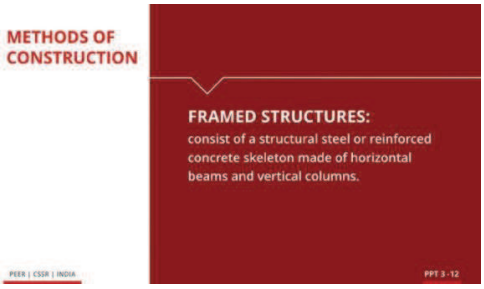


3-10

3-11



3-12



LESSON 3
— PPT's

3-13

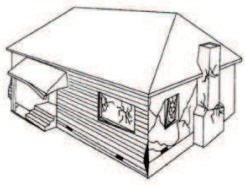
STRUCTURAL TYPES

- Light frame
- Heavy wall
- Heavy floor
- Pre-cast concrete

PEER | CSSR | INDIA PPT 3-13

3-14

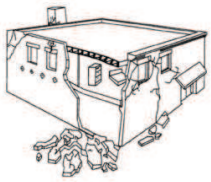
LIGHT FRAME STRUCTURE



PEER | CSSR | INDIA PPT 3-14

3-15

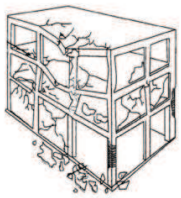
HEAVY WALL STRUCTURE



PEER | CSSR | INDIA PPT 3-15

3-16

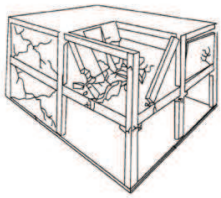
HEAVY FLOOR STRUCTURE



PEER | CSSR | INDIA PPT 3-16

3-17

PRE-CAST CONCRETE STRUCTURE



PEER | CSSR | INDIA PPT 3-17

3-18

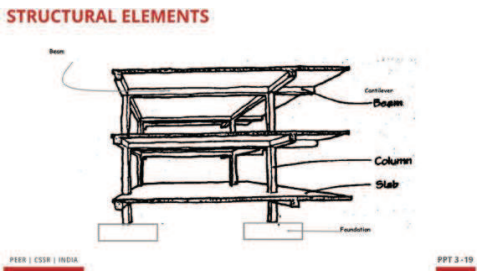
CHARACTERISTICS OF A STRUCTURE

- General
- Architecture
- Structural elements
- Non-structural elements

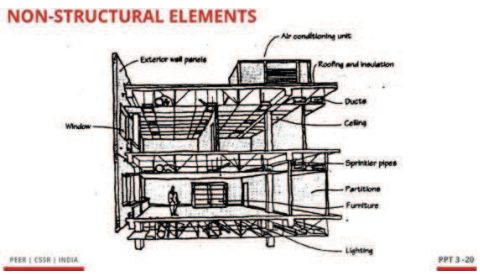
PEER | CSSR | INDIA PPT 3-18

LESSON 3
— PPT's

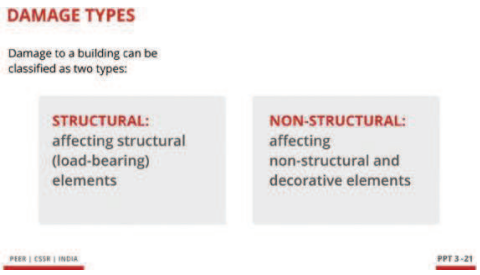
3-19



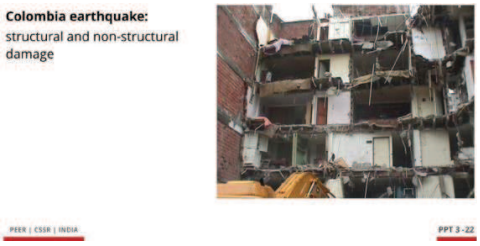
3-20



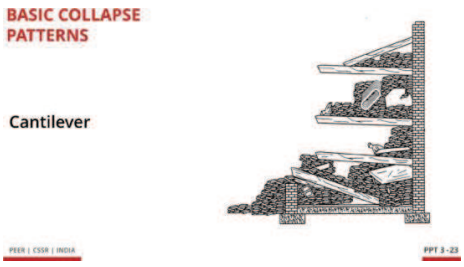
3-21



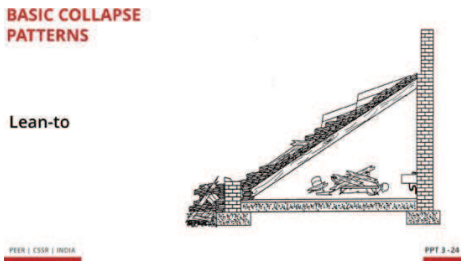
3-22



3-23



3-24

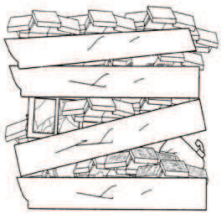


LESSON 3
— PPT's

3-25

BASIC COLLAPSE PATTERNS

Pancake



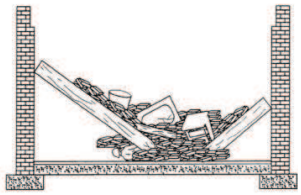
PEER | CSSR | INDIA

PPT 3 -25

3-26

BASIC COLLAPSE PATTERNS

V-Shape

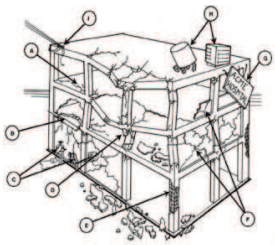


PEER | CSSR | INDIA

PPT 3 -26

3-27

IDENTIFY STRUCTURAL DAMAGE

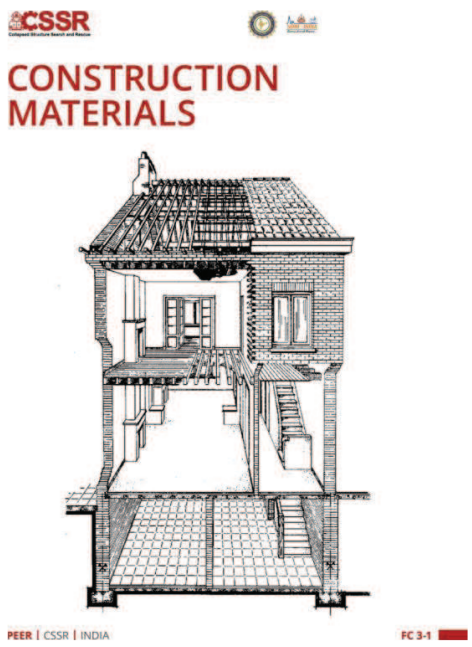


PEER | CSSR | INDIA

PPT 3 -27

LESSON 3
— FLIP CHARTS

FC3-1



LESSON 4 — OVERVIEW

Structural Triage and the INSARAG Marking System

Duration	**Lecture:** 03 Periods Practical: 02 Periods, Total-05 Periods
Main Points	• Define Sectorization • Describe Assessment, Search and Rescue Levels. • Describe Worksite Triage. • Define the INSARAG marking system
Suggested Preparation	• Thoroughly study reference material (RM-04) “ • Based on the Lesson Objectives, highlight the reference material on related subjects. • Fill in the blanks in the participant is manual to guide you in helping participants with needed information. • Read and complete the written test so that you will be able to review and discuss it with the participants the following day.
Evaluation System	Written test on the end of week.
Materials and Resources Needed	• PowerPoint presentation (32) • Lesson flipchart (4) • Computer and multi-media projector • Projector screen • Flipchart paper, markers and board • Post-Test
Importance of This Lesson	• To familiarize the participants with the different aspects of structural triage and how to read the different symbols related to building and victim markings.