

A collection of safety equipment is arranged on a rustic wooden surface. At the top left is a black respirator mask with two circular filters. Below it is a pair of clear safety goggles with a black strap. To the right of the goggles is a pair of grey work gloves with yellow accents. Further right is a pair of orange safety glasses with black frames. A yellow high-visibility vest is partially visible in the background. The entire scene is set against a background of horizontal wooden planks.

Structural Design Considerations: Construction Materials

Prepared by:
Lance L. Luke, CCC, CCI, CCPM, CSI
Construction Management Inspection LLC

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STRUCTURAL DESIGN CONSIDERATIONS: CONSTRUCTION MATERIALS

TYPES OF STRUCTURAL MATERIALS

The most common materials specified in structural engineering design, and used in the construction of buildings are steel, concrete and wood/timber.

STRUCTURAL STEEL

Steel is an alloy that is made of iron and carbon.

REINFORCED CONCRETE & MASONRY

Reinforced concrete is made of concrete and reinforcing steel.
Masonry is made of concrete blocks or bricks.

HEAVY TIMBER & WOOD

Heavy timber is from harvested trees but can also be defined as large sections of wood glued and laminated together.

VARIOUS DESIGNS FOR EACH MATERIAL TYPE

DEFINITIONS ACCORDING TO NUMBER OF STORIES

Low Rise- a few stories high, 1 to 3 stories

Mid Rise- 4 to 11 stories

High Rise- 12 stories and above.

NOTE: there is no universally accepted definition.

For example- Portland Oregon West Quadrant of the Central City gives this definition.

Low Rise- 1-6 stories

Mid Rise- 7-12 stories

High Rise- 13 stories and above.

A skyscraper is defined as 40 stories or greater. 400 feet high.

High rise building definitions.

The NFPA (National Fire Protection Association) definition of a high rise is a building that is 75 feet or 7 stories.

The International Conference of Fire Safety in High Rise Buildings definition: any structure where the height can have a serious impact on evacuation.

The IBC (International Building Code) definition is a building with an occupied floor located more than 75 feet above the lowest level of fire department access.

An example would be a mixed-use building with the bottom floor retail, floors 2-4 residential and the last 3 floors office. 7 floors total.

LOW RISES: APARTMENT BUILDINGS, WAREHOUSES, SCHOOLS,
SHOPPING CENTERS

MID RISES: OFFICE BUILDING, TOWNHOUSES, RETAIL

HIGH RISES: HOTELS, OFFICE BUILDINGS, APARTMENTS,
CONDO BUILDINGS

There is no hard and fast design guideline for each type of building, and it is up to the design consultants to determine the building materials specified. Generally, the geotechnical and structural engineer have a greater role in this along with the project architect.

CONSIDERATIONS FOR EACH STRUCTURE TYPE

COMPARISONS BETWEEN THE VARIOUS STRUCTURAL
COMPONENTS

COST CONSIDERATIONS

The difference in cost considerations of course largely depend on the design of the building.

All things being equal, there are limitations to each type of building material. For example, today an 85-story building cannot be built of wood. It can be built of steel or reinforced concrete, with certain exceptions. More than likely the tall buildings today are built using a combination of steel and reinforced concrete.

Building a low-rise building is cheaper using wood. A midrise building could be built with either wood, steel or reinforced concrete. A high-rise building is built with steel and reinforced concrete.

FIRE AND BUILDING CODES

Fire and building codes come into play depending upon the use of the building and the size of the building. An industrial warehouse has different requirements than a church. The larger and higher the building, the more requirements and considerations such as fire sprinklers, fire alarm systems, standpipe, fire pump, stairways, ingress and egress, elevators, HVAC systems, mechanical and electrical systems etc.

COMMON PROBLEMS

Discussion in the next section titled "Advantages and Disadvantages"

ADVANTAGES AND DISADVANTAGES

STEEL

Structural steel is used for various construction projects such as buildings, bridges, warehouses etc. Steel can be shaped and cut to any form and is lighter than concrete. Steel can be fabricated off site and delivered to the construction site saving time and increases the production of the construction process. The material is less expensive than the other building materials. It has strength, scrap value and is easy to transport. Steel can be

100% recycled. Concrete may be, but in general it is considered a hazardous waste.

Downside to steel. Steel is not resistant to fire at high temperatures so there is an added cost in the form of fireproofing. When steel gets too hot, the members buckle and twist in the high heat. The longer the span of the steel member, the higher chance of buckling. Also steel is an excellent conductor of heat and there have been times during a fire where the steel heated up and caused other areas of the building to burn. Steel also has a high expansion rate with changing temperatures, and this could lead to problems with the general structure. Other disadvantages are corrosion or rust, not only on the steel members but on the detailed components such as the bolts, anchors and welded seams. Generally specifications call for surface treatment of the steel which adds to the cost of construction. Steel may also be subject to fracture and fatigue when exposed to excessive tension, which may reduce its overall strength.

Steel uses a lot of energy to produce and thus more expensive.

REINFORCED CONCRETE

Reinforced concrete is a mixture of cement, water and aggregates. Concrete is high in compressive strength. The addition of reinforcing steel added to the concrete adds to the tensile strength.

Compression strength is defined as the capacity of a material or structure to withstand the loads tending to reduce size.

Tensile strength is defined as the capacity to withstand loads tending to elongate.

Compressive strength is a key value for the design of structures.

Advantages of reinforced concrete include high compressive and tensile strength as compared to other building materials. Other advantages are, protection from a fire, good fire resistance. Many cities and locations have adequate supply of the materials to produce concrete. Thus, the material is locally available, and for the most part readily available thereby reducing added costs of high transportation and delivery. The concrete is more durable than other building systems. Concrete can be virtually used to construct any shape or form due to its liquid state. Concrete is easier to use compared to steel and requires less skilled labor. The material withstands deflection. It is the most economical material for structures like dams, piers, bridges etc.

The material is not subject to extensive insect damage as compared to wood which is food for termites, powder post beetles and large bumble or carpenter bees.

Reinforced concrete is the most widely used construction material. Concrete alone has little strength for a building. That is why the need for reinforcement by way of reinforcing steel or rebar.

Disadvantages of reinforced concrete range from shrinkage cracks and water damage to spalling and maintenance.

Other issues are failure due to high chlorides, salt, carbonation, mechanical failure and corrosion. Believe it or not, humidity, wind, rain and the sun are natural elements that cause millions of dollars a year in concrete repair.

The cost of forms is added to the overall construction estimate and the more intricate and complex the design, the higher the cost. The curing time for concrete is generally 30 days which adds to the production time and project schedule. The concrete construction is thus slower than the speed of steel erection. To speed up the process, concrete admixtures or fast curing compounds can be used. Also in lieu of cast in place concrete, the engineering design may call for the use of precast concrete.

WOOD/TIMBER

Wood is natural and organic, and it is possible to build an entire house or structure out of wood. This has been done for centuries not only in the US but in other countries such as in Asia and Europe. In Japan there are houses and temples built out of wood using no nails.

In this discussion we are not talking about houses, barns or log cabins, which are considered mainly light frame construction. Our discussion for this seminar focuses on heavy frame or heavy timber construction commonly called post and beam construction.

Wood is easy to get and does not require an extensive manufacturing process as compared to steel and concrete. Wood absorbs sound better than concrete and steel. And is basically is considered a local product. Wood also is good protection from electrical currents as compared to steel and concrete.

The downsides to wood is that it is not fire, insect or rot resistive. Thus, after milled, the wood must go to a process for special treatment. The material also is prone to cracking and shrinking. Also, it does stand up well to natural elements such as wind, rain, sun etc., and therefore needs constant protection such as paint and waterproofing.

In addition to wood and timber, there are manufactured wood products such as laminated lumber, Glulam beams and other products as well.

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