TUTORIAL MATERIAL FOR BLD 401 (CONSTRUCTION TECHNOLOGY)

1.0 STRUCTURAL SYSTEMS IN BUILDINGS:

1.1: THE FRAME STRUCTURE SYSTEM: This structure system is the most widely used and best known / controlled in terms of earthquake behavior. It consists of columns, beams and reinforced concrete slabs. These elements are designed to take all the loads that may occur throughout the life of a building. This type of structure system enables enough flexibility in terms of configuring the interior space of the future house, allowing openings between columns of about 6.7 meters, or even larger. The masonry used for this type of structure system plays the simple role of closing or subdividing spaces, because loads of the structure is taken by the concrete frames. When using this type of structure system, first the beams, the columns and the concrete slabs are made, and then the exterior and interior walls are achieved.

1.2: THE STRUCTURE WALLS SYSTEM: It exists in two forms:

1.2.1: THE STRUCTURE SYSTEM WITH REINFORCED CONCRETE WALLS: are made of reinforced concrete slabs, beams, and reinforced concrete structural walls. These elements take the vertical and lateral loads that may occur throughout the life of the building. In the case of using this type of structure system and as well as that of the frame system, both exterior closing walls and interior subdivision ones are made of masonry blocks after the structure is in place to serve as non-structural elements. This system is used in tall buildings where earthquake loads and gravitational forces are very strong and cannot be taken effectively by reinforced concrete frames, or it is used in constructions that require high rigidity.

1.2.2: THE STRUCTURE SYSTEM WITH LOAD-BEARING MASONRY: The structure system with load-bearing masonry is used quite frequently nowadays. It is made of masonry walls with reinforced concrete beam at the intersections of walls and additionally where needed, and perimeter belts on top of the masonry wall. The reinforced concrete belts are poured together with the reinforced concrete slab over the previously made wall (with columns). As about costs, the system is a bit cheaper than the one with reinforced concrete frames, but it has many drawbacks in terms of inside space arrangement. Thus, a home built on this type of structural system is like a box, and requires masonry wall continuity on the next floor, identical to those on the ground floor. A further disadvantage is the surface of the empty spaces in the masonry walls which suffer limitations. A mixed system of reinforced concrete frames and masonry can be used to provide greater freedom in point of interior space configuration. Nevertheless, from structure perspective, this system is viewed as flawed. A house project based on this solution (load-bearing masonry walls) will result in a space with smaller openings as compared to the solution of reinforced concrete frames, with limitations in the masonry walls gaps that will not allow future interior repartitioning without interventions on the existing structural system.

1.3: THE MIXED SYSTEM: The mixed system, comprises of both the structural walls and the reinforced concrete frames. In the case of the mixed structural system of reinforced concrete frames and walls, the exterior and interior masonry walls serve a non-structural purpose. In the case of the mixed system with reinforced concrete frames and masonry walls, the exterior ones play a structural role, so they take vertical and horizontal loads.

2.0 MODULAR COORDINATION IN BUILDINGS

Modular coordination is a concept of dimension and space, in which buildings components are dimensioned and positioned in a term of basic unit or module. Dimensional coordination is possible if the coordinating dimensions of all parts, as well as the dimensions of the building to be erected are in multiples of one basic dimensional unit- The basic module. Such dimensional coordination is called modular coordination. MC has been introduced in Malaysia since 1986, but has not been widely implemented in the building industry.

2.1 Objectives for implementing MC: The main objective of modular coordination is rationalization and industrialization within the building industry by standardization of components so that there is an ease to manufacturing the components in industries and erecting them on site with proper efficiency and achieving economy. Modular system provides a practical and coherent solution for coordination of the position and dimensions of elements components and space in the building design.

Other are as follows:

i. To facilitate cooperation between building designer manufacturer, distributor and contractor.
ii. The use of standard size of building blocks in the design of the building.
iii. To simplify the building design and preparation of building drawings.
iv. To determine the size and position of each component in relation to each component and the building as a whole.
v. To optimize the standard sizes of building components.
vi. With Open System approach, building components could combine in a variety of individual building projects while ensuring the architect freedom in their designs.
vii. MC is an important factor in application of Industrialized Building System by way of standardization of components and dimensions such as reduce time of production and installation of components, achieving repeatability and able to construct building at lower cost.

2.2 **Basics of Modular Coordination (M.C.):** The main purpose of Modular Coordination is to achieve the Dimensional Compatibility between the Building Dimensions, Span or Spaces and the Size of Components and Equipment by using related Modular Dimensions. Modular Coordination generally provide the easy grasped layout of the positioning of the building components in relation to each other and to the building and facilitate collaboration between planners, manufactures, distributors and contractors. Modular coordination is essentially based on:

i. The use of modules (basic module, multi-module and sub module)
ii. A reference system to define coordinating spaces and zones for building elements and for the components which form them.
iii. Rules for location of building elements within the reference system.
iv. Rules foe sizing building components in order to determine their work sizes.
v. Rules for defining preferred sizes for building components and coordinating dimensions for buildings.

2.3: Benefit of Modular Coordination:

- Better coordination and cooperation between various parties in the construction.
- Reduction in design time, especially with the use of standard details and

dimensional coordination.

- Benefits through computer aided design and drafting.
- Reduction in manufacturing and installation cost.
- Reduction in wastage of materials, time and manpower in cutting and trimming on site.
- Facilitating prefabrication.
- Improved balance between quality and cost.

3.0 HIGH RISE BUILDING SYSTEMS:

A ‘tall building’ or ‘high-rise building’ is a building whose height creates different conditions in the design, construction and use than those that exist in common buildings of certain region and period. The tallness of a building is a matter of a person’s or community’s perception therefore; a particular definition of a tall building cannot be universally applied. Therefore, Tallness is a relative term. However, construction/engineering field, a tall building is one that is primarily affected by lateral forces from wind and earthquakes. The International Conference on Fire Safety – “High – Rise Building is any structure where the height can have a serious impact on evacuation. “Massachusetts, United States General Laws – A high-rise is being higher than 70 feet (21 m).

Tall building structures frame requires special structural arrangements, if they are subjected to appreciable lateral loads such as high wind pressures and earthquake loadings. In modern era, tall buildings structures are in great demands because of the following reasons which are as follows:

i. Scarceness of land in urban areas
ii. Greater demand for business and residential space
iii. Economic growth
iv. Technical advancements
v. Innovations in Structural Systems
vi. Desire for aesthetics in urban areas
vii. Cultural significance and prestige
viii. Human ambitions to build higher

Tall buildings are subjected to various types of loads during its service life time. It must be so designed to resist the gravitational and lateral forces, both permanent and transitory, that will be called on to sustain during its construction and subsequent service life. Major loads of which a tall building structures are subjected to are given below:

i. Gravity loads
   - Dead loads
   - Live loads
ii. Lateral loads
   - Wind loads
   - Seismic loads
iii. Special loads
   - Impact loads
   - Blasts loads

3.2: STRUCTURAL FORMS:

1. Rigid frames: Rigid frames connect the columns and girders by moment-resistant connections. The lateral stiffness of a rigid frame depends on the bending stiffness of the columns, girders and connections to the frame. A major advantage of the rigid frame is the open rectangular spaces which allow greater planning for windows and doors. Rigid frames typically frame 6 m to 9 m bays. When used as the sole lateral load resisting system, rigid frames are economical only to 25 stories. Above that height they are too flexible. Increasing the member sizes would call for uneconomical solutions. Rigid frames are ideal for reinforced concrete, because of the high rigidity of the joints. Steel frames are costlier to stiffen the moment-resistant connections. The size of the columns and girders at any level are directly as function of the external shear at that level. Therefore, they increase in size towards the base. Floor designs are not repetitive as in braced frames. Ceiling height also increase towards the base because of the larger girders, so story heights vary.

2. Braced frames: This system is used in steel construction, it is both an efficient and economical way for improving the lateral stiffness and resistance of rigid frame system. The bracing will almost eliminate the bending of columns and beams by resisting lateral loads primarily through axial stress, thus allowing for slenderer elements. In braced frames the lateral resistance of the structure is provided by diagonal members that together with the girders, form the "web" of the vertical truss, with the columns acting as the "chords". A very well-known example of braced frame structural system can be seen in the Empire State Building.

3. **In-filled frames:** The Infilled-frame is common in Europe for buildings up to 30 stories in height. The reinforced concrete frame of columns and girders is in-filled by panels of brickwork, blockwork or cast-in place concrete. When subjected to lateral loads, the infill acts as a strut along the compression diagonal to brace the frame. The random flow of lateral loads makes the infill frame difficult to analyze. In addition, the possible removal of walls by future tenants may weaken the frame in unpredictable ways.

4. Shear walls: Concrete or masonry continuous vertical walls may serve both architecturally as partitions and structurally to carry gravity and lateral loading. Their very high in plane stiffness and strength makes them ideally suited for bracing tall building structures. Because of their stiffness, shear wall structural system can be economical up to 35 stories building structure. It is especially important in shear wall system to try to plan the wall layout so that the lateral load tensile stresses are suppressed by the gravity load stresses. Shear walls are usually provided along both length and width of buildings. Shear walls are like vertically-oriented wide beams that carry earthquake loads downwards to the foundation. Such a wall acts as a beam cantilevered out of the foundation and just as with a beam, part of its strength derives from its depth. Although not as efficient from a strictly structural point of view, interior shear walls do leave the exterior of the building open for windows which is a more realistic situation because both wind and earthquake forces need to be resisted in both directions. Shear walls need not to be symmetrical in plan, but symmetry is preferred in order to avoid torsional effects.

5. Wall frame: Coupled wall structures are a common form of shear walls, wherein two or more walls in the same plane are connected at the floor levels by means of beams or stiff slabs. The effect is to cause the set of walls to behave in a composite centroid axis of the walls. The consequent horizontal stiffness is very much greater than if the cantilever, bending about the common walls acted separately. Coupled shear walls are commonly used in residential buildings, with reinforced concrete elements. Some heavy steel plates have been used with steel frames, for locations where there are very large shear forces, such as at the base of elevator shafts.

6. Framed tube: The ‘tube’ system evolved from a quest to develop a bracing configuration that would place as much gravity load on the exterior columns as possible to help counter the overturning effects of lateral loads while taking advantage of exterior column’s large distance to the neutral axis to resist bending moment. The solution was to create a system in which the exterior frames encircling the structure would be rigid enough to behave as nearly as possible like a three-dimensional vertical cantilever.

The "Framed Tube" structural system in tall building structures has been widely used in resisting a wide range of lateral loads. It usually consists of closely spaced wide exterior columns connected at each floor level with relatively deep spandrel beams through moment connections. This tubular concept is generally economically attractive, possesses torsional rigidity, and also provide greater flexibility in space planning since most framed columns are located at the perimeter of the building. A well-known example of framed tube structural system is World Trade Center which is 110 story high structure

7. Outrigger braced: Outrigger are rigid horizontal structures designed to improve building overturning stiffness and strength by connecting the core or spine to distant columns. Outrigger systems functions by tying together two structural systems- typically a core system and a perimeter system to yield whole structural behaviors that are much better than those of component system. The benefits of an outrigger system lie in the fact that building deformations resulting from the overturning moments get reduced, on the other hand greater efficiency is achieved in resisting forces. Outrigger engages the perimeter columns in lateral load resisting action which would otherwise acts as a gravity load resisting elements.

Outrigger system performance is affected by outrigger locations through the height of the building, the number of levels of outrigger provided, their plan locations, outrigger truss depths and the primary structural materials used. Outrigger systems may be formed of any combination of steel, concrete and composite constructions. This structural form system also helps in reduction and possibly the elimination of uplift and net tension forces throughout the columns and foundations.

8. Suspended: A suspended structure consists of a central core with horizontal cantilevered outrigger trusses at the roof level, from which are suspended vertical hangers of steel cables. The floor slabs are connected to these cables. This permits the ground floor to be exempt of any perimeter columns, thereby allowing an open concourse. The cables have very small cross-sectional areas compared to columns, and can be embedded around window sills. Another advantage is the casting of the floors at ground level and then raised into position. The system is limited to relatively small heights (about 10 to 15 stories) because of structural disadvantages, such as live-load floor-to-floor connection variations, and limited core dimensions.

4.0 UTILIZATION AND MAINTENANCE OF CONSTRUCTION PLANTS AND EQUIPMENTS

4.1: FUNCTIONAL CLASSIFICATION OF EQUIPMENT'S

4.1.1: Earthwork Equipment

It includes excavation and lifting equipment which is a back actor (or backhaul, face shovels, draglines, grata or clamshell and trenchers. Another type is earth cutting and moving equipment like bulldozers, scrapers, front-end loaders. Transportation equipment also comes under this category like tippers dump truck, scrapers rail wagons and conveyors. Last types are compacting and finishing equipment like tamping foot rollers, smooth wheel rollers, pneumatic rollers, vibratory rollers, plate compactors, impact compactors and graders.

4.1.2: Materials Hoisting Plant

It includes Mobile cranes, Tower cranes and Hoists. Mobile cranes are crawler mounted, self-propelled rubber-tired, truck-mounted. Tower cranes are stationary, travelling and climbing types. Hoists are mobile, fixed fork-lifts.

4.1.3: Concreting Plant & Equipment

Concreting Plant & Equipment includes Production equipment for batching plants, concrete mixers, Transportation equipment like truck mixers, concrete dumpers, placing equipment are like concrete pumps, concrete buckets, elevators, conveyors, hoists, grouting equipment, Pre-casting special equipment like vibrating and tilting tables, battery moulds, surface finishes equipment, pre-stressing equipment, GRC equipment, steam curing equipment, shifting equipment. Erection equipment, Concrete vibrating, repairing and curing equipment, Concrete laboratory testing equipment etc comes under this category.

4.1.4: Support and Utility Services Equipment

The equipment for Support and Utility Services is Pumping equipment, Sewage treatment equipment, Pipeline laying equipment, Power generation and transmission line erection equipment, Compressed air equipment, Heating ventilation and air-conditioning (HVAC) equipment, Workshop including wood working equipment.

4.1.5 Special Purpose Heavy Construction Plant

The major equipment's comes under this category are Aggregate production plant & rock blasting equipment, Hot mix plant and paving equipment, Marine equipment, Large-diameter pipe laying equipment, Piles and pile driving equipment, Coffer dams and caissons equipment, Bridge construction equipment, Railway construction equipment.

4.2: CRITERIA FOR EQUIPMENT SELECTION: Certain considerations are made in the selection of equipment's in the construction procedure. They are:

i. Task considerations,

ii. Site constraints,
iii. Equipment suitability,
iv. Operating reliability,
v. Maintainability,
vi. Economic considerations and;
vii. Commercial considerations.

5.1 SIMPLE BRIDGES

5.1.1: **Bridge Components:** In general, all bridges are separated into a superstructure and a substructure. Figure 1 below illustrates these two parts. The superstructure is defined as all portions of the bridge above the substructure. The function of the super structure is to collect the live loads and concentrate them into the substructure. The main components of the superstructure are the wearing surface, the deck, the primary members, and the secondary members. This is the most visible portion of the bridge. The substructure acts as a foundation to the bridge. It is comprised of the abutments, piers, bearings, pedestals, and retaining walls.

5.1.1.1: Wearing Surface: When traveling over any bridge, the most visible portion is its wearing surface. The wearing surface is generally made of bituminous concrete or asphalt. It is exposed to all traffic travelling across the bridge. It is also exposed to the weather. Over time, the wearing surface becomes increasingly damaged by the elements and has to be repaired or completely resurfaced. Generally, this layer of bituminous concrete is between 2 and 4 inches thick (i.e. 50mm – 100mm). Due to the constant repair and resurfacing, this thickness generally increases over time.

5.1.1.2: Bridge Deck: The bridge deck sits directly below the wearing surface. It is what supports the wearing surface. The bridge deck is generally made of a reinforced concrete slab or a large steel plate. The purpose of the bridge deck is to distribute the loads transversely. It distributes the loads along the bridge to the underlying structural elements, such as the girders and stringers. The deck is generally directly connected to the supporting girders/stringers, or is separated by a steel plate which connects the two together.

5.1.1.3: Primary Members: The primary members of the bridge are responsible for distributing the loads from the bridge deck longitudinally. The primary members are the girders that run below the bridge deck. These girders are typically made of structural steel or concrete. The most common types of steel girder are the rolled beam and the rolled beam with cover plates.

5.1.1.4: Secondary Members: The secondary members act as bracing for the primary members. They run perpendicular to the primary members. This prevents lateral movement and they can prevent tensional forces.

5.1.1.5: Abutments: The abutments are a part of the substructure or foundation of the bridge. They act as end supports. Abutments provide vertical support to the bridge and lateral support to the soil at the ends of the roadway.

5.1.1.6 Piers: A pier is a structure located at the end of a bridge span which provides the basic function of supporting spans at intermediate points between end supports (abutments)". Piers have three main functions which are to carry their own weight, support the dead and live loads provided by the superstructure, and to transmit all loads to the foundation of the bridge or overpass. Like abutments, there are a number of different types of piers. Selection of which type of pier/column to use is based on aesthetics, shape of the superstructure, and the fact that the pier/column should provide limited interference to passing traffic. There are six different types of piers. They include hammerhead, column bent, pile bent, solid wall, integral, and single column.

5.1.1.7: Bearings: Bearings may be a small portion of any bridge or overpass, but their importance cannot be overlooked. The main function of a bearing is to transmit loads from the superstructure to the substructure. There are two main categories of bearings, fixed bearings and expansion bearings. Fixed bearings allow for rotation at the member's end and resist translation. On the other hand, expansion bearings allow both rotation and translation. These types of movements occur due to creep, shrinkage, settlement, uplift, loading, and thermal forces. These bearings are also exposed to various types of loading which include the dead load of the superstructure, traffic live loads, wind loads, and seismic loads. Within the two categories of bearings, there are several different types. These are rocker bearings, roller bearings, sliding plate bearings, pot bearings, spherical bearings, elastomeric bearings, and lead rubber bearings. Although there are seven different types of bearings, for the purpose of this specific overpass and its loadings/dimensions, we chose to focus on three: roller bearings, rocker bearings, and elastomeric bearings.

Figure 1: Superstructure and Substructure (Oklahoma Bridge Tracker, 2009)