3.2 Loading

Loading on tall buildings is different from low-rise buildings in many ways such as large accumulation of gravity loads on the floors from top to bottom, increased significance of wind loading and greater importance of dynamic effects. Thus, multi-storeyed structures need correct assessment of loads for safe and economical design. Except dead loads, the assessment of loads can not be done accurately. Live loads can be anticipated approximately from a combination of experience and the previous field observations. Wind and earthquake loads are random in nature and it is difficult to predict them. They are estimated based on a probabilistic approach. The following discussion describes some of the most common kinds of loads on multi-storeyed structures.

3.2.1 Gravity loads

Dead loads due the weight of every element within the structure as well as live loads that are acting on the structure when in service constitute gravity loads. The dead loads are calculated from the member sizes and estimated material densities. Live loads prescribed by codes are empirical and conservative based on experience and accepted practice. The equivalent minimum loads for office and residential buildings as per IS 875 are as specified in Table -3.1

Table – 3.1 Live load magnitudes [IS: 875 - 1987 Part -II]

Occupancy classification	Uniformly distributed load (kN/m^2)	Concentrated load (kN)
Office buildings		
• Offices and Staff rooms	2.5	2.7
• Class rooms	3.0	2.7
• Corridors, Store rooms and Reading rooms	4.0	4.5
Residential buildings		
• Apartments	2.0	1.8
• Restaurants	4.0	2.7
• Corridors	3.0	4.5

A floor should be designed for the most adverse effect of uniformly distributed load and concentrated load over 0.3 m by 0.3 m as specified in Table-3.1, but they should not be considered to act simultaneously. All other structural elements such as beams and columns are designed for the corresponding uniformly distributed loads on floors.

Reduction in imposed (live) load may be made in designing columns, load bearing walls etc., if there is no specific load like plant or machinery on the floor. This is allowed to account for reduced probability of full loading being applied over larger areas. The supporting members of the roof of the multi-storeyed building is designed for 100% of uniformly distributed load; further reductions of 10% for each successive floor down to a minimum of 50% of uniformly distributed load is done. The live load at a floor level can be reduced in the design of beams, girders or trusses by 5% for each $50m^2$ area supported, subject to a maximum reduction of 25%. In cases where the reduced load of a lower floor is less than the reduced load of an upper floor, then the reduced load of the upper floor should be adopted in the lower floor also.

3.2.2 Wind load

The wind loading is the most important factor that determines the design of tall buildings over 10 storeys, where storey height approximately lies between 2.7 – 3.0 m. Buildings of up to 10 storeys, designed for gravity loading can accommodate wind loading without any additional steel for lateral system. Usually, buildings taller than 10 storeys would generally require additional steel for lateral system. This is due to the fact that wind loading on a tall building acts over a very large building surface, with greater intensity at greater heights and with a larger moment arm about the base. So, the additional steel required for wind resistance increases non-linearly with height as shown in Fig. 3.7.

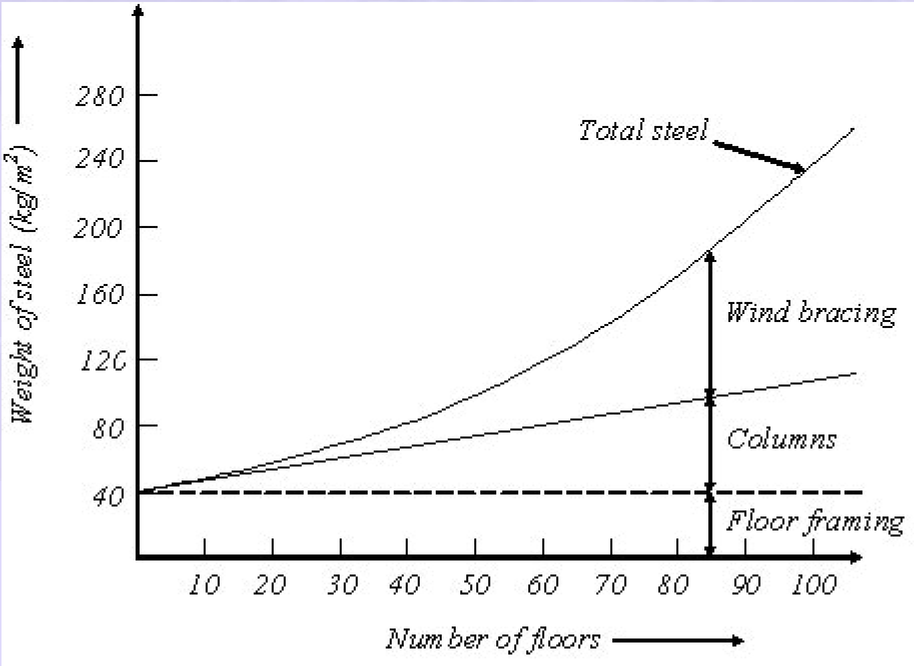

Fig.3.7 Weight of steel in multi-storeyed buildings

As shown in Fig.3.7 the lateral stiffness of the building is a more important consideration than its strength for tall multi-storeyed structures. Wind has become a major load for the designer of multi-storeyed buildings. Prediction of wind loading in precise scientific terms may not be possible, as it is influenced by many factors such as the form of terrain, the shape, slenderness, the solidity ratio of building and the arrangement of adjacent buildings. The appropriate design wind loads are estimated based on two approaches. Static approach is one, which assumes the building to be a fixed rigid body in the wind. This method is suitable for buildings of normal height, slenderness, or susceptible to vibration in the wind. The other approach is the dynamic approach. This is adopted for exceptionally tall, slender, or vibration prone buildings. Sometimes wind sensitive tall buildings will have to be designed for interference effects caused by the environment in which the building stands. The loading due to these interference effects is best ascertained using wind tunnel modeled structures in the laboratory.

However, in the Indian context, where the tallest multi-storeyed building is only about 35 storeys high, multi-storeyed buildings do not suffer wind-induced oscillation and generally do not require to be examined for the dynamic effects. For detailed information on evaluating wind load, the reader is referred to IS: 875-1987 (Part-III).

3.2.3 Earthquake load

Seismic motion consists of horizontal and vertical ground motions, with the vertical motion usually having a much smaller magnitude. Further, factor of safety provided against gravity loads usually can accommodate additional forces due to vertical acceleration due to earthquakes. So, the horizontal motion of the ground causes the most significant effect on the structure by shaking the foundation back and forth. The mass of building resists this motion by setting up inertia forces throughout the structure.

The magnitude of the horizontal shear force F depends on the mass of the building M, the acceleration of the ground a, and the nature of the structure. If a building and the foundation were rigid, it would have the same acceleration as the ground as given by Newton's second law of motion, i.e. F = Ma. However, in practice all buildings are flexible to some degree. For a structure that deforms slightly, thereby absorbing some energy, the force will be less than the product of mass and acceleration. But, a very flexible structure will be subject to a much larger force under repetitive ground motion. This shows the magnitude of the lateral force on a building is not only dependent on acceleration of the ground but it will also depend on the type of the structure. As an inertia problem, the dynamic response of the building plays a large part in influencing and in estimating the effective loading on the structure. The earthquake load is estimated by Seismic co-efficient method or Response spectrum method. The later takes account of dynamic characteristics of structure along with ground motion. For detailed information on evaluating earthquake load, reader is referred to IS: 1893 - 2002 and the chapter on Industrial Buildings.