Loads on structures

INTRODUCTION

The structures and structural members are designed to meet the functional and structural aspects. Both aspects are interrelated. The functional aspect takes in to consideration the purpose for which the building or the structure is designed. It includes the determination of location and arrangement of operating utilities, occupancy, fire safety and compliance with hygienic, sanitation, ventilation, special equipment, machinery or other features, incident to the proper functioning of the structures. In the structural aspect, it is ensured that the building or the structure is structurally safe, strong, durable and economical. The minimum requirements pertaining to the structural safety of buildings are being covered in codes dealing with loads by way of laying down minimum design loads which have to be assumed for dead loads, imposed loads, wind loads and other external loads, the structure would be required to bear. Unnecessarily, heavy loads without proper assessment should not be assumed. The structures are designed between two limits, namely, the structural safety and economy. The structures should be strong, stable and stiff.

Estimation of the loads for which a structure should be designed is one of the most difficult problems in structural design. The designer must be able to study the loads which are likely to be acting on the structure throughout its life time and the loads to which the structure may be subjected during a short period. It is also necessary to consider the combinations of loads for which the structure has to be designed.

2 TYPES OF LOADS

The loads to which a structure, will be subjected to consist of the following

1. Dead loads,
2. Live loads or imposed loads,
3. Wind load,
4. Snow load
5. Seismic load
6. Temperature effects

In addition o the above loads, following forces and effects are also considered while designing the structures.

1. Foundation movements
2. Elastic axial shortening
3. Soil and fluid pressures
4. Vibrations
5. Fatigue
6. Impact
7. Erection loads
8. Stress concentration effects

DEAD LOADS

Dead load of a structure means the weight of the structure itself. The dead load in a building will consist of the weight of all wall partitions, floors and roofs. Loads due to partition shall be estimated on the basis of actual constructional details of the proposed partitions and their positioning in accordance with plans and the loads thus estimated shall be included in the dead load for the design of the floors and the supporting structures. If the loads due to partitions cannot be actually computed for want of data, the floors and the supporting structures shall be designed to carry in addition to other loads a uniformly distributed dead load per square metre of not less than 33⅓ per cent of the weight per metre run of finished partitions over the

entire floor area subjected to minimum uniformly distributed load of 1000 N/m2 in the case of floors used for office purposes. Dead loads can be estimated using the unit-weight of materials used in building construction as per IS : 875 (part I) -1987

LIVE LOADS OR IMPOSED LOADS

Live loads are the loads which vary in magnitude and in positions. Live loads are also known as imposed or transient loads. Imposed loads consist of all loads other than dead loads. Live loads are assumed to be produced by the intended use of occupancy in building including the weight of movable partitions, distributed loads, concentrated loads, loads due to impact and vibration and snow loads. Live loads are expressed as uniformly distributed static loads. Live loads include the weight of materials stored, furniture and movable equipments. Efforts have been made at the international level to decide live loads on floors and these have been specified in the International standards (2103 Imposed floor loads in residential and public building and 2633 Determination of imposed floor loads in production buildings and warehouses). These codes have been published in the International Organization.

Code IS : 875 (part 2) -1987 defines the principal occupancy for which a building or part of a building is used or intended to be used. The buildings are classified according to occupancy as per IS : 875 (part 2)-1987.

WIND LOAD

The wind loads are the transient loads. The wind usually blows horizontal to the ground at high wind speeds. The vertical components of atmospheric motion are relatively small, therefore, the term wind denotes almost exclusive the horizontal wind. The winds of very high speeds and very short duration are called Kal Baisaki or Norwesters occur fairly frequently during summer months over North East India.

The liability of a building or a structure to high wind pressure depends not only upon the geographical location and proximity of other obstructions to airflow but also upon the characteristics of the structure itself. In general, wind speed in the atmospheric boundary layer increases with height from zero at ground level to maximum at a height called the gradient height. The variation of wind with height depends primarily on the terrain conditions. However, the wind speed at any height never remains constant and it has been found convenient to resolve its instantaneous magnitude in to an average or mean value and a fluctuating component around this average value. The magnitude of fluctuating component of the wind speed is called gust, it depends upon averaging time. In general, smaller the averaging interval, greater is the magnitude of the gust speed. The wind load depends upon terrain, height of the structure and the shape and size of structure. It is essential to know the following terms to study the new concept of wind as described in IS : 875 (Part 3) – 1987 .

SNOW LOAD

The snow load depends upon latitude of place and atmospheric humidity. The snow load acts vertically and it is expressed in kN/m2 of plan area. The actual load due to snow depends upon the shape of the roof and its capacity to retain the snow. When actual data for snow load is not available, snow load may be assumed to be 25 N/m2 per mm depth of snow. It is usual practice to assume that snow load and maximum wind load will not be acting simultaneously on the structure.

SEISMIC LOAD (EARTHQUAKE LOAD)

It becomes essential to consider ‘seismic load’ in the design of structure, if the structure is situated in the seismic areas. The seismic areas are the regions which are geologically young and unstable parts and which have experienced earthquakes in the past and are likely to experience earthquakes in future. The Himalayan region, Indo Gangetic Plain, Western India, Cutch and Kathiawar are the places in our country which experience earthquakes frequently. Sometimes these earthquakes are violent also. Seismic load is caused by the shocks due to an earthquake. The earthquakes range from small tremors to severe shocks. The earthquake

shocks cause movement of ground, as a result of which the structure vibrates. The vibrations caused because of earthquakes may be resolved in three perpendicular directions. The horizontal direction of vibration dominates over other directions. In some cases structures are designed for horizontal seismic forces only and in some case both horizontal seismic forces and vertical seismic forces are taken in to account. The seismic accelerations for the design may be arrived at from seismic coefficient, which is defined as the ratio of acceleration due to earthquakes and acceleration due to gravity. Our country has been divided in to seven zones for determining seismic coefficients. The seismic coefficients have also been recommended for different types of soils for the guidance of designers. IS : 1893-1962 Indian Standard Recommendations for Earthquake Resistant Design of Structure, may be referred to for actual design.

SOIL AND HYDROSTATIC PRESSURE

The pressure exerted by soil or water or both should be taken in to consideration for the design of structures or parts of structure which are below ground level. The soil pressure and hydrostatic pressure may be calculated from established theories.

ERECTION EFFECTS

The erection effects include all effects to which a structure or part of structure is subjected during transportation of structural members and erection of structural member by equipments. Erection effects also take in to account the placing or storage of construction materials. The proper provisions shall be made, e.g., temporary bracings, to take care of all stresses caused during erection. The stress developed because of erection effects should not exceed allowable stresses.

DYNAMIC EFFECTS (IMPACTS AND VIBRATIONS)

The moving loads on a structure cause vibrations and have also impact effect. The dynamic effects resulting from moving loads are accounted for, by impact factor. The live load is increased by adding to it the impact load. The impact load is determined by the product of impact factor and live load.

TEMPERATURE EFFECTS

The variation in temperature results in expansion and contraction of structural material. The range of variation in temperature varies from localities to localities, season to season and day to day. The temperature effects should be accounted for properly and adequately. The allowable stress should not be exceeded by stress developed because of design loads and temperature effects.

LOAD COMBINATIONS

All the parts of the steel structure shall be capable of sustaining the most adverse combination of the dead loads, prescribed live loads, wind loads, earthquake loads where applicable and any other forces or loads to which the steel structure may reasonably be subjected without exceeding the stress specified. The load combinations for design purpose shall be the one that produces maximum forces and effects and consequently maximum stresses from the following combinations

1. Dead load + Imposed (live) load

2. Dead load + Imposed (live) load + wind or earthquake loads and

3. Dead load + wind or earthquake loads

Design Philosophies of Steel Structures

There are 2 types of limit state,

a) Limit state of strength

b) Limit state of serviceability

a) Limit state of strength

The limit states of strength are those related to failures (or imminent failure), under the action of probable and most unfavorable combination of loads on the structure using the appropriate partial safety factors, which can endanger the security of life and property. The limit state of strength includes:

a) Loss of equilibrium of the structure as an entire or any of its components or elements.

b) Loss of stability of the structure (including the impact of sway wherever applicable and overturning) or any of its components together with supports and foundations.

c) Failure by excessive deformation, rupture of the structure or any of its components or elements,

d) Fracture because of fatigue,

e) Brittle fracture.

b) Limit state of serviceability

The limit state of serviceability include:

Deformation and deflections, have an effect on|which can} adversely have an effect on the appearance or effective use of the structure or might cause improper functioning of apparatus or services or may cause damages to finishes and non-structural members.

a) Vibrations in the structure or any of its parts creating discomfort to individuals, damages to the structure, its contents or which can limit its purposeful effectiveness.

Special consideration shall tend to systems at risk of vibration, like massive open floor areas free of partitions to make sure that such vibrations are acceptable for the supposed use and occupancy.

b) Repairable damage or crack because of fatigue.

c) Corrosion, durability.

d) Fire.