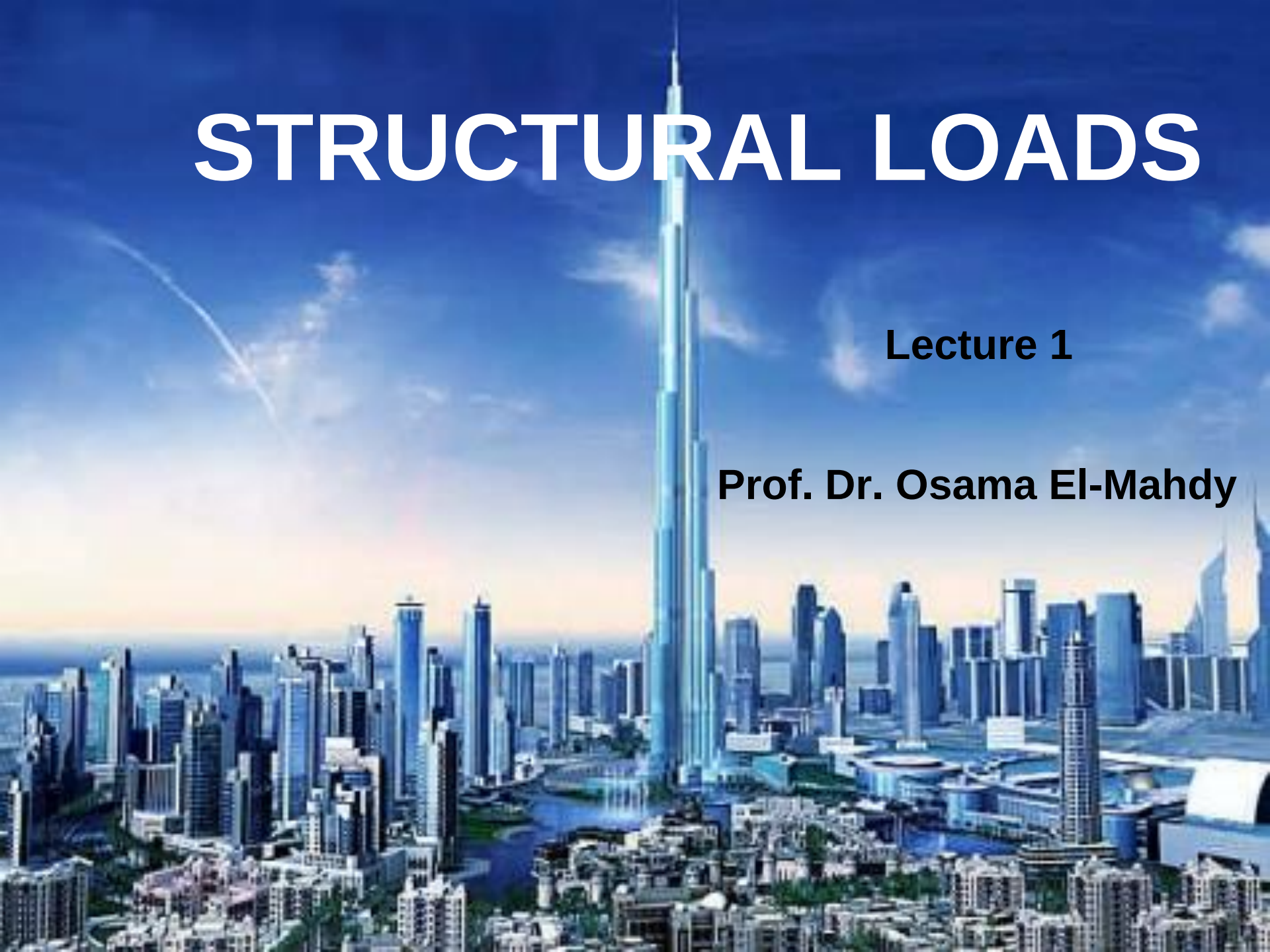
STRUCTURAL LOADS



Lecture 1

Prof. Dr. Osama El-Mahdy

Introduction

تتوقف سلامة الأعمال الإنشائية وأعمال المبانى بصفة عامة على طريقة حساب الأحمال والقوى فى العناصر الأنشائية المختلفة ومدى كفاءة هذه العناصر وقدرتها على تحمل الأنواع المختلفة من الأحمال والقوى المعرضة لها بما يحقق الأداء الأمثل والإقتصادى لهذه المنشأت وكذا توافر الأمان الكافى لها طوال فترة الإستخدام.

الكود المصرى للأحمال (ECP201)

Structural Loads

- **Structural loads are forces applied to a component of a structure or to the structure as a whole.**
- **In structural design, assumed loads are specified in national and local design codes for types of structures, geographic locations, and usage.**
- **In addition to the load magnitude, its frequency of occurrence, distribution, and nature (static or dynamic) are important factors in design.**

Structural Loads

- Loads cause stresses, deformations and displacements in structures. Assessment of their effects is carried out by the methods of structural analysis.
- Excess load or overloading may cause structural failure, and hence such possibility should be either considered in the design or strictly controlled.
- The structural loads are broadly classified as vertical loads, horizontal loads and longitudinal loads.

Determination of Structural Loads

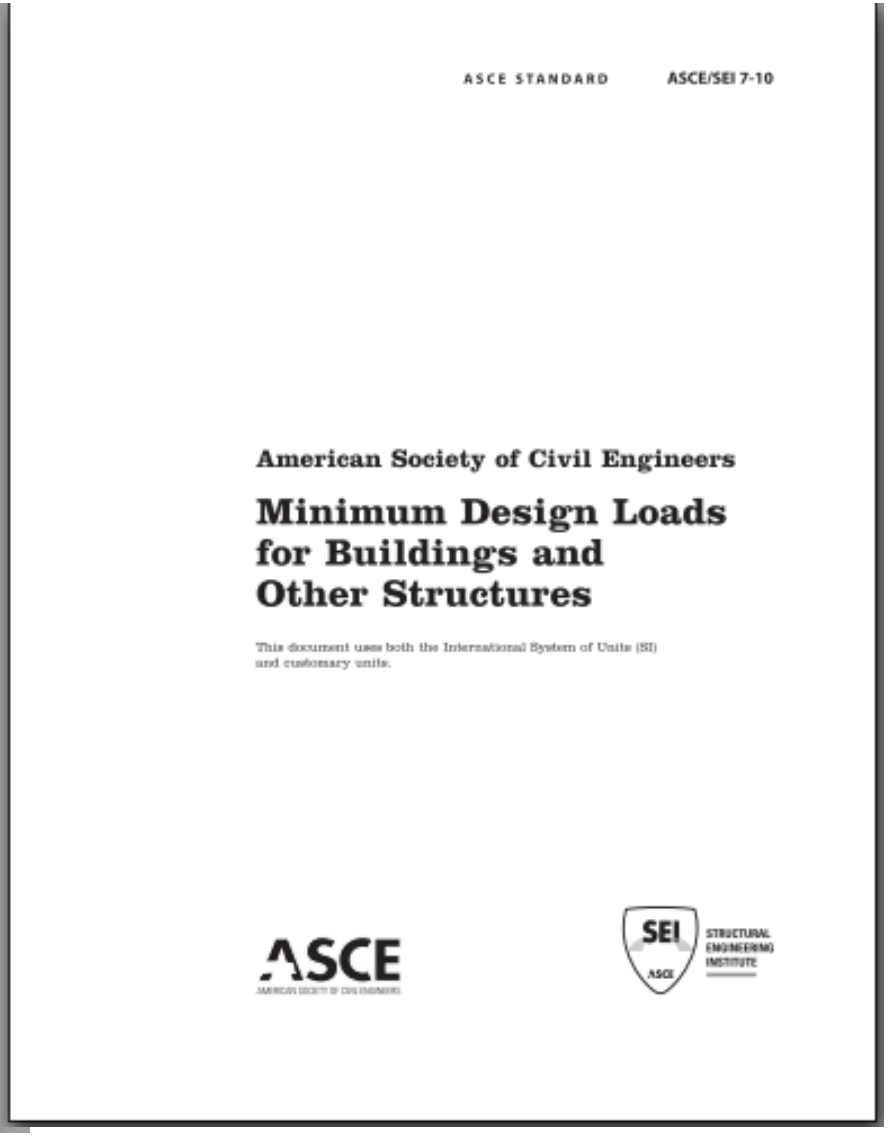
The gravity and lateral loads can be determined using Building Codes such as:

- **Egyptian Code for Loads Calculation (ECP201)**
- **British Standards (BS 6399 Parts 1,2 &3)**
- **Uniform Building Code (UBC)**
- **International Building Code (IBC)**
- **ASCE 7 "Minimum Design Loads for Buildings and Other Structures"**

Determination of Structural Loads

Determination of Structural Loads

Determination of Structural Loads



Vertical Loads (Gravity Loads)

- **Dead Loads**
- **Live Loads**
- **Snow Loads**

Dead Loads

Dead loads consist of the weight of the various structural members and the weights of any objects that are permanently attached to the structure. Hence, for a building, the dead load include the weights of the columns, beams, and girders, the floor slab, roofing, walls, windows, plumbing, electrical fixtures, and other miscellaneous attachments

Dead Loads

Dead Loads (ECP 201 Chapter 3)

جدول (٣-١)

الأوزان الفعلية للمواد المختلفة

المـــــــادة	الوزن كن/م^{٣} (كجم/م^{٣})
أولا : مواد البناء:	
الخرسانة المسلحة:	
خرسانة مسلحة بركام سليسى	٢٥ (٢٥٠٠)
خرسانة مسلحة بركام دولوميت	٢٥ (٢٥٠٠)
الخرسانة العادية:	
خرسانة بركام سليسى	٢٢ (٢٢٠٠)
خرسانة بركام دولوميت	٢٢ (٢٢٠٠)
خرسانة خفيفة	١٠-٢٠ (١٠٠٠-٢٠٠٠)
خرسانة مهواه	٦-٩ (٦٠٠-٩٠٠)
خرسانة ثـــقيلة	٢٥فأكثر (٢٥٠٠فأكثر)
خرسانة بركام البازلت	٢٣-٢٥ (٢٣٠٠-٢٥٠٠)
خرسانة بركام الفرن العالى	١٦-١٩ (١٦٠٠-١٩٠٠)

Live Loads

Live loads can vary both in their magnitude and location. They may be caused by the weights of objects temporarily placed a structure, moving vehicles, or natural forces. The minimum live loads specified in codes are determined from studying the history of their effects on existing structures. Usually, these loads include additional protection against excessive deflection or sudden overload.

Live Loads

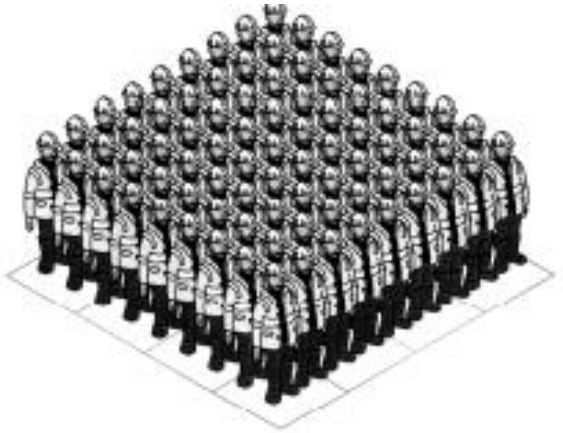
Live Loads

- **The following pictures indicate how closely people need to stand in order to generate live loads between 1.0 KN/m^2 to 5 KN/m^2.**
- **The pictures assume that an average person weights 70 kg. The grid beneath comprises 1mx1m squares.**

Live Loads

1.0kPa

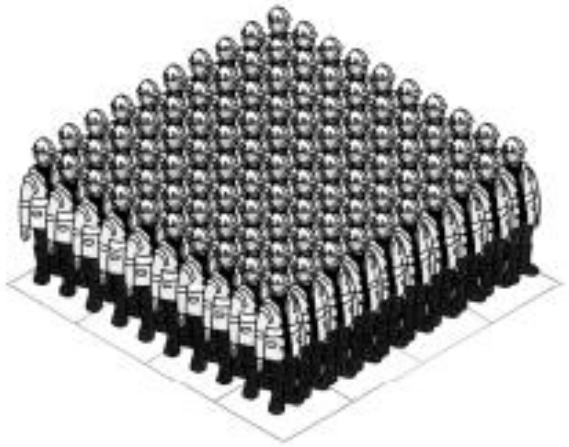
2.5kPa



4.0kPa

2.0kPa

3.0kPa



5.0kPa

Building Live Loads

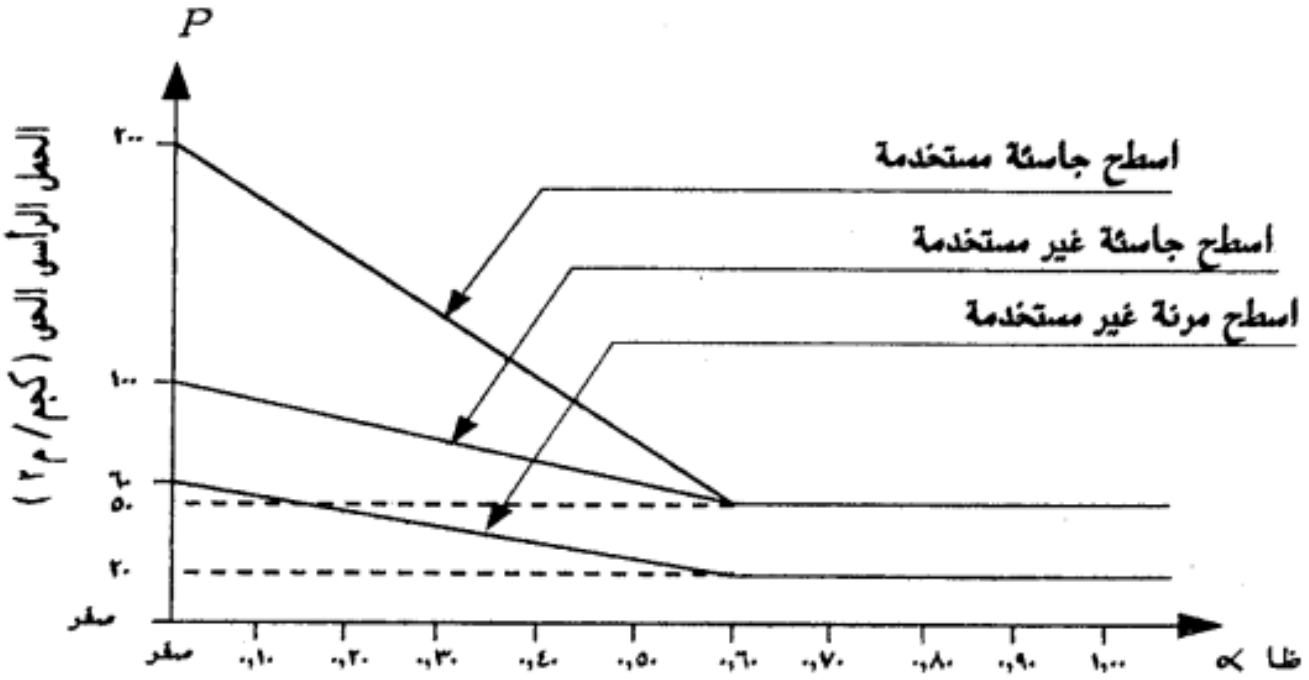
The floors of buildings are assumed to be subjected to uniform live loads, which depend on the purpose for which the building is designed. These loadings are generally tabulated in local, state, or national codes.

Building Live Loads (ECP 201 Chapter 4)

تابع جـــــــــدول (٤ - ١) الأحمال الحية للمباني المختلفة*

عنصر المبنى	(كجم/م٢)	كن/م٢
ب- المباني السكنية:		
١- غرف سكنية	(٢٠٠)	٢
٢- سلالم، مطابخ، حمامات	(٣٠٠)	٣
٣- بلكونات	(٣٠٠)	٣
جـ - المباني الإدارية:		
١- غرف مكاتب	(٢٥٠)	٢,٥
٢- غرف حفظ الملفات فى المكاتب	(٢٠٠/م ارتفاع)	٢/م ارتفاع
٣- أرشـــيف	(١٠٠٠-٥٠٠)	١٠-٥
٤- ســـلالم	(٤٠٠)	٤
٥- بلكونات	(٤٠٠)	٤
د - المستشفيات:		
١- غرف علاج المرضى	(٢٥٠)	٢,٥
٢- عنابر علاج المرضى	(٢٥٠)	٢,٥
٣- غرف الجراحة	(٤٠٠ فأكثر)	٤ فأكثر

Building Roof Live Loads



ظل زاوية ميل السطح مع الافقى

شكل (٤-١) الأحمال الحية على الأسطح النهائية

Demountable Partition Loads

- **ECP 201 requires a minimum live load allowance of 1.0kN/m^2, unless the live load is > 5kN/m^2, in which case the allowance for demountable partitions can be wavered.**
- **Permanent partitions should, of course be part of the SDL load and calculated based on the self weight of the materials specified and allow for plastering as necessary.**

Live Load Reduction in ECP 201

Floor location	Reduction in live load (%)
Upper floor or roof	0
First to fourth floor below roof	0
Fifth floor below roof	10
Sixth floor below roof	20
Seventh floor below roof	30
Eighth floor below roof	40
Ninth floor below roof up to ground	50

Bridge Live Loads

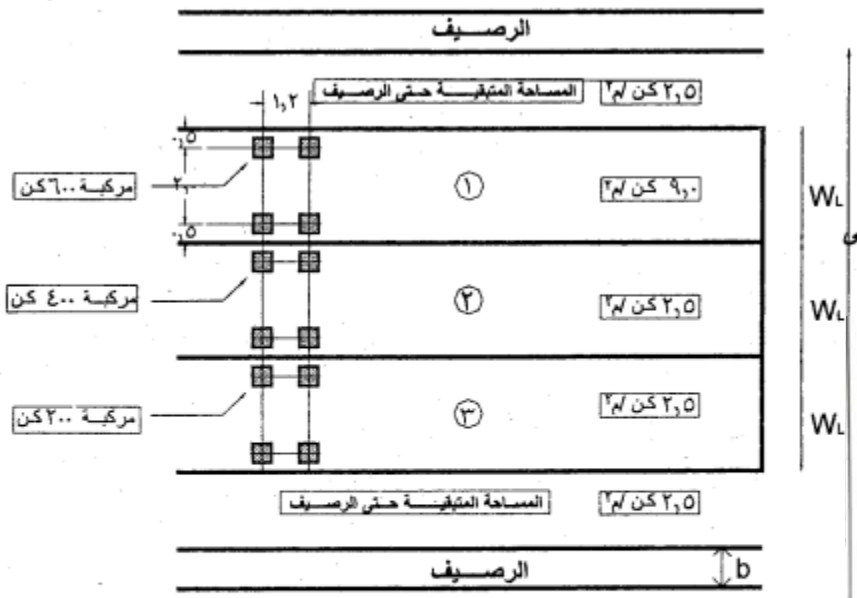
Design live loadings for highway bridges are specified in the other codes such as the American Association of State Highway and Transportation Official (AASHTO).

ECP 201

- **Chapter 5: Loads on Roadway and Pedestrian Bridges**
- **Chapter 6: Loads on Railway Bridges**
- **Chapter 9: Earthquake Loads on Bridges**

Bridge Live Loads

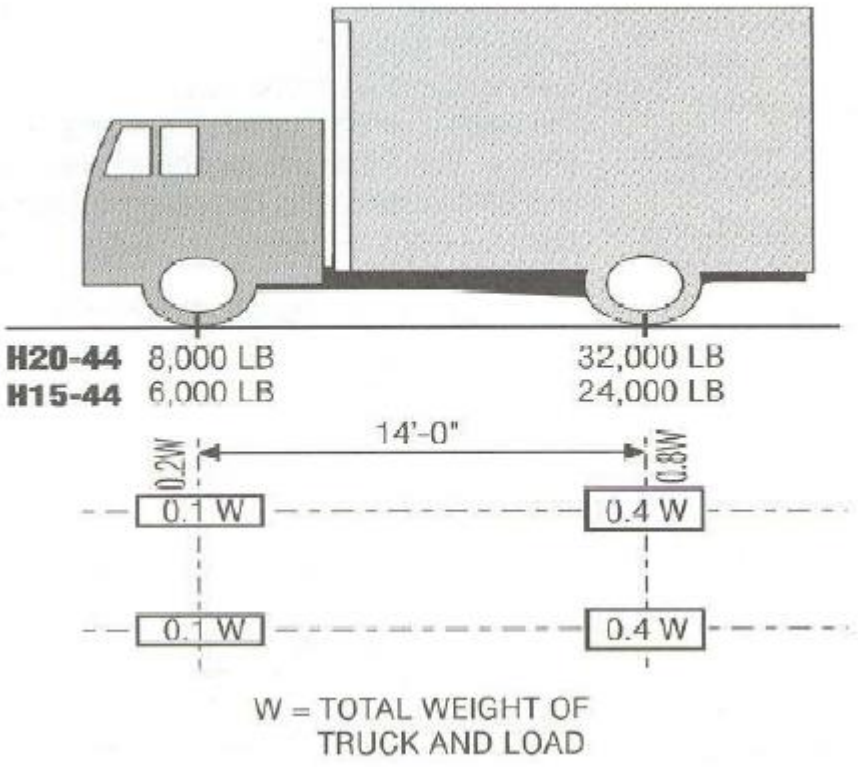
Bridge Live Loads



b أقل من ١,٥ متر ——— ٢,٥ كن/م٢

b أكبر من أو يساوى ١,٥ متر ——— ٥ كن/م٢

شكل (٥-٢) نموذج التحميل رقم (١)



Snow Loads

In some parts of the country, roof loading due to snow can be quite severe, and therefore protection against possible failure is of primary concern. Design loadings typically depend on the building's general shape and roof geometry, wind exposure, and location. Like wind, snow loads are generally determined from a zone map 50-year recurrence intervals of an extreme snow depth.

Snow Loads

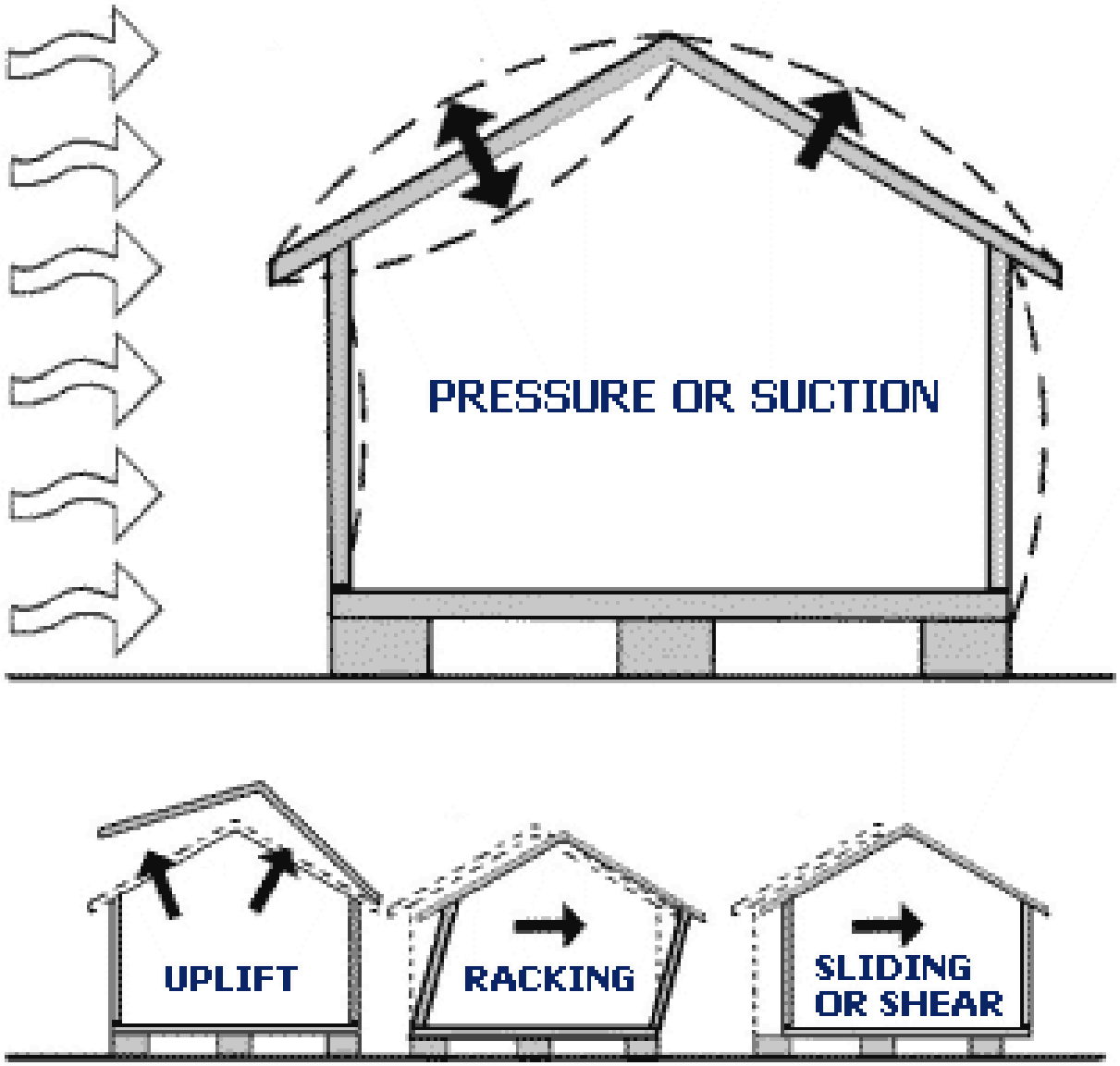
Horizontal loads (Lateral Loads)

- **Wind Loads**
- **Earthquake (Seismic) Loads**
- **Hydrostatic and Soil Pressure Loads**

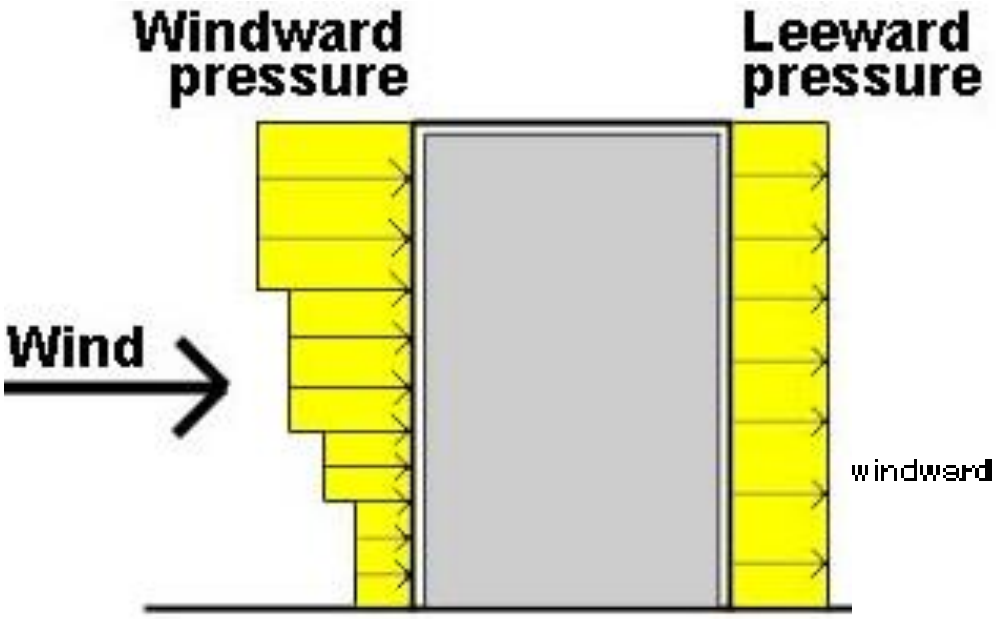
Wind Loads

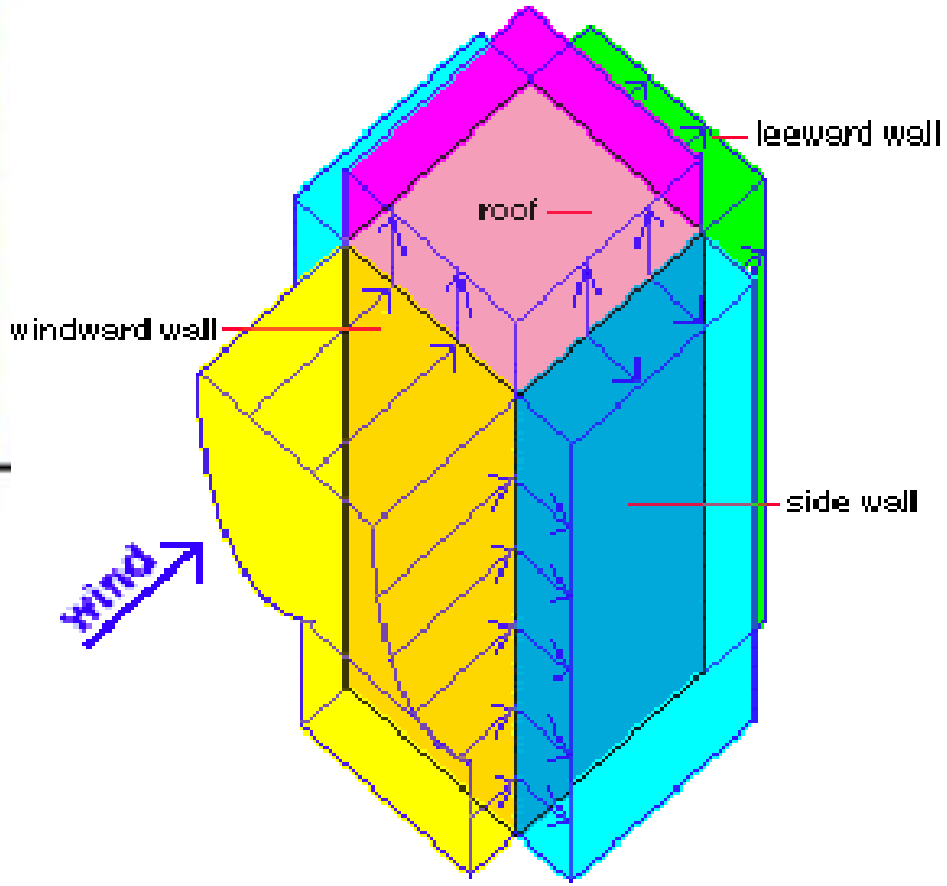
When structures block the flow of wind, the wind's kinetic energy is converted into potential energy of pressure, which causes a wind loading. The effect of wind on a structure depends upon the density and velocity of the air, the angle of incidence of the wind, the shape and stiffness of the structure, and the roughness of its surface. For design purposes, wind loadings can be treated using either a static or a dynamic approach.

Wind Loads



Wind Loads





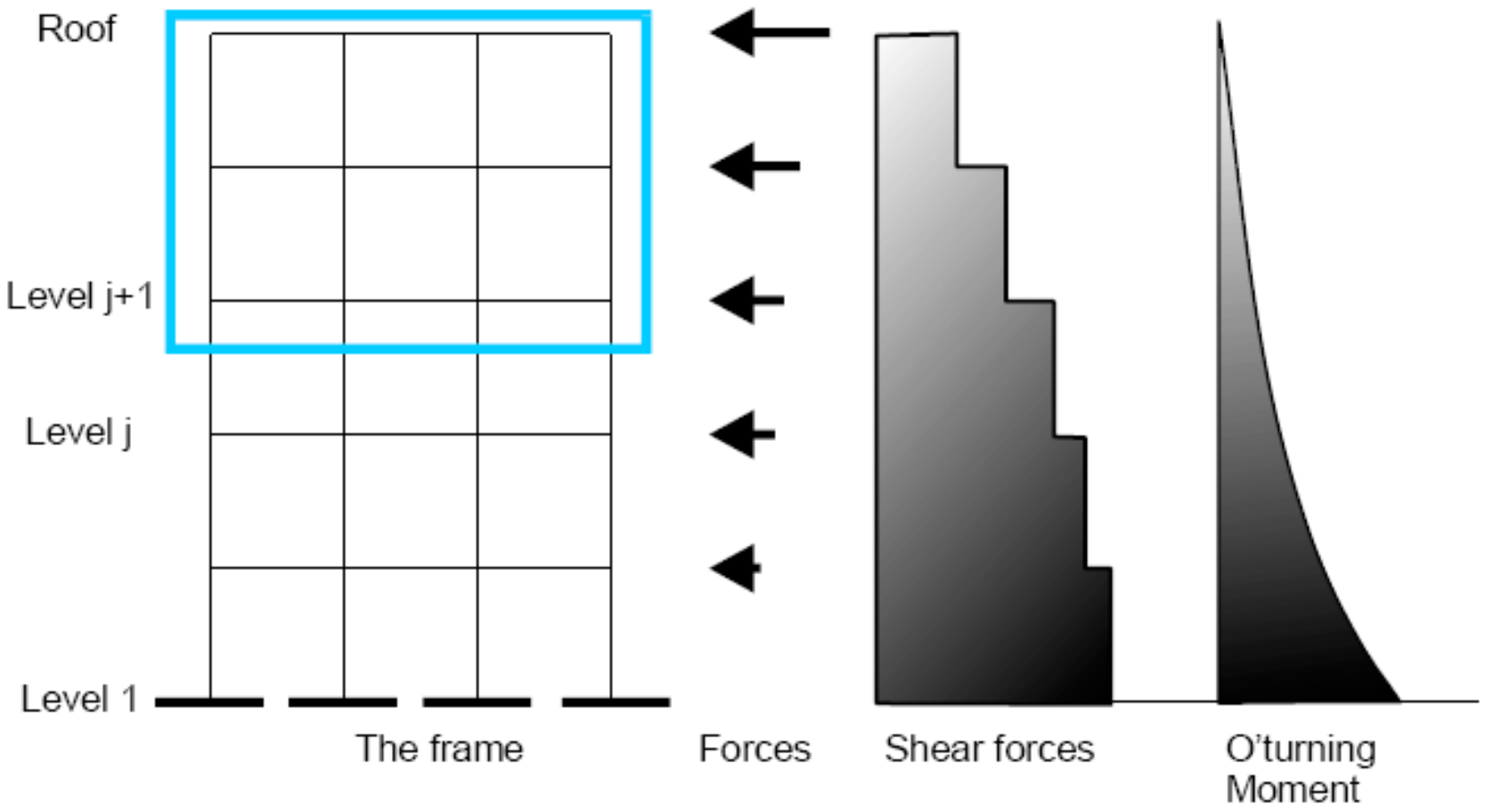
Wind pressure on buildings

Earthquake Loads (Seismic Loads)

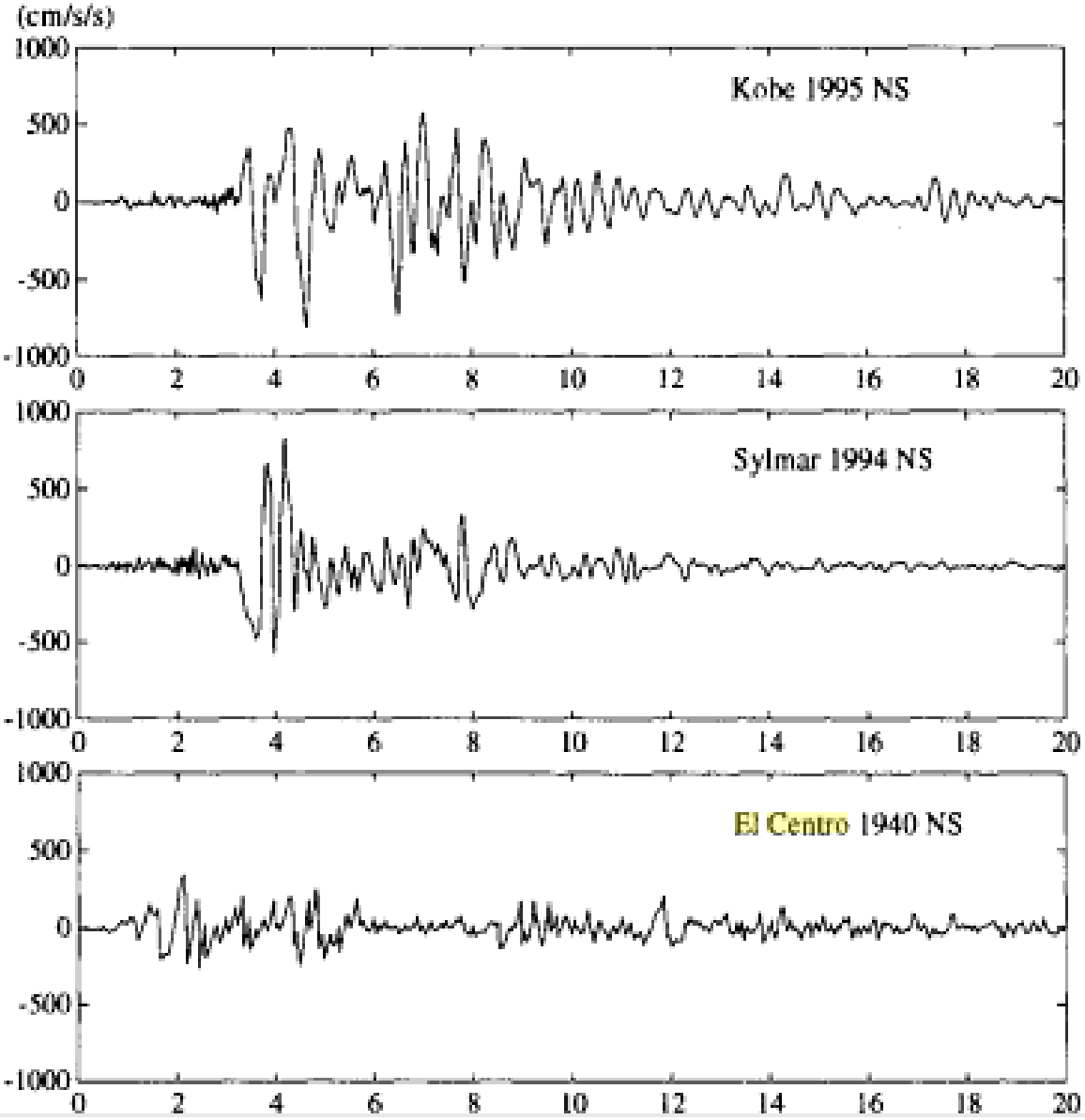
Earthquakes produce loadings on structure through its interaction with the ground and its response characteristics. These loadings result from the structure's distortion caused by the ground's motion and the lateral resistance of the structure. Their magnitude depends on the amount and type of ground accelerations and the mass and stiffness of the structure.

Earthquake Loads

Earthquake Loads



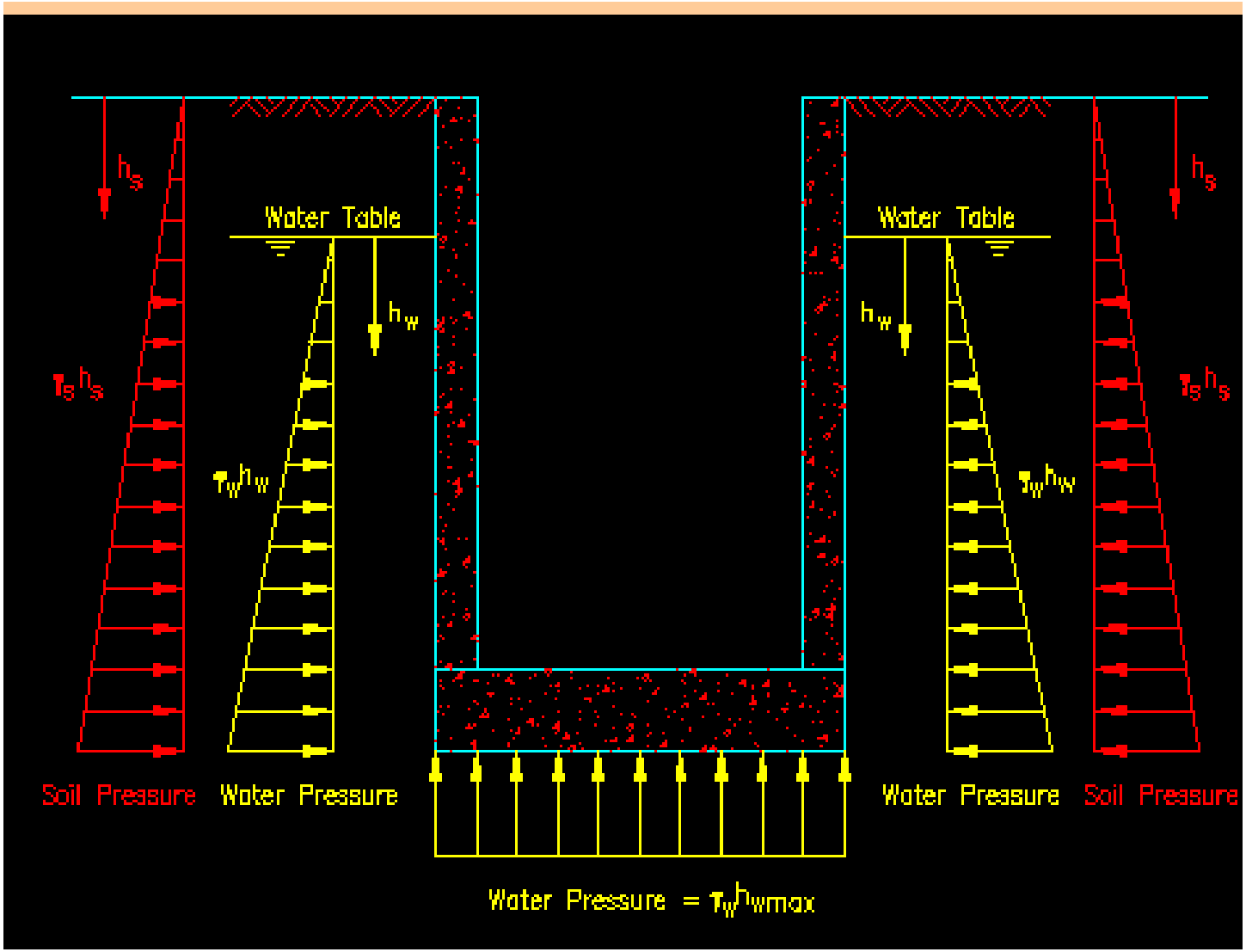
Earthquake Loads



Hydrostatic and Soil Pressure Loads

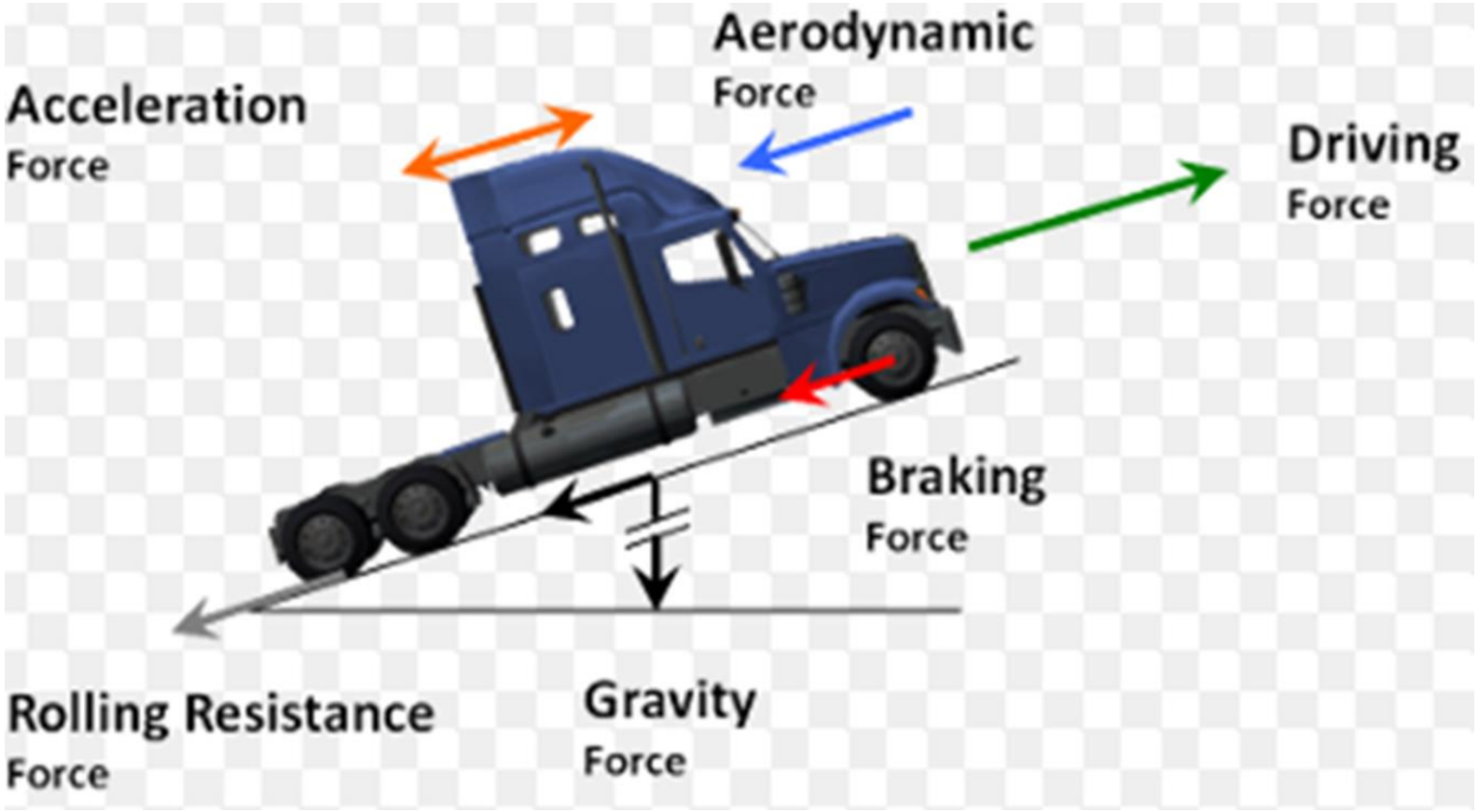
When structures are used to retain water, soil, or granular materials, the pressure developed by these loadings becomes an important criterion for their design. Examples of such type of structures include tanks, dams, ships, bulkheads, and retaining walls. Here the laws of hydrostatics and soil mechanics are applied to define the intensity of the loadings on the structure.

Hydrostatic and Soil Pressure Loads



Longitudinal Loads (Braking Forces)

These loads are considered in the design of bridges and parking ramps.



Other Structural Loads

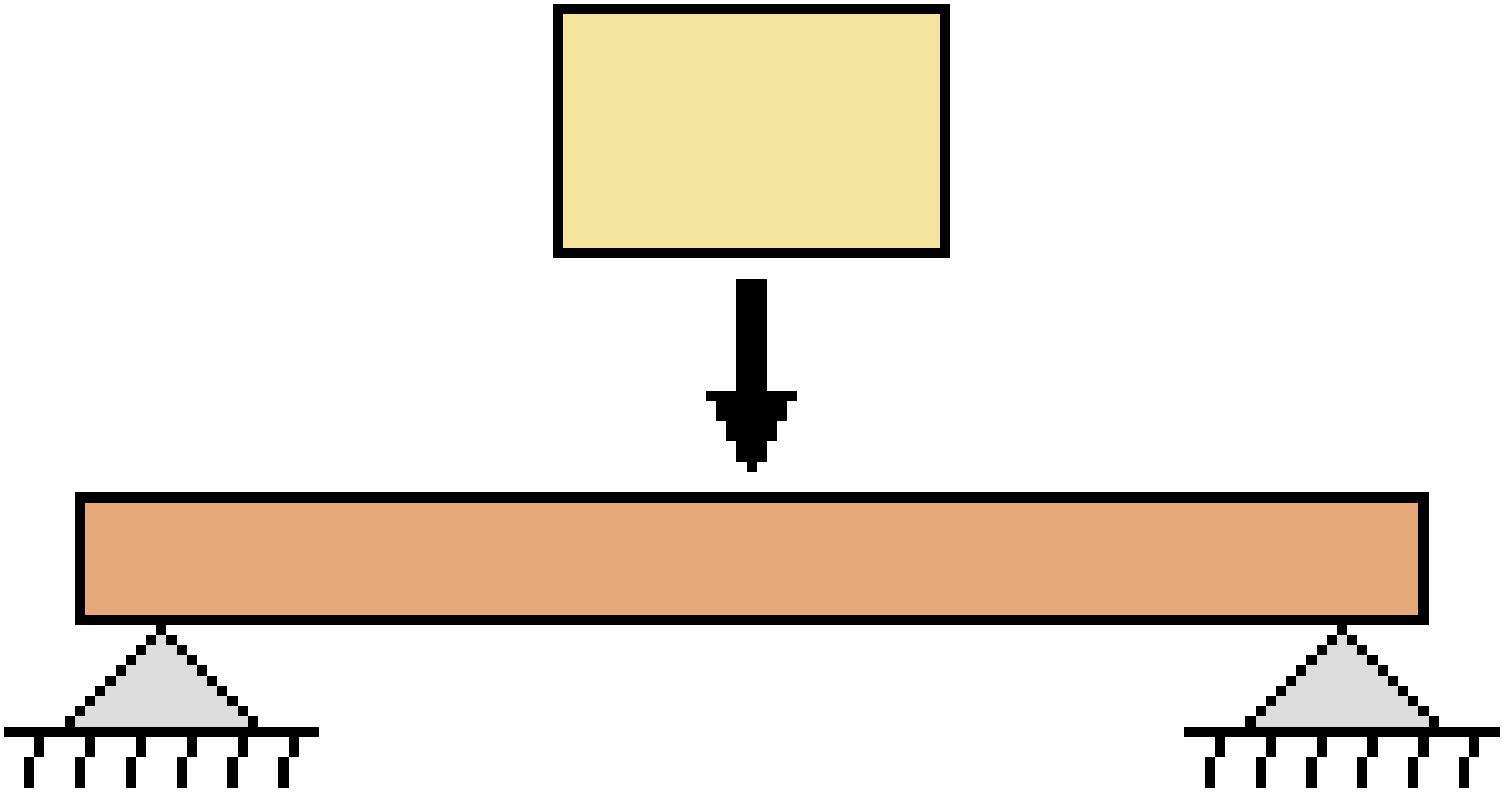
Several other types of loads may also have to be considered in the design of a structure, depending on its location or use. These include the effect of:

- **Impact Loads**
- **Temperature Loads**
- **Settlement Loads**
- **Blast (Explosion) Loads**

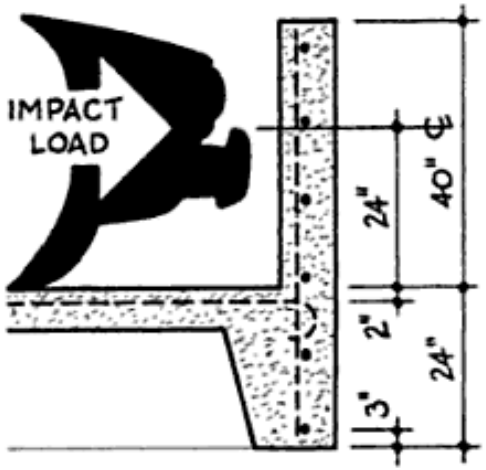
Impact Loads

Impact load is caused by vibration or impact or acceleration. Thus, impact load is equal to imposed load incremented by some percentage called impact factor or impact allowance depending upon the intensity of impact.

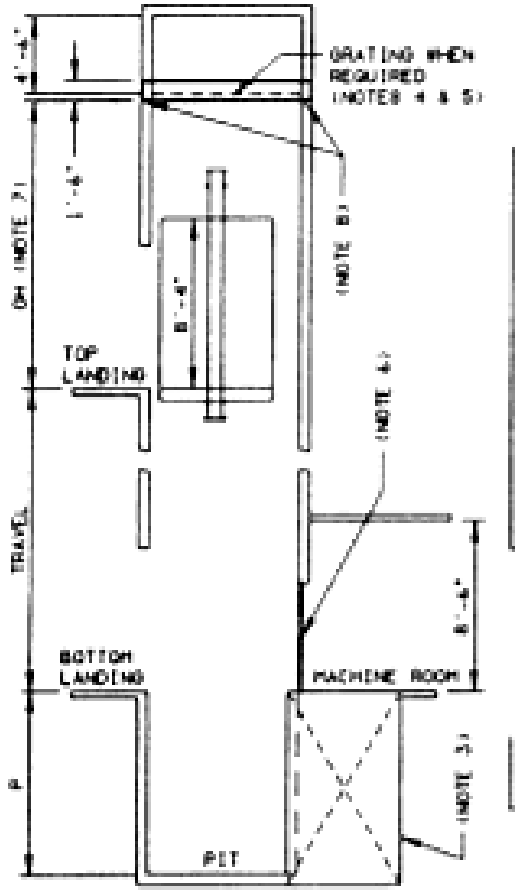
Impact Loads



Impact Loads



Parking Garage

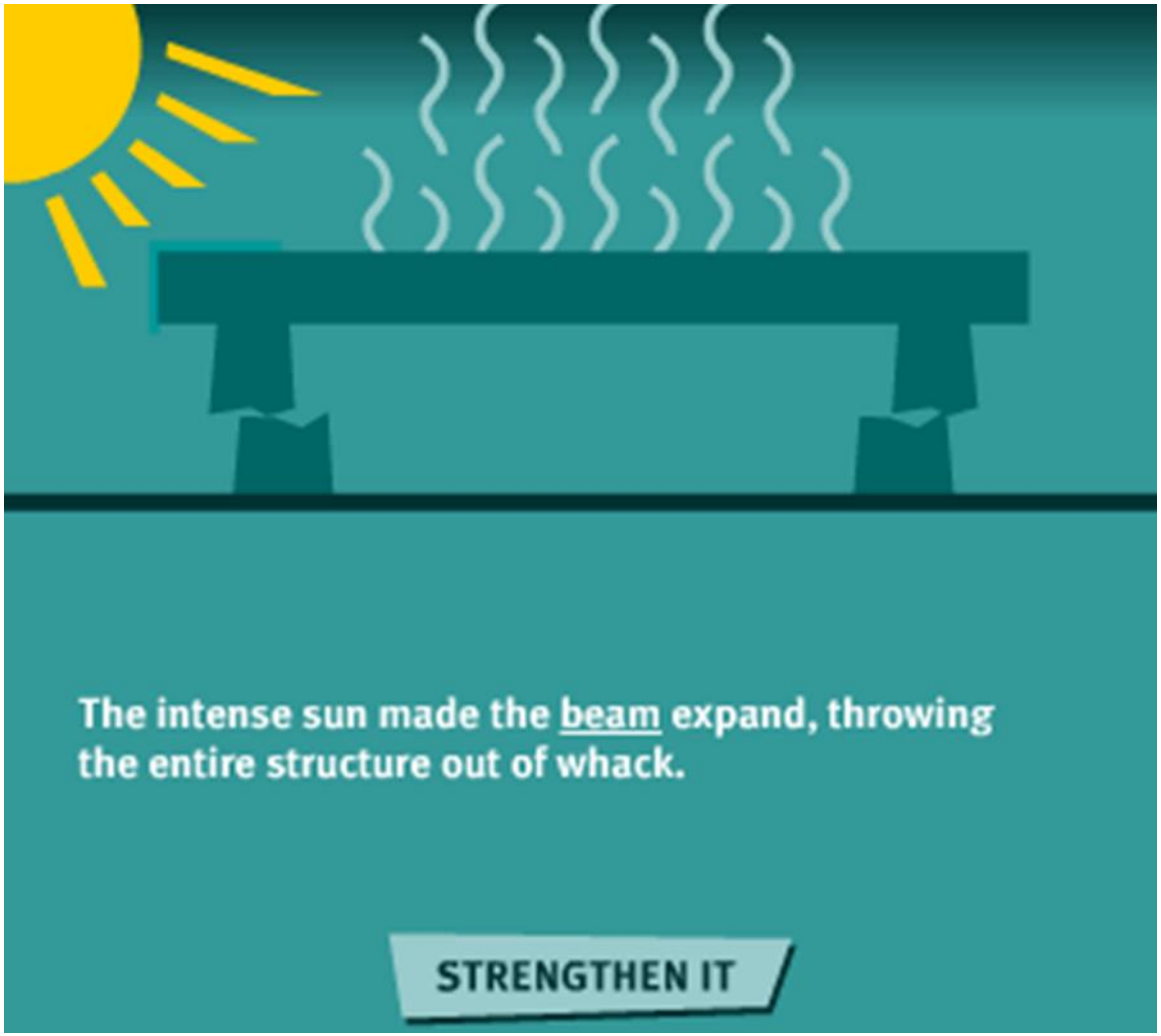


Elevators

Temperature (Thermal) Loads

Thermal load is defined as the temperature that causes the effect on buildings, such as outdoor air temperature, solar radiation, underground temperature, indoor air temperature and the heat source equipment inside the building. The change of the temperature in the structural and non-structural member causes thermal stress and is defined as the effect of thermal load.

Temperature Loads



Settlement Loads

Settlement is the downward movement of the ground caused by a load consolidating the soil below it or causing displacement of the soil.

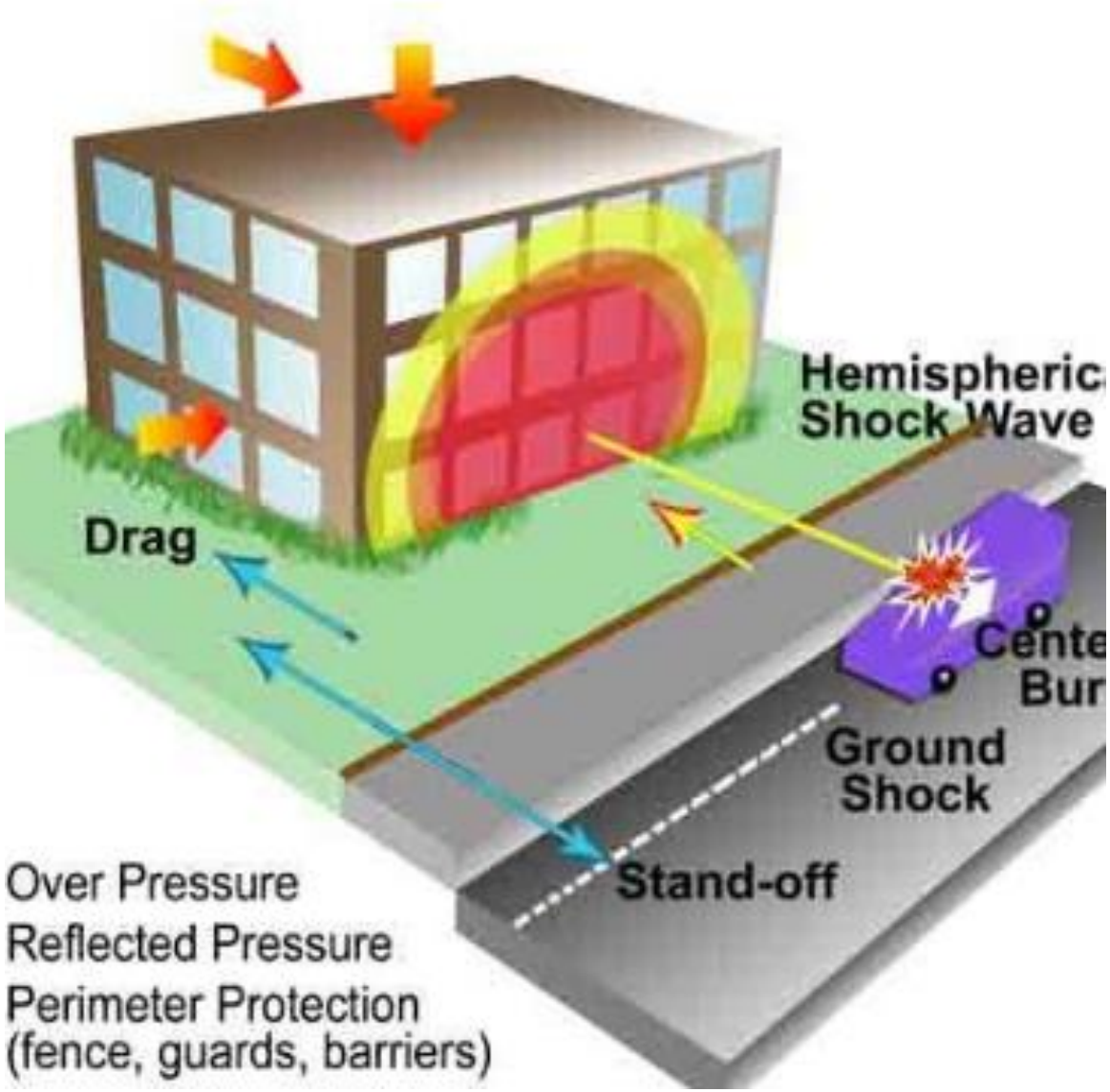
Settlement Loads

Settlement Loads

Blast Loads

The blast explosion nearby or within structure is due to pressure or vehicle bomb or quarry blasting. These causes catastrophic damage to the building both externally and internally. Resulting in collapsing of walls, blowing out of windows, and shutting down of critical life-safety systems.

Blast Loads


Hemispheric
Shock Wave
Drag
Cente
Bur
Ground
Shock
Stand-off
Over Pressure
Reflected Pressure
Perimeter Protection
(fence, guards, barriers)

Static Loads

These are loads that build up gradually over time, or with negligible dynamic effects. Since structural analysis for static loads is much simpler than for dynamic loads, design codes usually specify statically-equivalent loads for dynamic loads caused by wind, traffic or earthquake.

Dynamic Loads

These are loads that display significant dynamic effects. Examples include impact loads, waves, wind gusts and strong earthquakes. Because of the complexity of analysis, dynamic loads are normally treated using statically equivalent loads for routine design of static structures.

Working Stress Design Approach

- **[Actual (working) loads for Dead and Live] ➔ [working stresses = strength/FOS]**
- **[Actual (working) loads for Dead and Live and (Wind or Earthquake)] ➔[working stresses=(strength/FOS)*1.25 or1.33]**

Ultimate Strength Design Approach

- **[Load multiplier * (Dead and Live)] ➔ strength**
- **Load reduction * [Load multiplier * (Dead and Live and Wind or Earthquake)] ➔ strength**

Load Combinations

A load combination results when more than one load type acts on the structure. Design codes usually specify a variety of load combinations together with weighting factors for each load type in order to ensure the safety of the structure under different probable loading scenarios.

Ultimate Load Combinations

- **1.4D + 1.6L**
- **1.12D + 1.28L +/- 1.12T**
- **1.4D +/- 1.4 T**
- **1.4D + 1.6L + 1.6 E**
- **1.12D + 1.28L +/- 1.28W**
- **1.12D + αL +/- 1.0S**
- **0.9D + 1.6 E**
- **0.9D +/- 1.3W**
- **0.9D +/- 1.0S**

*

D = dead load
L = live load
E = load due to lateral pressure of soil and water in soil
W = wind load
S = earthquake load
T = temperature change, shrinkage, creep, differential settlement, etc.

Service Load Combinations

- 1.0D + 1.0L
- 1.0D +1.0L+/- 1.0W
- 1.0D + 0.833αL +/- 0.714S
- 0.9D +/- 1.0W
- 0.9D +/- 0.714S

For combinations including W or S, 25% increase shall be permitted in allowable beaning stress for soils or piles.

Dead Load Calculations

Slab

Own weight = 0.12 (thickness)*25 (specific weight)*1m*1m =3.00 KN/m^2

Beam

Own weight=0.25(width)*0.70(depth)* 25(specific weight)*1m=4.40 KN/m

Column

Own weight = 0.30 (width) * 0.70 (depth) * 3 (height) * 25 = 15.75 KN

Dead Load Calculations

Typical Flooring

6cm sand = 0.06 * 15 (specific weight) =0.90 KN/m^2

2cm mortar = 0.02 * 21 (specific weight) =0.42 KN/m^2

2cm marble = 0.02*28 (specific weight) =0.56 KN/m^2

Total = 1.88 KN/m^2

Choose flooring = 2.0 KN/ m^2

Dead Load Calculations

Bath Room Flooring

16cm sand =0.16* 15 (specific weight) = 2.40 KN/ m^2

2cm mortar = 0.02 * 21 (specific weight) =0.42 KN/m^2

2cm marble = 0.02*28 (specific weight) = 0.56 KN/m^2

Total = 3.38 KN/ m^2

Choose flooring = 3.50 KN/ m^2 (including moisture insulation)

Dead Load Calculations

Roof Flooring

6cm sand =0.06 *15 (specific weight) = 0.90 KN/ m^2

9cm mortar =0.09* 21 (specific weight) = 1.89 KN/ m^2

2cm marble = 0.02*28 (specific weight) =0.56 KN/ m^2

Total = 3.35 KN/ m^2

Choose flooring = 3.50 KN/ m2 (including moisture and thermal insulation)

Dead Load Calculations

Block Wall

Own weight = [0.25 (thickness)*16(specific weight)+0.05(plaster)*20 (specific weight)] * 2.3 (height)*1.0m=11.50 KN/m

- **Watch out for marble or granite cladding**
- **Watch out for case of partitions**

Dead Load Calculations

Fixtures (suspended or collateral loads)

Suspending Ceiling = 0.20

Lighting = 0.05

Elec. Conduits = 0.05

HVAC Ducting = 0.20

Total load = 0.50 KN/ m^2

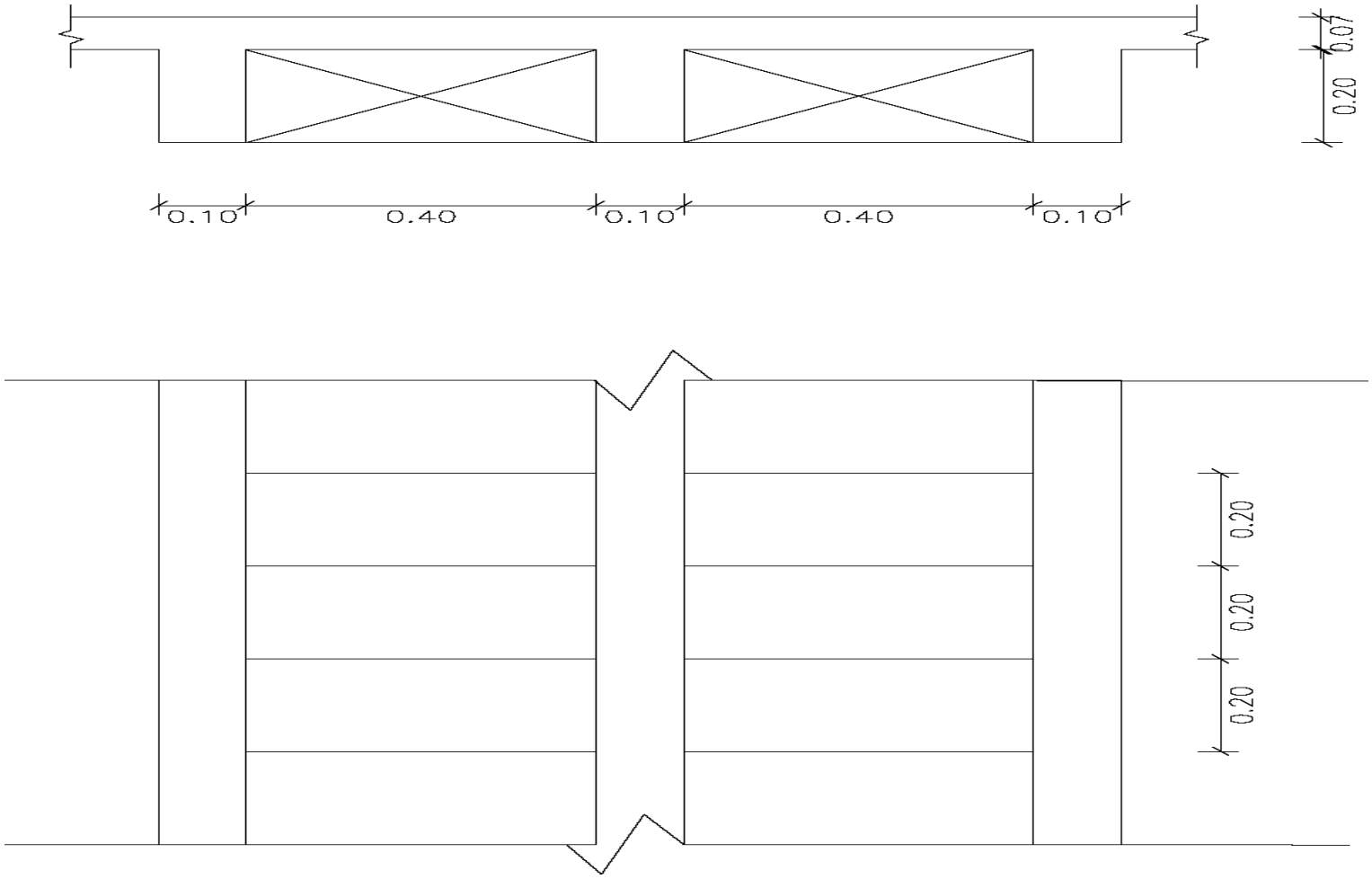
Dead Load Calculations

Steel Portal Frame

Dead weight ranges from **0.30 to 0.45 KN/m^2**

(includes steel, roofing material, and collateral loads)

Dead Loads Calculations for Hollow Blocks Slab



PLAN
(HOLLOW BLOCKS)

Dead Loads Calculations for Hollow Blocks Slab

Blocks 20*20*40cms (10 blocks/ m^2) = 1.90 KN/ m^2

7cm slab = 0.07 * 25 (specific weight) = 1.75 KN/ m^2

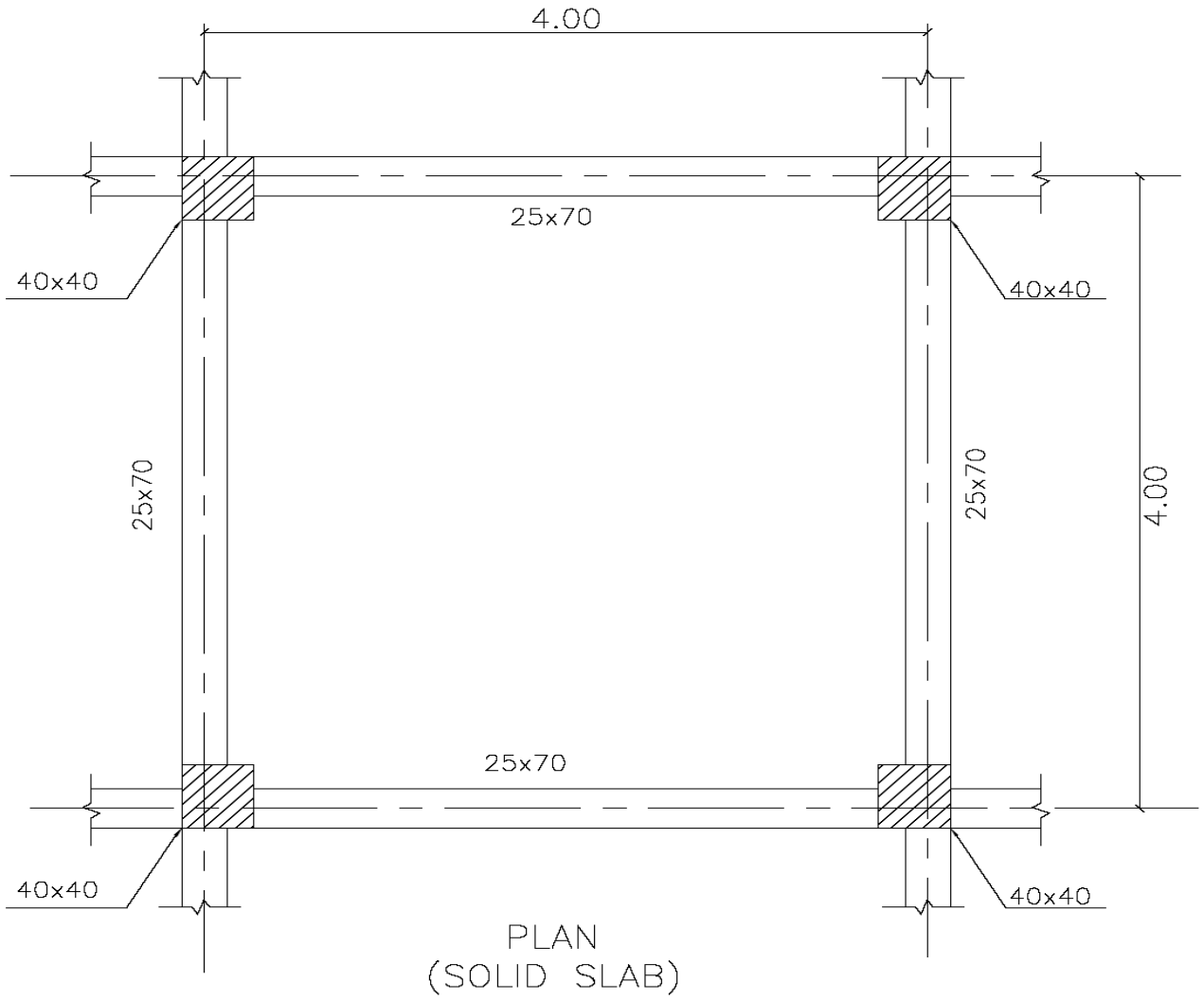
Ribs (joists) = 2*0.10*0.20*25 = 1.00 KN/ m^2

Flooring = 2.00 KN/ m^2

Total = 6.65 KN/ m^2

D.L/rib = 0.5 *6.65 = 3.33 KN/m

Dead Loads Calculations for Solid Slab



Dead Loads Calculations for Solid Slab

Minimum loads

Flooring = 2.0*4*4 = 32.00 KN

12cm slab = 0.12*25*4*4 = 48.00 KN

Beams (12*70) = 0.12*0.58*25*8 = 13.92 KN

Walls (12cm) = [0.12*16+0.05*20]*2.3*8 = 53.73 KN

Column (40*40*300) = 0.40*0.40*2.30*25 = 9.20 KN

Total =156.85 KN

D.L/m^2 = 156.85/(4*4) =9.80 KN/m^2≈10.00 KN/m^2

Dead Loads Calculations for Solid Slab

Maximum loads

Flooring	= 2.0*4*4	= 32.00 KN
12cm slab	= 0.12*25*4*4	= 48.00 KN
Beams (25*70)	= 0.25*0.58*25*8	= 29.00 KN
Walls (25cm)	= [0.25*16+0.05*20]*2.3*8	= 92.00 KN
Column (40*40*300)	= 0.40*0.40*2.30*25	= 9.20 KN

Total = 210.20 KN

D.L/m^2 = 210.2/(4*4) = 13.15 KN/m^2