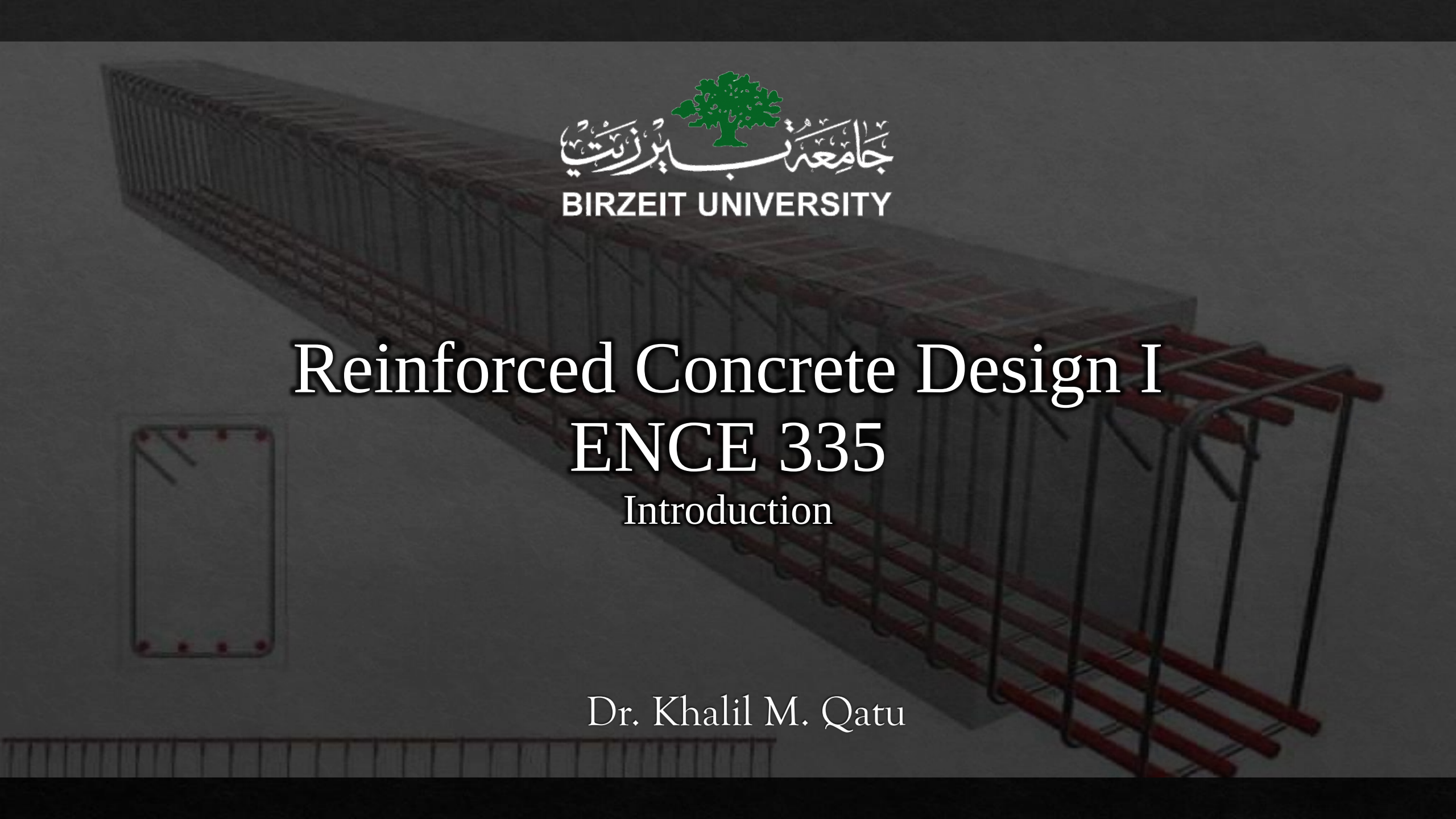

جامعة بيرزيت
BIRZEIT UNIVERSITY

Reinforced Concrete Design I
ENCE 335

Introduction

Dr. Khalil M. Qatu

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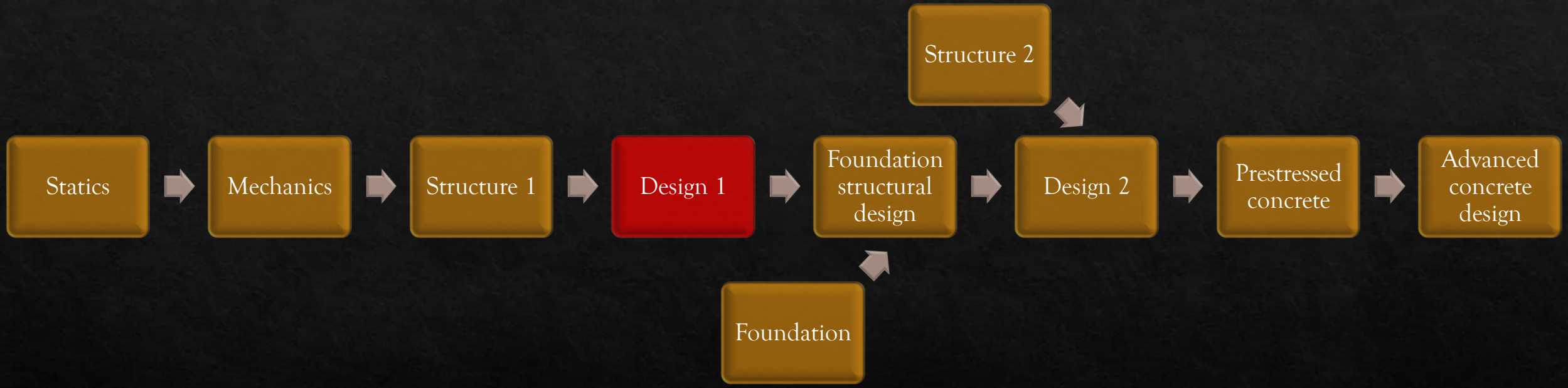
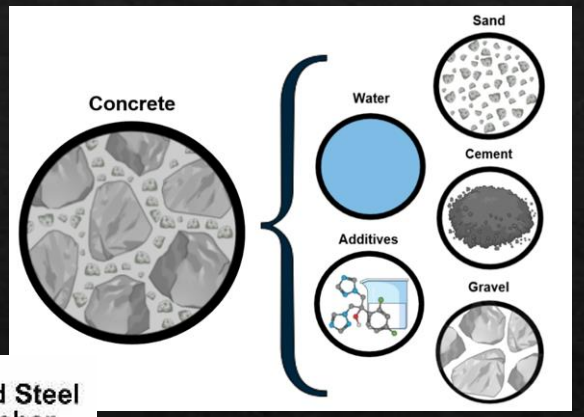
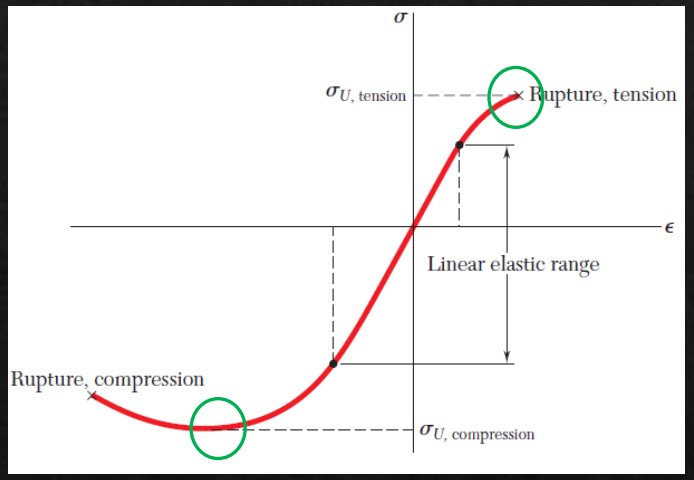

Statics
Mechanics
Structure 1
Design 1
Foundation structural design
Design 2
Prestressed concrete
Advanced concrete design
Structure 2
Foundation

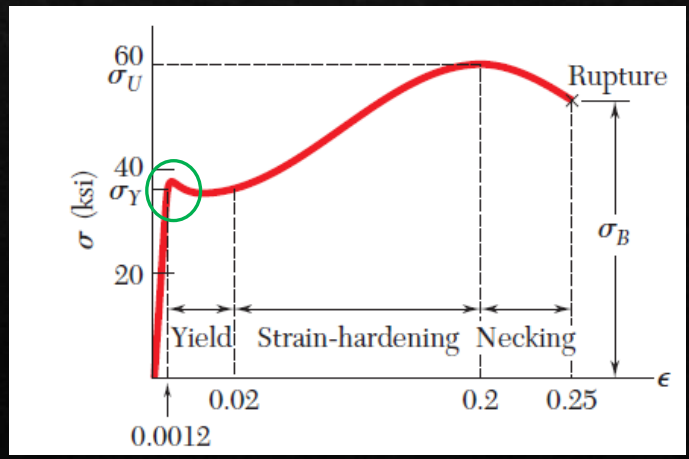
What is reinforced concrete (RC) ?

- Concrete is very durable and easy to construct material
- Relatively cheap
- High _____ Strength
- Strength range
  - Normal Strength 10 – 40 MPa
  - High strength 40-150 MPa
- BUT ??





- Steel is more expensive
- High _____ strength



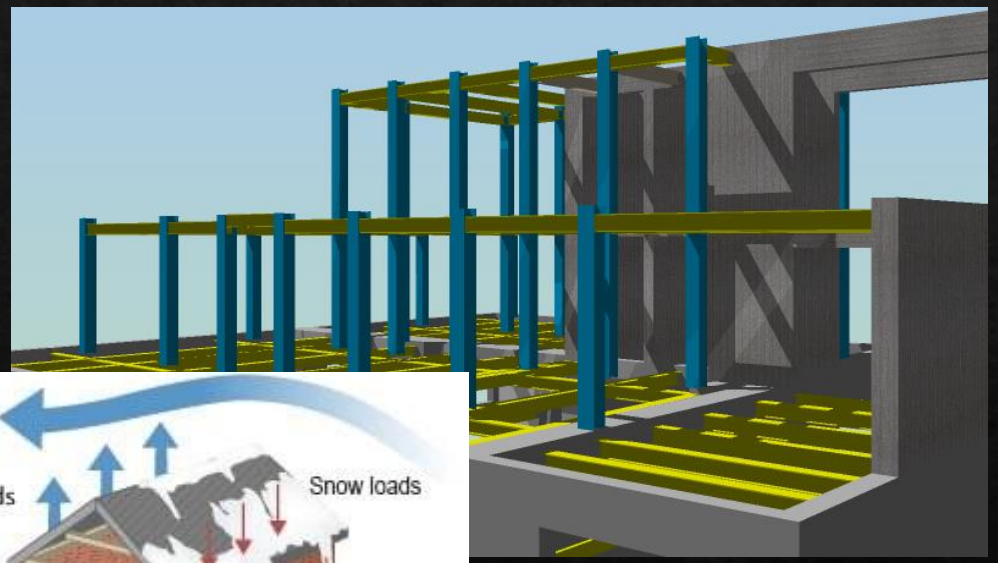
- Reinforced concrete takes the durability and affordability of concrete and high strength and ductility of steel
- Location of needed steel reinforcement ??

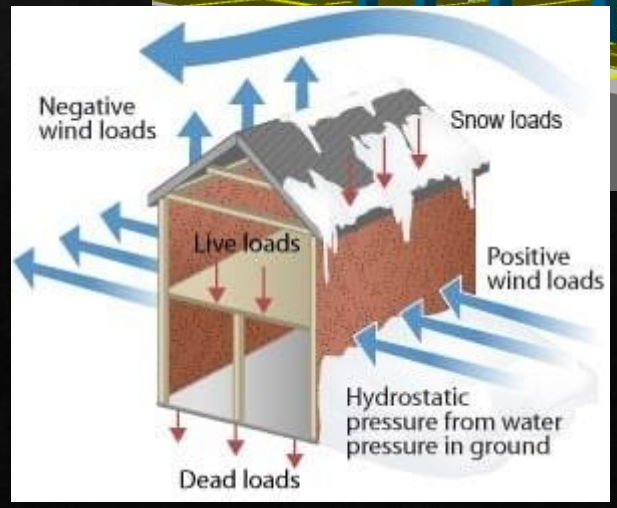
What is reinforced concrete ?

Product	ASTM Specification	Designation	Minimum Yield Strength, MPa (psi)	Minimum Tensile Strength, MPa (psi)
Reinforcing bars	A615	Grade 280 Grade 420 Grade 520	280 (40,000) 420 (60,000) 520 (75,000)	420 (60,000) 620 (90,000) 690 (100,000)
	A706	Grade 420	420 (60,000) [540 (78,000) maximum]	550 (80,000)[a]
	A996	Grade 280 Grade 350 Grade 420	280 (40,000) 350 (50,000) 420 (60,000)	420 (60,000) 550 (80,000) 620 (90,000)
	A1035	Grade 690	690 (100,000)	1030 (150,000)

What is Design ??

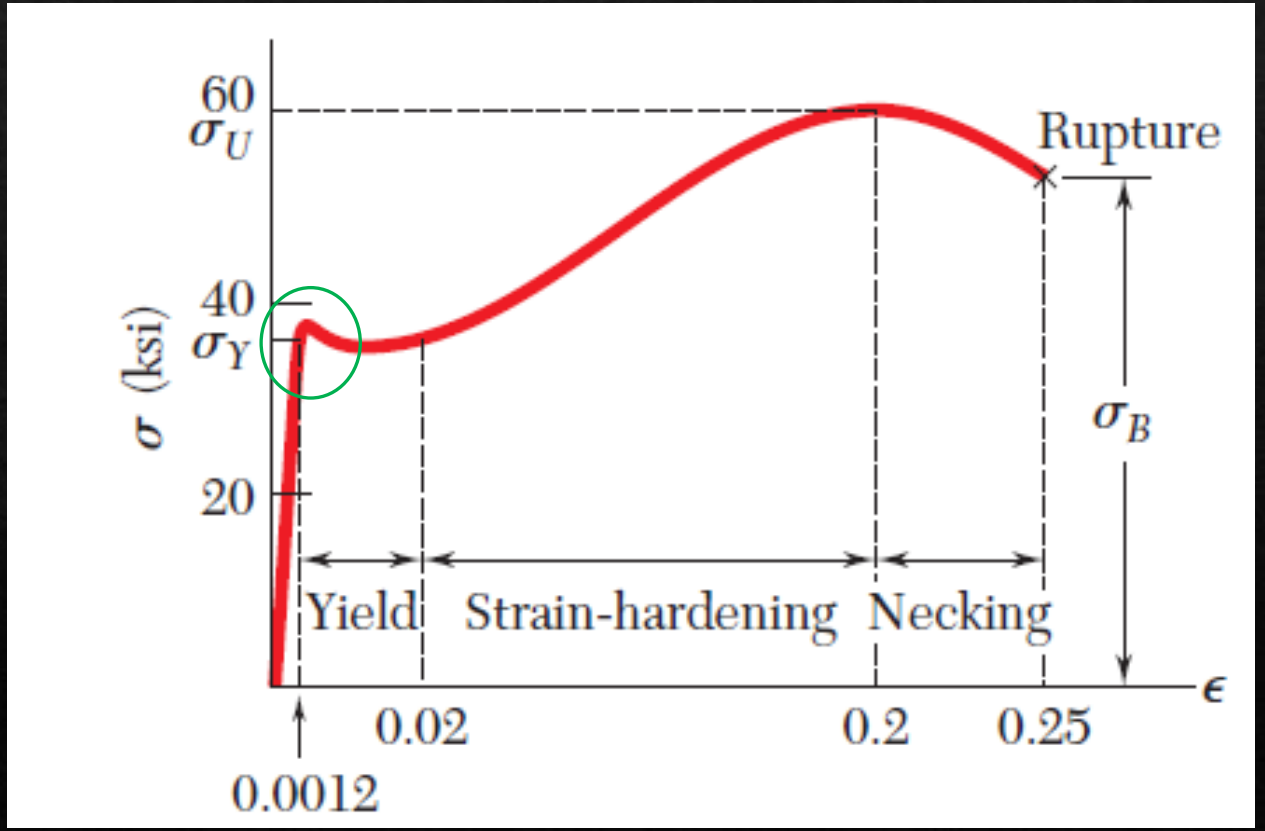
- Design is the process of devising a system and/or a component to meet desired demand
- In Civil Engineering :
  - The system:
  - The demand:
- Reinforced Concrete Design ??
  - Determine Geometry of concrete member
  - Amount and location of steel reinforcement





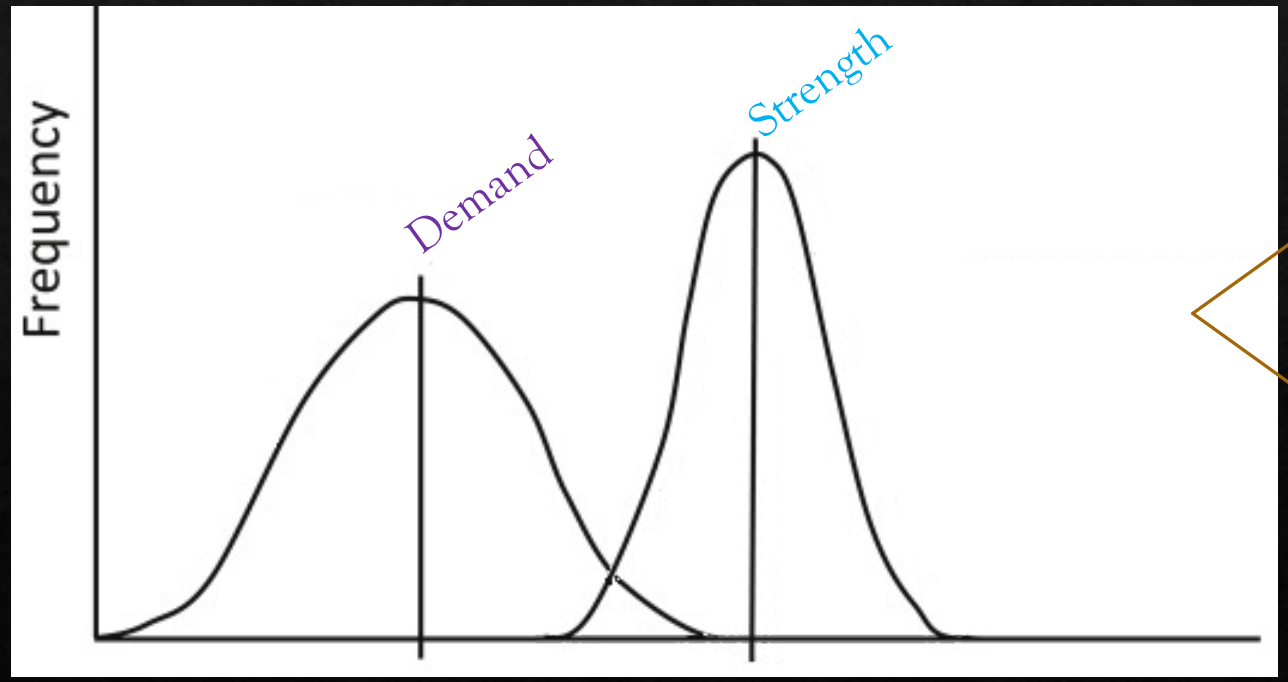
Design methods

- Allowable stress design (ASD)



Design methods

- Load and resistance factored design (LRFD)
  - This methods considers the variability in the applied loads (internal) and component strength



Design methods

- Load and resistance factored design (LRFD)
  - Load Factors and load combinations

Table 5.3.1—Load combinations

Load combination	Equation	Primary load
$U = 1.4D$	(5.3.1a)	D
$U = 1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$	(5.3.1b)	L
$U = 1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (1.0L \text{ or } 0.5W)$	(5.3.1c)	L_r or S or R
$U = 1.2D + 1.0W + 1.0L + 0.5(L_r \text{ or } S \text{ or } R)$	(5.3.1d)	W
$U = 1.2D + 1.0E + 1.0L + 0.2S$	(5.3.1e)	E
$U = 0.9D + 1.0W$	(5.3.1f)	W
$U = 0.9D + 1.0E$	(5.3.1g)	E

Note that factors are higher for loads with high variability

- After structural analysis we get ultimate internal forces in the member in consideration

M_u V_u P_u

Minimum uniformly distributed live loads

Occupancy or Use	Live Load, kN/m²
Apartments (see residential)	
Access floor systems	
Office use	2.4
Computer use	4.8
Armories and drill rooms	7.2
Assembly areas and theaters	
Fixed seats (fastened to floor)	2.9
Lobbies	4.8
Movable seats	4.8
Platforms (assembly)	4.8
Stage floors	7.2
Balconies (exterior)	4.8
On one and two-family residences only, and not exceeding 9.3 m²	2.9
Bowling alleys, poolrooms, and similar recreational areas	3.6
Catwalks for maintenance access	1.9
Corridors	
First floor	4.8
Other floors, same as occupancy served except as indicated	
Dance halls and ballrooms	4.8
Decks (patio and roof)	
Same as area served, or for the type of occupancy accommodated	
Offices	2.4
Corridors above first floor	3.8
Penal institutions	
Cell blocks	1.9
Corridors	4.8
Residential	
Dwellings (one and two-family)	
Uninhabitable attics without storage	0.5
Uninhabitable attics with storage	1.0
Habitable attics and sleeping areas	1.4
All other areas except stairs and balconies	1.9
Hotels and multifamily houses	
Private rooms and corridors serving them	1.9
Public rooms and corridors serving them	4.8
Reviewing stands, grandstands, and bleachers[b]	
Roofs	
Ordinary flat, pitched, and curved roofs	1.0
Roofs used for promenade purposes	2.9
Roofs used for roof gardens or assembly purpose	4.8
Roofs used for other special purposes[e]	
Awnings and canopies	
Fabric construction supported by a lightweight rigid skeleton structure[f]	0.25
All other construction	1.0
Dining rooms and restaurants	4.8
Dwellings (see residential)	
Fire escapes	4.8
On single-family dwellings only	1.9
Garages (passenger cars only)	1.9
Trucks and buses[d]	
Grandstands (see stadium and arena bleachers)	
Gymnasiums, main floors and balconies[b]	4.8
Hospitals	
Operating rooms, laboratories	2.9
Patient rooms	1.9
Corridors above first floor	3.8
Hotels (see residential)	
Libraries	
Reading rooms	2.9
Stack rooms[c]	7.2
Corridors above first floor	3.8
Manufacturing	
Light	6.0
Heavy	12.0
Marquees and canopies	3.6
Office buildings	
File and computer rooms shall be designed for heavier loads based on anticipated occupancy	
Lobbies and first-floor corridors	4.8
Schools	
Classrooms	1.9
Corridors above first floor	3.8
First-floor corridors	4.8
Sidewalks, vehicular driveways, and yards subject to trucking[d]	12.0
Stadiums and arenas	
Bleachers[b]	4.8
Fixed seats (fastened to floor)[b]	2.9
Stairs and exit ways	4.8
One and two-family residences only	1.9
Storage areas above ceilings	1.0
Storage warehouses (shall be designed for heavier loads if required for anticipated storage)	
Light	6.0
Heavy	12.0
Stores	
Retail	
First floor	4.8
Upper floors	3.6
Wholesale, all floors	6.0
Walkways and elevated platforms (other than exitways)	2.9
Yards and terraces, pedestrians	4.8

Design methods

- Load and resistance factored design (LRFD)
  - Strength reduction factors (ϕ)

$$\phi M_n \qquad \phi V_n \qquad \phi P_n$$

  - We get Nominal strength is calculated using concepts from Statics & Mechanics of Materials

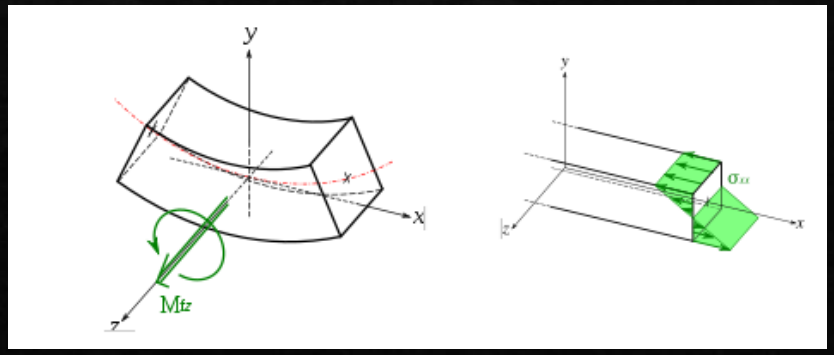


Table 21.2.1—Strength reduction factors ϕ

Action or structural element		ϕ	Exceptions
(a)	Moment, axial force, or combined moment and axial force	0.65 to 0.90 in accordance with 21.2.2	Near ends of pretensioned members where strands are not fully developed, ϕ shall be in accordance with 21.2.3.
(b)	Shear	0.75	Additional requirements are given in 21.2.4 for structures designed to resist earthquake effects.
(c)	Torsion	0.75	—
(d)	Bearing	0.65	—
(e)	Post-tensioned anchorage zones	0.85	—
(f)	Brackets and corbels	0.75	—
(g)	Struts, ties, nodal zones, and bearing areas designed in accordance with strut-and-tie method in Chapter 23	0.75	—
(h)	Components of connections of precast members controlled by yielding of steel elements in tension	0.90	—
(i)	Plain concrete elements	0.60	—
(j)	Anchors in concrete elements	0.45 to 0.75 in accordance with Chapter 17	—

Design CODE

- In our region we use the ACI code 318-14 (or 19??)
  - Load Factors
  - Strength requirements
  - Serviceability requirements
  - Reinforcement limits
  - Reinforcement detailing

CHAPTER 3—REFERENCED STANDARDS
CHAPTER 4—STRUCTURAL SYSTEM REQUIREMENTS
CHAPTER 5—LOADS
CHAPTER 6—STRUCTURAL ANALYSIS
CHAPTER 7—ONE-WAY SLABS
CHAPTER 8—TWO-WAY SLABS
CHAPTER 9—BEAMS
CHAPTER 10—COLUMNS
CHAPTER 11—WALLS
CHAPTER 12—DIAPHRAGMS
CHAPTER 13—FOUNDATIONS
CHAPTER 14—PLAIN CONCRETE
CHAPTER 15—BEAM-COLUMN AND SLAB-COLUMN JOINTS
CHAPTER 16—CONNECTIONS BETWEEN MEMBERS
CHAPTER 17—ANCHORING TO CONCRETE
CHAPTER 18—EARTHQUAKE-RESISTANT STRUCTURES
CHAPTER 19—CONCRETE: DESIGN AND DURABILITY REQUIREMENTS
CHAPTER 20—STEEL REINFORCEMENT PROPERTIES, DURABILITY, AND EMBEDMENTS
CHAPTER 21—STRENGTH REDUCTION FACTORS
CHAPTER 22—SECTIONAL STRENGTH
CHAPTER 23—STRUT-AND-TIE MODELS
CHAPTER 24—SERVICEABILITY REQUIREMENTS
CHAPTER 25—REINFORCEMENT DETAILS
CHAPTER 26—CONSTRUCTION DOCUMENTS AND INSPECTION
CHAPTER 27—STRENGTH EVALUATION OF EXISTING STRUCTURES