University of Global Village (UGV), Barishal

Concrete Mix Design

Content of Laboratory Course

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Program: B.Sc. in CE

BASIC COURSE INFORMATION

Course Title	Concrete Mix Design
Course Code	CE 0732-2104
Credits	01
CIE Marks	30
SEE Marks	20
Exam Hours	2 hours (Semester Final Exam)
Level	3rd Semester

Concrete Mix Design

COURSE CODE: CE 0732-2104

CREDIT:01

TOTAL MARKS:50

CIE MARKS: 30

Semester End Exam Hours 2

SEE MARKS: 20

Course Learning Outcomes (CLOs): After completing this course successfully, the students will be able to-

CLO 1	**Understand** concepts of Structural Design of Reinforced concrete members.
CLO 2	**Analyze** various structural components of slab bridge, balanced cantilever bridge and PC girder bridge.
CLO 3	**Develop** intellectual communication skills through working in groups in performing the laboratory experiments/field supervisions and by interpreting the experimental results.
CLO 4	**Generate** the detailing of various structural components of buildings and bridges.

SL	Content of Course	Hrs	CLOs
1	Basic concepts of coarse aggregate, fine aggregate and cement	10	CLO1
2	Concrete Mix Design Math Solved	20	CLO3
3	Materials purchasing and Mixing	20	CLO2, CLO4
4	Determination of Slump Value	5	CLO1, CLO3
5	Details of Bridges	10	CLO1
6	Practice, Review/Reserved Day, Lab Report Assessment, Self study	10	CLO3
7	Lab Test, Viva, Quiz, Overall Assessment, Skill Development Test (Competency)	10	CLO1

Text Book:

1. Design of Concrete Structures by Arthur H. Nilson, David Darwin, Charles W. Dolan (Mc Graw Hill) – 13th edition.
2. Design of Concrete Structures by Arthur H. Nilson – 7th edition.
3. Design of Reinforced Concrete by Jack C. McCormac, Russell H. Brown – 9th edition
4. Design of Prestressed Concrete Structures by T. Y. Lin and Ned H. Burns
5. Design of Modern Highway Bridges by Narendra Tally
6. Bangladesh National Building Code (BNBC)-2012
7. AASHTO LRFD Bridge: Design Specifications 2012

ASSESSMENT PATTERN

CIE- Continuous Internal Evaluation (30 Marks)

SEE- Semester End Examination (20 Marks)

SEE- Semester End Examination (40 Marks) (should be converted in actual marks (20))

Bloom's Category	**Tests**
Remember	**05**
Understand	**07**
Apply	**08**
Analyze	**07**
Evaluate	**08**
Create	**05**

CIE- Continuous Internal Evaluation (100 Marks) (should be converted in actual marks (30))

Bloom's Category Marks (out of 100)	Lab Final (30)	Lab Report (10)	**Continuous lab performance** (30)	Presentation & Viva (10)	External Participation in Curricular/**Final Project Exhibition** (10)
Remember/**Imitation**	05		05	02	Attendance 10
Understand/**manipulation**	05	05	05	03	
Apply/**Precision**	05		05		
Analyze/**Articulation**	05		05		
Evaluate/**Naturalisation**	05	05	05		
Create	05		05	05	

Couse plan specifying content, CLOs, teaching learning and assessment strategy mapped with CLOs

Week	Topic	Teaching-Learning Strategy	Assessment Strategy	Corresponding CLOs
1-2	Basic concepts of coarse aggregate, fine aggregate and cement	Lecture, discussion, Experiment	Quiz, Lab Test	CLO1
3-5	Concrete Mix Design Math Solved	Oral Presentation, Project Exhibition	Lab Report Assessment, viva	CLO3
6-9	Materials purchasing and Mixing	Presentation, Field visit	Skill Development Test	CLO2, CLO4
10	Determination of Slump Value	Lecture, discussion, Experiment, Demonstration	Quiz, Lab Test	CLO1, CLO3
11-13	Details of Bridges	Oral Presentation, Project Exhibition	Lab Report Assessment, viva	CLO1
14-15	Practice, Review/Reserved Day, Lab Report Assessment, Self study	Presentation, Field visit	Skill Development Test	CLO3
16-17	Lab Test, Viva, Quiz, Overall Assessment, Skill Development Test (Competency)	Lecture, discussion, Experiment	Quiz, Lab Test	CLO2, CLO4

Basic concepts of coarse aggregate, fine aggregate and cement

Week 1-2

Pages 8-57

Contents

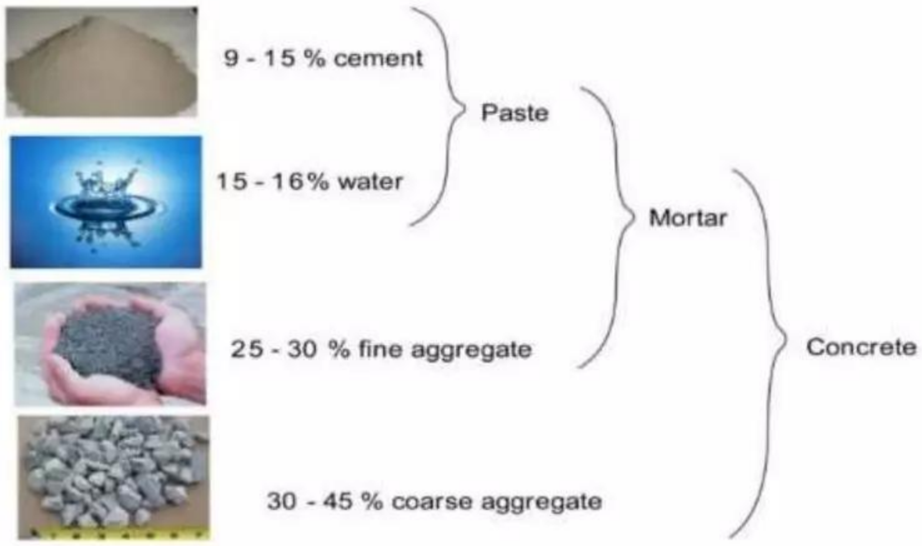
Introduction to Concrete

- Concrete is one of the most commonly used building materials.
- Concrete is a composite material made from several readily available constituents (aggregates, sand, cement, water).
- The cement and water form a paste or gel which coats the sand and aggregate.
- Concrete is a versatile material that can easily be mixed to meet a variety of special needs and formed to virtually any shape.
- Concrete's versatility, durability, sustainability, and economy have made

  it the world's most widely used construction material.

Constituents of Concrete

- Concrete is a mixture of cement (9 – 15%), water (15 – 16%), fine aggregate (sand, 25 – 30%), coarse aggregate (gravel or crushed rocks, 30 – 45%), air (2 – 6%) and chemical admixtures in which the cement and water have hardened by a chemical reaction – hydration – to bind the nearly (non - reacting) aggregate.



Cement

- A cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together.
- Cement contains limestone, clay, rock and iron ore blended and heated to 1200 to 1500 C°.
- The resulting product "clinker" is then ground to the consistency of powder. Gypsum is added to control setting time.

Fine Aggregate (Sand)

- This component can be natural sand or crushed stone, and represents particles smaller than 4.0 mm.
- Generally accounts for 25%-30% of the mixture.
- For the purpose of construction Pit sand, River sand, Sea sand, and manufactured sand are used in which pit sand is most common for concrete.

Course Aggregate

- May be either gravel or crushed stone comprised of particles greater than 4mm.
- Makes up 30%-45% of the mixture.
- These are Rounded, Angular, Flaky and Elongated in shape. Round aggregate give better workability and angular aggregate is very suitable for high strength concrete.

Water

- Mixing water is the quantity of water that comes in contact with cement, impacts slump of concrete and is used to determine the water to cementitious materials ratio (w/cm) of the concrete mixture.
- Strength and durability of concrete is controlled to a large extent by its w/cm.

Abrams' Law

- The law states the strength of a concrete mix is inversely related to the mass ratio of water to cement.
- As the water content increases, the strength of concrete decreases.

Admixtures

Admixtures are the materials added to alter the properties of concrete, it includes:

- Air entraining admixtures: add microscopic air bubbles to the concrete, enhancing its resistance to freeze/thaw cycles and makes the concrete easier to finish.
- Set accelerators: speed the set-time of the mixture, enabling finishing operations to begin sooner, useful during cold weather pours.
- Set retarders: have the opposite effect, slowing the set and enabling delivery to distant sites and finishing during hot weather.
- Water reducers: used to reduce the amount of water required to produce a given slump. They also provide a ball bearing effect, making the concrete easier to finish, and produce better cement hydration.

Manufacturing of Concrete

- **STAGES OF CONCRETE PRODUCTION:**

Batching → Mixing → Transporting → Placing → Compacting → Finishing → Curing

Batching

Measurement of different material for making concrete.

1. Weigh Batching

- Material are taken by weighing.
- Used for large construction.
- More precise method.
- Need skilled workers.

2. Volume Batching

- Material are taken by volume .
- Used for small construction
- Less precise method.
- No need to required skilled workers

Mixing

To make concrete homogeneous, uniform in color and consistency.
It is essential for production of uniform concrete.

1. Hand Mixing

- Mixing is done by manually labours and method is adopted for small construction works.
- Requirement of cement is more than machine mixing(10%).
- Normally the mixing time is about 3 minutes.

2. Machine Mixing

- Mixing is carried out in a rotating drum.
- This method is adopted for large construction works.
- Normally the mixing time is about 2 minutes.

Transporting

- It is transferring of concrete from mixing plant to the construction site.
- The homogeneity obtained at time of mixing should be maintained while transporting to final place of deposition.
- The wet mix should be transported before it becomes stiff.

Methods of Transportation:

- Mortar Pan
- Wheel Barrow, Hand Cart
- Crane , Bucket and Rope way
- Truck Mixer and Dumpers
- Belt Conveyor
- Transit Mixer
- Pump and Pipe line

Placing

- It is a process of depositing a fresh concrete on its final position.
- Before placing concrete form work must be checked for its rigidity and cleanliness.

Methods of Placing:

- Placing concrete within large earth mould or timber plank formwork.
- Placing concrete in layers within timber or steel shutters.
- Placing concrete within earth mould.
- Placing concrete within usual formwork .
- Placing concrete under water.

Compaction

- It is the process of removing entrapped air bubble from the fresh concrete and improving the packaging of aggregates to form dense concrete.
- If air bubble present in structure or placed concrete then honey combing or blow holes are caused in concrete.
- It effects strength of concrete.

Methods of Compaction:

- Hand compaction
- Compaction by Vibration
- Compaction by Pressure and Jolting
- Compaction by Spinning

Finishing

- It is process of levelling, smoothing, compacting of fresh concrete or recently place concrete to produce desirable appearance.
- It make concrete attractive and serviceable.

Steps of Concrete finishing:

1. Screening.
2. Floating.
3. Troweling.

Curing

- It is maintenance of moisture and temperature of freshly placed concrete to ensure proper hardening of concrete for attainment of desirable strength and durability.

Method of Curing:

1. Water curing.

- Immersion.
- Ponding.
- Spraying.
- Wet covering.

2. Steam curing

3. Self curing/ membrane curing.

Different Types of Concrete.

- A brief account of different types of concrete is given below.
- Plain or Ordinary Concrete.
- Lightweight Concrete.
- High-Density Concrete.
- Reinforced Concrete.
- Precast Concrete.
- Prestressed Concrete.
- Air Entrained Concrete.
- Glass Concrete.

Plain or Ordinary Concrete

- It is one of the most commonly used types of concrete.
- In this type of concrete, the essential constituents are cement, sand and coarse aggregates designed, and mixed with a specified quantity of water.
- The ratio of essential constituents may be varied within wide limits.
- A very commonly used mix design, commonly known as Nominal Mix Design, is 1:2:4.
- Plain concrete is mostly used in the construction of pavements and in buildings, where very high tensile strength is not required.

Lightweight Concrete

- Any types of concrete having a density less than 1920 Kg/m3 is classed as lightweight concrete.
- Various types of aggregates that are used in the manufacturing of lightweight concrete include natural materials like pumice and scoria, artificial materials like expanded shales and clays and processed materials like perlite and vermiculite.
- The single important property of lightweight concrete is its very low thermal conductivity.
- Lightweight Concretes are used, depending upon their composition, for thermal insulation, for protecting steel structures, they are also used in long span bridge decks, and even as building blocks.

High-density Concrete

- This type of concrete is also called heavy weight concrete.
- In this concrete type, the density varies between 3000-4000 Kg/m3.
- These types of concrete are prepared by using high density crushed rocks as coarse aggregates.
- Among such materials, Barytes is the most commonly used material, which has a specific gravity of 4.5.
- They are mostly used in atomic power plants and other similar structures because it provides good protection from all type of radiations.

Reinforced Concrete

- In this concrete type, steel in various forms is used as reinforcement to give very high tensile strength.
- In fact, it is because of the combined action of plain concrete (having high compressive strength) and steel (having high tensile strength).
- The steel reinforcement is cast in the form of rods, bars, meshes, and all conceivable shapes.
- Every care is taken to ensure the maximum bond between the reinforcement and the concrete during the setting and hardening process.
- The resulting material (RCC) is capable of bearing all types of stress in any type of construction. RCC is the most important concrete type.

Precast Concrete

- This term refers to numerous types of concrete shapes that are cast into molds either in a factory or at the site.
- They are not used in construction until they completely set and hardened in a controlled condition.
- Precast Concrete are; precast poles, fence posts, concrete lintels, staircase units, concrete blocks, and cast stones, etc.
- Perfect proportioning of the ingredients of concrete.
- Thorough mixing of the cement, aggregates, and water to obtain the mix of the desired design and consistency.

Prestressed Concrete

- It is a special type of reinforced concrete in which the reinforcement bars are tensioned before being embedded in the concrete.
- Such tensioned wires are held firm at each end while the concrete mix is placed.
- The result is that when the concrete sets and hardens, the whole concrete members, so the cast is put into compression.
- This sort of arrangement makes the lower section of the reinforced concrete also stronger against tension, which is the principal cause of the development of tension cracks in un-tensioned reinforced concrete.
- The risk of development of tension cracks in the lower sections of beams is considerably reduced.

Air Entrained Concrete

- It is a specially prepared plain concrete in which air is entrained in the form of thousands of uniformly distributed particles.
- The Volume of air thus, entrained may range between 3-6 percent of the concrete.
- The air entrainment is achieved by adding a small quantity of foaming or gas-forming agents at the mixing stage.
- Fatty acids, fatty alcohols, and resins are some common air entraining agents.
- Air entrained concrete is more resistant to;

1. Scaling.
2. Deterioration due to freezing and thawing.
3. Abrasion.

Glass Concrete

- When the recycled glass is used as an aggregate in the concrete, this type of concrete is known as Glass Concrete.
- They provide better thermal insulation and also have a great appealing look as compared to other types.

Properties of Concrete

- Compressive Strength
- Tensile Strength
- Workability
- Durability
- Segregation
- Bleeding
- Modulus of Elasticity
- Poisson Ratio
- Creep
- Shrinkage
- Harshness

Compressive Strength

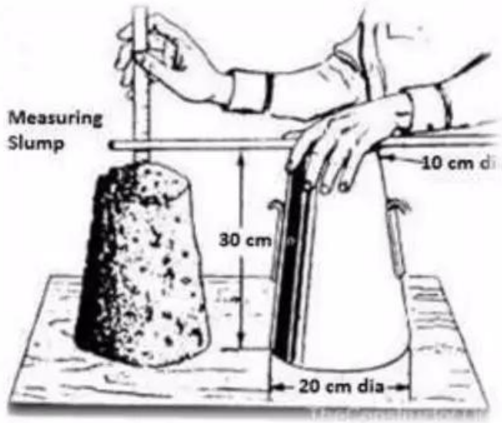
- Concrete has very high compressive strength.
- Cubes, cylinders, and prisms are compression testing specimens used to determine the compressive strength on testing machines.
- The specimens are casted, cured and tested as per standards prescribed.
- The cubes have a side of length 100 mm or 150 mm, the cylinders are having diameter 150 mm and height 300 mm and the prisms used have 100 mm *100mm*500mm in size.

Tensile Strength

- Concrete has very low tensile strength. The tensile strength affects the extent and width of crack in the structure.
- A good concrete should have tensile strength 1/10th of compressive strength.
- The tensile strength can be calculated by split cylinder method.

Workability

- Workability is the property determining the ease with which concrete can be mixed, transported, placed, and compacted without any segregation.
- It depends upon number of factors like quantity of water, mixing proportion, grading, shape and size of aggregate, admixture, time.
- Slump test can be carried out for the determination of workabilility of Concrete.



Durability

- The property of concrete which determines whether a structure will withstand or not the condition for which it has been designed without deterioration over a period of years.
- There may be lack of durability due to either internal agent within the concrete or the external agent from the environment.

Segregation

- The separation of coarse aggregate from the rest of the concrete mass.
- The quality of concrete is seriously affected due to segregation.
- It may happen due to lack of sufficient quantity of finer particles in concrete or due to throwing of concrete from greater height at the time of placing.
- Segregation causes loss of homogenity , reduces the bond between reinforcement and concrete.

Bleeding

- Bleeding refers to the appearance of water along with cement particles on the surface of laid concrete.
- It may occur due to excessive quantity of water in the mix or due to compaction.
- It can be reduced by adding more cement and fine aggregate, and also by reducing water in the mix.

Modulus of Elasticity

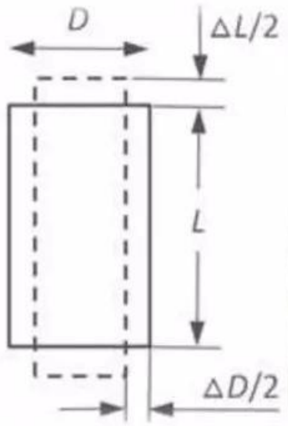
- It is the ratio of stress to the strain
- It is an very important property required to determine deflections of structural concrete members
- As per IS 456: 2000 the tensile strength of concrete can be calculated from characteristic cube compressive strength.

$$E_c = 5000\sqrt{F_{ck}}\ N/mm^2$$

- where F_{ck} is Characteristic Compressive Strength of concrete cube at the rate 28 days.

Poisson Ratio

- It is the ratio of lateral strain and longitudinal strain.
- The concrete when compressed in one direction tens to expand in the other two directions perpendicular to the direction of compression.
- The value of Poisson ratio may vary between 0.1 for high strength concrete and 0.2 for weak concrete.



Creep

- It is the gradual increase in strain in a member with time which has been subjected under constant load or stress.
- Creep strain is much larger than the elastic strain on loading.
- The factors which affect creep are curing, aggregates used, magnitude and duration of constant loading and age of concrete.
- Creep Cracks In Concrete Walk Way.

Shrinkage

- Shrinkage is a property of decrease in volume of concrete due to loss of moisture and hardening of concrete at different stages.
- It can lead to cracks.
- The factors which causes shrinkage are aggregate size, decrease in ambient relative humidity, environment condition.

Harshness

- It is the roughness on the surface of concrete ever after certain amount of troweling.
- It is caused by the presence of lesser quantity of fine aggregate, less cement mortar, and also due to use of poorly graded aggregates.

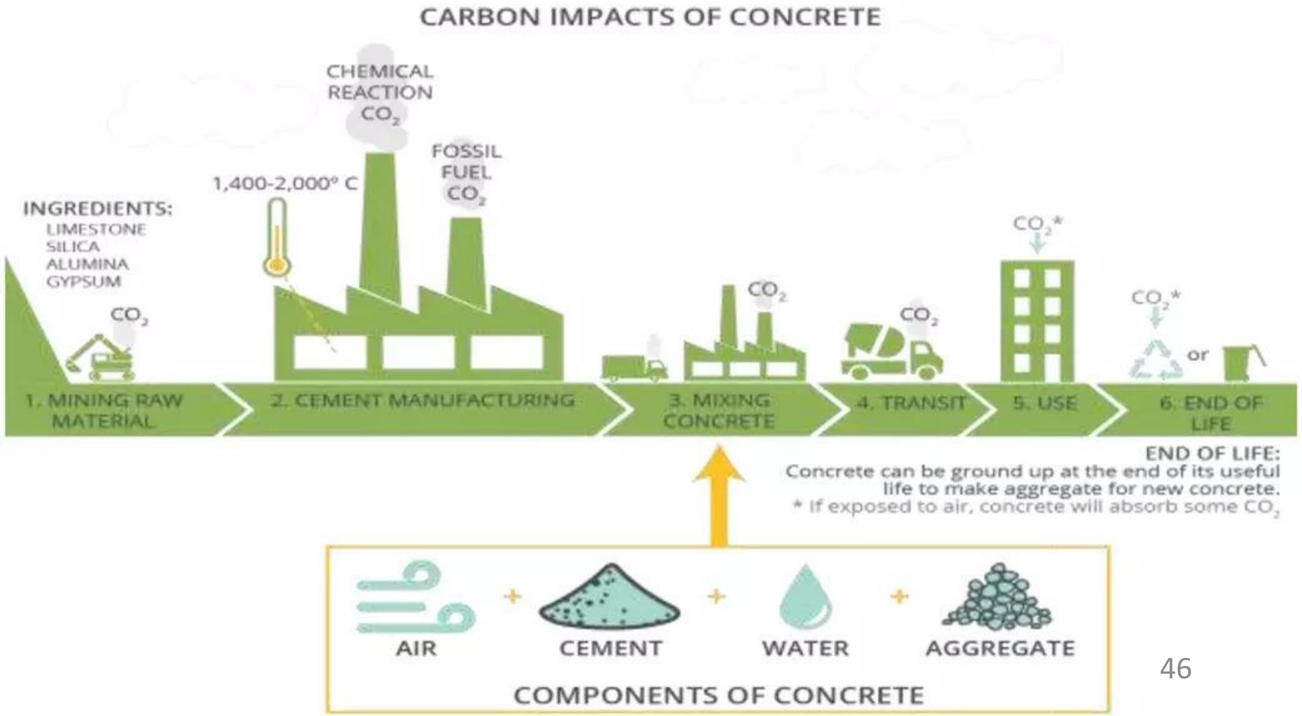
Advantages of Concrete

Concrete is so integral to our communities because it is the only building material that cost-effectively delivers:

- The lowest carbon footprint for a structure or pavement over its lifecycle.
- Unparalleled strength, durability, longevity and resilience.
- Maximized energy efficiency via thermal mass.
- Durability in any environment.
- A building material that doesn’t burn, rust or rot.
- Safety and security.
- Versatility – It can be molded into any shape, colour or pattern imaginable.
- No off-gas.

Lowest Carbon Footprint

- Carbon emission reduction up to 75% in comparison to conventional products Accelerated early strength.
- Improved durability due to the formation of nano-CaCO3 crystals.
- Low cement and low embodied energy.
- Steam can be replaced by carbon dioxide.



Strong, Durable and Low Maintenance

- Durability is the ability to last a long time without significant deterioration.
- A durable material helps the environment by conserving resources, reducing wastes and the environmental impacts of repair and replacement.
- Concrete durability is defined as the concrete ability to resist weathering actions, chemical attack and abrasion while maintaining its desired engineering properties.
- Strength of the concrete is a main structural requirement that determines the capacity of the concrete to support the designed loads (weight, force, etc...) without breaking and maintain the structure stability and integrity.
- Strength is the property generally specified in concrete design and quality control.

Resilient

- Concrete doesn’t burn, rust, or rot. It is resistant to fire, wind, water, vibrations, and earthquakes, keeping people safer and reducing costs. In the aftermath of extreme weather events, concrete structures have proven to be the most resilient.
- Of all construction materials for buildings and other infrastructure, concrete is by far the most disaster-resilient.
- Buildings and structures with resilient design and materials are not only better able to recover following disasters, such as hurricanes or fires, they are also the new “green” buildings.

Energy-Efficient

- Concrete's ability to store energy (its thermal mass) helps moderate interior temperature conditions, reducing a building's heating and cooling demands over its service life by up to 8.
- Used in combination with technologies such as radiant floors and geothermal or hydronic heating and cooling systems, concrete enables energy efficiency improvements of 70% over the Model National Energy Code for Building.

Cost-Effective

- There is a need to adopt cost-effective construction methods either by upgradation of traditional technologies using local resources or applying modern construction materials and techniques with efficient inputs leading to economic solutions.
- This has become the most relevant aspect in the context of the large volume of housing to he constructed in both rural and urban areas and the consideration of limitations in the availability of resources such as building materials and finance.

100% Recyclable

- The research with recycled: aggregate, cement mortar and powder was carried out.
- The use of 100% recycled aggregate and 25% recycled powder is possible.
- Recycled cement mortar can be used as an active ingredient in sand-lime products.
- The recovery of high quality coarse aggregates and useful cement mortar (fine fraction) is the subject of research by scientists all over the world.

Produced Locally

- Concrete is typically manufactured within 160 kilometers of a project site, using local resources. This greatly minimizes shipping and pollution and makes a significant contribution to the local economy.
- Small industries generate local employment, halt rural exodus and are conducive to the emergence of regional poles of economic development.
- The local production of construction materials contributes in the field of construction industry which ultimately increases the GDP of the country.

Uses of Concrete

- Residential buildings
- Streets – pavement – driveways
- Concrete Dams
- Concrete Bridges
- Commercial buildings





Uses of Concrete

- Culverts and sewers
- Concrete Floating Docks
- Concrete Parking
- Fences
- Foundations





Tests for Concrete

Various test on concrete

- Specific gravity
- Bulk Density
- Fineness Modulus
- Moisture content
- Water Absorption
- Bulking of sand

Workability tests on concrete

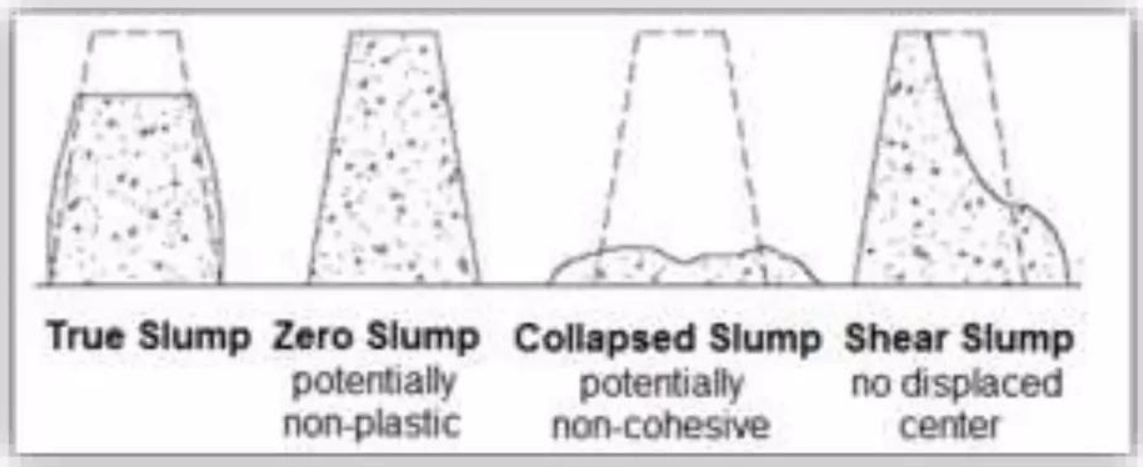
- Slump test
- Compaction Factor test
- Vee-Bee test

Strength tests on concrete

- Compressive strength (Cube and Cylinder)
- Split Tensile strength
- Flexural strength
- Abrasion resistance

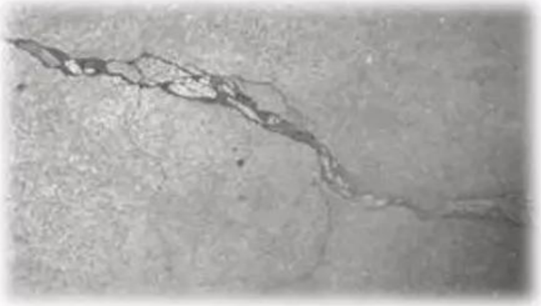
Slump Test

- The concrete slump test measures the consistency of fresh concrete before it sets.
- It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows.
- It can also be used as an indicator of an improperly mixed batch.



Innovations…

- Self-healing concrete
- 3D-printed concrete
- Eco-friendly concrete
- Pervious concrete
- Martian concrete



Concrete Mix Design Math

Week 3-5

Pages 59-79

Workability of Concrete

- The ease with which concrete mixes can be compacted as completely as possible while using the lowest possible water/cement ratio.

OR

- *Workability* is the ability of a fresh (plastic) concrete mix to fill the form/mold properly with the desired work (vibration) and without reducing the concrete's quality

Water for Lubrication

- The function of water is also to lubricate the concrete so that the concrete can be compacted with specified effort forthcoming at the site of work.
- The lubrication required for handling concrete without segregation, for placing without loss of homogeneity, for compacting with the amount of efforts forth-coming and to finish it sufficiently easily, the presence of a certain quantity of water is of vital importance.

Factors Affecting Workability

- Water Content
- Mix Proportions
- Size of Aggregates
- Shape of Aggregates
- Surface Texture of Aggregate
- Grading of Aggregate
- Use of Admixtures.

Water content or Water Cement Ratio

- More the water cement ratio more will be workability of concrete. Since by simply adding water the inter particle lubrication is increased.
- High water content results in a higher fluidity and greater workability. Increased water content also results in bleeding. another effect of increased water content can also be that cement slurry will escape through joints of formwork.
- More water can be added, provided a correspondingly higher quantity of cement is also added to keep the water/cement ratio constant, so that the strength remains the same.

Mix Proportions

- The higher the aggregate/cement ratio, less quantity of paste is available for providing lubrication, per unit surface area of aggregate and hence the mobility of aggregate is restrained.
- On the other hand, in case of rich concrete with lower aggregate/cement ratio, more paste is available to make the mix cohesive and fatty to give better workability.

Size of Aggregate & Surface Texture

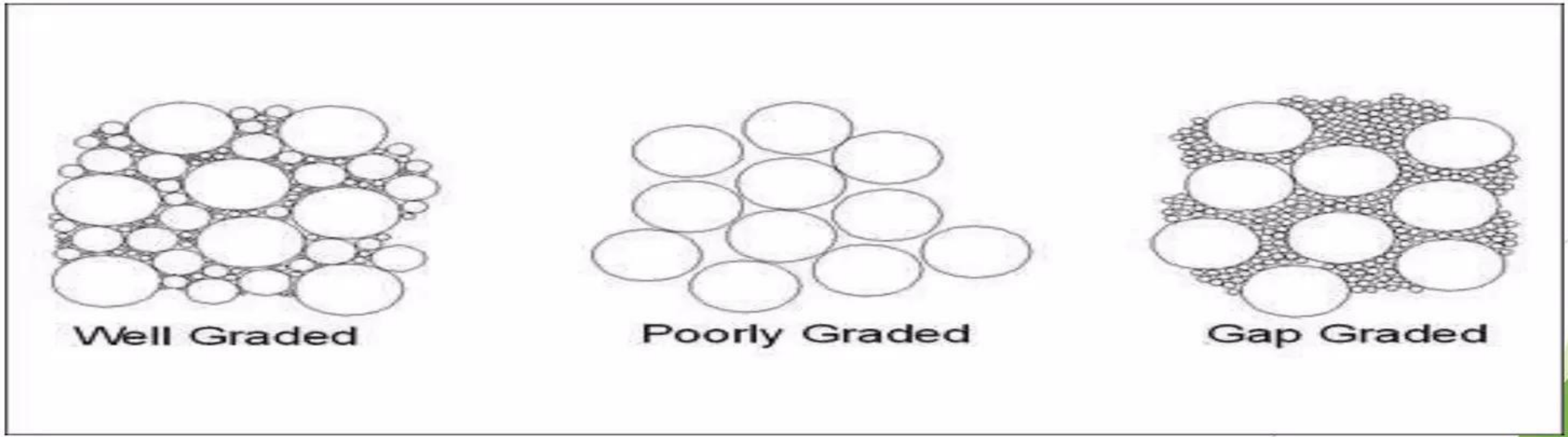
- The bigger the size of the aggregate, the less is the surface area and hence less amount of water is required for wetting the surface and less matrix or paste is required for lubricating the surface to reduce internal friction.
- Greater size of Aggregate- less water is required to lubricate it, the extra water is available for workability
- Porous aggregates require more water compared to non absorbent aggregates for achieving same degree of workability.

Shape of Aggregates

- Angular, elongated or flaky aggregate makes the concrete very harsh when compared to rounded aggregates or cubical shaped aggregates.
- Contribution to better workability of rounded aggregate will come from the fact that for the given volume or weight it will have less surface area and less voids than angular or flaky aggregate.
- Not only that, being round in shape, the frictional resistance is also greatly reduced. This explains the reason why river sand and gravel provide greater workability to concrete than crushed sand and aggregate.

Grading of Aggregates

- A well graded aggregate is the one which has least amount of voids in a given volume and higher the workability.
- Other factors being constant, when the total voids are less, excess paste is available to give better lubricating effect.
- With excess amount of paste, the mixture becomes cohesive and fatty which prevents segregation of particles.



Use of Admixtures

- Chemical admixtures can be used to increase workability.
- Use of air entraining agent produces air bubbles which acts as a sort of ball bearing between particles and increases mobility, workability and decreases bleeding, segregation.
- The use of fine pozzolanic materials also have better lubricating effect and more workability.

Weather Conditions

- If temperature is high, evaporation increases, thus workability decreases.
- If wind is moving with greater velocity, the rate of evaporation also increase reduces the amount of water and ultimately reducing workability.

Measurement of Workability

It is discussed earlier that workability of concrete is a complex property which can be measured by

- Slump Test
- Compacting Factor Test
- Flow Test
- Vee Bee Consistometer Test.

Freeze-thaw Effect on Concrete

The freeze-thaw cycle is a major cause of damage to concrete, and can lead to cracking, flaking, and settling:

How it happens

When water in concrete freezes, it expands by about 9%. This expansion puts pressure on the concrete's pores, which can "pop".

The effect

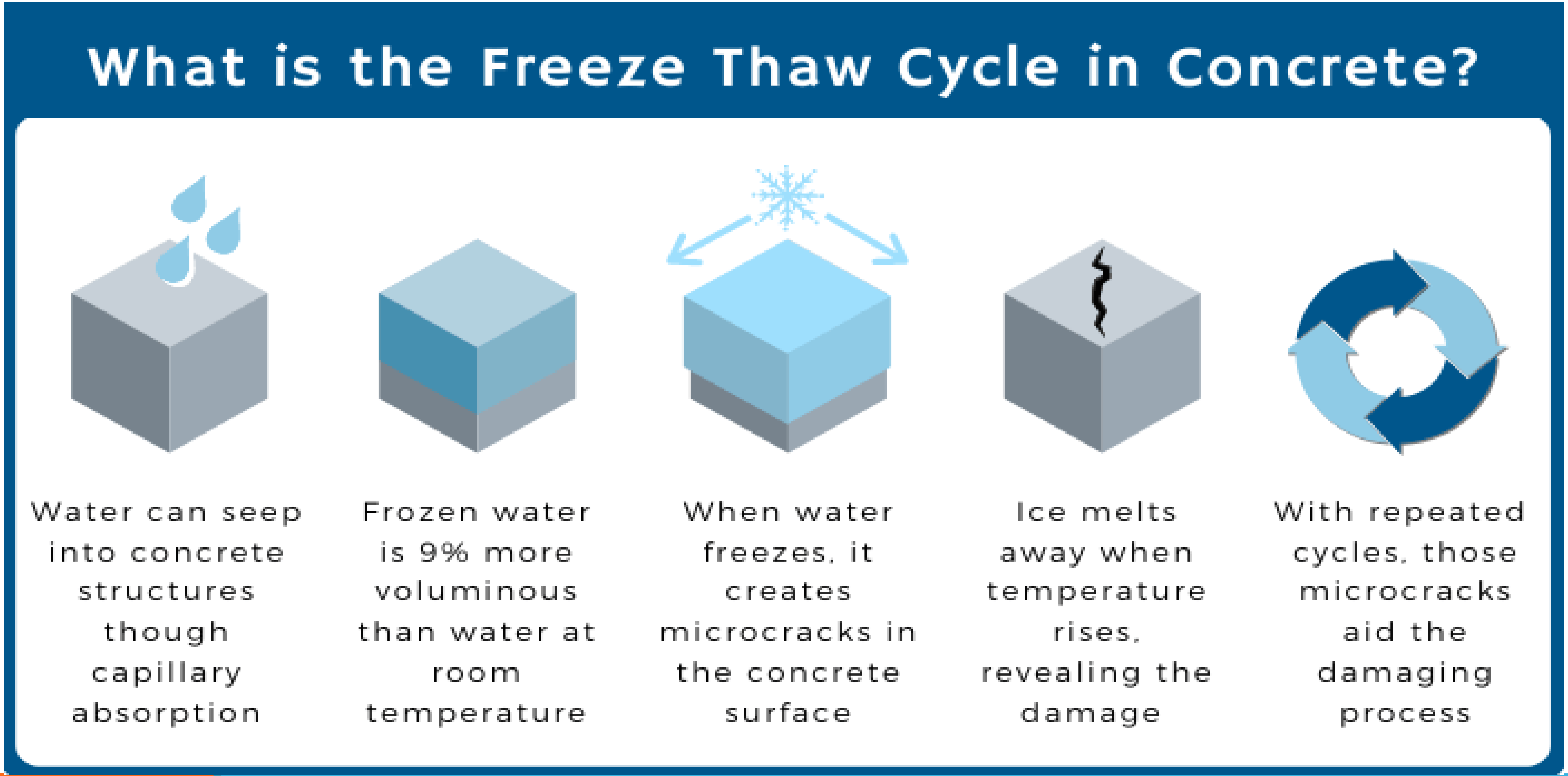
When the water thaws, it leaves behind larger empty pockets in the concrete. This allows more water to enter the pores, which can lead to more cracking when it freezes again.

The result

Over time, the repeated freeze-thaw cycle can weaken the concrete and cause structural defects.

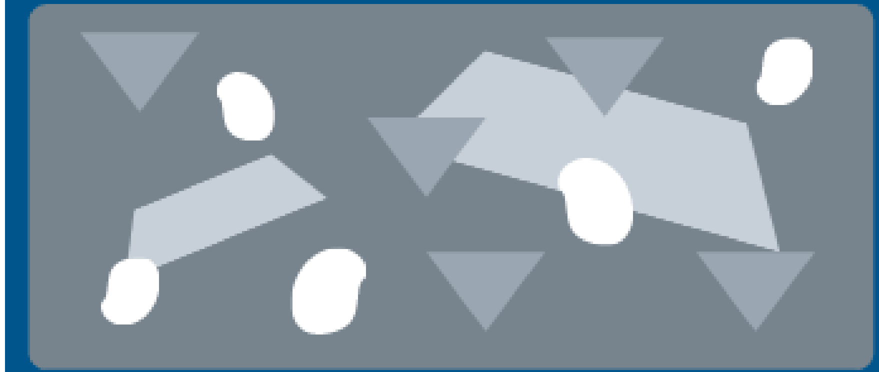
Other effects

Freeze-thaw cycles can also disrupt the soil or sub-material below the concrete, causing it to shift and settle.


What is the Freeze Thaw Cycle in Concrete?
Water can seep into concrete structures though capillary absorption
Frozen water is 9% more voluminous than water at room temperature
When water freezes, it creates microcracks in the concrete surface
Ice melts away when temperature rises, revealing the damage
With repeated cycles, those microcracks aid the damaging process

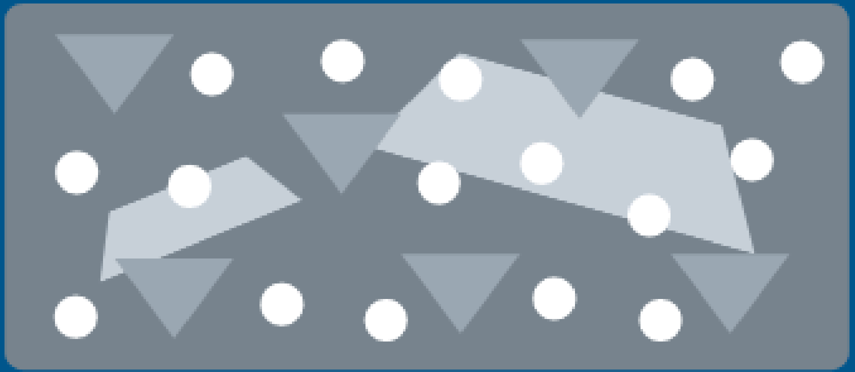
What is Air Entrainment in Concrete?

Entrapped Air



- Air bubbles: Large, irregular, nonuniform distribution
- Air content: Approx. 1.5%
- Due to mixing process and insufficient compaction

Entrained Air



- Air bubbles: Microscopic, spherical, uniform distribution
- Air content: Approx. 4-6%
- Due to intentional creation using air entraining agents

The ACI Method of Mix Design

Example Problem:

Data Known:

Specified strength = 20 MPa

Required Slump = 50 mm

Maximum size of aggregate = 20 mm

FM of fine aggregate = 2.20

Grading of aggregate as satisfied by by ASTM C33

SSD specific gravity of fine and coarse aggregate = 2.65

Rodded bulk density of coarse aggregate = 1600 kg/cubic m

Absorption Capacity of coarse aggregate = 0.5 %

Absorption Capacity of fine aggregate = 0.7%

Moisture Content of fine and coarse aggregate = Zero

Exposure Conditions = Normal

Type of Construction	Range of slump mm
Reinforced foundation walls and footings	20-80
Plain footing, cassions and substructure wall	20-80
Beams and Reinforced Wall	20-100
Building Column	20-100
Pavement and Slabs	20-80
Mass Concrete	20-80

- Decide maximum size of aggregate to be used. Generally, **for RCC work 20 mm** and for **pre-stressed concrete 10 mm** size are used.
- **specific gravity, is the ratio of the density of a substance to the density of a given reference material.**

Type of soil	Specific gravity
Sand	2.65-2.67
Silty sand	2.67-2.70
Inorganic clay	2.70-2.80
Soil with mica or iron	2.75-3.00
Organic soil	1.00-2.60

SOLUTION:

Step 1: Specified Strength.

The first step is the determination of specific strength

In this case the specified strength is given as **20 MPa**

Step 2: Target Strength.

Design average strength = fcr = fc + 7.0

= 20 +7 = 27 MPa

where,

fc = Characteristic/Specified Strength of concrete.

fcr = Target strength of concrete.

Note:

Specified Strength is the result of the actual compression testing done of properly prepared, cured and tested samples.

Whereas, Target strength implies what it was supposed to be, according to its designers.

If previous statistical data is not given then, the required average strength is determined according to the ACI code as follows:

$$f_{cr} \geq f_c + 7.0 \text{ MPa} \quad \text{for} \quad f_c \leq 21 \text{ MPa}$$

$$f_{cr} \geq f_c + 8.5 \text{ MPa} \quad \text{for} \quad f_c = 21 \text{ to } 35 \text{ MPa}$$

$$f_{cr} \geq 1.1 f_c + 5.0 \text{ MPa} \quad \text{for} \quad f_c > 35 \text{ MPa}$$

Step 3: Water/Cement Ratio.

Water/Cement ratio of the concrete mix will depend upon the target strength of concrete mix. The following table show the relationship between the two by proposed by ACI Code.

Average Compressive strength at 28 days (MPa)	Effective water/cement ratio by mass for Non-Air Entrained Concrete
45	0.38
40	0.43
35	0.48
30	**0.55**
25	**0.62**
20	0.70
15	0.80

As in our case the target strength is 27 MPa for which the required water/cement ratio is not given so we will find the required value using interpolation.

Strength	W/C ratio
30 MPa	0.55
27 MPa	?
25 MPa	0.62

W/C ratio = 0.55 + (0.62-0.55) / (30-25) = 0.59

Step 4: Water Content.

The water content of cement depends upon the slump value and the maximum aggregate size. The following table shows the relationship between them as proposed by the ACI code.

Workability (Slump)	Water Content of Concrete for Maximum Aggregate Size (mm) for Non-Air Entrained Concrete				
	10	**12.5**	**20**	**25**	**40**
30 – 50	205	200	**185**	180	160
80 – 100	225	215	200	195	175
150 – 180	240	230	210	205	185
Approximate Entrapped Air Content Percent	3	2.5	2.0	1.5	1.0
Recommended Avg. Air Content percent for					
Mild Exposure	4.5	4.0	3.5	3.0	2.5
Moderate Exposure	6.0	5.5	5.0	4.5	4.5
Extreme Exposure	7.5	7.0	6.0	6.0	5.5

So as in our case the mixing water content for non-air entrained concrete with a slump of 50 mm and maximum aggregate of 20 mm is **185 kg/cubic m** (from table)

Step 5:

The approximate entrapped air content is **2%**.

Step 6:

Cement Content: Cement content can be calculated by the ratio between water content to W/C ratio.

Cement Content = Water Content / W/C Ratio

= 185/0.59

= 314 kg/cubic meter

Step 7: Mass of Coarse Aggregate.

It depends upon maximum size of aggregate and fineness modulus of fine aggregate.

The following table shows the relation as proposed by ACI.

Maximum Size of Aggregate	Dry bulk volume of Rodded Coarse Aggregate per unit volume of concrete for fineness modulus of sand of:							
	1.6	**1.8**	**2.0**	**2.2**	**2.4**	**2.6**	**2.8**	**3.0**
10	0.56	0.55	0.54	0.52	0.50	0.48	0.46	0.44
12.5	0.65	0.64	0.63	0.61	0.59	0.57	0.55	0.55
20	0.72	0.71	0.70	**0.68**	0.66	0.64	0.62	0.60
25	0.77	0.76	0.73	0.73	0.71	0.69	0.67	0.65
40	0.81	0.80	0.79	0.77	0.75	0.73	0.71	0.69
50	0.84	0.83	0.82	0.80	0.78	0.76	0.74	0.72
70	0.86	0.85	0.85	0.84	0.82	0.80	0.78	0.76
150	0.91	0.90	0.89	0.88	0.87	0.85	0.86	0.81

In this case as maximum size of aggregate is 20 mm and fineness modulus of fine aggregate is 2.20 So dry bulk volume of the aggregate per unit volume of concrete = **0.68**.

Volume of SSD coarse aggregate required = 0.68 cubic m/cubic m of concrete

Mass of coarse aggregate = 0.68 * 1600 (Rodded bulk density of Coarse aggregate)

Mass of coarse aggregate = **1088 kg/cubic m**

Step 8: Mass of fine aggregate.

Specific gravity of fine aggregate = Yf = 2.65

Water content = W = 185 kg/cubic m

Cement content = C = 314 kg/cubic m

Specific gravity of cement = Y = 3.15

Mass of coarse aggregate = Ac = 1088 kg/cubic m

Specific gravity of coarse aggregate = Yc = 2.65

Air content = 2 %

Mass of fine aggregate = Yf [1000- (W + C/Y + Ac/Yc + 10A)]

= 2.65 [1000- (185 + 314/3.15 + 1088/2.65 + 20)]

= 755 kg/cubic m

Step 9:

Extra water required for absorption of Aggregate = 0.005 * 1088 (Ac) + 0.007 * 755 (Af)

= 10.73 kg/cubic m

Total water content = 185 + 10.73 = 196 kg/cubic m

Note:

If excess water is present in the aggregate the required water is to be reduced accordingly.

Step 10:

The quantities of the mix of 1.0 cubic m are as under:

Cement	:	314 kg/cubic m
Fine aggregate	:	755 kg/cubic m
Coarse Aggregate	:	1088 kg/cubic m
Water	:	196 kg/cubic m

The mix ratio is as follows :

Cement : Fine Aggregate : Coarse Aggregate = 314 : 755 : 1088

= 1 : 2.40 : 3.46

Aggregate / Cement ratio = 5.87

W/C ratio = 0.59

It’s time to Materials Purchasing and Mixing

Week 6-9

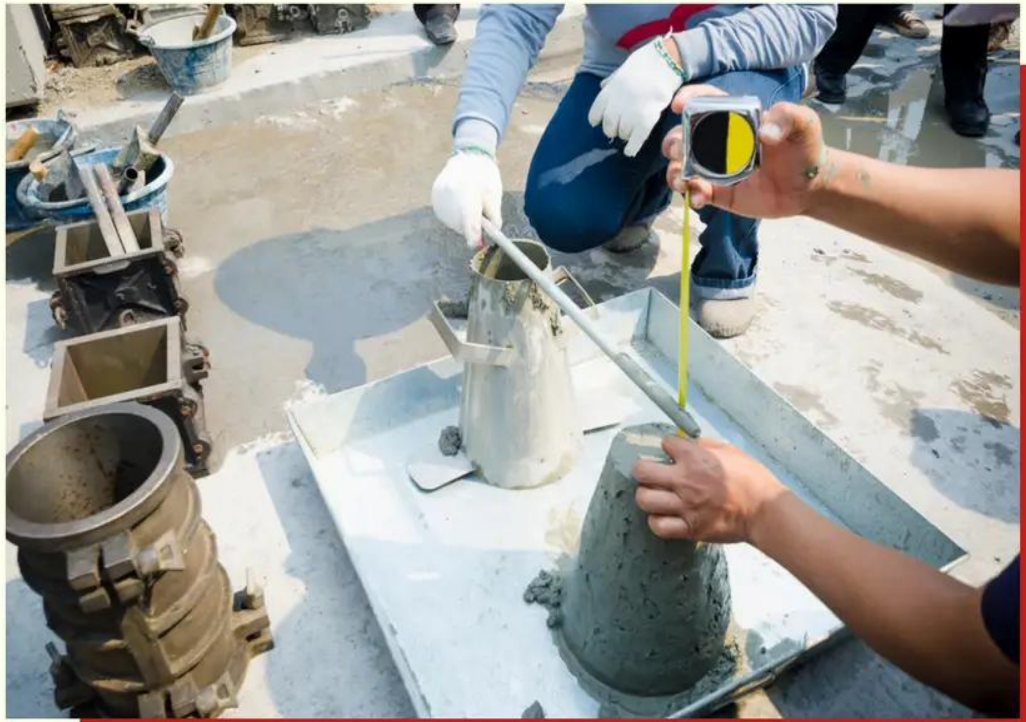
Determination of Slump Value

Week 10

Pages 82-86

What is a Concrete Slump Test?

- The slump test helps civil consultants understand the consistency and workability of concrete.
- The slump is the distance of concrete settlement after cone removal.
- Slump values vary based on usage requirements and concrete mix types.

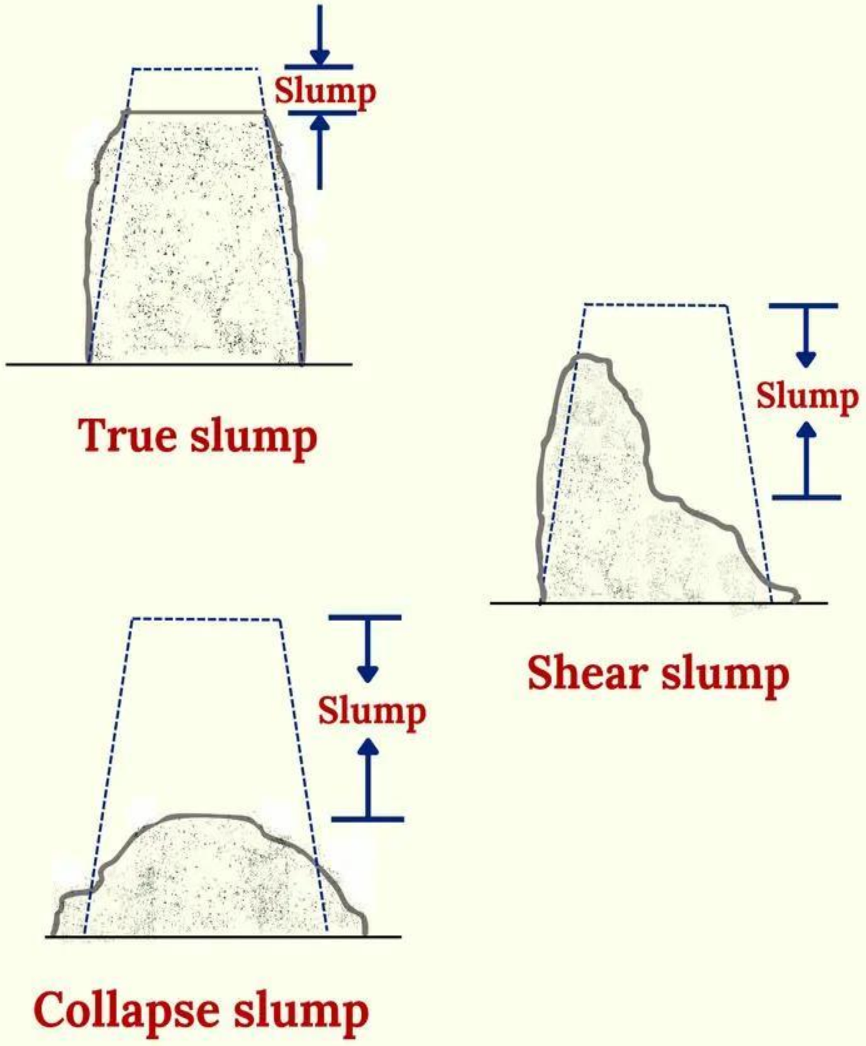


Slump Cone and Testing Process

- The slump test determines concrete workability on-site.
- Equipment includes a slump cone.
- Concrete is poured in four layers, each compacted properly.
- BIS IS1199 guidelines are used by civil consultants to conduct the slump test.

Types of Slump

- True Slump: Concrete drops evenly without disintegration, indicating correct cohesion and workability.
- Shear Slump: Concrete has little or no cohesion, segregates, and bleeds.
- Collapse Slump: High water content leads to collapse.



Slump Value Types

- Very Low Workability: Slump value of 0 mm to 25 mm.
- Low Workability: Concrete is dry and stiff, with a slump value of 25 mm to 50 mm. Admixtures or water improve workability.
- Medium Workability: Ideal slump value between 50 mm and 100 mm.
- High Workability: The concrete mix is too wet, with a slump value of 100 mm to 175 mm, leading to segregation and bleeding.

Concrete Workability and Factors

- Workability means the consistency and usability of concrete.
- Consistency refers to concrete's fluidity or mobility.

Factors enhancing workability:

- Water Content
- Mix Proportions
- Aggregate Size
- Surface Texture
- Admixtures

Bridge Details

Week 11-13

Pages 88-114

History of Bridge Development

Natural Bridges

Clapper Bridge

- Tree trunk
- Stone

700 A.D. Asia

Great Stone Bridge in China

- Low Bridge
- Shallow Arch

Roman Arch Bridge

- The Arch
- Natural Cement

100 B.C. Romans

- Strength of Materials
- Mathematical Theories
- Development of Metal

1300 A.D. Renaissance

History of Bridge Development

1800 A.D.

First Cast-Iron Bridge

Coalbrookdale, England

1850 A.D.

Britannia Tubular Bridge

- Wrought Iron

1900 A.D.

Truss Bridges

- Mechanics of Design

1920 A.D.

Suspension Bridges

- Use of Steel for the suspending cables

2000 A.D.

- Prestressed Concrete
- Steel

How Bridges Work?

Every passing vehicle shakes the bridge up and down, making waves that can travel at hundreds of kilometers per hour. Luckily the bridge is designed to damp them out, just as it is designed to ignore the efforts of the wind to turn it into a giant harp. A bridge is not a dead mass of metal and concrete: it has a life of its own, and understanding its movements is as important as understanding the static forces.

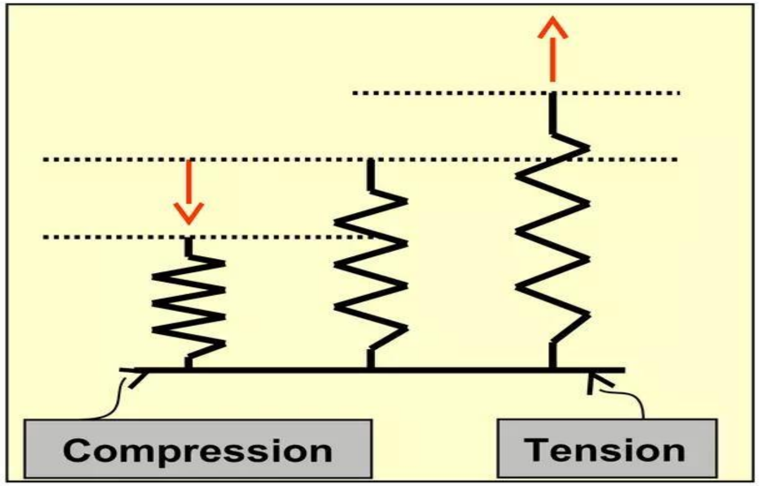
Basic Concepts

Span - the distance between two bridge supports, whether they are columns, towers or the wall of a canyon.

Force - any action that tends to maintain or alter the position of a structure

Compression - a force which acts to compress or shorten the thing it is acting on.

Tension - a force which acts to expand or lengthen the thing it is acting on.



Basic Concepts

Beam - a rigid, usually horizontal, structural element

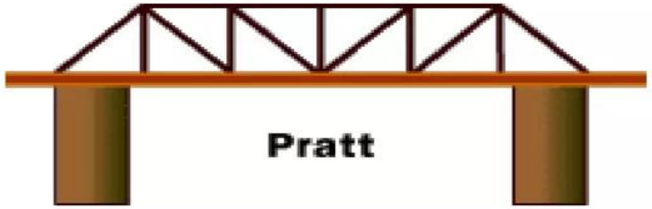
Pier - a vertical supporting structure, such as a pillar

Cantilever - a projecting structure supported only at one end, like a shelf bracket or a diving board

Load - weight distribution throughout a structure

Basic Concepts

Truss - a rigid frame composed of short, straight pieces joined to form a series of triangles or other stable shapes

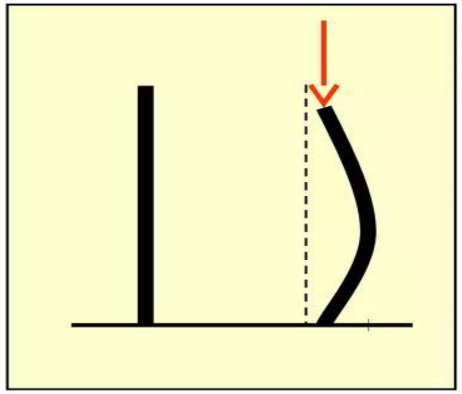


Stable - (adj.) ability to resist collapse and deformation; stability (n.) characteristic of a structure that is able to carry a realistic load without collapsing or deforming significantly

Deform - to change shape

Basic Concepts

Buckling is what happens when the force of compression overcomes an object's ability to handle compression. A mode of failure characterized generally by an unstable lateral deflection due to compressive action on the structural element involved.



Snapping is what happens when tension overcomes an object's ability to handle tension.

To **dissipate** forces is to spread them out over a greater area, so that no one spot has to bear the brunt of the concentrated force.

To **transfer** forces is to move the forces from an area of weakness to an area of strength, an area designed to handle the forces.

Types of Bridges

Basic Types:

- Beam Bridge
- Arch Bridge
- Suspension Bridge

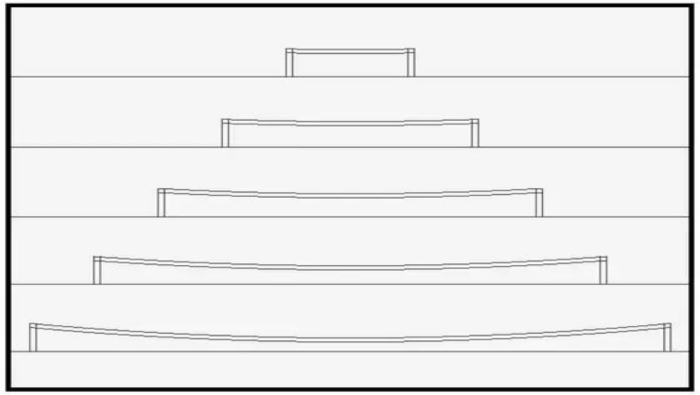
The type of bridge used depends on various features of the obstacle. The main feature that controls the bridge type is the size of the obstacle. How far is it from one side to the other? This is a major factor in determining what type of bridge to use.

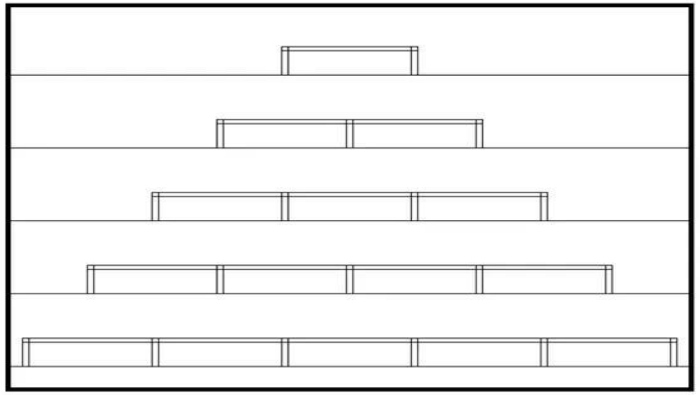
The biggest difference between the three is the distances they can each cross in a single span.

Types of Bridges

Beam Bridge

Consists of a horizontal beam supported at each end by piers. The weight of the beam pushes straight down on the piers. The farther apart its piers, the weaker the beam becomes. This is why beam bridges rarely span more than 250 feet.



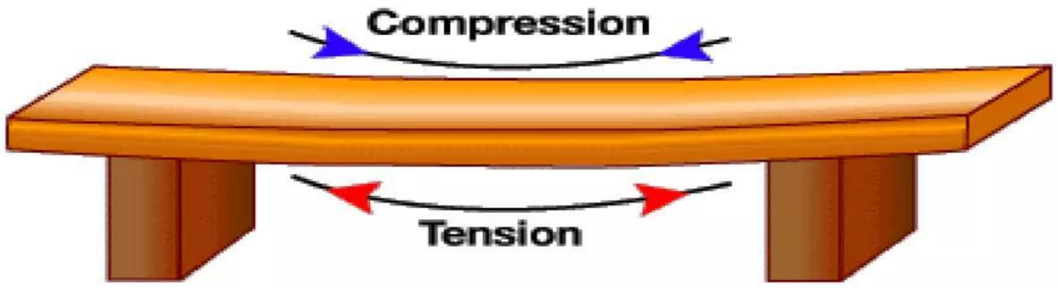


Types of Bridges

Beam Bridge

Forces

When something pushes down on the beam, the beam bends. Its top edge is pushed together, and its bottom edge is pulled apart.



Types of Bridges

Truss Bridge

Forces

Every bar in this cantilever bridge experiences either a pushing or pulling force. The bars rarely bend. This is why cantilever bridges can span farther than beam bridges

Types of Bridges

Arch Bridges

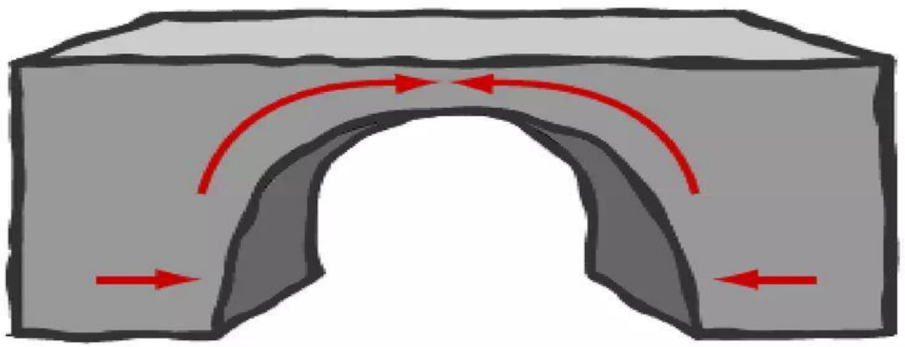
The arch has great natural strength. Thousands of years ago, Romans built arches out of stone. Today, most arch bridges are made of steel or concrete, and they can span up to 800 feet.

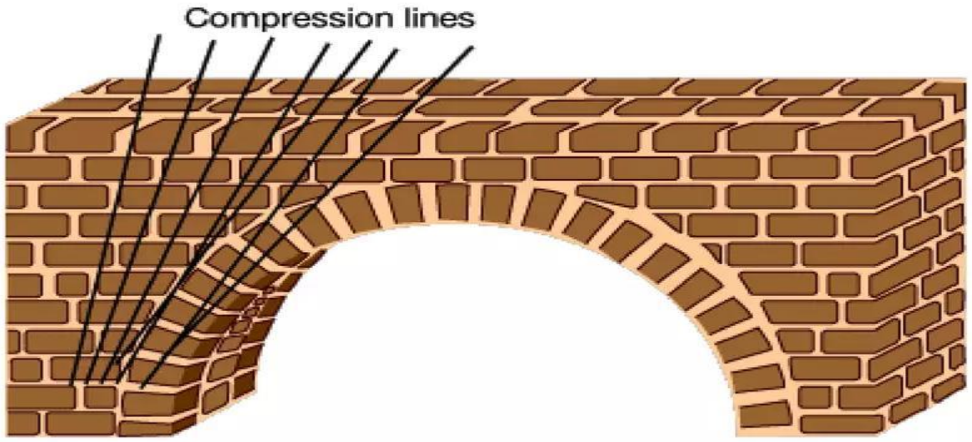
Types of Bridges

Arch Bridges

Forces

The arch is squeezed together, and this squeezing force is carried outward along the curve to the supports at each end. The supports, called abutments, push back on the arch and prevent the ends of the arch from spreading apart.

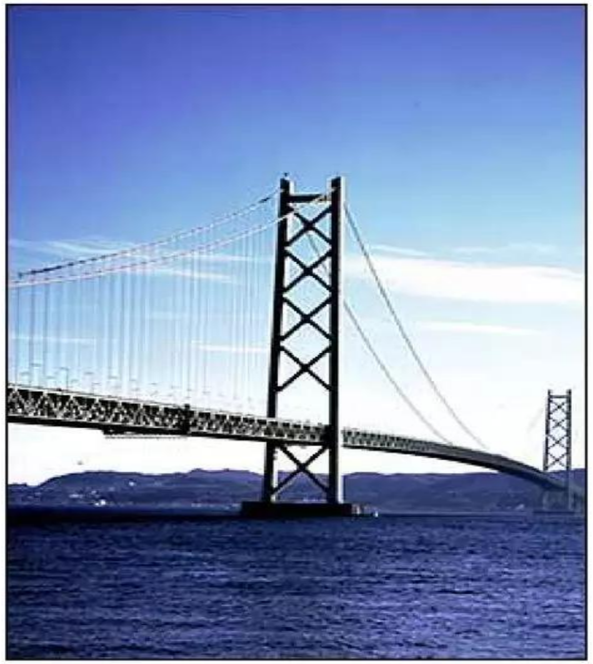




Types of Bridges

Suspension Bridges

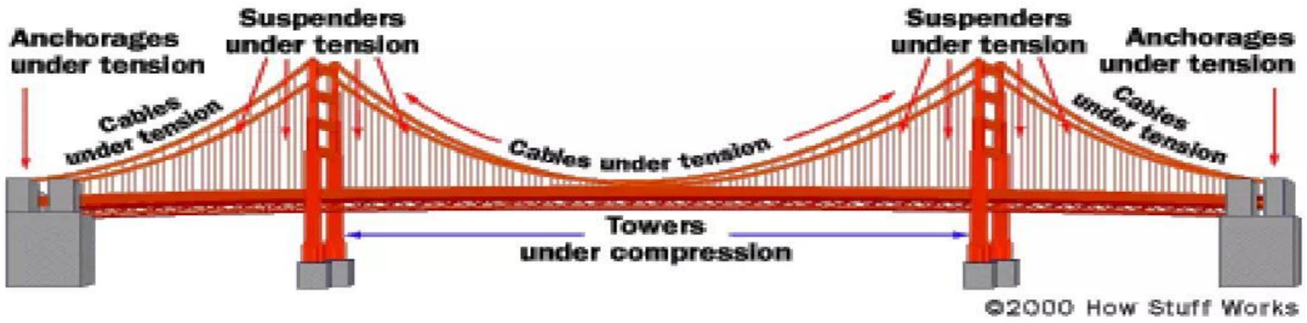
This kind of bridges can span 2,000 to 7,000 feet -- way farther than any other type of bridge! Most suspension bridges have a truss system beneath the roadway to resist bending and twisting.



Suspension Bridges

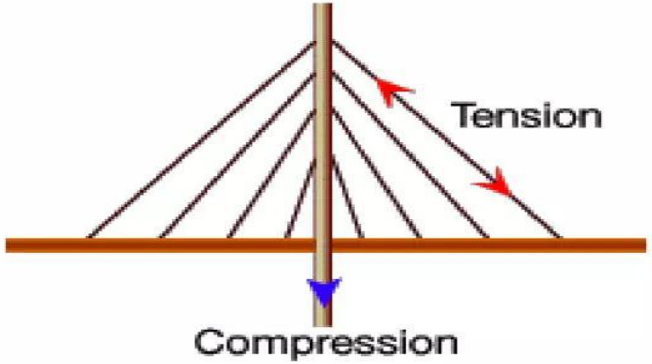
Forces

In all suspension bridges, the roadway hangs from massive steel cables, which are draped over two towers and secured into solid concrete blocks, called anchorages, on both ends of the bridge. The cars push down on the roadway, but because the roadway is suspended, the cables transfer the load into compression in the two towers. The two towers support most of the bridge's weight.

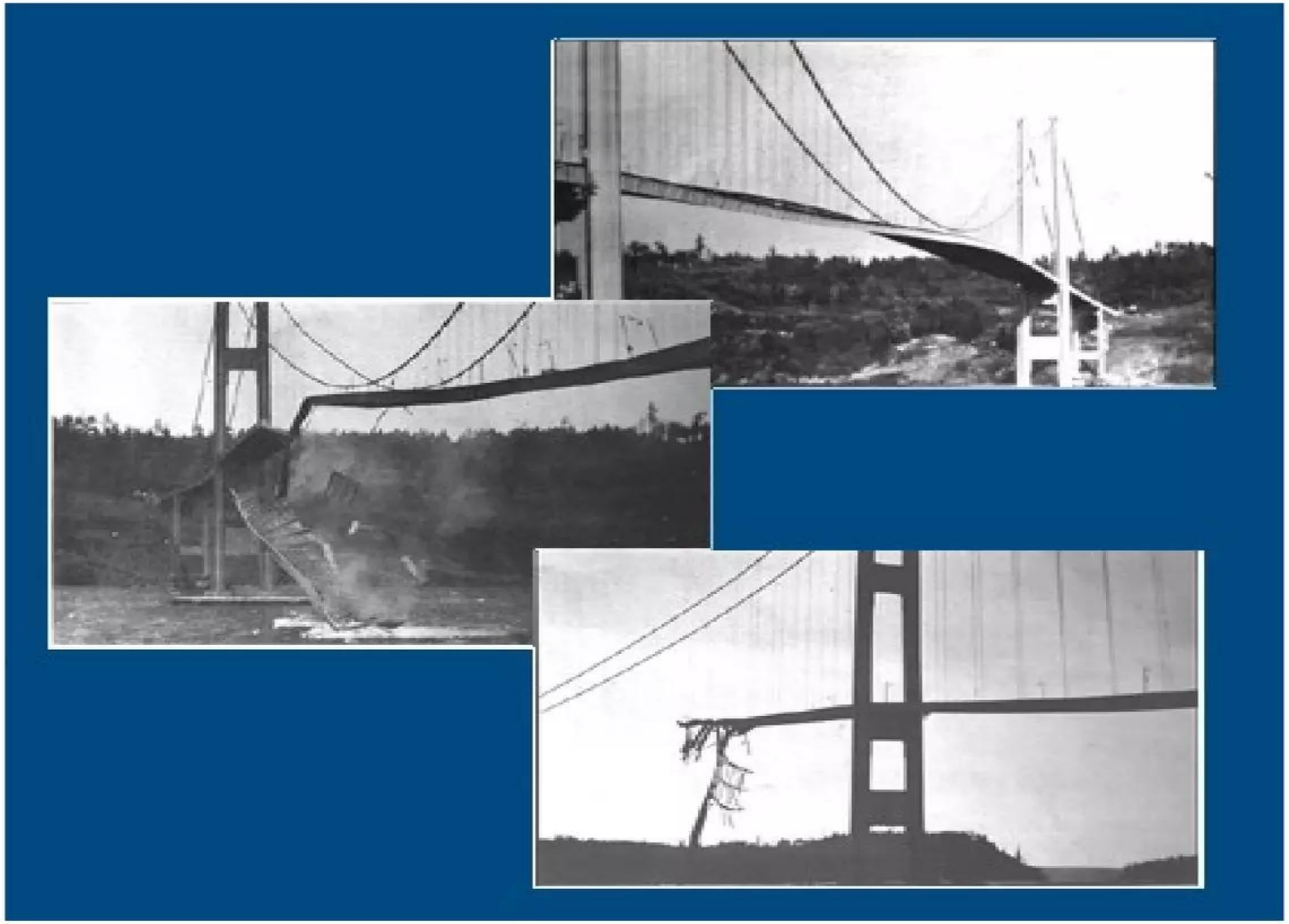


Cable-Stayed Bridge

The cable-stayed bridge, like the suspension bridge, supports the roadway with massive steel cables, but in a different way. The cables run directly from the roadway up to a tower, forming a unique "A" shape.
Cable-stayed bridges are becoming the most popular bridges for medium-length spans (between 500 and 3,000 feet).



Tacoma Narrows Failure



Bridge Basic Components

R by Rubieyat Bin Ali

Introduction to Bridge Design

Spanning Gaps

Bridges are structures that span gaps, connecting roadways, railways, and waterways. They play a crucial role in transportation, facilitating movement and accessibility.

Engineering Challenges

Designing bridges requires careful consideration of factors like structural integrity, load capacity, environmental conditions, and aesthetic appeal. Engineers face challenges in ensuring the bridge's stability and safety.

Superstructure Components

1

Deck

The bridge's deck, which carries the traffic, is typically made of concrete or steel. It is supported by beams or girders, which transfer the weight to the substructure.

2

Beams & Girders

Beams and girders provide horizontal support to the deck, distributing the load evenly. They are usually made of steel or reinforced concrete.

3

Railings

Railings provide safety and prevent vehicles from falling off the edge of the deck. They are typically made of steel or concrete and are designed to withstand wind forces.

Substructure Components

Supports

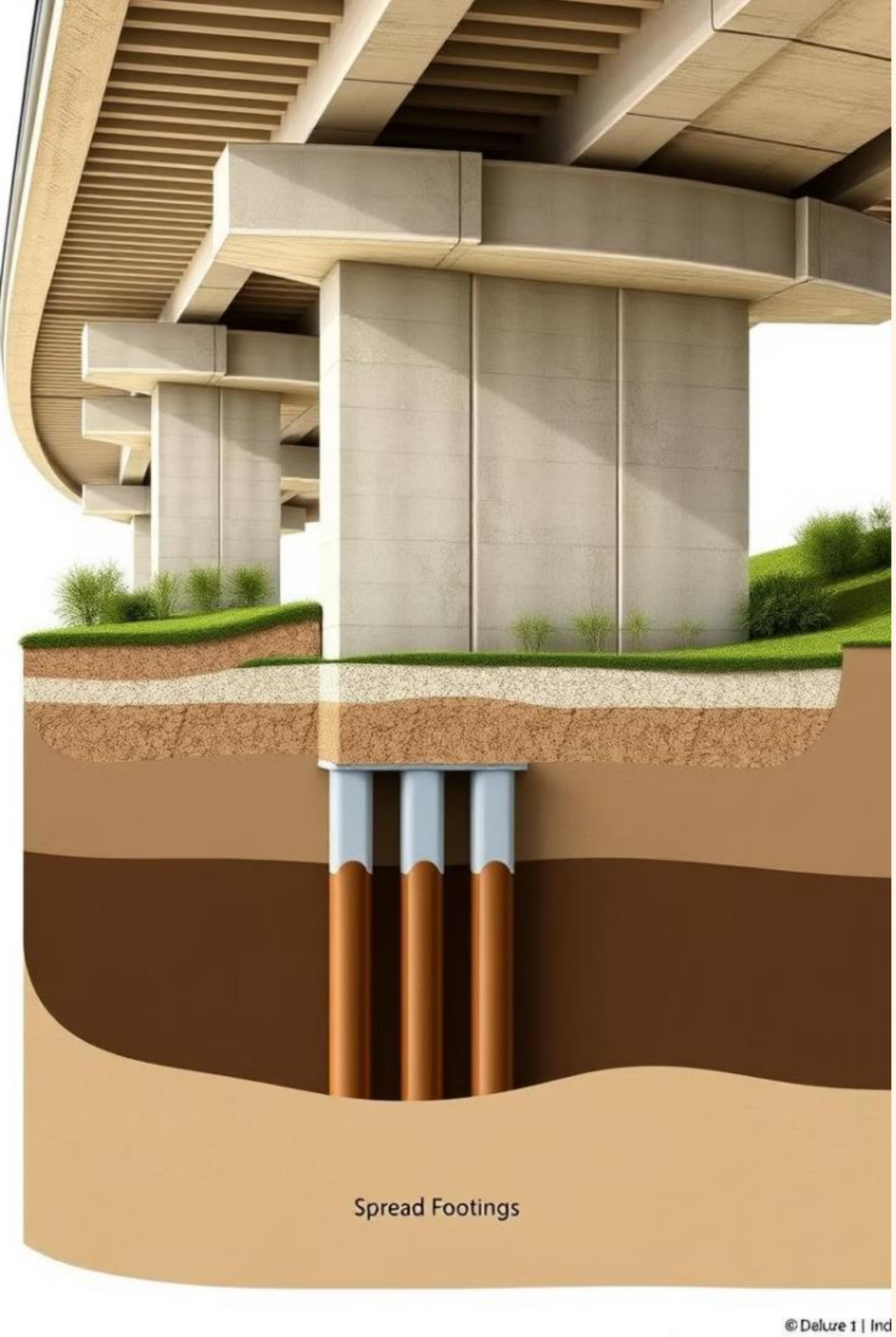
The substructure, the foundation of the bridge, supports the superstructure and transfers loads to the ground. It consists of piers, abutments, and foundations.

Anchoring

The substructure provides stability and anchors the bridge to the ground, ensuring its resilience against forces such as wind, earthquakes, and traffic loads.

Resilience

The substructure must be designed to withstand extreme weather conditions, seismic activity, and the constant wear and tear of traffic, ensuring the bridge's longevity.



Foundations

Pile Foundations

Used in soft ground, pile foundations consist of driven or drilled shafts that transfer loads to deeper, more stable soil layers.

Caissons

Large, hollow structures sunk into the ground to provide support in challenging soil conditions. They are often used for bridges with large spans.

Spread Footings

Wide, flat foundations distributed over a large area, suitable for stable ground conditions and lighter loads.

Abutments

1

Transitional Structure

Abutments are structural elements that support the bridge deck at the ends and transition the structure to the ground, forming a connection with the roadway or waterway.

2

Wing Walls

Wing walls extend from the abutments to contain the backfill, preventing erosion and ensuring stability.

3

Backfill

Backfill is the material placed behind the abutment to provide stability and support to the structure.

Piers

1

Intermediate Supports

Piers are intermediate supports that provide vertical support to the bridge deck, transferring loads from the beams to the foundation.

2

Column & Beam System

Piers are typically constructed of columns and beams, designed to withstand significant forces and maintain stability.

3

Environmental Conditions

Piers must be designed to withstand various environmental conditions, such as water currents, temperature changes, and ice forces.

Bearings

1

Movement

Bearings are essential components that allow the bridge deck to move freely, accommodating thermal expansion and contraction, seismic activity, and traffic loads.

2

Types

Types include fixed, expansion, and roller bearings, each serving a specific purpose and providing the necessary movement.

3

Transferring Forces

Bearings transfer the weight of the bridge deck to the piers or abutments, ensuring the stability and longevity of the structure.

Expansion Joints

1

Bridge Movement

Expansion joints are gaps incorporated into the bridge deck to accommodate thermal expansion and contraction, preventing damage to the structure.

2

Flexible Material

The gaps are filled with flexible materials like rubber or asphalt, which allow for movement without compromising the structural integrity.

3

Traffic Flow

Expansion joints are designed to ensure smooth traffic flow by minimizing the impact of bridge movement on vehicles.

Approach Slabs

1

Smooth Transition

Approach slabs are the sections of roadway that connect to the bridge deck, providing a smooth transition for vehicles entering and exiting the bridge.

2

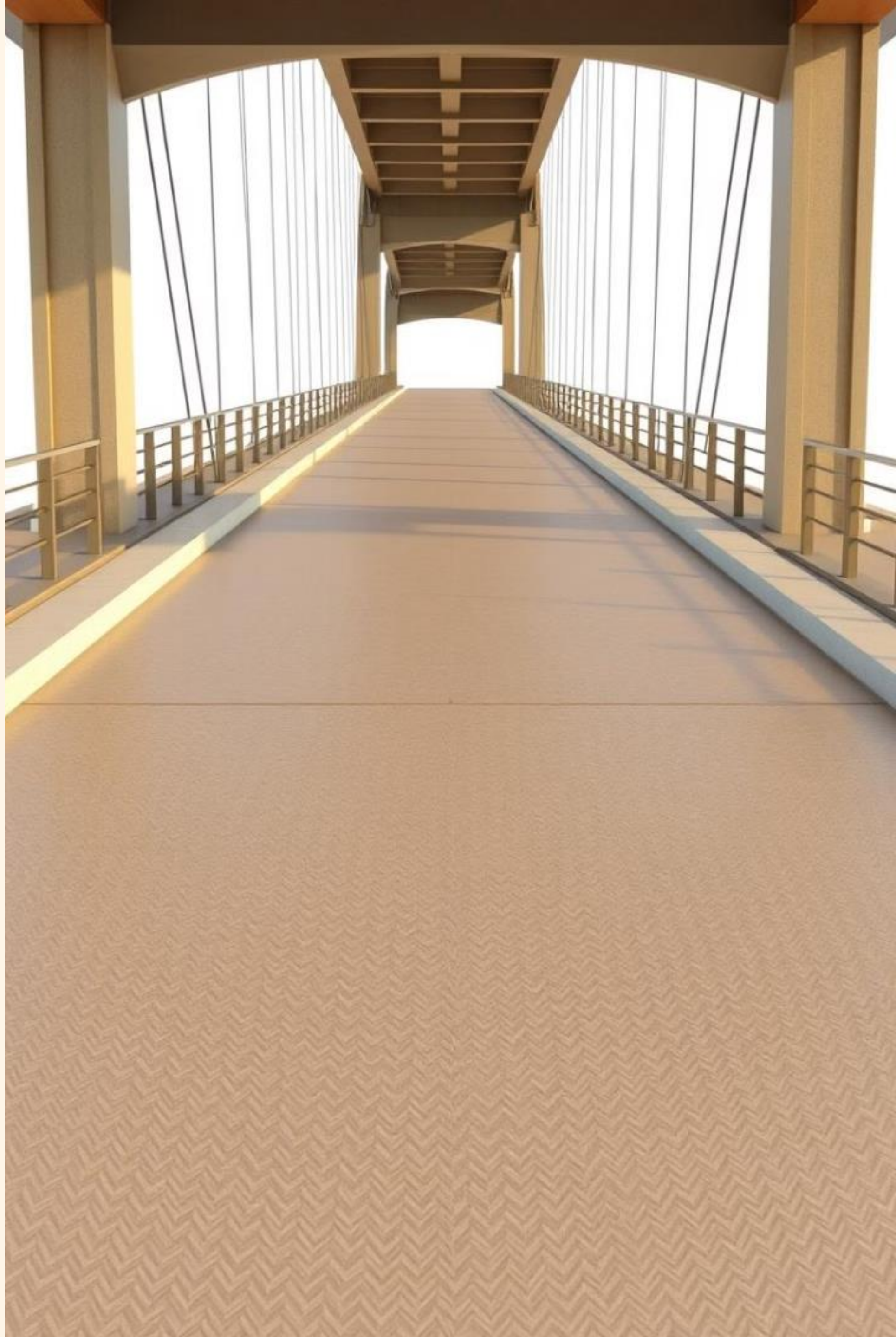
Drainage

Approach slabs are typically designed with a slight incline to facilitate drainage, preventing water accumulation and potential damage.

3

Load Distribution

They are reinforced to distribute the load from vehicles, ensuring the stability of the roadway and the bridge deck.



Click the link for Report writing

Design of Concrete Structure I Manual

Any Questions?

Thank you for your kind attention

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