-CONCRETE CONSTRUCTION-

OBJECTIVES:

- Students will be introduced to the basic engineering principles of concrete construction, in terms of:
  - → the component materials of concrete
  - → the concept of concrete mix specification and design
  - → the flexural & compressive strength of concrete
- Students will utilise principles to make concrete beams.
- Students will understand important aspects of concrete construction such as components and strength of materials.

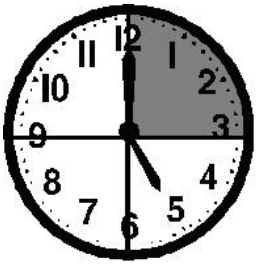
WORDS TO KNOW:

- Concrete
- Cement
- Aggregate
- Workability
- Reinforcing
- Slump
- Formwork
- Homogeneous
- Tamping
- Flexure
- Compression
- Plastic State
- Hardened State
- Compaction
- Screeding
- Air voids
- Mortar
- Curing
- Failure

KEY CONCEPTS:

- The importance and widespread uses of concrete.
- The component materials used to make concrete.
- The effect of aggregates and reinforcing on the strength of concrete structures.

PREPARATION TIME:



LESSON TIME:

SAFETY NOTES:

Supervision is recommended for this activity.

- When using the equipment designated for the practical, strict adherence to the instructions is vital.
- Appropriate covered footwear must be worn.
- Old clothing or lab coats should be worn.
- To protect the skin from the abrasive and alkaline effects of concrete, latex gloves should be worn when working with concrete mixes.
- Upon completion of the activity, a full concrete mould will weigh approximately 7kg. Ensure a two-person lift is used when moving the samples.

MATERIALS:

1 QUT Concrete Construction Activity Kit containing:

Part One:

- Instruction Booklet
- 4 formwork moulds
- 1 sheet of reinforcing mesh
- 1 concrete slump cone
- 1 tamping rod
- 4 mixing trays
- 4 metal trowels
- 1 can oil spray
- 4 x 1L water containers
- 3 bags of 10mm aggregate
- 3 bags of sand
- 4 bags of cement powder
- box of latex gloves
- cardboard boxes for disposal of excess concrete

Part Two:

- H-shaped loading frame
- Large bucket
- 2 concrete mounts
- 2 litre water jug

Extras required:

- Tap water for mixing concrete and cleaning up.

STEPS:

Part One:

This exercise demonstrates the physical properties and characteristics of concrete in its **plastic** state. The impact of component materials on **workability** and strength will be investigated through the comparison of three different mix designs

1. Place students into four equal groups and allocate one concrete mix type to each group. Provide each group with the following materials:

Group 1:

- 1 formwork mould
- 1 mixing tray
- 1 metal trowel
- 1 water jug
- 1 bag of cement powder
- Group 1 bag of 10mm aggregate
- Group 1 bag of sand
- 1 sheet of reinforcing mesh
- latex gloves
- 600ml water

Group 2:

- 1 formwork mould
- 1 mixing tray
- 1 metal trowel
- 1 water jug
- 1 bag of cement powder
- Group 2 bag of 10mm aggregate
- Group 2 bag of sand
- latex gloves
- 600ml water

Group 3:

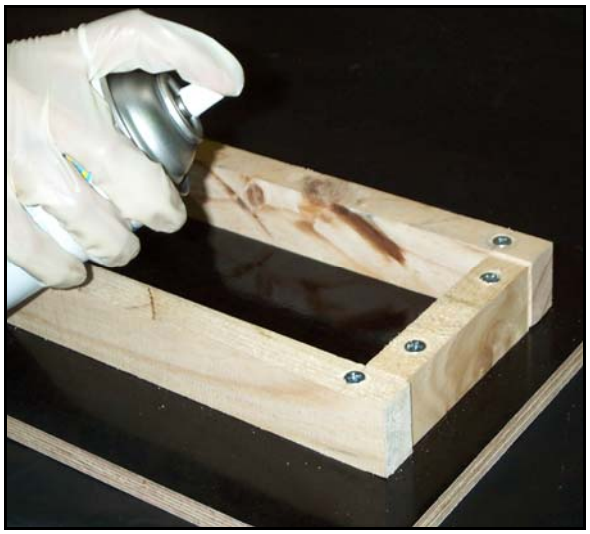
- 1 formwork mould
- 1 mixing tray
- 1 metal trowel
- 1 water jug
- 1 bag of cement powder
- Group 3 bag of 10mm aggregate
- latex gloves
- 600ml water

Group 4:

- 1 formwork mould
- 1 mixing tray
- 1 metal trowel
- 1 water jug
- 1 bag of cement powder
- Group 4 bag of sand
- latex gloves
- 600ml water

2. Ensure each student is wearing enclosed footwear, old clothing and a pair of the latex gloves.

Preparing the Moulds:



3. Use the can of oil spray provided to oil the inside of the **formwork**. This will allow easy removal of the concrete once it has set.

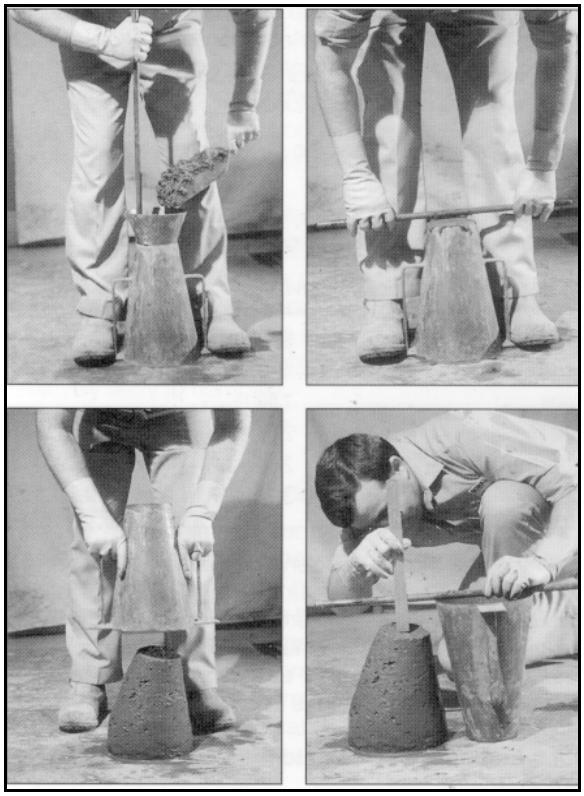
Preparing the Concrete Mix:

4. Gently place the cement, aggregate and sand into the mixing tray. Mix materials thoroughly using the trowels provided.

5. Add ¼ of the water to the dry materials and mix through using a folding action.

6. Continue adding the water in equal portions and mixing, until a homogeneous concrete mix is achieved.

Slump Test:



7. Ask each group to perform a slump test (technique pictured above) in front of the class to investigate the cohesion and workability of their concrete mix.

8. Move the concrete mix to one end of the mixing tray. Place the slump cone provided on the cleared surface of the tray.

9. Fill the bottom third of the slump cone with the concrete mix.

10. **Tamp** the bottom layer of concrete by placing the tamping rod inside the cone and pushing down the concrete in random places. This will ensure each layer of the concrete mix is **compacted**.

    Repeat steps 9 & 10 for 2 more layers (remember to tamp each layer as you go) until the slump cone is full.

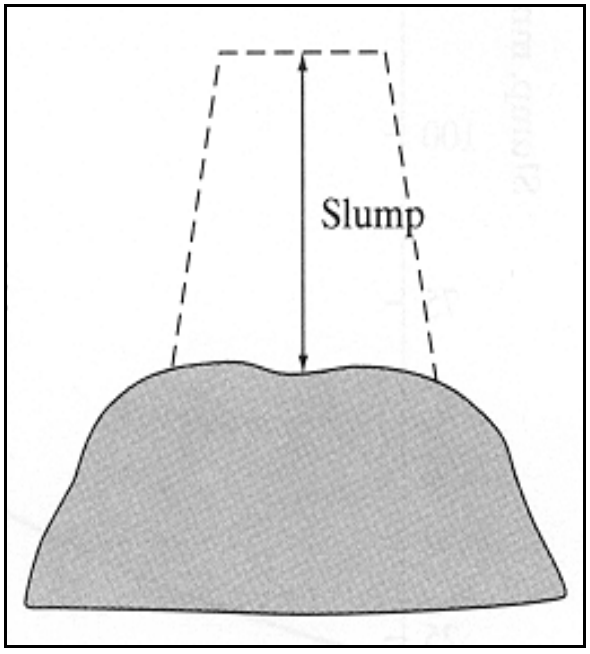
11. To achieve a level surface, use the tamping rod to **screed** the excess mixture from the top of the cone as shown in the picture above.

IMPORTANT NOTE:

Do not, at any stage during the slump test, tap or strike the sides of the slump cone to settle the concrete inside.

12. Carefully remove the slump cone in one smooth movement. Place the cone next to the unmoulded concrete.

13. Measure the amount of **slump** (in millimetres) that occurs in comparison to the original height of the cone. Record your observations on the result sheet provided.



Workability Test:

14. To test the **workability** of the concrete, cut the slumped concrete with the trowel as if you were cutting a cake. Manipulate the concrete and record your observations.

Placing the Concrete:

15. Group 1 is required to place the sheet of reinforcing mesh centrally in the base of the formwork as pictured above.

16. Using the trowel, place the concrete from the tray and slump test into the oiled formwork in two separate layers.

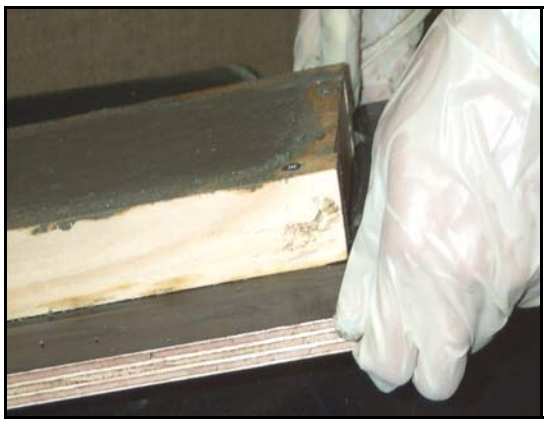
IMPORTANT NOTE:

Compact the first layer of concrete prior to the placement of the second layer. Pay particular attention to the concrete at the corners and edges of the formwork when compacting.

17. Remove excess concrete material from in and around the mould with the edge of the trowel. Dispose of any excess material in the cardboard boxes provided.

18. Finish off the concrete by smoothing the surface with the trowel. This is otherwise known as **screeding** the surface.

Removing Air Voids:



19. To expel the trapped air within the concrete carefully raise one end of the formwork 5cm above the table top and release. Repeat this 10 times at each end of the formwork. Note the small bubbles of air rising and appearing at the concrete surface.

Setting Concrete:

20. Place samples in a safe place to allow concrete to **cure** undisturbed for 7 days.

Cleaning Up:

21. Clean all equipment with water provided in the mixing container and dispose of all gloves in the bin.

IMPORTANT NOTE:

Concrete will set and cause blockages in pipes.

DO NOT wash leftover concrete down any sinks or drains; empty all dirty water onto a grassed area.

Part Two:

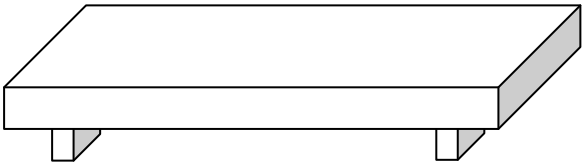
Unmoulding Samples:

1. Gently remove the concrete from the surrounding formwork by unscrewing the four sides of the frame. This is called **stripping** the formwork.

Testing Concrete Samples:

2. To ensure testing is done safely, only one concrete sample should be tested at a time. All testing should take place on the floor and each sample will be tested until it breaks. This is called testing to **failure**.

3. Place sample on the concrete mounts supplied. The beam should sit **simply supported** at either end as shown below.



4. Place the H-shaped loading frame in the centre of the beam as shown below.

5. Gently place a bucket over the loading frame. Have someone hold the top of the bucket at all times.

NOTE: Approximate loads resisted and compressive strengths are given at the end of this copy.

6. Slowly load the concrete sample by filling the bucket with 2 litres of water at a time. If the full bucket does not break the beam, select students of varying weights to load the beam. Starting with the lightest person, step onto the beam and continue increasing the weight until failure is achieved.

7. Record the weight required to break the concrete sample on the testing sheets provided.

NOTE:

1 litre of water = 1 kilogram

BACKGROUND INFORMATION:

Concrete is one of the most widely used construction materials in the world today. Properly designed and constructed, concrete structures compare favourably with regard to economy, durability and functionality with structures made from other structural materials, such as steel and timber.

The properties of concrete depend on the selection and proportioning of component materials, as well as handling, placement, compaction, finishing and curing methods.

Advantages of Concrete:

- Economical
- Durable
- Versatile
- Fire resistant
- Energy efficient
- Environmentally friendly
- Easy to cast
- Easy to fabricate on-site
- Recyclable
- Aesthetic properties

Applications of Concrete:

Concrete is everywhere and has a wide range of applications including:

- Buildings and skyscrapers,
- Roads
- Footpaths and driveways
- Highways
- Houses
- Bridges
- Dams
- Pipes
- Swimming pools
- Airport runways
- Tunnels

Properties of Concrete;

Concrete has many properties that make it a popular and unique construction material. The correct proportion of ingredients, placement, and curing are needed in order for these properties to be optimal.

Good-quality concrete has many advantages that add to its popularity. Firstly, it is economical when ingredients are readily available. Concrete's long life and relatively low maintenance requirements increase its economic benefits. Concrete is not as likely to corrode or decay as other building materials. Concrete has the ability to be moulded or cast into almost any desired shape. Building of the moulds and casting can occur on the work-site which reduces costs.

Concrete is a non-combustible material which makes it fire-safe and able to withstand high temperatures. It is resistant to wind, water, rodents, and insects. Concrete can also tolerate low impacts. Hence, concrete is often used for storm shelters.

Concrete does have some limitations despite its numerous advantages. Concrete has a relatively low tensile strength (compared to other building materials), low ductility, low strength-to-weight ratio, and is susceptible to cracking. Concrete remains the material of choice for many applications regardless of these limitations.

Strength Characteristics of Concrete:

- Performs best under compression
- Lacks tensile strength

Concrete States:

Concrete is the preferred construction material for a wide range of civil engineering structures and regardless of whether we are involved in design or construction, it is essential to gain a proper understanding of concrete in both the plastic and hardened state.

1. **Plastic State** – concrete is classified as plastic when it is first mixed and it can be moulded into any desired shape.

   Plastic state properties must suit the application i.e. placing conditions and compaction equipment.

   If not properly placed and compacted, concrete will not achieve the desired strength and durability

   The key properties:
   → Workability
   → Cohesiveness

2. **Hardened State** – when hardened, concrete is strong, durable, able to support loads and resists deterioration.

Concrete Constituents:

- Cement
- Aggregates
- Admixtures
- Water

DEFINITIONS:

Accelerators

Admixtures that decrease the setting time by increasing the rate of hydration.

Admixtures

Admixtures are substances other than the key ingredients or reinforcements which are added during the mixing process to control setting and early hardening, workability, or to provide additional cementing properties.

Concrete's strength is affected by the addition of admixtures.

Admixtures are commonly used to entrain air, increase workability, accelerate or retard drying time, reduce water requirements, or perform a variety of other functions.

Aggregates

Aggregates are inert solid bodies such as gravel textured rocks and sand-like materials (Figure1).

Aggregates come in different sizes and textures: coarse, fine or very fine. Most aggregates come from nature: crushed rock or gravel for coarse aggregates; natural sand or finely crushed rocks for fine aggregates.

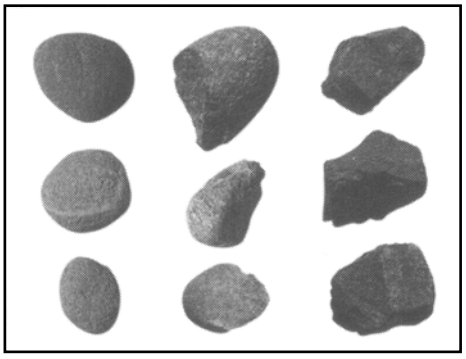


Figure 1.

Cement

Cement is a mixture of compounds made by burning limestone and clay together at very high temperatures. This component combines with water to bind the concrete together.

Compression

Forces that act inwardly to compress a body.

Concrete

Concrete is hard compact building material formed when a mixture of cement, aggregates and water bind and harden by a chemical reaction.

Curing

Curing is the establishment of an environment where the temperature and moisture content of concrete is maintained within certain boundaries, and especially above certain levels.

Curing ensures that concrete is kept moist during initial hardening period to allow the material to achieve the designed strength and durability.

Durability

Durability is a very important concern in using concrete for a given application. Concrete provides good performance through the service life of the structure when concrete is mixed properly and care is taken in curing it.

Good concrete can have an infinite life span under the right conditions.

Formwork

Timber or steel moulds in which concrete is placed to harden.

Hydration

The reaction of cement with water to form a chemical compound.

Mortar

Cement paste mixed with sand.

Porosity

The amount of air or empty space in the concrete matrix.

Retardants

Admixtures that increase the setting time by slowing down hydration.

Set

Transformation of cement paste or concrete from a fluid-like consistency to a stiff mass.

Slump Test

Test used to determine workability and cohesiveness of the concrete mix.

Steel Reinforcing

Steel is the most commonly used reinforcing to give concrete tensile strength.

Water

Water is a key ingredient in concrete. When mixed with cement it forms a paste that binds the aggregate together.

The water causes the hardening of concrete through a process called hydration. Hydration is a chemical reaction in which the major compounds in cement form chemical bonds with water molecules and become hydrates or hydration products.

The role of water is important because the water to cement ratio is the most critical factor in the production of "perfect" concrete.

Too much water reduces concrete strength, while too little will make the concrete unworkable.

Workability

Workability refers to the ease with which the plastic concrete mix can be effectively moved, consolidated in forms, placed and finished.

Concrete Summary

Concrete is everywhere. Take a moment and think about all the concrete encounters you have had in the last 24 hours. All of these concrete structures are created from a mixture of cement and water with added aggregate. It is important to distinguish between cement and concrete as they are not the same. Cement is used to make concrete!

(cement + water) + aggregate = concrete

Cement is made by combining a mixture of limestone and clay in a kiln at 1450°C. The product is an intimate mixture of compounds collectively called clinker. This clinker is finely ground into the powder form. The raw materials used to make cement are compounds containing some of the earth's most abundant elements, such as calcium, silicon, aluminium, oxygen, and iron.

Water is a key reactant in cement hydration. The incorporation of water into a substance is known as hydration. Water and cement initially form a cement paste that begins to react and harden (set). This paste binds the aggregate particles through the chemical process of hydration. In the hydration of cement, chemical changes occur slowly, eventually creating new crystalline products, heat evolution, and other measurable signs.

cement + water = hardened cement paste

The properties of this hardened cement paste, called binder, control the properties of the concrete. It is the inclusion of water into the product that causes concrete to set, stiffen, and become hard. Once set, concrete continues to harden (cure) and become stronger for a long period of time, often up to several years.

The strength of the concrete is related to the water to cement mass ratio and the curing conditions. A high water to cement mass ratio yields a low strength concrete. This is due to the increase in porosity (space between particles) that is created with the hydration process. Most concrete is made with a water to cement mass ratio ranging from 0.35 to 0.6.

Aggregate is the solid particles that are bound together by the cement paste to create the synthetic rock known as concrete. Aggregates can be fine, such as sand, or coarse, such as gravel. The relative amounts of each type and the sizes of each type of aggregate determine the physical properties of the concrete.

sand + cement paste = mortar

mortar + gravel = concrete

Sometimes other materials are incorporated into the batch of concrete to create specific characteristics. These additives are called admixtures.

Admixtures are used to: alter the fluidity (plasticity) of the cement paste; increase (accelerate) or decrease (retard) the setting time; increase strength (both bending and compression); or to extend the life of a structure. The making of concrete is a very complex process involving both chemical and physical changes. It is a material of great importance in our lives.

RESULTS:

Part One:

Mix 1 - (Group 1 & 2 have the same mix design)

In terms of workability, consistence and cohesiveness describe the characteristics of mix 1:

Amount of slump (mm): _____

Diagram of slump test:

Mix 2 - (Group 3)

In terms of workability, consistence and cohesiveness describe the characteristics of mix 2:

Amount of slump (mm): _____

Diagram of slump test:

Mix 3 - (Group 4)

In terms of workability, consistence and cohesiveness describe the characteristics of mix 3:

Amount of slump (mm):_____

Diagram of slump test:

Part Two: Testing the Flexural Strength of the Concrete Samples

Sample Mix	Failure Weight (kilograms)
1	
2	
3	
4	

QUIZ CHALLENGE:

1. Distinguish between cement and concrete.

Cement is a component of concrete. Cement and water make the "glue" which holds concrete together.

2. Name at least 5 items you have encountered today which are concrete.

Answers will vary.

3. What are the major ingredients for concrete, and what role do they play?

Cement- reacts with water to form "glue"

Water- reacts with cement, the amount also determines strength

Aggregate- makes concrete stronger, more durable, and less costly

4. What is meant by "workable"? Why is it important for concrete to be workable?

Cement which is workable is able to be poured into forms without difficulty. A slump test is used to measure workability.

5. Give an example of an aggregate.

Gravel or sand.

6. What is the practical use for this aggregate in making concrete?

Aggregate makes the concrete stronger and cheaper.

7. What can be used to slow the hardening of concrete? Why would slowing this process be desirable?

A retarding admixture will slow the hardening process of the concrete. This may be required if the concrete needs to be transported a long distance, or if it is a hot day when casting the concrete.

8. What can be used to speed the hardening of concrete? Why would speeding up this process be desirable?

An accelerator would be added to a concrete mix to speed the hardening. This may be necessary in cold weather where it is desirable to speed up the hardening process and produced higher heat of hydration.

9. What will happen to concrete if it dries out too quickly?

Concrete will most likely crack due to drying shrinkage. The hydration reaction which strengthens concrete will be halted from lack of water resulting in weaker concrete.

10. Suppose you were to be the chief designer in charge of building a concrete ship to carry people overseas. What aggregate might you choose to put in your concrete and why?

A lightweight aggregate would be desirable for building a ship needing to float. However, the boat would be dangerous because of poor tensile properties of concrete. It would have to be reinforced to be safe.

11. Explain how you can measure the consistency of freshly mixed concrete?

A slump test can be performed on freshly mixed concrete to determine its consistency. This is done by pouring it into an inverted cup with the bottom cut out. Once the cup is removed, the concrete is observed. It is desirable that the concrete stay 50-75% of its original height for good workability.

12. Briefly discuss the importance of a proper water-to-cement ratio.

The water to cement ratio determines the strength of concrete. The less water that is used to obtain a workable concrete, the more strength the resulting hardened concrete will have. However, remember that workability is lost if water to cement ratio is too low.

13. Explain the purpose of a superplasticizer in making concrete.

A superplasticizer is an admixture which is used to make concrete more workable with the use of less water. Using a superplasticizer will result in a stronger concrete because less water is used.

14. Why should gloves be worn when mixing concrete?

Gloves should be worn while mixing concrete because one of the products of the hydration reaction is calcium hydroxide. In fact, upon mixing concrete, the pH rises to 12 which means the solution is strongly basic (alkaline). This can burn, irritate, and dry out the skin.

15. Water is important in making concrete, however, it can also be harmful to concrete. Explain this statement.

Water transports harmful substances that lead to concrete degradation. Water is the central issue in freeze-thaw damage of concrete.

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ACKNOWLEDGMENT

Created by Tracie Fong in the School of Civil Engineering, 2002

CONCRETE MATERIALS:

FORMWORK VOLUME: 600 X 100 x 35 mm = 2.1 litres

CONCRETE STRENGTH: 15 MPa

(0.23%) Group	Water (mls)	Cement (kg)	Coarse Aggregate (kg)	Fine Aggregate (kg)
1 & 2	600	0.7	1.9	2.3
3	600	0.7	-	4.2
4	600	0.7	4.2	-

Approximate breaking loads for concrete beams:

Mix 1 – reinforced	90kg
Mix 2 – non-reinforced	50kg
Mix 3 - coarse mix	18kg
Mix 4 – fine mix	15kg

Results of Compressive tests:

Mix Type	Strength	Density
Good mix (1&2)	15.6 MPa	2.22 g/cm^3
Coarse mix (3)	2.3 MPa	1.77 g/cm^3
Fine mix (4)	4.2 MPa	1.78 g/cm^3