



Lecture #5

PROTECTION CONCEPT FOR MARINE CONCRETE STRUCTURES



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Research Interests

- Phd – Ductile High-Strength Concrete
- Concrete Ductility and Confinement
- Concrete Materials and Concrete Technology


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Types of structures and applications in marine environment

- Port Structures
 - Quay Walls
 - Jetties
 - Tidal pools
 - Boat Ramps, etc
- Seaside Structures
- Offshore Structures


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Methods of Protection

- Durable & Dense Concrete
- Surface Coatings
- Confined Concrete With Advanced Composites
- Rebar Coatings
- FRP Rebar

DURABILITY
PROBLEM



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Steel Corrosion Process

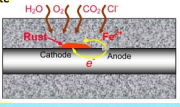
Concept of electro-chemical process of corrosion of steel in concrete

Corrosion product: $Fe + Fe^{2+} + 2e^-$

Anode: $Fe \rightarrow Fe^{2+} + 2e^-$

Cathode: $0.5O_2 + 2H_2O + 2e^- \rightarrow 2OH^-$

Overall: $Fe + 0.5O_2 + 2H_2O \rightarrow Fe(OH)_2$




Moisture enters hairline cracks and porous areas

Rust begins to form

Build up of bulky corrosion products causes disruptive tensile stresses

Finally pressure causes spalling of concrete, exposure of steel bars

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Mechanism

General mechanism for the corrosion of rebars

Silt crystal growth and alternate freeze and thaw cycles promote the formation of cracks.

Low alkaline concrete

$O_2, H_2O, NaCl$ inhibit the possibility of self-limiting corrosion.

End view of embedded rebar.

High alkaline concrete

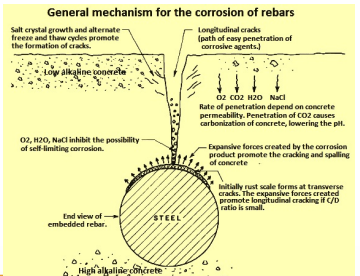
Longitudinal cracks (path of easy penetration of corrosive agents)

$O_2, CO_2, H_2O, NaCl$

Rate of penetration depend on concrete permeability. Penetration of CO_2 causes carbonation of concrete, lowering the pH.

Expansive forces created by the corrosion product promote the cracking and spalling of concrete

Initially rust scale forms at transverse cracks. The expansive forces created promote longitudinal cracking if L/D ratio is small.



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Factors affecting reinforcement corrosion

- CHLORIDE**
- CO₂; CARBONATION**
- SULFATE**

- Chlorides either contributed from the concrete ingredients or penetrated from the surrounding chloride-bearing environment.
- Carbonation of concrete or penetration of acidic gases into the concrete, are the other causes of reinforcement corrosion.

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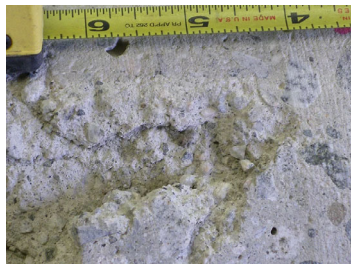
- WATER TO CEMENT RATIO**
- CEMENT CONTENT**
- CONCRETE INGREDIENTS**
- EXTERNAL ENVIRONMENT**

- Properties related to the concrete quality, such as w/c ratio, cement content, impurities in the concrete ingredients, presence of surface cracks, etc. and others related to the external environment, such as moisture, oxygen, humidity, temperature, bacterial attack, stray currents, etc...

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Porous Material



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High-Performance Concrete

HIGH DURABILITY DENSE

- Properties of Concrete Ingredients
- Concrete Mix Design – w/c, cement content,
- Preparation/Workmanship – curing, compaction

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Basic Materials for Concrete


- Cement
- Aggregates – Fine Aggregate & Course Aggregate
- Water
- Admixtures – Chemical & Pozzolanic/Mineral

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CEMENT

Is the product obtained by grinding clinker formed by burning raw-materials (argillaceous and calcareous) primarily consisting of lime (CaO), silicate (SiO₂), alumina (Al₂O₃), and iron oxide (Fe₂O₃)




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Common Raw Materials

Raw Materials	Compound
Cement rock	Lime, Silica, Alumina
Limestone	Lime
Chalk	Lime
Slag	Lime, Silica, Alumina
Oyster shell	Lime
Marble	Lime
Clay	Silica, Alumina, Iron Oxide
Shale	Alumina
Fly Ash	Silica, Alumina, Lime
Kaolin	Alumina
Bauxite	Alumina
Sand	Silica


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History of Portland Cement



- 1824 – patented by Joseph Aspdin
- Materials to produce cement were found and after manufactured resemble the stone found on the English Isle of Portland
- Thus, called **PORTLAND CEMENT**

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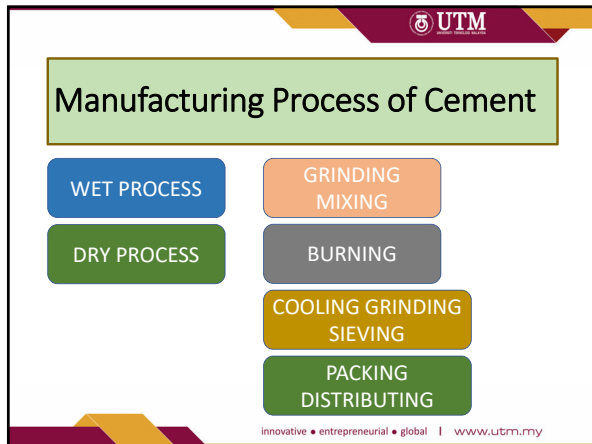


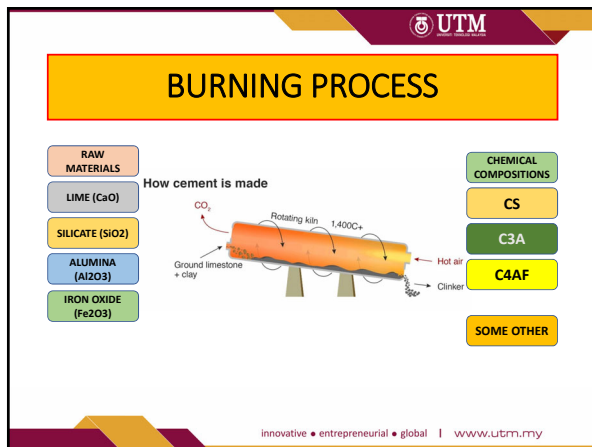
Characteristics of cement

- **Set** and **harden** when mix to a paste with water
- **Cohesive** and **Adhesive**
- A material that binds concrete ingredients – **essentially like GLUE**

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Chemical Composition of Portland Cement

Abb.	Compound	Oxide	Percent (%)	Reaction with water
C ₃ S	Tricalcium silicate	3CaO.SiO ₂	45-60	Medium
C ₂ S	Dicalcium silicate	2CaO.SiO ₂	15-30	Slow
C ₃ A	Tricalcium Aluminate	3CaO.Al ₂ O ₃	6-12	Fast
C ₄ AF	Tetracalcium Aluminoferrite	4CaO.Al ₂ O ₃ .Fe ₂ O ₃	6-8	Medium
Others			8	

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Others of Minor Compounds


- Magnesium oxide
- Titanium oxide
- Manganese oxide
- Sodium oxide
- Potassium oxide
- Minor – refers to quantity not important

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Alkalis in Cement

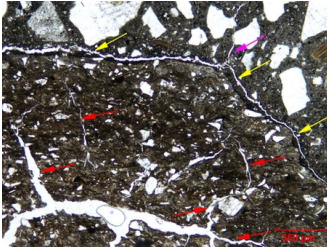
- Sodium oxide (Na_2O) and Potassium oxide (K_2O)
- May cause problem – Alkali Silica Reaction



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Microstructure - ASR



- Internal Microfractures
- concentric external microfractures
- Paste Microfractures


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HYDRATION PROCESS OF PORTLAND CEMENT

- Is the chemical **reaction between the compounds of cement and water** that yields products that achieve the binding property after hardening
- Two stages:
setting and hardening
Setting - cement starts to stiffen


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Types of Cement Setting

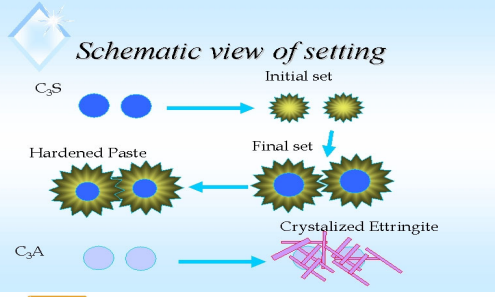
- **Initial setting** – when the paste beginning to stiffen
- **Final setting** - when the paste beginning to harden and able to carry some loads
- **Flash set** – rapid development of permanent rigidity of the cement paste – along with high heat
- **False set** – rapid development of rigidity without the evolution of heat, premature stiffening, can be reworked

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Set – reaches a state in which its form cannot be changed without rupture

Schematic view of setting



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Hydration Process of Cement

Cement + H₂O →



C-S-H gel + Ca(OH)₂

For complete hydration, it is estimated that 1 g of cement requires 0.32 g of water (w/c=0.32)


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Factors Affecting Rate of Hydration

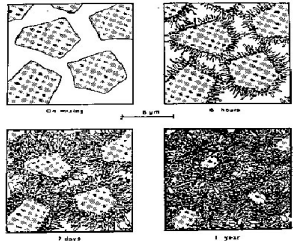
- Chemical compositions Amount C₃S, C₂S, C₃A, C₄AF
- Fineness – *measuring the surface area per unit mass (m²/kg)*
 -  Finer
 -  Coarser

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Hydration of cement

CSH Production

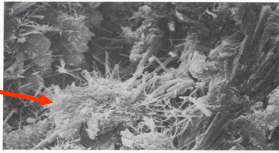


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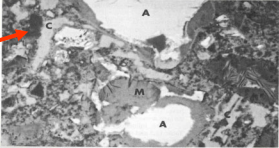
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C-S-H gel and Ca(OH)_2

C-S-H gel



Ca(OH)_2



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Hydration Process of Cement

- The silicates, C_3S and C_2S (75%), are the most important compounds, which are responsible for the **strength** of the hydrated cement paste
- C_3S provides the early strength and liberated higher **heat of hydration** (twice compared to C_2S)

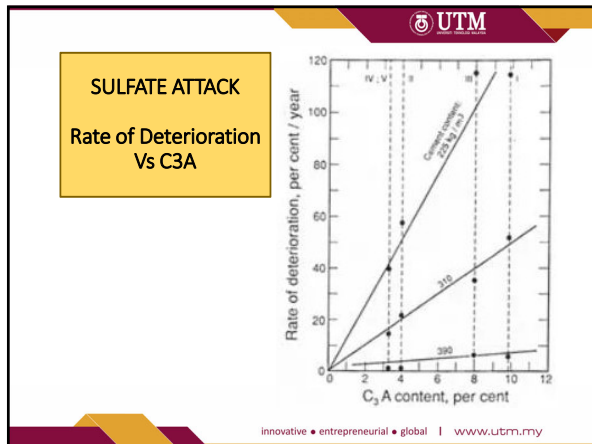
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Hydration Process of Cement – cont'd

- C_2S reacts slowly, provide later strength, highly chemical resistance (sulphate, chloride)
- C_3A is undesirable, contribute little or nothing to the strength of cement except at early ages, and when hardened cement paste is prone to be **attacked by sulphates**, forming sulphoaluminate that may cause disruption in concrete

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Hydration Process of Cement – cont'd

- **C₄AF** does not affect significantly the behaviour of cement hydration.
- However, it reacts with gypsum to form calcium sulphoferrite and its presence may accelerate the hydration of silicates

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CHEMICAL COMPOSITION OF PORTLAND CEMENT

Will affect:

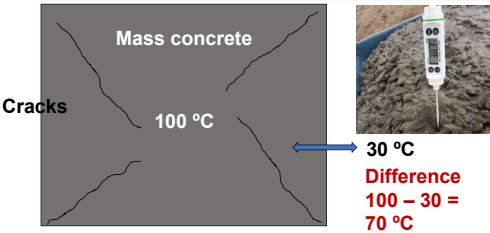
- Strength of cement/mortar/concrete
- Rate of hydration
- Amount of heat of hydration
- Durability of cement/mortar/concrete

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Hydration Process of Cement

- It is an **exothermic** process where heat is liberated (*heat of hydration*)

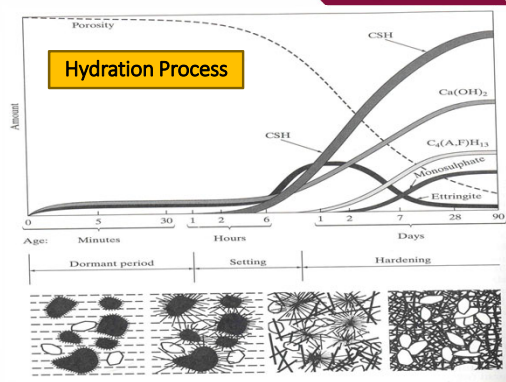


Mass concrete
Cracks
100 °C
30 °C
Difference
 $100 - 30 = 70$ °C

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Hydration Process



Amount

Porosity

CSH

Ca(OH)₂

C₄(A,F)H₁₃

Monosulphate

Ettringite

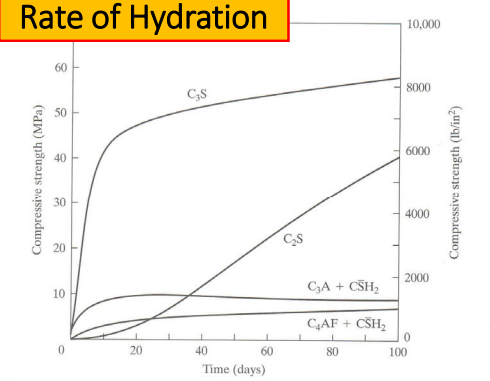
Age: Minutes, Hours, Days

Dormant period, Setting, Hardening

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Rate of Hydration



Compressive strength (MPa)

Compressive strength (lb/in²)

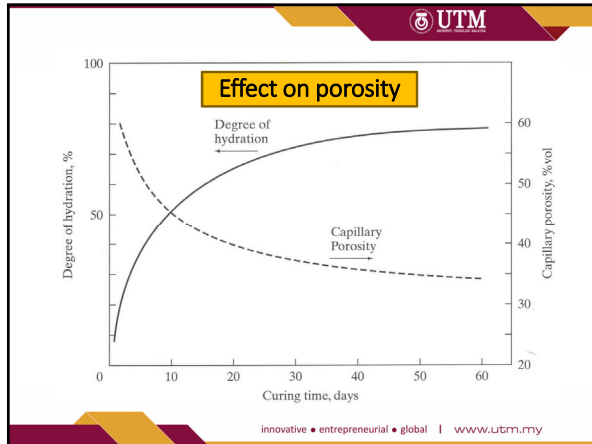
Time (days)

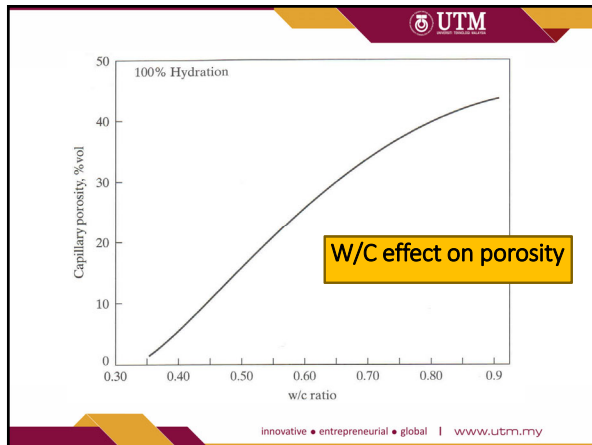
C₃S

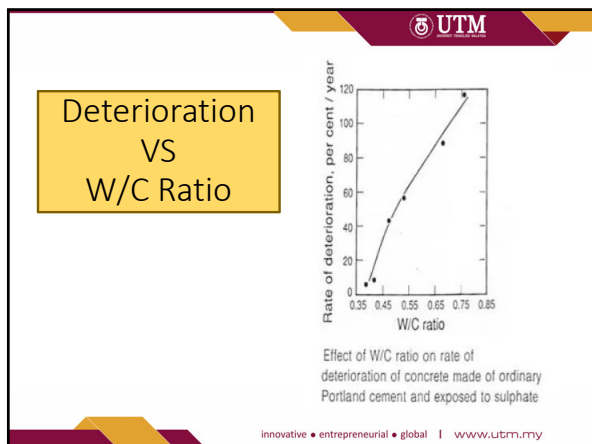
C₂S

C₃A + CSH₂

C₄AF + CSH₂







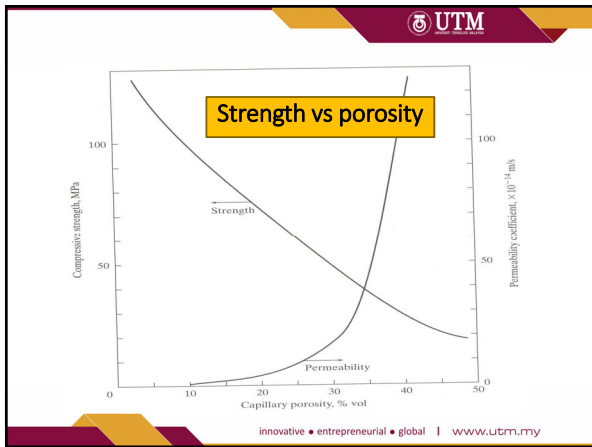
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ACI 357R- 84

Zone	Maximum w/c ratio	Concrete compressive strength (f _c) MPa
Submerged	0.45	35
Splash	0.40	35
Atmospheric	0.40	35

f_{cu} = 42 MPa

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Types of Cement


- Ordinary Portland Cement (OPC)
- Portland Pozzolana Cement (PPC)
- Rapid Hardening Cement
- Low Heat Cement
- Sulphate Resisting Cement
- Blast Furnace Cement
- High Alumina Cement
- Air Entraining Cement

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Cement Type and Strength Class

PHOENIX complies with the requirements specified in the British Standard BS EN 197-1 : 2000 - CEM II/B - M 32.5 R which corresponds to European Standard EN 197-1 : 2000, Composition, Specification and Conformity Criteria for Common Cements.




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Cement Type and Strength Class


CERTIFICATIONS
 DRAGON is certified to MS 522-1 : 2007, CEM II/B-M 32.5N / CEM III/A 32.5N / CEM I/A 32.5N. DRAGON also certified as a Green Label Eco-Friendly cement by the Singapore Environment Council. As such, it has significantly lower carbon foot print as compared to normal portland cement.



Tests	Units	Specification	Test Results
		MS 522-1 : 2007 (32.5N)	
Chemical Composition			
Sulfate Content (SO ₃)	%	3.5 max	2.04
Chloride (Cl ⁻)	%	0.01 max	0.01
Physical Properties			
Setting Time (Initial)	mins	Not less than 75	185
Soundness	mm	Not more than 10	<1
Compressive Strength (Mortar Prism) (1:3:0.5)	MPa	Not less than 16	18
		32.5 ≤ x ≤ 52.5	36




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Cement Type and Strength Class

CERTIFICATIONS
 ORANG KUAT is certified to MS 522-1 : 2007 (EN 197-1 : 2000), CEM I 42.5N / 52.5N and MS 522 : Part 1 : 2003.



Tests	Units	Specification	Test Results
		MS 522-1 : 2007 (42.5N)	
Chemical Composition			
Insoluble Residue	%	≤ 5.0	0.4
Loss On Ignition (LOI)	%	≤ 5.0	3.2
Sulfate Content (SO ₃)	%	≤ 3.5	2.7
Chloride (Cl ⁻)	%	≤ 0.10	0.02
Physical Properties			
Fineness (According to Blaine)	m ² /kg		345
Setting Time (Initial)	mins	≥ 60	130
Soundness	mm	≤ 10	1.0
Compressive Strength (Mortar Prism) (1:3:0.5)	MPa	≥ 10	29.7
		≥ 42.5; ≤ 62.5	48.9



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Effect of chemical composition

- **Cement differing in chemical compositions may exhibit different properties when hydrated i.e. Strength, durability, rate of strength gain, heat of hydration**

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Ordinary Portland Cement (Type I)

- By far **the most common (60%)** cement used in general concrete construction when there is **no exposure to sulphates** in the soil or groundwater
- Minimum fineness of 225 m²/kg
- Rate of hardening is moderate
- Standards: **BS 12:1991, MS 522, ENV 197-1:1992**

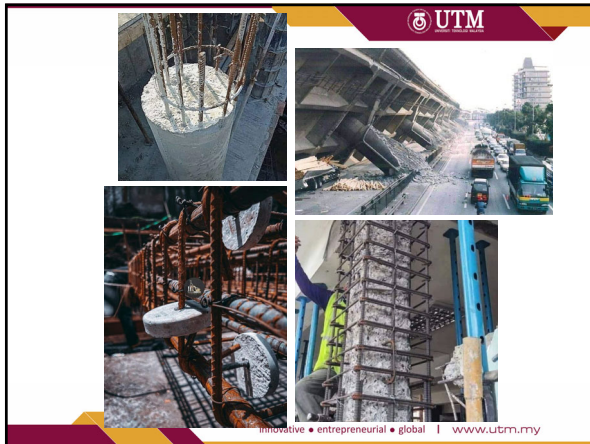
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- **Cement loses its binding properties**



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Rapid Hardening Portland Cement (RHPC – Type III)


- Rapid strength gain due to higher C_3S content (70%)
- Minimum fineness of $325 \text{ m}^2/\text{kg}$
- Used when:
formwork is to be removed early for reuse or where sufficient strength for further construction is required quickly
- Should not be used in mass concrete construction or in large structural sections because of its higher rate of heat development that can cause cracking

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RHPC (cont.)

- For construction at low temperatures, the use of RHPC may provide a satisfactory safeguard against early frost damage
- The setting time and chemical compositions of RHPC and OPC is relatively the same


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Sulphate Resisting Portland Cement (SRPC – Type V)

- This cement has **low C₃A (3.5%)** content so as to avoid sulphate attack from outside the concrete
- Minimum fineness of 250 m²/kg
- Active salts are **magnesium and sodium sulphates** – increase in volume, cause concrete to disintegrate and crack
- Sulphate attack is greatly accelerated if accompanied by wetting and drying (splash zone)
- The heat develop by SRPC is not much higher than the low-heat cement, which is an advantage


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Sulphate attack




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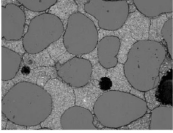
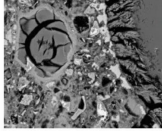

Sulphate Exposure Levels

Exposure	Concentration of water-soluble sulphates in soil percent	Concentration of water-soluble sulphates in water ppm
Mild	<0.1	<150
Moderate	0.1 to 0.2	150 to 1500
Severe	0.2 to 2	1500 to 10000
Very severe	>2	>10000


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Microscopic View

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What happens when sulphates get into concrete?

When sulphates enters into concrete:

- It combines with the C-S-H, or concrete paste, and begins destroying the paste that holds the concrete together. As sulphate dries, new compounds are formed, often called **ettringite**.

- These new crystals occupy empty space, and as they continue to form, they cause the paste to crack, further damaging the concrete.

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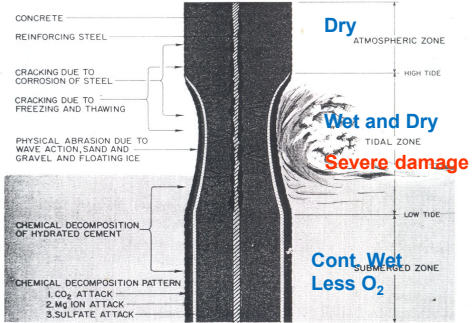


Fig. 5.3. Physical and chemical processes responsible for deterioration of a reinforced concrete element exposed to seawater.

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Concrete Characteristics

POROUS PERMEABLE

LESS PERMEABLE

DENSE

DURABLE

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Blended Cement

- Is a combination between Ordinary Portland Cement (60%) and Pozzolanic materials (40%) (*contains reactive SiO₂*)
- Blended Cement = OPC + Slag
= OPC + Fly Ash
= OPC + Silica Fume
= OPC + RHA

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Blended Cement VS SRPC

BLENDED IMPERMEABLE/
DENSE/DURABLE - PROTECTION

SRPC RESISTANCE


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Portland-Blastfurnace Cement

- Made by inter-grinding or **blending Portland cement** clinker with **granulated blast-furnace slag**
- Known as slag cement
- Slag contains **lime, silica and alumina**, but not in the same proportions as in Portland cement
- **Minimum fineness of 275 m²/kg**
- Early strength are generally lower than OPC but later strength are similar or even higher


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Portland-Blastfurnace Cement

- Typical uses are in mass concrete because of low heat of hydration and in seawater construction due to better sulphate resistance (**lower C₃A content**) than with the OPC
- The amount of slag replacement between 25 to 70% of the mass of the mixture


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Portland-Pozzolan Cement

- Made by inter-grinding or **blending pozzolans** with **Portland cement**
- A **pozzolan** is a **siliceous or siliceous and aluminous** material which itself possesses little or no cementitious value **BUT** in finely divided form and in the presence of moisture, **chemically react with Ca(OH)₂** liberated during the hydration of Portland cement to form compounds possessing cementitious properties


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Cont.

- Portland-Pozzolan cement gain strength slowly and therefore require curing over a comparatively a long period of time, but the long-term strength is higher than OPC
- Amount replacement between 25 to 40%
- **More durable than OPC**

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Hydration Process of Blended Cement

Cement + H₂O → **C-S-H (gel) + Ca(OH)₂**

SiO₂ + Ca(OH)₂ → **C-S-H (gel)**

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<p>Concrete with silica fume <small>Microsilica concrete</small></p> <p>Hydration crystals growing from cement grain and from 'nucleation centres' of microsilica.</p>  <p>Crystals from microsilica and cement grain interacting to form a complete and dense structure with no voids.</p> <p>DENSE CONCRETE</p> <p>(b)</p>	<p>Normal plain concrete <small>Conventional concrete</small></p> <p>Hydration crystals growing from cement grain.</p>  <p>Hydration complete; voids left between crystal structure.</p>
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Aggregates

TYPES

PROPERTIES



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Strength & Durability Issues




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Normal Weight Aggregate

- 1) Density in the range of 2300 – 2500 kg/m³
- 2) Mostly obtained from quarry, river
- 3) Specific gravity in the range of 2.5-3.0
- 4) Suitable for most constructions
- 5) Need to be cleaned from impurities
- 6) Chloride content should be less than 1%


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Water in Concrete

Water is used:


- For the hydration process of cement
- For the workability of concrete
- Controlling concrete temperature



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Water




QUESTIONABLE WATER

STRENGTH ?

DURABILITY ?


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Maximum permissible limits of solids

Types of solids	Limits
Organic solids	200 mg/liter
Inorganic solids	3000 mg/liter
Sulphates	400 mg/liter
Chlorides	2000 mg/liter for concrete not containing embedded steel, and 500 mg/liter for reinforced concrete work
Suspended matter	2000 mg/liter

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Admixtures

Chemical admixtures

Pozzolanic admixtures

A material added to concrete or mortar, other than water, aggregates, cement, and fibre **TO CHANGE** one or more properties of fresh or hardened concrete

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Chemical Admixtures

Chemical added in very small amount or quantity to the mixture to develop special properties in fresh or hardened concrete

- 1) **Accelerating** admixture
- 2) **Retarding** admixture
- 3) **Water-reducing**/high-range water-reducing admixture
- 4) **Air-entraining** admixture
- 5) others


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Chemical Admixture

Description	Applications
Water-reducing Admixture	To get dense concrete, to improve workability
Retarding admixture	To delay setting and hardening, hot weather concreting, large structures
Accelerating admixture	To accelerate setting and early strength development, cold weather concreting
Air-entraining admixture	To improve durability and workability


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Pozzolanic Admixtures

- Are natural pozzolanic materials or industrial by-products that are used in concrete to replace part of cement
- It is known as *supplementary cementing material*
- Are generally added in relatively large quantities in comparison with chemical admixtures
- Contains reactive silica (SiO₂)


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Pozzolans

- Are siliceous or silicious and aluminous materials which in themselves possess little or no cementitious property
- BUT in finely divided form and in the presence of moisture, these materials can react with calcium hydroxide of concrete at ordinary temperatures to form compounds of cementitious properties.
- This reaction is called POZZOLANIC REACTION

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Pozzolanic Reaction

Cement + H₂O --->
C-S-H gel + Ca(OH)₂


SiO₂ + Ca(OH)₂ → C-S-H gel

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Example of Pozzolans

- Ground Granulated Blastfurnace Slag
- Pulverised Fuel Ash
- Silica Fume
- Rice Husk Ash
- Palm Oil Fuel Ash



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Effect of pozzolanic admixtures

- Replacing part of the cement content (by weight of cement)
- Can be added during mixing process or grind together with cement (pozzolan cement)

- Lower early strength
- Lower heat of hydration
- Higher ultimate strength
- Less permeable
- Reduce cost
- Increase workability (some)


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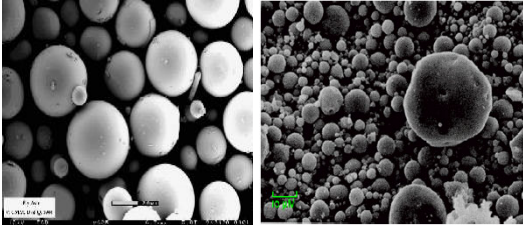
Fly Ash

- Is a by-product of burning powdered coal in electric generating power plant
- Generally finer than Portland cement and consists mainly of small spheres of glass involving silica, alumina, and ferric oxide
- Amount of replacement : 20 to 70%
- Two types:
 - Class F Fly Ash – low calcium fly ash. Has no cementitious properties but can react with calcium hydroxide
 - Class C Fly Ash – high-calcium fly ash. Has cementitious properties in addition to pozzolanic properties


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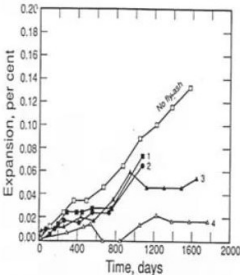
Microstructure of Fly Ash



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Fly Ash Content VS Expansion (Deterioration) Due to Sulfate Attack



Sulphate expansion of concrete containing low-calcium fly-ash of different compositions marked 1 to 4.


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Ground Granulated Blast Furnace Slag (GGBS)

- Is a non-metallic product, consisting essentially of silicates and aluminates of calcium bases
- Not only pozzolanic but also cementitious
- It is develop in a molten condition simultaneously with iron in a blastfurnace
- Is the glassy granular material formed when molten blastfurnace slag is rapidly chilled as by immersion in water
- Amount replacement : up to 80%


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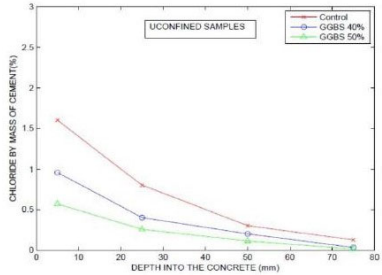
Physical & Chemical Properties

Description of Test	OPC	GGBS
Physical Tests		
Specific gravity	3.28	2.90
Surface area (m ² /kg)	314	420
Chemical analysis (%)		
Silica dioxide (SiO ₂)	20.20	28.2
Aluminium oxide (Al ₂ O ₃)	5.7	10.0
Ferric oxide (Fe ₂ O ₃)	3	1.8
Calcium oxide (CaO)	62.58	50.4
Magnesium oxide (MgO)	2.60	4.6
Sulphur trioxide (SO ₃)	1.80	2.2
Sodium oxide (Na ₂ O)	0.16	0.14
Potassium oxide (K ₂ O)	0.87	0.6
Loss on Ignition (LOI)*	2.7	0.2


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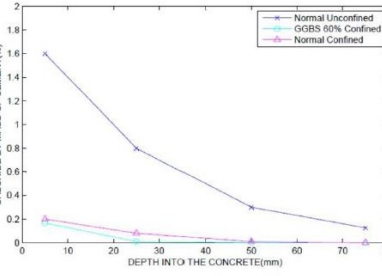
Ground Granulated Blast Furnace Slag (GGBS)



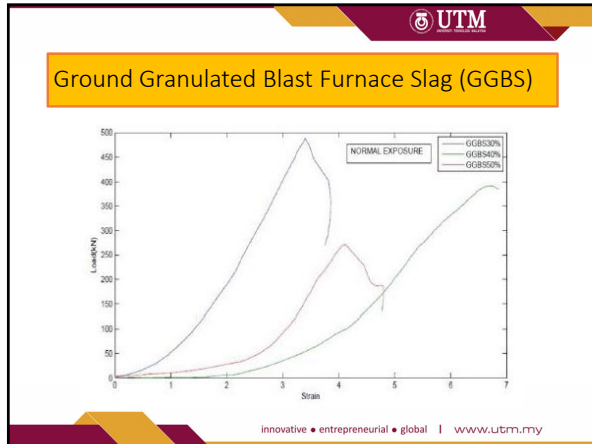
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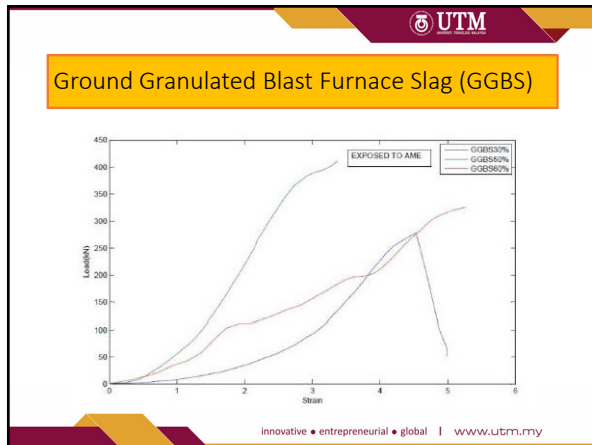


Ground Granulated Blast Furnace Slag (GGBS)



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Ground Granulated Blast Furnace Slag (GGBS)

SpecimenID	Type	Exposure	GGBS%	Failure Load(kN)	Stress(MPa)	Failure Mode
C1	Unconfined	Normal		353.4	19.99	
C2		Normal		293.5	16.60	
C3		AME		288.6	16.32	
C4		AME		224.8	12.72	
G1		Normal	30	488.1	27.61	
G2		AME	40	318.5	18.02	
G3		AME	50	391.5	22.15	
G4		Normal	60	271.5	15.56	
C1W	Wrapped	Normal		549.5	31.08	Rupture
C1W	With GFRP	Normal		544.5	30.80	Rupture, splitting
C1W		AME		621.6	35.16	Rupture
C1W		AME		473.6	26.79	Rupture
G1W		AME	30	561.5	31.76	Rupture, splitting
G2W		Normal	40	560	31.08	Rupture
G3W		AME	50	523.6	29.62	Rupture, splitting
G4W		Normal	60	479.2	27.11	Rupture

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Unconfined and Confined Concrete



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Palm Oil Fuel Ash (POFA)

- **Obtained from the burning of palm oil clinker**
- **Amount replacement : 10 to 30%**


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Silica Fume

- **Is a by-product of the electric arc furnaces in the silicon metal and ferrosilicon alloy industries**
- **Consist of non-crystalline silica (85 to 90% silicon oxide)**
- **Very fine particles – less than 0.1um (100 times finer than cement)**
- **Highly pozzolanic and very reactive**
- **Amount replacement : 10 to 20%**


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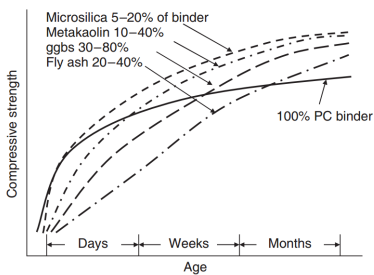
Rice Husk Ash (RHA)

- Is an agricultural fly ash which is obtained from burning and grinding of rice husk
- Contains silica
- Amount replacement : 10 to 30%

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Pozzolanic Effects on Strength



The graph plots Compressive strength on the y-axis against Age on the x-axis, which is divided into Days, Weeks, and Months. Five curves are shown, representing different binder compositions. The 100% PC binder curve is the lowest. The other curves, representing Microsilica (5-20%), Metakaolin (10-40%), ggbs (30-80%), and Fly ash (20-40%), all show higher strength gain over time compared to the 100% PC binder, with ggbs showing the highest strength gain.

Fig. 21.14 Schematic of typical strength gain characteristics of concrete containing Type 2 additions. utm.my

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Factors Affecting the Suitability and Performance of Admixtures in Concrete

- Type of cement
- Mix proportions and method of mixing
- Temperature and time when the admixture is added into the mix
- Chemical composition of the admixture

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Monitoring and Precaution

- Selection of material
- Trial mix
- Short-term and long-term effect
- Eliminate overdosing – on site
- Manufacturer’s advice

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Effect of Curing

Curing and Strength Development

The graph plots Strength on the y-axis against time on the x-axis. Four curves represent different curing conditions: 'moist cured entire time' (topmost, blue), 'in air after 7 days' (yellow), 'in air after 3 days' (red), and 'in air entire time' (bottommost, green). A vertical pink line is drawn at 28 days on the x-axis, with a horizontal line extending to the y-axis at the 100% strength mark. The 'moist cured entire time' curve reaches 100% strength before 28 days. The 'in air after 7 days' curve reaches 100% strength at 28 days. The 'in air after 3 days' curve reaches approximately 90% strength at 28 days. The 'in air entire time' curve reaches approximately 80% strength at 28 days.

Strength

100%

28

time

moist cured entire time

in air after 7 days

in air after 3 days

in air entire time

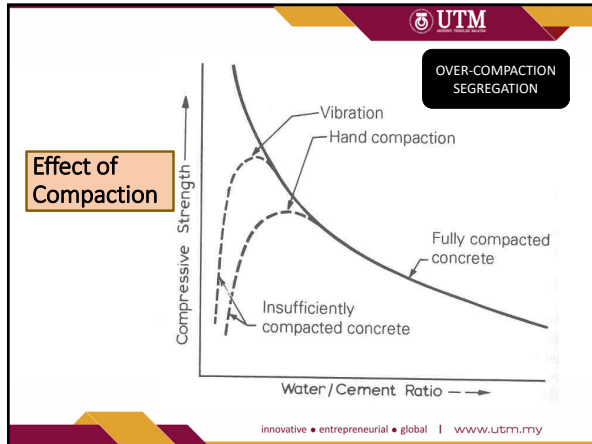
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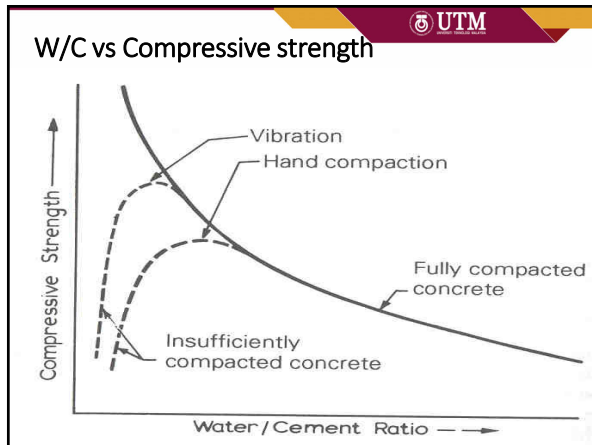
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A microscopic image showing a spherical aggregate particle in a concrete matrix. The particle is dark and smooth, surrounded by a lighter, porous matrix. A scale bar in the bottom right corner indicates 500 µm.

500 µm

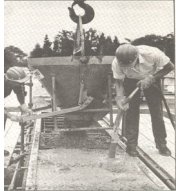
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Compaction

- Compaction is to eliminate air from concrete, reduce voids
- **Compaction – internal (poker) and external**
- Compaction is important to produce the required strength and durability of concrete



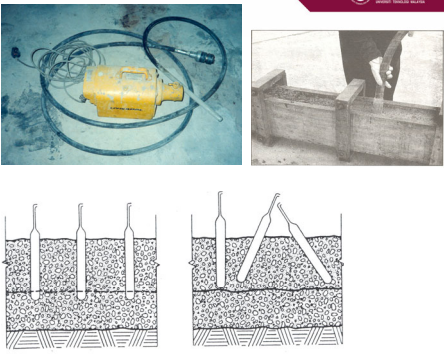
The UTM logo is in the top right corner, and the footer contains the text 'innovative • entrepreneurial • global | www.utm.my'.

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Correct Incorrect

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SURFACE COATINGS

- EPOXY MORTAR
- DURABLE PAINTS
- POLYMER etc..



MATERIAL PROPERTIES THICKNESS SURFACE CONDITION BONDING


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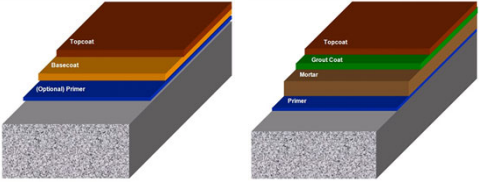
EPOXIES

Epoxies are two component products consisting of an epoxy resin which is cross-linked with a co-reactant or hardener. Epoxy coatings are formulated based upon the performance requirements of the end product. When properly catalyzed and applied, epoxies produce a hard, chemical and solvent resistant finish. They are typically used on concrete and steel to give resistance to water, alkali and acids.

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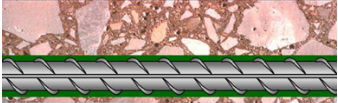


COATING LINING SYSTEMS



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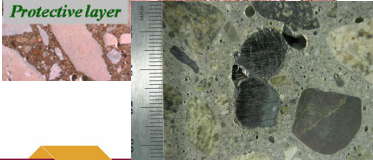
Reinforcement Coatings



Coating Materials

Bonding Issue


Protective layer



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Fiber Reinforced Polymer (FRP) REBAR



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The image shows two parts: on the left, several bundles of FRP rebar with labels indicating sizes like 20mm, 16mm, 14mm, 12mm, 10mm, 8mm, and 6mm; on the right, a grid of FRP rebar being used in a construction project, secured with yellow ties.

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FRP Characteristics

- Durable – solve corrosion problem
- Lightweight but strong
- Vandalism problem – missing manhole cover
- New material for better performance
- Others

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Thank You



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The image contains three photographs: an aerial view of a coastal city, a cityscape with a Ferris wheel, and a large circular architectural structure over water.