Question 1. Common masonry materials (15p)

1.1 The CE marking system for clay bricks proves conformity for products in the European market. Durability against freeze and thaw is an item in the CE marking.
- Explain the freeze/thaw damage mechanism in clay bricks
- Describe the different freeze/thaw categories for clay bricks
- What are the suitable applications for each category?

1.2 Compare between clay bricks and calcium-silicate bricks in terms of their:
- raw materials
- mixing process of materials
- forming (molding) of brick units
- hardening of brick units

Answer to question – 1

1.1 points			1.2 points			
F/T mech	F/T classes	applications	Raw mat.	mixing	forming	hardening
3	2	2	2	2	2	2

1.2 Freeze/thaw damage in clay bricks

- Freeze/thaw damage mechanism in clay bricks: (3 points)
  - Clay bricks and joining mortars are porous materials that have the ability to absorb water from their environment.
  - Freeze-thaw damage occurs when water fills the voids of the bricks and then freezes and expands.
  - The volume of frozen water is 9% greater than liquid water, so when water freezes pressure is exerted on the surrounding pores, and when the pressure exceeds the tensile strength of the brcks, cracks will result.
  - During this process, the voids are enlarged, enabling the accumulation of additional water during the next thaw; this results in additional cracking during the next freeze.
  - Substantial damage can occur over subsequent freeze-thaw cycles.
- Describe the different freeze/thaw categories for clay bricks (2 points)
  - Category F2 - Severe exposure: If no damage after 100 F-T cycles.
  - Category F1 - Moderate exposure: If the bricks were assessed as not failed after (n) cycles where (n) is a number of less than 100. The result is recorded as F1(n).
  - Category F0 - Passive exposure: If the freezing thawing test FAILED.
- What are the suitable applications for each category? (2 points)

- F2 bricks are used for unprotected masonry (e.g. facade) and brick units permanently in contact with water (e.g. canal etc.)
- F1 bricks are good for general purpose brickwork but are only moderately frost resistant. Areas of concern include retaining walls, chimneys and bricks between ground level and a damp proof course.
- F0 bricks are suitable for internal use and the inner leaf of cavity walls. If used externally, bricks are damaged by freezing and thawing action if not protected by impermeable cladding or suitable render.

1.2 Compare between clay bricks and calcium-silicate bricks

	clay bricks	calcium-silicate bricks	Points
raw materials	• Sand 50 – 60% • Clay 20 – 30% • Iron oxide 7 – 8% • Lime 2 – 5% • Magnesia 5% • Sawdust for porosity	o Sand and lime (sand–lime ratio of 10 or 20). o Pigments (0,2-3% by brick weight) to give the brick color.	2
mixing process of materials	• Materials are batched and mixing together with water	o Sand is mixed with lime. o Pigments are added to the sand and lime while mixing.	1
forming (molding) of brick units	• Semidry process: clay with about 10% moisture is ground and pressed into moulds. • Stiff plastic process: clay with about 15% moisture is extruded. • Wire cut process: clay with about 20% moisture is extruded and cut to thickness with tensioned wires. • Soft-mud molding: clay with about 30% moisture content. This process is used for handmade bricks.	o The mix is compressed into steel moulds	3
hardening of brick units	• 0 – 100°C: free water is lost • 100 – 150°C: weakly bound water lost • 150 – 600°C: Hardening • 600 – 950°C: Chemical changing • Up to 1200°C: vitrification (strong, hard and dense)	o "autoclaved" in steam at about 200°C and 16 bar pressure for 8 hours. o Some gel is formed, and this bonds the sand particles together.	2

Question 2. Miscellaneous questions (15p)

2.1 Describe shortly the pre-stressing method for (a) small sections of hollow core slabs (≈ 17 m span) manufactured in factory and (b) long-span concrete girder bridge (≈ 250 m span) constructed on site.

2.2 Write short note about the bitumen emulsion and its use.

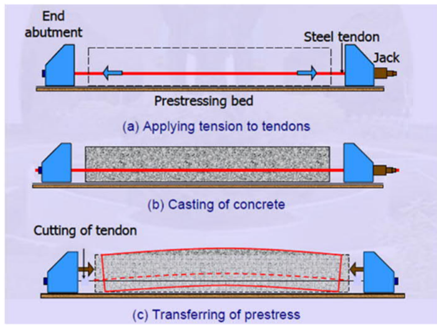
2.3 Explain shortly the cement hydration process and its stages.

2.4 Write short note on the moisture effects on the performance of building materials.

Answer to question – 2

2.1	2.2	2.3	2.4
4 points	4 points	4 points	3 points

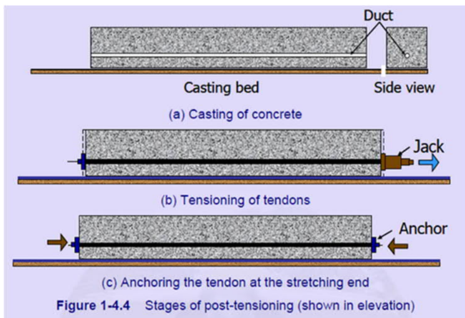
2.1 (4 points)



Pre-tensioning of hollow-core slab

1) Series of steel wires or strands are pretensioned
2) Concrete cast around these tensioned wires/strands.
3) Cutting of strands after hardened of the concrete
4) The concrete bonds directly to the strand

Post-tensioning of bridge girder



1) Installation of bearing plates and empty ducts inside the form work before casting the concrete
2) Casting of the concrete
3) After concrete hardening, tensioning of the tendon by jacking against the concrete (plates to spread jacking forces) after the concrete gained the required compressive strength
4) Tendon edges are jacked from one or both ends and then anchored

Two types of post tensioning:

– Bonded Post-tensioning where injection grouting is needed
– Unbonded Post-tensioning where tendons are encasing with a plastic sheathing filled with a corrosion-inhibiting grease.

2.2 Bitumen emulsion (4 points)

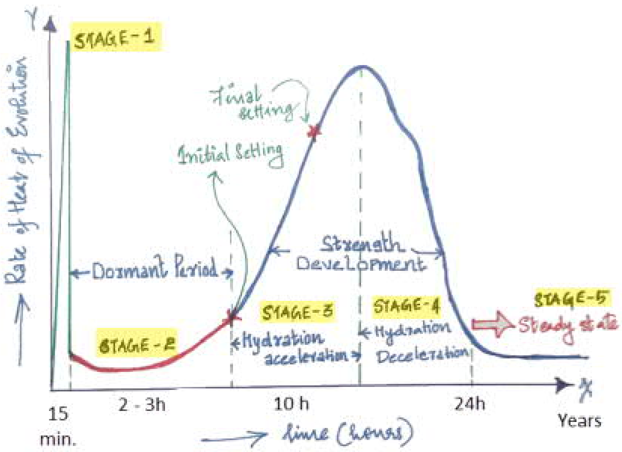
- As bitumen is a petroleum product it doesn't mix with water and as it is sticky in nature, it doesn't easily gets disintegrated into fine droplets, to overcome this problem an emulsifier is used
- A mixture of fine droplets of bitumen and water (A normal emulsion generally contains 55% to 70% bitumen and 0.5% to 3% emulsifying agent. The rest is water)
- Emulsifier can be defined as a surface-active agent. Emulsifier keeps the bitumen in its fine droplet state

Applications:

- Road construction and repairs
- Ground permeation
- Protection of concrete structures
- Coating of metal surfaces
- Electro and heat insulation materials
- Production of waterproof cardboard
- Sand grouting, soil insulation and waterproofing

2.3 Cement hydration (4 points)

1) Initial hydration stage: (15 min). Rapid heat generation.
2) Dormant stage (2 – 3h after mixing) concrete can be transported and casting
3) Acceleration stage: reaction of the hydration products (3 – 12h after mixing) – setting of concrete and strength development
4) Deceleration stage: Formation of hydration products (12 – 24h after mixing) strength development
5) Steady-state stage (for years) – Constant rate of hydration

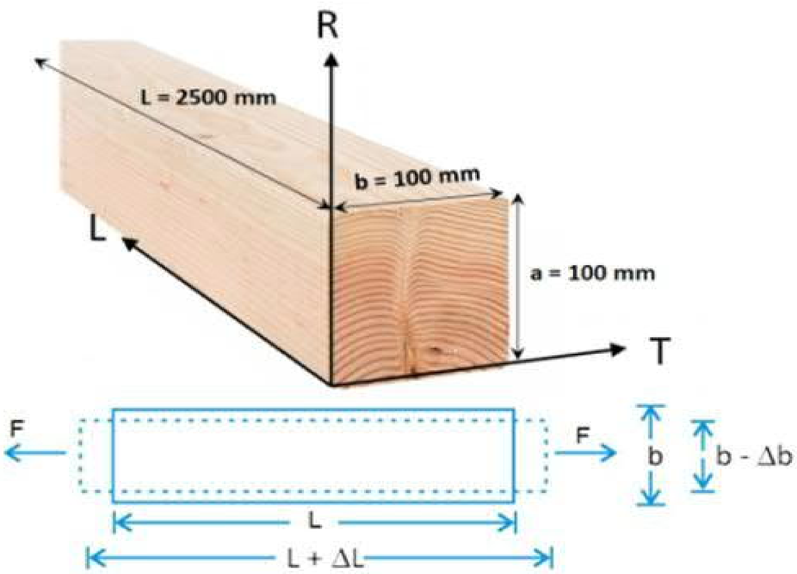


2.4 moisture effect on the performance of building materials (3points)

- Significant damage to inorganic building materials (wetting and drying)
  - Metal corrosion
  - Salt crystallization (Salt efflorescence)
  - Freeze/thaw damage of building materials (When volumetric moisture content exceeds 91%)
  - ASR (alkali aggregate rection) moisture over 75%
- For organic materials (e.g. wood)
  - Fungi and mold growth
  - Swelling and shrinkage

Question 3.1

L =	2,5	m	
a=	0,1	m	
b=	0,1	m	
Cross-sectional area under loading =	0,01	m²	
Tensile Load F =	240	kN	
Stress in MPa =	24	MPa = MN/m²	
Longitudinal deformation ΔL=	4	mm	
Strain in longitudinal direction εL=	0,0016	-	Strain = dL/L
(a) Modulus of elasticity (E_L)	15000	MPa	Stress/Strain
Modulus of elasticity (E_R)	1500	MPa	
Stress in MPa =	24	MPa = MN/m²	
Strain in radial direction εR=	0,016	-	Stress/E_R
(b) Radial deformation Δb=	1,6	mm	db = Strain * b

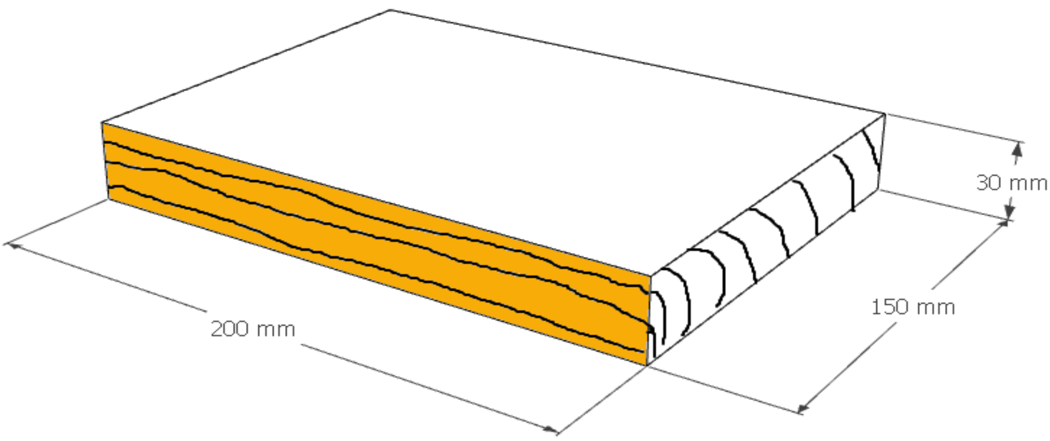


3.1a	3.1b	3.2a	3.2b	3.2c
3,5 points	3,5 points	2 points	3 points	3 points

Question 3.2

	L=	200	mm
	R=	150	mm
	T=	30	mm

		Mass, g	
	Initial mass of wood	473,76	
	Dry mass of wood	423	
	Wet mass of wood	549,9	
(a)	Density of wood in dry condition	470	kg/m³
(b)	i - Moisture content after cutting	12	%
	ii - Moisture content after wetting	30	%
c)	Volume of the wood specimen	0,0009	m³
	Weight of the dry specimen	0,423	kg
	Moisture difference after wetting (dw) =	0,18	
	Longitudinal swelling α_L=	0,0075	-
	Radial swelling α_R =	0,05	
	Tangetial swelling α_T =	0,09	
	ΔL=L*Δw*α_L =	0,27	mm
	ΔR=R*Δw*α_R =	1,35	mm
	ΔT=T*Δw*α_T =	0,486	mm
	Final L =	200,27	mm
	Final R =	151,35	mm
	Final T =	30,486	mm



Question 4

	density - cement	3,15	kg/dm³	
	density - SSD aggregates	2,67	kg/dm³	
	density - water	1	kg/dm³	
	diameter of mold	0,15	m	
	height of mould	0,3	m	
	Volume of mould	5,301438	dm³	
	mass of Mold	9	kg	
	mass of Mold + Concrete	21,7	kg	
	Mass of concrete	12,7	kg	12,72345025
(a)	Density of fresh concrete	2,395577	kg/dm³	

2 points

Target air content	2	%	
Portion of materials by	weight	Volume	
cement	1	0,317460317	
SSD aggregates	6	2,247191011	
water	0,5	0,5	
total volume portions		3,064651329	

Design the concrete mix for 1000 dm³(1m³)

Volume without air content	980	dm³	= 1000 dm³ - air content dm³
Volume of 1 portion	319,7754	dm³	= vol. without air/total (vol.) portions

initial mix design	weight		
cement	319,7754	kg	= portions of cement * vol. of 1 portion
SSD aggregates	1918,652	kg	= portions of SSD Agg * vol. of 1 portion
water	159,8877	kg	= portions of Water * vol. of 1 portion

initial mix design	weight		Free moisture	
cement	319,7754	kg		
SSD sand (40% of agg.)	767,4609	kg	3	%
SSD gravel (60% of agg.)	1151,191	kg	1,2	%
water	159,8877	kg		

8 points

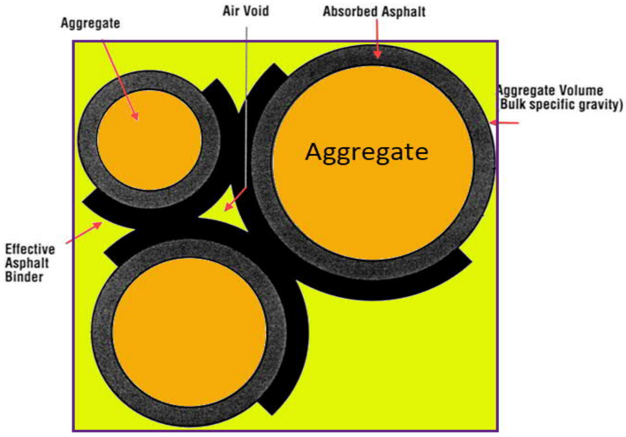
(b)	Batch mix design	1000 dm³	Culindrical specimen (5,3 dm³)		Free moisture / 1000 dm³	
	cement	319,7754	1,70	kg		
	Wet sand	790,4847	4,19	kg	23,714541	kg
	Wet gravel	1165,006	6,18	kg	13,980067	kg
	water	122,1931	0,65	kg		

c)			
	Theoritical density of the mix	2,446	kg/dm³
	Density of fresh concrete	2,396	kg/dm³
	Real air content, (%)	2,08	%

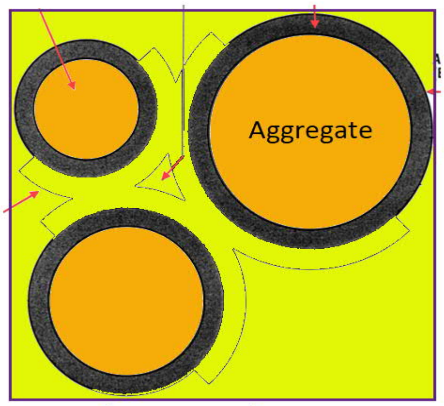
5 points

$$Air\ Content, A_r(\%) = \left(\frac{T - D}{T}\right) * 100$$

Question 5



Air voids in compacted mixtures



Voids in mineral aggregate
= air voids + effective binder

	Portion				SG
Fine aggregates	35	%	a=	0,368421	2,55
Coarse aggregates	60	%	b=	0,631579	2,75
Bitumen binder	5	%			1,02
Bitumen absorption	1,2	%			
SG Fine aggregate	2,55	-			
SG Coarse aggregate	2,75	-			
SG Bitumen binder	1,02	-			
SG laboratory compacted mixture	2,42	-			

a - portion = (35%)/(35%+60%)
b - portion = (60%)/(35%+60%)

(a) Specific gravity of the combined aggregates

SG agg = 2,672768 | SG=1/(a/SGa+b/SGb)

(b) Total effective bitumen content by weight of mix (%)

1. Calculate the mass of different materials in 1m³ of bituminous mixture
= (SG of mix * 1m³*water density kg/m³)

Mass of aggregates + binder =	2420	kg
Mass of Fine aggregates	847	kg
Mass of Coarse aggregates	1452	kg
Mass of Bitumen binder	121	kg

2. the amount of absorbed bitumen = amount of agg. In kg * bitumen absoprtion)

Mass of absorbed bitumen = 27,588 kg
Mass of effective bitumen = total mass of binder - mass of absorbed binder
Mass of effective bitumen = 93,412 kg
Total effective bitumen content by weight of mix = (mass of effective binder / mass aggregates + binder)*100
Total effective bitumen content by weight of mix 3,86 %

c) % voids filled with bitumen (VFA)

VFA = (volume of effective binder / (volume of air voids + volume of effective binder))*100

Volume of effective bitumen = 0,09158 m³ Volume = mass / density = mass / (SG*1000)

Volume of air voids = 1m³ - Volume of aggregates - Volume of effective binder

Volume of Fine aggregates = 0,332157 m³
Volume of Coarse aggregates = 0,528 m³
Volume of air voids = 0,048263 m³ =1m³ - Vagg - Veff.bitumen
% voids filled with bitumen (VFA) = 65,48794 %

d) % air voids in compacted mixtures.

% air voids (V_air) = 4,826275 % = (volume of air voids / 1 m³)*100

e) % voids in mineral aggregate (VMA)

VMA = ((volume of air voids + volume of effective binder)/(volume of the mix, 1m³))*100

% voids in mineral aggregate (VMA) = 13,98431 %

5.1a	5.1b	5.1c	5.1d	5.1e
2 points	3,5 points	3,5 points	3 points	3 points