CHEMICAL STABILISATION
Short course

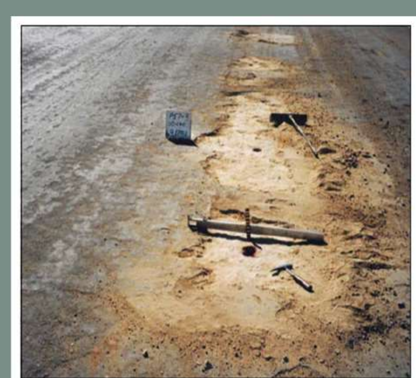
Ronnie Koen

MCEK

(road Materials and Construction Engineering Konsultant)

1

About this course



2

Content

1. Introduction
2. Stabilisation agents
3. Stabilisation mechanisms
4. Stabilisation design
5. Construction issues

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3

1. Introduction

- Stabilisation definition
- Types of stabilisation

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Definition

Stabilisation is the treatment of natural or crushed material to:

1. Enhance the strength (load bearing capacity) and stiffness, and/or
2. Make the material more water resistant to improve the durability

- Improved strength, workability, durability
- Reduced permeability, plasticity, swell, shrinkage

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5

Types of stabilisation

- Mechanical modification (granular stabilisation)
- Chemical stabilisation (modification, cementation)
- Material improvement (bitumen stabilisation)
- Electrical (ion exchange)
- Geosynthetic stabilisation

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6

2. Stabilising agents

- Cementitious agents
- Cement manufacturing and types
- Lime

7

Stabilisation agents (stabilisers)

1. Traditional agents:
- Cement
- Lime
- Bitumen

2. Non-traditional agents:
- Sulphonated products (SPPs, ionic stabilisers)
- Polymers
- Nano-technology products

8

Cementitious stabilising agents

- Cement (common cement) SANS 50197
- Proprietary stabilisation cement
- Slaked lime SANS 824

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9

Cement manufacturing

- Limestone and shale blended, fired at high temperatures to form clinker
- Clinker grounded with gypsum to fine powder (gypsum to retard rate of setting)
- Cements produced by blending with applicable extenders

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10

Cement types

Main types	Notation of products (types of common cement)		Composition, percentage by mass[a]										
			Clinker	Blast-furnace slag	Silica fume	Pozzolana Natural	Pozzolana Natural calcined	Fly ash Siliceous	Fly ash Calcareous	Burnt shale	Limestone	Limestone	Minor additional constituents
			K	S	D[b]	P	Q	V	W	T	L	LL	
CEM I	Portland cement	CEM I	95 - 100	-	-	-	-	-	-	-	-	-	0 - 5
CEM II	Portland-slag cement	CEM II A-S	80 - 94	6 - 20	-	-	-	-	-	-	-	-	0 - 5
		CEM II B-S	65 - 79	21 - 35	-	-	-	-	-	-	-	-	0 - 5
	Portland-silica fume cement	CEM II A-D	90 - 94	-	6 - 10	-	-	-	-	-	-	-	0 - 5
	Portland-pozzolana cement	CEM II A-P	80 - 94	-	-	6 - 20	-	-	-	-	-	-	0 - 5
		CEM II B-P	65 - 79	-	-	21 - 35	-	-	-	-	-	-	0 - 5
		CEM II A-Q	80 - 94	-	-	-	6 - 20	-	-	-	-	-	0 - 5
		CEM II B-Q	65 - 79	-	-	-	21 - 35	-	-	-	-	-	0 - 5
	Portland-fly ash cement	CEM II A-V	80 - 94	-	-	-	-	6 - 20	-	-	-	-	0 - 5
		CEM II B-V	65 - 79	-	-	-	-	21 - 35	-	-	-	-	0 - 5
		CEM II A-W	80 - 94	-	-	-	-	-	6 - 20	-	-	-	0 - 5
		CEM II B-W	65 - 79	-	-	-	-	-	21 - 35	-	-	-	0 - 5
	Portland-burnt shale cement	CEM II A-T	80 - 94	-	-	-	-	-	-	6 - 20	-	-	0 - 5
		CEM II B-T	65 - 79	-	-	-	-	-	-	21 - 35	-	-	0 - 5
	Portland-limestone cement	CEM II A-L	80 - 94	-	-	-	-	-	-	-	6 - 20	-	0 - 5
		CEM II B-L	65 - 79	-	-	-	-	-	-	-	21 - 35	-	0 - 5
		CEM II A-LL	80 - 94	-	-	-	-	-	-	-	-	6 - 20	0 - 5
		CEM II B-LL	65 - 79	-	-	-	-	-	-	-	-	21 - 35	0 - 5
	Portland-composite cement[c]	CEM II A-M	80 - 94	←				6 - 20				→	0 - 5
		CEM II B-M	65 - 79	←				21 - 35				→	0 - 5
CEM III	Blastfurnace cement	CEM III A	35 - 64	36 - 65	-	-	-	-	-	-	-	-	0 - 5
		CEM III B	20 - 34	66 - 80	-	-	-	-	-	-	-	-	0 - 5
		CEM III C	5 - 19	81 - 95	-	-	-	-	-	-	-	-	0 - 5
CEM IV	Pozzolanic cement[c]	CEM IV A	65 - 89	-	←		11 - 35		→	-	-	-	0 - 5
		CEM IV B	45 - 64	-	←		36 - 55		→	-	-	-	0 - 5
CEM V	Composite cement[c]	CEM V A	40 - 64	18 - 30	-	← 18 - 30	→	-	-	-	-	-	0 - 5
		CEM V B	20 - 39	31 - 50	-	← 31 - 50	→	-	-	-	-	-	0 - 5

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11

Lime

- Lime can be:
1. Calcium lime ($Ca(OH)_2$) – Slaked lime
2. Magnesium lime
3. Dolomitic lime

- Do not use:
1. Unslaked lime (quicklime) (CaO)
2. Agricultural lime ($CaCO_3$)

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12

Stabiliser storage

- **Cement**:
  1. In open area, max 2 weeks provided on pallets or raised platform, and covered with tarpaulin or 1,0 mm thick plastic
  2. Longer period, in a shed to requirements
  3. Cement shelf life 6 months (inland)
- **Lime**:
  1. In open area, up to 6 months provided on pallets or raised platform, and covered with tarpaulin or 1,0 mm thick plastic

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13

3. Stabilisation mechanisms

- Cement hydration
- Chemical stabilisation reactions
- Modification
- Cementation

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14

Cement hydration

- Hydration definition: when water is mixed to cement to form a paste
- Hydration produces:

1. Calcium silicate hydrate (C-S-H) gel (tobermorite)
2. Calcium hydroxide (lime)

- C-S-H gel crystalises and joins to form strong interlocking matrix, cementing (bound) material together
- Calcium hydroxide results in:

1. Modification of material
2. Maintaining a high pH to ensure long term durability

15

Cement hydration

By courtesy of Division of Building Technology: CSIR.

The formation of tobermorite crystals as seen by means of the electron microscope.

40

16

Effect of cement extenders

- **Blastfurnace slag** – when mixed with water and high pH forms C-S-H
- **Silica fume, pozzolana and fly ash** – reacts with calcium hydroxide to form C-S-H
- **Limestone** only filler, useful in concrete
- Careful to use cement containing silca fume, pozzolana and fly ash on high PI material (above 10)
- NB: Hydration properties of two identical cement compositions not the same

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17

Chemical stabilisation

- **Modification** (physico-chemical reaction):

1. Ion exchange
2. Flocculation
3. Employed mainly to reduce PI and increase CBR, not necessary to develop compressive or tensile strength

- **Cementation** (chemical reaction):

1. Bonding of individual material particles by secondarily developed materials (C-S-H)
2. Increased compressive and tensile strengths

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18

Modification – ion exchange

- Clay particles have Na^{+} ions that can hold 79 molecules of water
- The Ca^{++} ions in $Ca(OH)_2$, which can only hold 2 molecules of water , displace the Na^{+} ions
- **Results**:
1. Material becomes water repellent
2. Bound water is released
3. LL and PI are reduced

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19

Modification - flocculation

- Ca^{++} ions crowd on the surface of the negatively charged clay particles and create stronger attraction forces
- **Result**:
1. Material becomes more friable (less clay more silty)
2. Plasticity decreases

- NB: flocculation only of clay minerals, will not occur in sandy material

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20

Cementation

- Cement contains all C-S-Hs for cementation
- Lime cementation requires:-
1. Sufficient lime to remain after modification (ICS to be exceeded by at least 1 %)
2. Moisture
3. A high pH, in excess of about 12
4. Available clay, so that the lime can break down the clay mineral structure and form C-S-H
- Lime reacts with amorphous silica (calcrete) to form C-S-H without the presence of any clay minerals
- Lime cementation not as strong as cement, and takes longer

21

What type of cement

- Avoid:
1. Strength classes 42.5 and 52.5 (cracking)
2. "R" cements – too high early strength and short working time, but suitable for early trafficking and trench backfill
3. CEM 1 – sets too rapidly, use for concrete
4. CEM III/B, III/C and V/B – too low clinker content
5. Masonry cement (SANS 50413)

- PI indication:
1. PI < 10 Extender type not critical
2. PI 10-15 Lime in cement required. Careful for silica fume, pozzolana and fly ash extenders
3. PI > 15 Pre-treatment with lime required

22

4. Stabilisation design

- Design process
- Stabilised material requirements

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23

Chemical stabilisation design

- Four-step design process:

1. Test representative natural material: grading, soil constants, CBR, deleterious minerals
2. Determine ICS – cement same as during construction
3. Test stabilised samples for compliance with stabilised material requirements at 7-day curing
4. Determine:
   - Durability
   - Correlation 7-day and 24-hr curing results
   - Field working time

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24

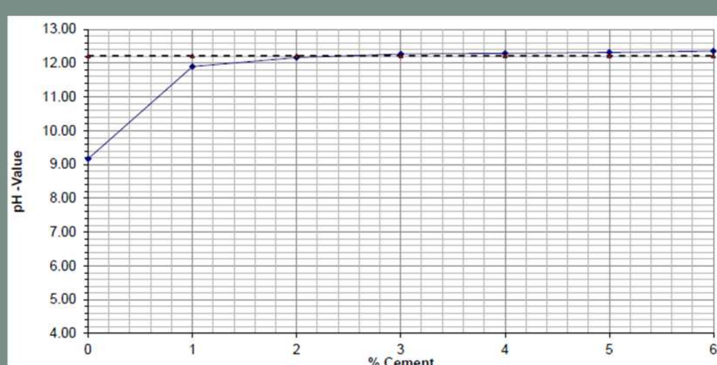
ICS

- Test to determine the stabiliser content to satisfy the modification requirements
- Testing of pH of the material with increasing stabiliser contents
- ICS where pH stabilises. Usually near 12,4
  (Test saturated cement paste for max value)

- For cementation: Add 1%
- For construction: Add further 0,5% - 1%

25

ICS determination



26

Stabilised material requirements

Classification		C2	C3	C4
Type of material before stabilisation (TRH 14 classification)		At least G4 quality	At least G5 quality	At least G6 quality
Maximum Particle size		50 mm	Base 50 mm / Subbase 63 mm	
Grading modulus (minimum)		N/A	Base 1,75 / Subbase 1,5	
PI after stabilisation (maximum)		Non-plastic	Basic crystalline material: NP	
			All other materials: 6	
UCS (Unconfined Compression Strength) (MPa) at 100 % of MDD	Min	3,0	1,5	0.,5
	Max	5,0	3,0	
ITS (Indirect Tensile Strength) (kPa) at 100 % of MDD – compliance with ITS requirement more important	Min	300	250	200
	Max	600	500	450
WDD (Wet/Dry Durability) (mass loss maximum)		10 %	20 %	30 %

27

Design issues

- **Design results only valid for specific agent and material**
- **New design required for change of supplier, source or type of agent**
- **New design required for change of material**
- **Incomplete testing, description of cement**
- **Who responsible for Design?**
- **Who responsible for compliance during Construction?**

28

5. Construction issues

- Stabilisation process evaluation
- Carbonation
- Cracking
- Curing

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29

Construction stabilisation evaluation

- **Prior to stabilisation:**

1. Natural material properties (Grading, LL, PI, CBR)
2. Compare properties with design
3. Visual inspection tipped material and stabiliser type
4. Verify spread rate (quantity of stabiliser)

- **During and/or after stabilisation:**

1. Visual and holes with phenolphthalein – very important
2. Curing efficiency
3. Lab tests – UCS, ITS, PI, WDD
4. Carbonation on surface before placing base material

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30

Phenolphthalein experiment

- pH < 8,5: Colourless
- pH 8,5 – 10,5: Pink
- pH > 10,5: Red

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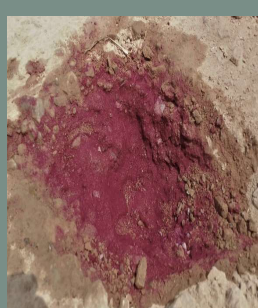
31

Phenolphthalein colours



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32

Carbonation

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33

Carbonation

- Carbonation involves the reaction between the lime and carbon dioxide (CO_2) in the air to form $CaCO_3$
- The pH of the stabilised material is reduced, preventing stabilisation
- Carbonation occurs immediately at a rate of 0,5 to 2 mm per day
- Carbonation results in a volume increase
- Detrimental (destructive) carbonation, weakening or disintegration of the material, occurs when the expansive forces induced by the volume change exceeds the tensile strength of the cemented matrix around the material particles
- Result: loose layer, loss of strength
- Carbonation tests: Phenolphthalein and dilute hydrochloric acid test, pH test, DCP?
- Minimise carbonation: high density, high ITS, high pH, efficient curing, short delay in placing next layer

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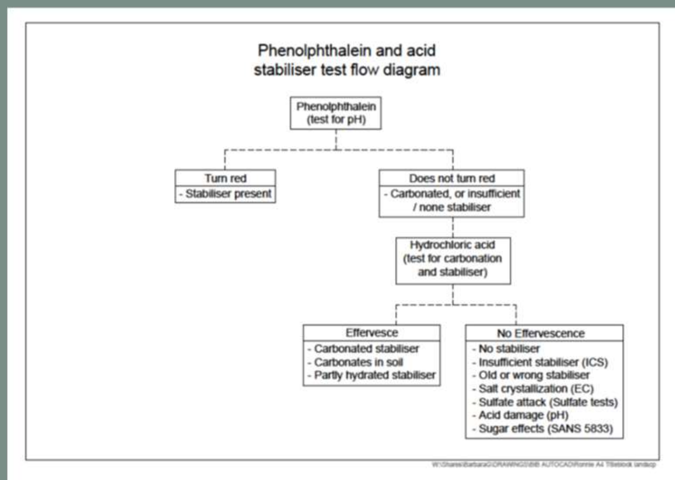
34

Phenolphthalein & acid test



35

Cracking

36

Cracking

- Cracking is a feature of chemical stabilisation
- Non-traffic (initial or shrinkage) cracking is manifested as block cracking
- Types of shrinkage:
  1. Drying – water evaporation
  2. Autogenous – water consumption during hydration
- **Cracking occurs when the layer is restrained in movement by the underlying layer and/or is restrained**

37

Cracking

- Shrinkage cracking caused by:
  1. Excessive stabiliser
  2. Marginal material and material with a high clay content
  3. Excessive compaction moisture
  4. Ineffective curing and wetting/drying cycles
- Minimise cracking:
  1. Limit stabiliser content
  2. Uniform mixing of material and stabiliser
  3. Compaction moisture < OMC (80 % of saturation mc)
  4. Thorough curing

38

Curing

- Hydration actions that cause cementation require a constant source of moisture, to supplement loss by evaporation and the hydration reactions
- Drying out, even once, inhibits the hydration actions
- The first 7 days are the most critical
- The layer shall be kept continuously wet for the first 2 days and then damp for the next 5 days
- Wetting and drying out cycles create a weak layer at the top
- Careful not to use a fully laden 20 kL water bowser on layer

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39

THANK YOU

40