INTRODUCTION TO HYDRAULICALLY BOUND MIXTURES (HBM)

Dr. Cliff Nicholls
TRL
Introduction to Hydraulically Bound Mixtures (HBM)

Dr Cliff Nicholls

16 November 2017
Contents for HBM

- Description
- Production
- Use in pavements
- Performance required
- Specifications
- Testing
- Résumé
HBM – Description

- Definition of HBM
- “a mixture that sets and hardens by hydraulic reaction”
  - Include:
    - cement bound materials (i.e. mixtures based on the fast setting and hardening characteristics of cement)
    - slow setting and hardening mixtures made from industrial by-products such as fly ash (FA) and ground granulated blast furnace slag (GGBS)
HBM – Description

Aggregate + Water + Hydraulic binder

Combined and compacted =

HBM
(Hydraulically Bound Mixtures)
HBM – Description

- Component materials
  - Aggregate
    - Freshly quarried
    - Reclaimed aggregate
  - Secondary aggregate
HBM – Description

- **Secondary aggregates**
  - China clay / Stent
  - Coal fly ash (CFA)
  - Pulverised fuel ash (PFA)
  - Foundry sand
  - Furnace bottom ash (FBA)
  - Colliery spoil (Burnt or Unburnt)
  - Incinerator bottom ash aggregate (IBAA)
  - Slag (Blast furnace, Phosphoric or Steel)
  - Slate aggregate
  - Spent oil shale / Blaise

- **Reclaimed aggregate**
  - Reclaimed asphalt
  - Reclaimed aggregate
  - Reclaimed concrete
  - Reclaimed glass
HBM – Description

- Component materials
  - Aggregate
    - Freshly quarried
    - Reclaimed aggregates
  - Water
  - Hydraulic binder
    - Cement
    - Fly ash (PFA)
    - Hydraulic road binder
  - Proprietary products
  - Secondary aggregate
    - Lime
    - Ground slag (GGBFS)
    - Other combinations
HBM – Production

- Produced on or off site
- Reinstatements
  - Delivered to site ready-made
  - Prepared partly or wholly on site
HBM – Production

- On-site production
HBM – Production

- On-site production
  - Using mobile plant
  - Binder usually rotovated into existing aggregate
  - Therefore reclaimed aggregate
    - Limited material transportation
    - Restricted choice of aggregate
  - More appropriate for large-scale works than minor trench reinstatements
HBM – Production

- Off-site production
HBM – Production

- Off-site production
  - Stockpiled aggregate
  - Design with laboratory test parameters
    - Enables greater control of finished product
    - Additional material transportation
  - Can use mobile or fixed mixing plant
  - Requires transporting HBM to site
HBM – Production

- Equipment for laying and compacting
  - Similar to that for unbound and bituminous
  - Compaction is critical ... but often easier and quicker
HBM – Use in pavements

- Sub-base and base layers
  - New construction and repairs
    - Minor roads (residential and commercial)
    - Design to TRL611 (cold recycled materials)
  - Trench reinstatements
- Alternative to conventional materials
  - Granular sub-base materials
  - Wet lean concrete bases
    - Hard, but not as hard as concrete
HBM – Use in pavements

- Classified by primary binder / rate of curing
  - Quick hydraulic (QH)
    - Hydraulic binder(s) only including cement
  - Slow hydraulic (SH)
    - Hydraulic binder(s) only excluding cement
  - Quick visco-elastic (QVE)
    - Bituminous and hydraulic binder(s) including cement
  - Slow visco-elastic (SVE)
    - Bituminous and hydraulic binder(s) excluding cement
HBM – Use in pavements

FAMILY 1
'HYDRAULIC' BINDERS (QH & SH)

FAMILY 2
VISCO-ELASTIC BINDERS (SVE)

FAMILY 3
VISCO-ELASTIC / 'HYDRAULIC' BINDERS (QVE & SVE)

Fully hydraulically bound

Fully visco-elastically bound

Unbound
HBM – Use in pavements

- Environmental advantages
  - Potential cost savings
  - Potential energy savings
  - Potential reduced demand for primary materials
  - Potential reduced excavated material to landfill
  - Potentially fewer lorry trips to and from the site
  - Potentially quicker compaction times
  - Reduce congestion for road users
HBM – Use in pavements

- Limitations with HBM
- Cracking
  - Fast setting HBM provide good strength initially
  - Prone to curing shrinkage and thermal stress cracks
- Low strength
  - Aggregate requirements relatively open
  - Poor choice can lead to premature failure
- Limited binder
  - Low strength
  - Susceptibility to frost heave
HBM – Performance required

- Load distribution

- Improves with curing
- Sufficient to protect lower layers
HBM – Performance required

- Deformation resistance
  - Improves with curing
- Compressive strength
  - Improves with curing
- Age is important in assessment
- Generally equivalent to alternatives
HBM – Performance required

- Factors influencing durability
  - Volumetric changes / thermal expansion
  - Aggregate deterioration / fragmentation
  - Sensitivity to water / frost heave
  - Chemical attack / aggressive ground conditions
  - Adverse curing conditions
    - Low temperatures, lack of water, drying shrinkage
  - Presence of organic material and clay
    - Limit strength gains
    - Organic impurities interfere with hydration reaction
HBM – Specifications

- British (European) standards
- Specification for Highway Works (SHW)
  - For new and repair works
- Specification for the Reinstatement of Openings in Highways (SROH)
  - For reinstatements
- Department for Transport TAL 9
  - Advice rather than specification
HBM – Specifications – British Standards

- BS EN 14227 - Mixtures
  - Part 1 – Cement bound
  - Part 2 – Slag bound ✓
  - Part 3 – Fly ash bound ✓
  - Part 5 – Hydraulic road binder
  - Part 10 – Soil treated by cement
  - Part 11 – Soil treated by lime ✓
  - Part 12 – Soil treated by slag
  - Part 13 – Soil treated by hydraulic road binder
  - Part 14 – Soil treated by fly ash ✓
HBM – Specifications – British Standards

- **Aggregates**
  - BS EN 13242 - Unbound & HBM Aggregates

- **Binders**
  - BS EN 197-1 – Cement
  - BS EN 459-1 – Lime
  - BS EN 14227-2 – Slag
  - EN 15167-1 – GGBFS
  - BS EN 14227-4 – Fly ash
  - BS EN 13282-1 - Hydraulic road binder
HBM – Specifications – SHW

- **Series 800: Road pavements – Unbound, cement & other hydraulically bound mixtures**
  - Unbound mixtures for subbase
    - Clauses 801 – 807
  - Cement and other hydraulically bound mixtures
    - Clauses 810 – 880
    - ... but only 22 used
Cement & other hydraulically bound mixtures
- General requirements for cement and other HBMs
- Binder constituents
- Storage of constituents
- General requirements for production & layer construction
- Mix-in-plant method of construction using batching by mass
- Mix-in-plant method of construction using volume batching
- Mix-in-place method of construction
- Method statement and demonstration area
- Induced cracking of HBM
HBM – Specifications – SHW

- Cement & other hydraulically bound mixtures
  - Aggregates
  - Cement Bound Granular Mixtures A (CBGM A), B (CBGM B) and C (CBGM C)
  - Fly Ash Bound Mixture 1 (FABM 1), 2 (FABM 2), 3 (FABM 3) and 5 (FABM 5)
  - Hydraulic Road Binder Bound Mixture 1 (HRBBM1), 2 (HRBBM 2) and 3 (HRBBM 3)
  - Slag Bound Mixture B1-1, B1-2, B1-3 & B1-4 (SBM B1), B2 (SBM B2) and B3 (SBM B3)
HBM – Specifications – SHW

- Cement & other hydraulically bound mixtures
  - Soil treated by cement (SC), slag (SS), fly ash (SFA) and hydraulic road binder (SHRB)
  - Testing, control and checking of HBM
  - Determination of the coefficient of linear thermal expansion
  - Laboratory mixture design procedure
HBM – Specifications – SROH

- New Roads and Street Works Act 1991
  - Section 71
  - Approved by the Secretary of State
  - Therefore statutory
HBM – Specifications – SROH

- Appendix A9 – Alternative reinstatement materials (ARMs)
  - Structural materials for reinstatement (SMRs)
  - Stabilised materials for fill (SMF)
- Structural materials for reinstatement
  - Foamed concrete (FCR)
  - Flowable SMRs (FSMR)
  - Non-flowable SMRs (NFSMR)
  - Hydraulically Bound Mixture (HBM)
HBM – Specifications – SROH

- Hydraulically bound mixture (HBM)
  - Mixtures called up in SHW
  - Plus SBM B4, FABM 4 and HRBBM 4
## HBM – Specifications – SROH

### Table A9.1 – SMR Minimum Layer Thickness and Compressive Strength Requirements

<table>
<thead>
<tr>
<th>Layer</th>
<th>Road Type</th>
<th></th>
<th></th>
<th></th>
<th>Footway Footpath or Cycle Track</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Combined Binder Course &amp; Sub-base</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
</tr>
<tr>
<td>Base</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>300 mm C 1.5/2</td>
<td>200 mm C 1.5/2</td>
</tr>
<tr>
<td>Base &amp; Sub-base</td>
<td>NP</td>
<td>450 mm C3/4</td>
<td>450 mm C3/4</td>
<td>450 mm C 1.5/2</td>
<td>350 mm C 1.5/2</td>
</tr>
<tr>
<td>Sub-base &amp;/or below</td>
<td>150 mm C 1.5/2</td>
<td>150 mm C 1.5/2</td>
<td>150 mm C 1.5/2</td>
<td>150 mm C 1.5/2</td>
<td>100 mm C 1.5/2</td>
</tr>
<tr>
<td>Crushing Strength at 28 days</td>
<td>C3/4 Minimum to C 9/12 Maximum C 1.5/2 Minimum to C9/12 Maximum</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
HBM – Testing

- Samples for testing purposes
  - Cast in cubes
  - Extracted as cores from site
- Testing to various parts of BS EN 13286
  - Parts 1 to 5 – Density and water content
  - Part 7 – Cyclic load triaxial test
  - Part 40 – Direct tensile strength
  - Part 41 – Compressive strength
  - Part 42 – Indirect tensile strength
HBM – Testing

- Part 43 – Modulus of elasticity
- Part 44 – Alpha coefficient of vitrified slag
- Part 45 – Workability period
- Part 46 – Moisture condition value
- Part 47 – California bearing ratio, immediate bearing index and linear swelling
- Part 48 – Degree of pulverisation
- Part 49 – Accelerated swelling test
- Parts 50 to 53 – Manufacture of test specimens
HBM – Testing

- Strength tests dependent on length of curing
- Immediate Bearing Index (IBI) [BS EN 13286-47]
  - Critical measure for reinstatements
  - Value defines immediate trafficking suitability
  - Varies with type of mixture, traffic loading and water content
- HBM outside BS EN 14227
  - Need “Approval Trials” to Appendix A9 of SROH
  - Very few HBMs will require such trials
HBM – Résumé

- Made of aggregate, water & hydraulic binder
- Produced on site or off site
  - Using conventional equipment
- Used for sub-bases and bases
  - New, repairs or reinstatements
- Produces a durable material that performs
- Specification standards
- Standardised tests
Any Questions?

Thank you for listening

*Introduction to Hydraulically Bound Mixtures (HBM)*

*Dr Cliff Nicholls*

Lime in Road Solutions – Pushing the Boundary
A British Lime Lime Association Conference