

Swell test requirements for lime-stabilised materials

This note summarises the evidence for retaining the current UK swell test requirements for lime-stabilised Class 7E Selected Cohesive Material for Capping Materials. It explains why swell testing matters, how the TRL505 programme was carried out, what the results showed, and what the findings mean for designers, contractors and specifications.

Executive summary

The current UK swell test requirements for lime-stabilised Class 7E capping materials should be retained. Advice Note DRMB 4.1.6 (Standard HA 74) sets limits on the permitted swell of standard samples of lime-stabilised cohesive material, helping determine whether selected cohesive fills are suitable for stabilisation beneath pavement foundations.

Why swell testing matters

The swell test is the main indicator of whether cohesive fills can be stabilised successfully with lime. It helps identify expansive reactions between lime and sulphates or sulphides in the fill. If unsuitable materials are stabilised, excessive swell can develop within the pavement foundation, leading to premature failure, costly repairs and traffic disruption.

Study approach

The research project reviewed published and unpublished evidence, examined the origins of the UK soaking test and compared relevant national standards and guidance. Seven British soils were stabilised with quicklime using current British Standard methods and relevant Specification for Highway Works clauses.

- CBR specimens were prepared, soaked and monitored for swell for up to 400 days.
- Strength was measured after 7 days, 28 days and long-term curing.
- The study assessed whether the DRMB 4.1.6 (HA 74/95) swell limits should be validated or revised.

Key findings

- Specimens compacted within current UK requirements generally achieved strengths around, or slightly above, the current acceptability requirement.
- Weald Clay was effectively stabilised with quicklime, despite poor performance reported elsewhere in the literature.
- Across the trial, recorded swell values remained below the DRMB 4.1.6 (HA 74/95) average upper limit of 5 mm.
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Method issues identified

- The British Standard CBR procedure should account for potential cone failure and displacement during testing.
- The Initial Consumption of Lime method should reflect the pH range observed in saturated lime solutions.

Recommendation

The existing laboratory tests, including the swell test, remain effective indicators for mix design and long-term durability. The swell test procedure should therefore remain in its current form, and the existing UK swell limits are appropriate for the British clays tested.

Study core findings and implications

Purpose of the study

- The Highways Agency commissioned TRL to validate or revise swell limits used to assess whether cohesive soils (Class 7E) are suitable for lime stabilisation in capping layers.
- Swell testing is critical because lime can react with sulphates/sulphides to form expansive minerals (e.g., ettringite, thaumasite) that cause pavement heave and premature failure.

Background and current limits

- Swell tests were introduced in the 1986 Specification for Highway Works to detect expansive reactions that aren't visible in dry-condition strength tests.
- UK practice uses:
 - Soaked CBR test (BS 1924)
 - Swell measurement (mm rise in CBR mould)
- Current limits (DRMB 4.1.6):
 - Average swell ≤ 5 mm
 - No individual specimen > 10 mm

Literature review

- Limited global data on swell behaviour.
- International practice varies:
 - USA: lime used mainly to reduce natural soil swell; no sulphate limits.
 - South Africa: sulphate limits included.
 - CEN draft standard proposes volumetric swell limits equivalent to 6.35 mm and 12.7 mm linear swell.
- UK remains one of the few regions with explicit swell limits for lime-treated soils.

Testing programme and materials

The testing programme used seven British clays selected to cover a broad chemical and mineralogical range:

- Mercia Mudstone
- Oxford Clay
- Lower Lias Clay
- London Clay
- Gault Clay
- Weald Clay
- Kimmeridge Clay

The specimens were prepared and tested using the following key steps:

- Lime addition based on Initial Consumption of Lime (ICL) + 0.5%.
- CBR specimens prepared at:
 - Standard compaction ($\leq 5\%$ air voids)
 - Mid compaction ($\approx 7\text{--}9\%$ air voids)
 - High compaction ($\approx 10\text{--}15\%$ air voids)
- Soaked for up to 400 days to capture long-term swell behaviour.

Strength results

- All soils except Gault Clay met the minimum 7-day CBR requirement of at least 8%.
- Long-term strength increased significantly:
 - Many soils achieved long-term CBR values two to four times higher than their 28-day values.
 - Weald Clay – previously thought to stabilise poorly – performed well.
- Poorly compacted specimens still developed reasonable long-term strength, though lower than standard compaction.

Swell results

- Sixty-two specimens were tested, and none exceeded the 10 mm individual-specimen limit.
- Only one specimen exceeded the 5 mm average-limit threshold.
- Swell continued beyond 28 days for most soils, but increases were small.
- Air void content strongly influenced swell in four materials:
 - Oxford Clay
 - London Clay
 - Gault Clay
 - Kimmeridge Clay
- By contrast, Mercia Mudstone, Lower Lias Clay and Weald Clay showed minimal sensitivity to air void content.
- Gault Clay was the most swell-susceptible material.

Issues identified in test methods

ICL test problems

- pH of saturated lime solutions often falls outside the BS 1924 acceptable range.
- Recommendation: update BS 1924 to reflect real-world pH values (12.94–13.08 observed).

CBR test problems

- Some specimens experienced bearing capacity failure under the CBR plunger.
- This caused abnormal force readings (2.5 mm load > 5 mm load).
- Recommendation: amend BS CBR procedure for lime-stabilised materials.

Conclusions

- Current UK swell limits of 5.0 mm average and 10.0 mm maximum are appropriate and should be retained.
- The swell test is a valid and effective indicator of long-term durability for lime-stabilised capping.
- Lime stabilisation worked effectively across all tested British clays, including those previously considered problematic (e.g., Weald Clay).
- Changing the swell limits would create a specification trade-off:
 - Tighten limits → unnecessarily exclude suitable clays.
 - Relax limits → increase risk of differential swell and pavement failure.

Practical implications for designers and contractors

- Maintain current DRMB 4.1.6 swell limits.
- Maintain air voids at or below 5% during compaction, because compaction is critical to controlling swell.
- Expect long-term strength gains well beyond 28 days.
- Review ICL and CBR testing procedures in specifications and QA processes.