Compaction Methods & Equipment for Reinstatement of Openings in the Highway: Test Bed Trials

- Research into commonly utilised materials, methods, and equipment employed in reinstatement of openings in the highway.
- Compaction behaviour of proprietary and modified backfill materials.
- Performance criteria of methods and equipment used as prescribed within current specification requirements.
- Evaluation of test beds reinstatement for commonly selected bituminous materials relating to air voids.
- Comparison of results in relation to SROH (Specification for Reinstatement for Openings in the Highway) – NRSWA (New Roads and Street Works Act) 1991.

Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

Research period: April 2012 to August 2012 Date: November 2012

Contents

Figures

Tables

Acknowledgements

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- **Affinity Water**
- **London Borough of Enfield**
- **Stanmore Quality Surfacing**
- **Quality Recycling Solutions**

We wish to convey a special thanks to personnel tasked with excavation and preparation of test beds as supplied by Stanmore Quality Surfacing as we are extremely grateful for their efforts and assistance in this undertaking.

Method Summary

- Nine test beds excavated within concrete slab to depth 1m with surface area of 1m²
- 1m measurement scale placed within each excavation to allow for verification of compacted layer depth for each material and method.
- Selected backfill materials were:
    - Type 1
    - Recycled Type 1
    - Hydraulically Bound Mixture
- Selected compaction equipment:
    - 50kg Vibrotamper
    - 1800kg/m² Vibrating Plate
    - 1000kg/m Vibrating Roller
- Backfill materials laid as prescribed under SROH with greater depths being applied in some test beds for comparative and measurement purposes as detailed in 2.1 to 2.9 of this document.
- Backfill on all test beds subjected to UKAS accredited test method to determine effectiveness of compaction efforts.
- All bituminous materials were laid as per prescribed methods detailed in 2.10 to 2.19 of this document.
- All bituminous layers were applied within optimum temperature ranges prescribed within SROH for each material.
- Laboratory core samples were extracted to allow UKAS approved test methods relating to compaction of backfill, bituminous air voids testing, and bituminous materials analysis.
- Once samples were retrieved for each test bed it was prepared for introduction of next product.
- Continuous monitoring of methodology prescribed, temperature of material, and digital imaging utilised to ensure no deviation from requirement.

Conclusions & Observations summary

- All backfill layers to be completed as recommended in SROH for all materials
- Visual inspection alone cannot determine compaction effort.
- 300mm layer application of GSB Type 1 and Recycled Type 1 (Test beds 2 & 5) both achieved compaction requirements in relation to this trial.
- HBM materials should always be laid in accordance with current requirement of SROH to ensure performance criteria are achieved immediately after completion.
- Operatives to have a clearer understanding of suitability of differing compaction equipment in relation to selected materials.
- Operatives to have a clearer understanding of importance of compaction efforts and recognised means of achieving conformance.
- Impact hammers can only verify surface modulus and would require application on each compacted backfill layer to provide reasonable results for overall performance.
- 50kg Vibrotamper provided good results on all backfill materials when used in recommended manner for layer thickness and passes required.
- Full depth backfill penetrographs clearly show dissipation of force from compaction equipment regardless of number of passes. Again, such instances will show high readings on impact hammers and dynamic plate testing devices due to high surface modulus.
- Results from penetrometer testing shows compaction failure on all materials backfilled to full depth in test beds 3, 6, and 9.
- Bituminous materials should be laid in accordance with SROH requirement for compacted layer value and temperature for each product.
- Observation of vibrotamper used in multiple layers and passes for bituminous materials appeared to be beyond design capability where device was having no further visual influence on material and was causing distress to both the material and the equipment.
- In relation to AC 20 Binder Course material on test bed 4 there was separation at bond layer when core sample was extracted. It appears that the surface of the lower level was so densely compacted that the upper layer could not achieve bond even at optimum working temperature.
- Compaction methods used on 6mm ACDSC had achieved specification requirement for voids across all nine test beds regardless of method applied.
- The exact same methods only achieved voids content conformance in three instances on 10mm ACCSC even when applying recommended methods under A2.6.1 and Table NG A8.3 of SROH.
- Voids testing is a requirement quoted within Manual of Contract Documents for Highways Works (MCHW) section 903, clauses 8 to 14 which relates to machine laying methods.
- Laboratory testing has shown when applying methods prescribed in SROH some of the results have not achieved voids conformance criteria.
- There is no compromise of minimum voids criteria across all bituminous test samples.

- When considering the above comment should voids testing be undertaken immediately after laying of materials where dynamic loading may have considerable influence on flexible bituminous materials.

Recommendations Summary

- Specific training for operatives in correct selection and application of compaction equipment for relevant backfill materials.
- Training for operatives in verifying and testing compaction of backfills to ensure compliant reinstatement.
- A need for greater understanding of application of impact hammers (Clegg – quoted in SROH) as surface modulus measurement on top layer cannot verify compaction.
- A coding system (possibly colour related) which could be applied to compaction equipment to make it readily identifiable for operatives where job packs could include a basic compaction requirement schedule for selected materials.
- All bituminous materials are flexible by definition and intervention by traffic loading will affect all reinstatements. Consideration and research should be given to time period between time of reinstatement and application of voids testing where continuous dynamic loading will influence outcome.
- Current voids criteria published in SROH should be based on comprehensive research for both materials and equipment commonly used other than machine lay methods. Reference to such research would greatly assist in training and understanding as compliance has to be achievable using quoted methodologies within SROH.
- If this is not readily available, it is suggested that all voids testing results should be excluded from non-compliant specification requirements until research into reinstatement methodologies currently specified within SROH can achieve minimum requirement through traceable and repeatable test methods (other than theoretical).
- Simplification and clarification of compaction requirements for bituminous materials where current version of SROH in Table A2.1 and Table NG A8.3 provides confusion to operatives as they appear to contradict each other.

1.1 PURPOSE

The purpose of this document and associated trial was to determine the suitability and selection of primary compaction devices currently employed in reinstatement of unbound and bituminous materials.
In light of developments relating to bituminous materials being tested for compaction and voids issues, the possibility of easily identifying correct compaction equipment and procedures to ensure compliance with SROH is highly relevant.

This trial was undertaken through fully traceable and accredited measurement, whilst validating all methods and procedures employed and was based primarily around current standard materials, procedures, and relevant compaction equipment used in relation to reinstatements subject to specification requirements of the SROH (Specification for Reinstatement of Openings in the Highway).

Along with identifying the materials, methods, and equipment being used, it was decided that a coding (possibly colour) system could be introduced to provide an easier method for operatives to correctly select compaction equipment. This could be applied for all primarily used bituminous materials within the utilities and street-works industry. The idea being that such a system would allow operatives to select the best option for successful compaction of the material and the correct application of its usage.

In relation to utilities and street-works applications there are three primary types of compaction equipment, commonly known as:

- Trench rammer
- Vibro-plate (wacker plate)
- Single drum vibrating roller

Major works or undertakings are more likely to employ the use of heavier or more specialised equipment more suited to individual tasks.

With regard to current bituminous materials being used the primary examples would be:

- Asphalt Concretes
- Hot Rolled Asphalt
- Stone Mastic Asphalt

Individual specifications and preparations exist for each of the above which relate to aggregate size, binder strength and content, material selection.

These materials have a method for compacted lift thickness which will also be related to the individual type and application of equipment selected. At time of compiling this document, there is no absolute minimum requirement for compaction equipment. However, it is advisable to introduce materials in compacted lift thicknesses as shown within the SROH and applying sufficient usage of selected compaction device to ensure compliance.

Compliance will be further assisted by application of easily identifiable system to ensure whatever equipment is selected, that it is used in such a manner to ensure required level of compaction is achieved. Also to allow operatives to fully understand and relate to effort required to ensure occurrence of air voids within materials are far less likely when selecting correct compaction equipment.

In most cases there is a combination of compaction equipment being employed primarily due to size of excavations utilised. An example would be a narrow road trench has multiple layers of bituminous materials compacted to requirement using a trench rammer, with a roller being employed for the final finished layer.

Where a coding system is developed and applied, an allowance for a recommended method of compacted lifts for material and compaction device could be employed.

Advanced testing will provide information to show extent (if any) of voids present for each material used and the compaction effort required by each device to ensure compliance is more readily achieved.

Evidence of traceability in relation to material options and compliance with relevant BS EN standards has been recorded. All compaction equipment has up to date service or calibration records to verify each device was suitable for purpose and working at full functionality.

Selected materials were used within an area of nine trial test beds, each at a minimum of 1000mm depth which will allow for majority of site based requirement scenarios. Greater depths still required recommended compacted lift thickness and will not have a bearing on the outcome of this trial.

Prior to introduction of bituminous materials all test beds had a well compacted and level base which was verified by laboratory test to ensure no loss of compaction effort was dissipated or lost. This also allowed for identification of compacted layers of proprietary and recycled materials for conformance measurement using a variable energy input dynamic cone penetrometer (Panda2).

Once material was selected, each test bed was reinstated according to a pre-prescribed method for layer values and equipment options applied whilst ensuring optimum working temperatures were maintained and recorded. This allowed for traceability of results to ensure all performance criteria were maintained in relation to workability of material. The primary objective was to apply the use of each material through minimum SROH requirement for each device and to identify issues arising from single layer (full depth reinstatement) for such devices.

Once material test beds reached ambient temperature (following day), a core sample was extracted using approved laboratory methods from each test bed, and subsequently tested for presence and extent of voids for each procedure. Results gained from each material supplied a clear and traceable measurement to identify what compaction devices are suited to each product, the application of such devices, and the recommended lift thickness for each.

This allows for the possibility of a coding to be applied for each device, along with a guideline as to what materials and compacted lift thickness it is suited for if any.

1.2 OBSERVATION & BENEFIT

The methods used within this trial allowed for full and controlled scrutiny in relation to material selection, equipment selection, and methods applied or required when compacting both unbound and bituminous materials.
This provided invaluable information to assist in identifying suitable equipment and work methods applied with regard to compliant compaction achievement for each material selected. All testing was carried out under controlled and accredited laboratory conditions in order to provide traceable results to ensure compliance with method under current specification requirements.
This document will report on all methods and materials used within the trial which was compiled to provide definitive results in relation to ascertaining suitable compaction machinery for each task.

1.3 TEST BEDS

The following will show installation criteria for each test bed and location prior to bituminous application and allowed for testing of backfill layers and compaction efforts.

Test Bed 1 Type 1 at 150mm layers leaving 100mm for bituminous	**Test Bed 4** Recycled Type 1 at 150mm layers leaving 100mm for bituminous	**Test Bed 7** HBM at 150mm layers leaving 100mm for bituminous
Test Bed 2 Type 1 at 300mm layers leaving 100mm for bituminous	**Test Bed 5** Recycled Type 1 at 300mm layers leaving 100mm for bituminous	**Test Bed 8** HBM at 300mm layers leaving 100mm for bituminous
Test Bed 3 Type 1 to full depth leaving 100mm for bituminous	**Test Bed 6** Recycled Type 1 to full depth leaving 100mm for bituminous	**Test Bed 9** HBM to full depth leaving 100mm for bituminous

1.4 Test beds bituminous (all layers compacted)

Once each test was completed and core samples extracted the test beds were prepared for the next bituminous sample.
Materials identified to be subjected to testing were:

6mm ACDSC
10mm ACCSC
20mm ACDBC
10mm SMASC
30/14 HRASC

Test Bed 1 1-Vibrotamper 1-Vibrating Plate	**Test Bed 4** 1-Vibrotamper 1-Roller	**Test Bed 7** 1-Vibrating Plate
Test Bed 2 2-Vibrotamper 1-Vibrating Plate	**Test Bed 5** 2-Vibrotamper 1-Roller	**Test Bed 8** 2-Vibrating Plate
Test Bed 3 3-Vibrotamper 1-Vibrating Plate	**Test Bed 6** 3-Vibrotamper 1-Roller	**Test Bed 9** 3-Vibrating Plate

All equipment and methods used were monitored and recorded in accordance with current version of SROH recommended specification requirements. Each test bed was also subjected to UKAS accredited testing and methods in relation to acquiring accurate measurement for each scenario.

Personnel selected for these works were all current holders of NRSWA accreditation and relevant CITB qualifications for operation of plant and machinery. Full safety guidelines and PPE was employed at all times.

2.0 METHOD

Nine test beds had been prepared at Scratchwood recycling facility which were inspected and deemed as suitable for purpose in relation to undertaking. These were located within a concrete slab with suitable separation for works to be completed without hindrance.
Each test bed was excavated to a depth of 1m which allowed for introduction of backfill layers using differing materials and methods with the top 100mm being left for introduction of bituminous materials. All personnel involved with excavation and reinstatement were fully accredited NRSWA operatives with all relevant training and qualifications in place.
For the purpose of this document the materials selected for backfill were as follows:

- GSB Type 1
- Certified Recycled Type 1
- Certified HBM material

In relation to bituminous materials, all of the 9 test beds had the top 100mm reinstated with a single product using differing methods and equipment for each. Upon reaching ambient temperatures, each location was subjected to testing to determine performance, specification, and methodology compliance.
The initial bituminous materials selected for inclusion (but not limited to) were:

- AC 6 Dense Surface Course
- AC 10 Close Surface Course
- AC 20 Binder Course
- SMA 10 Surface Course
- HRA Surface Course

A works method was prepared for each test bed and its relevant components and full traceability on materials specification, operating procedures, equipment selection, and works methods were applied.

Prior to undertaking any works relating to reinstatement within test beds the following requirements were in place.

1. Vibrotamper (50kg minimum) with relevant documentation to confirm it is suitable for purpose.
2. Vibrating Plate (Over 1800kg/m²) with relevant documentation to confirm it is suitable for purpose.
3. 1000-2000kg/m Single Drum Vibrating Roller with relevant documentation to confirm it is suitable for purpose.
4. Temperature probe to measure delivery (Arrival = In the lorry within 30 minutes of arrival on site) and laying temperature of bituminous materials to ensure compliance with SROH Table A2.3
5. 1metre reference scale for photographic purposes relating to introduction of backfill layers only (not to be used as a definitive measurement but also a guide for operatives to achieve proposed compacted layer thickness).

6. Clear identification labels for each trial pit for photographic reference and verification.

Preparation of each test bed was as follows:

- Ensure minimum 1m depth from concrete slab surface
- Installation of 1m “E” scale for photographic reference
- Removal of any debris, spoil, and water (if present)
- Record weather conditions.
- Area around each test pit to be clean and free of obstruction
- Clear identification for photographic reference
- Installation of backfill materials as per work method prescribed for each trial pit.
- Continuous monitoring and measurement of layer depths, working methods, and selected equipment relating to backfill materials.
- Ensure all test beds are at prescribed levels and prepared as ready to receive bituminous material layers.
- After each individual suite of tests for bituminous material has been completed, the bound materials will be removed and test beds prepared for next product.

The material and method of laying for each test bed was as outlined below. This allowed for subsequent laboratory testing in relation to compaction efforts and achievements.

2.1 TEST BED 1 – GSB TYPE 1 (8 passes per layer)

1. 150mm compacted layer using min 50kg vibrotamper - photograph
2. 150mm compacted layer using min 50kg vibrotamper - photograph
3. 150mm compacted layer using min 50kg vibrotamper – photograph
4. 150mm compacted layer using min 50kg vibrotamper – photograph
5. 150mm compacted layer using min 50kg vibrotamper – photograph
6. 150mm compacted layer using min 50kg vibrotamper - photograph

2.2 TEST BED 2 – GSB TYPE 1 (8 passes per layer)

1. 300mm compacted layer using min 50kg vibrotamper - photograph
2. 300mm compacted layer using min 50kg vibrotamper - photograph
3. 300mm compacted layer using min 50kg vibrotamper - photograph

2.3 TEST BED 3 – GSB TYPE 1 (8 passes per layer)

1. Single 900mm compacted layer using min 50kg vibrotamper - photograph

2.4 TEST BED 4 – CERTIFIED RECYCLED TYPE 1 (8 passes per layer)

1. 150mm compacted layer using min 50kg vibrotamper - photograph
2. 150mm compacted layer using min 50kg vibrotamper - photograph
3. 150mm compacted layer using min 50kg vibrotamper – photograph
4. 150mm compacted layer using min 50kg vibrotamper – photograph

5. 150mm compacted layer using min 50kg vibrotamper – photograph
6. 150mm compacted layer using min 50kg vibrotamper – photograph

2.5 TEST BED 5 - CERTIFIED RECYCLED TYPE 1 (8 passes per layer)

1. 300mm compacted layer using min 50kg vibrotamper - photograph
2. 300mm compacted layer using min 50kg vibrotamper - photograph
3. 300mm compacted layer using min 50kg vibrotamper - photograph

2.6 TEST BED 6 - CERTIFIED RECYCLED TYPE 1 (8 passes per layer)

1. Single 900mm compacted layer using min 50kg vibrotamper - photograph

2.7 TEST BED 7 - CERTIFIED HBM MATERIAL (8 passes per layer)

1. 150mm compacted layer using min 50kg vibrotamper - photograph
2. 150mm compacted layer using min 50kg vibrotamper - photograph
3. 150mm compacted layer using min 50kg vibrotamper - photograph
4. 150mm compacted layer using min 50kg vibrotamper - photograph
5. 150mm compacted layer using min 50kg vibrotamper - photograph
6. 150mm compacted layer using min 50kg vibrotamper - photograph

2.8 TEST BED 8 - CERTIFIED HBM MATERIAL (8 passes per layer)

1. 300mm compacted layer using min 50kg vibrotamper - photograph
2. 300mm compacted layer using min 50kg vibrotamper - photograph
3. 300mm compacted layer using min 50kg vibrotamper - photograph

2.9 TEST BED 9 - CERTIFIED HBM MATERIAL (8 passes per layer)

1. Single 900mm compacted layer using min 50kg vibrotamper - photograph

A laminated information card will be provided for each test bed which will provide details for test bed number, material selection, compacted layers, and method of application for equipment used.
An example of which is shown below:

TEST BED 1

GSB Type 1

6 Compacted Layers at 150mm
Using 50kg Vibrotamper
8 passes for each layer

Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

Research period: April 2012 to August 2012 Date: November 2012

2.10 BITUMINOUS MATERIALS

Each material was utilised across all 9 test beds and laid using the following procedures for each. This allowed for traceable measurement to be extracted from each test bed and its relevant properties.

The method criteria for each material and equipment for each test bed was as follows.
Take thermometer reading on rear of delivery lorry prior to using for each test bed to ensure material is at recommended arrival temperature as per SROH Table A2.3

Take thermometer reading at each test bed when laying material to ensure laying temperature achieves recommended values as per SROH Table A2.3
All aspects and methods were recorded on appropriate site documentation and each aspect of the process was digitally recorded through imaging with relevant identification labels in place.

When test beds were deemed as suitable for the introduction of bituminous materials the working procedure for each product was clearly outlined for operative assistance in relation to layer thickness, compaction, and selected equipment.
An example of information card follows:

TEST BED 1

6mm ACDSC

2 Compacted Layers

L1: 50mm - 50kg Vibrotamper at 6 passes
L2: 50mm - 1800kg/m² Vibrating Plate at 5 passes

2.11 TEST BED 1 *(Temperature and photograph taken for each layer)*

1. 50mm compacted layer using min 50kg vibrotamper at 6 passes
2. 50mm compacted layer using 1800kg/m² vibrating plate at 5 passes

2.12 TEST BED 2 *(Temperature and photograph taken for each layer)*

1. 35mm compacted layer using min 50kg vibrotamper at 5 passes.
2. 35mm compacted layer using min 50kg vibrotamper at 5 passes.
3. 30mm compacted layer using 1800kg/m² vibrating plate at 3 passes.

2.13 TEST BED 3 *(Temperature and photograph taken for each layer)*

1. 25mm compacted layer using min 50kg vibrotamper at 5 passes.
2. 25mm compacted layer using min 50kg vibrotamper at 5 passes.
3. 25mm compacted layer using min 50kg vibrotamper at 5 passes.
4. 25mm compacted layer using 1800kg/m² vibrating plate at 3 passes.

2.14 TEST BED 4 *(Temperature and photograph taken for each layer)*

1. 50mm compacted layer using min 50kg vibrotamper at 6 passes.
2. 50mm compacted layer using 1000kg/m single drum roller at 12 passes.

2.15 TEST BED 5 *(Temperature and photograph taken for each layer)*

1. 35mm compacted layer using min 50kg vibrotamper at 5 passes.
2. 35mm compacted layer using min 50kg vibrotamper at 5 passes.
3. 30mm compacted layer using 1000kg/m single drum roller at 10 passes.

2.16 TEST BED 6 *(Temperature and photograph taken for each layer)*

1. 25mm compacted layer using min 50kg vibrotamper at 5 passes.
2. 25mm compacted layer using min 50kg vibrotamper at 5 passes.
3. 25mm compacted layer using min 50kg vibrotamper at 5 passes.
4. 25mm compacted layer using 1000kg/m single drum roller at 10 passes.

2.17 TEST BED 7 *(Temperature and photograph taken for each layer)*

1. 100mm compacted layer using 1800kg/m² vibrating plate at 8 passes.

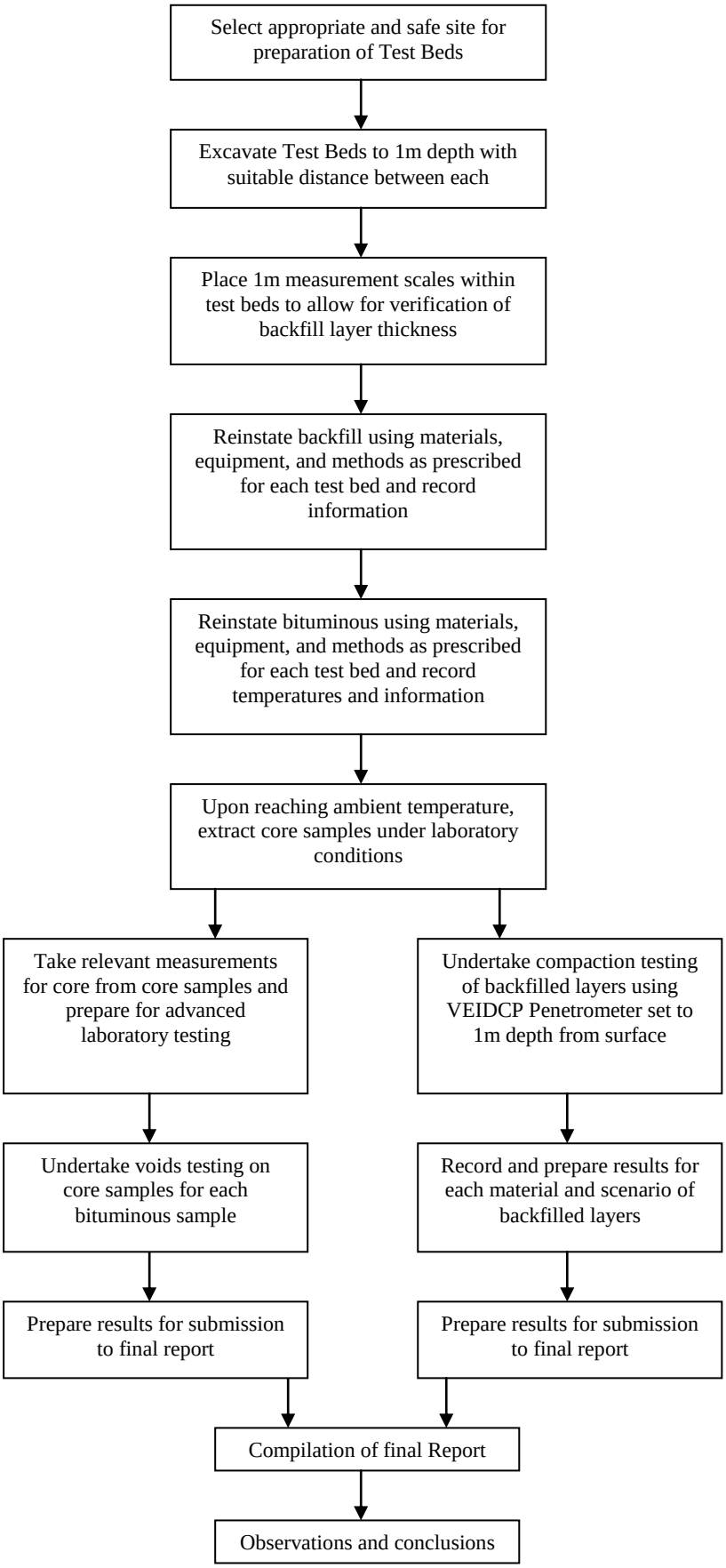
2.18 TEST BED 8 *(Temperature and photograph taken for each layer)*

1. 50mm compacted layer using 1800kg/m² vibrating plate at 5 passes.
2. 50mm compacted layer using 1800kg/m² vibrating plate at 5 passes.

2.19 TEST BED 9 *(Temperature and photograph taken for each layer)*

1. 35mm compacted layer using 1800kg/m² vibrating plate at 3 passes.
2. 35mm compacted layer using 1800kg/m² vibrating plate at 3 passes.
3. 30mm compacted layer using 1800kg/m² vibrating plate at 3 passes.

Method flow chart



3.0 COMPACTION EQUIPMENT

Equipment used in this trial had been fully serviced with compliance and service records and labels in place.
These devices are also the most commonly employed in relation to reinstatement of openings in the highway.

Vibrotamper

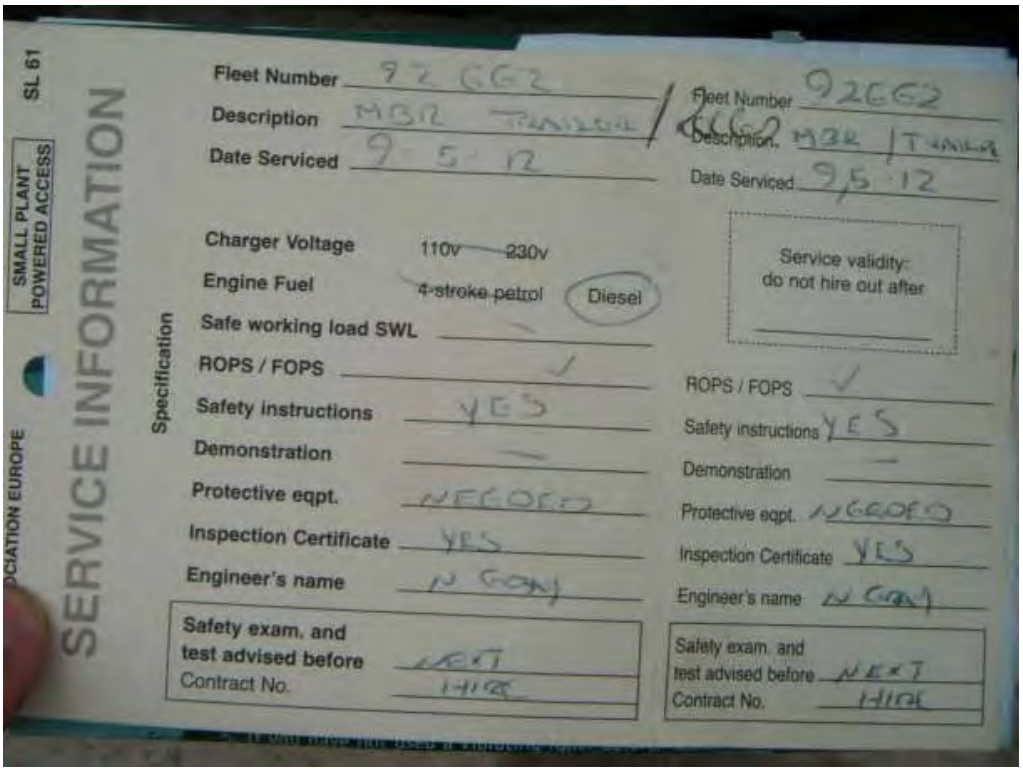
Figure 1. *Vibrotamper with service information tag*

Vibrating Plate

Figure 2. *Vibrating Plate with service information tag*

Single Drum Vibrating Roller

Figure 3. *Vibrating Roller with service information tag*



Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

Research period: April 2012 to August 2012 Date: November 2012

3.1 Thermometer

The thermometer selected for bituminous temperature readings was verified as suitable for use by scale comparison with calibrated laboratory thermometer C3156/11and showed a variation of +0.8°C and -0.7°C over the five days of bituminous testing

The device was regularly checked for deviation and was found to be functioning within acceptable parameters of +/- 1°C

Figure 4. *Verification of bituminous probe thermometer*

Table 1: **Thermometer verification at ambient temperature**

Material	Time	Temp	Control	Value	Time	Temp	Control	Value
Day 1 – 6mm ACDSC	10.30	17.6°C	18.0°C	**-0.4°C**	15.33	18.5°C	17.7°C	**0.8°C**
Day 2 – 10mm ACCSC	11.32	19.7°C	19.2°C	**0.5°C**	15.45	23.6°C	23.1°C	**0.5°C**
Day 3 – 10mm SMASC	10.21	20.2°C	19.9°C	**0.3°C**	16.05	26.1°C	25.5°C	**0.6°C**
Day 4 – 20mm ACDBC	09.58	18.5°C	19.1°C	**-0.6°C**	15.22	24.2°C	24.9°C	**-0.7°C**
Day 5 – 30/14 HRASC	10.40	19.1°C	19.3°C	**-0.2°C**	14.52	23.4°C	23.5°C	**-0.1°C**

4.0 INTRODUCTION OF BACKFILL MATERIALS

The test beds were prepared as described in sections 1 and 2 of this document and excavated to a depth of minimum 1m from surface of concrete slab.
Each test bed had a sacrificial measurement scale placed to verify that prescribed compacted lift thickness had been achieved.
All layers had been recorded individually by laboratory personnel and digital photographs taken to confirm requirement had been adhered to.

Grab lorry was used to place materials into each test bed and closely monitored in relation to process and methods utilised for individual layers. All activities were recorded through digital imaging

Figure 5. *Grab lorry used for placement of materials*

Figure 6. *Digital imaging of all applied layers and measurement*

Backfill materials used

There were three backfill materials selected for these trials

- Proprietary GSB Type 1
- Recycled Type 1
- Hydraulically Bound Mixture (HBM)

Delivery tickets for these materials have been included to provide evidence of correct selection and can be viewed below:

Figure 7. *Copy of delivery ticket for GSB Type 1*

Figure 8. *Copy of delivery ticket for additional Type 1 required for Test bed 3*

Figure 9. *Copy of delivery ticket for recycled Type 1 and HBM materials*

Weighbridge Ticket / Waste Transfer Note

Quality Recycling Solutions Ltd.

Operations - Scratchwood Quarry, London Gateway Services, Mill Hill, London NW7 3HU. Tel: 0333 240 0203

Head Office / Accounts - 12 Priestley Way, London NW2 7AP. Tel: 0333 240 0201 Email: info@sqsltd.co.uk

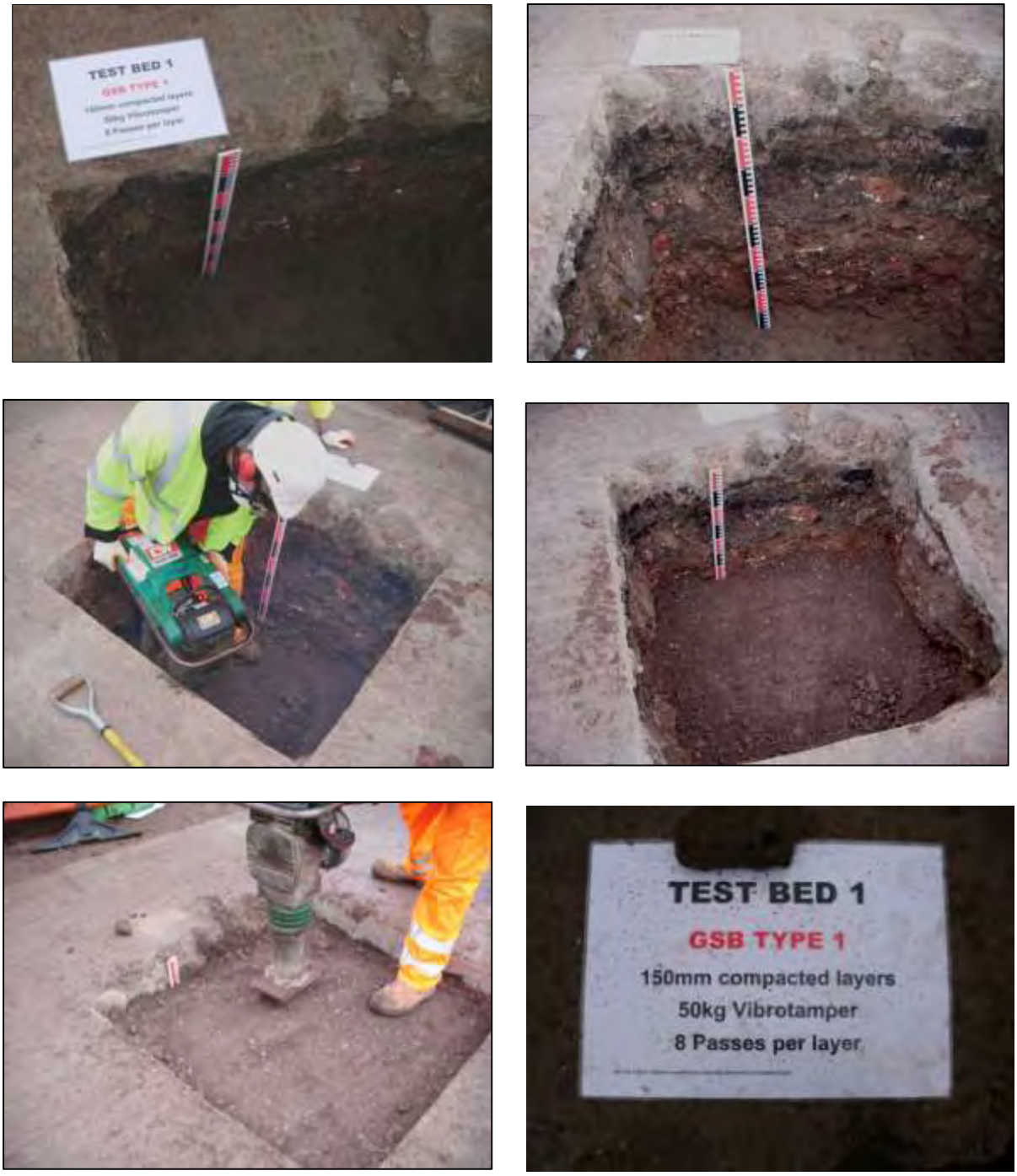
Driver's Name (PRINT) | Driver's Signature | Operator's Signature

Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

Test Bed 1 – GSB Type 1

Proprietary GSB Type 1 laid in 150mm compacted layers as per Table A8.1 of the SROH with 8 passes of Vibrotamper as prescribed. The following images will show the procedure as it progressed.

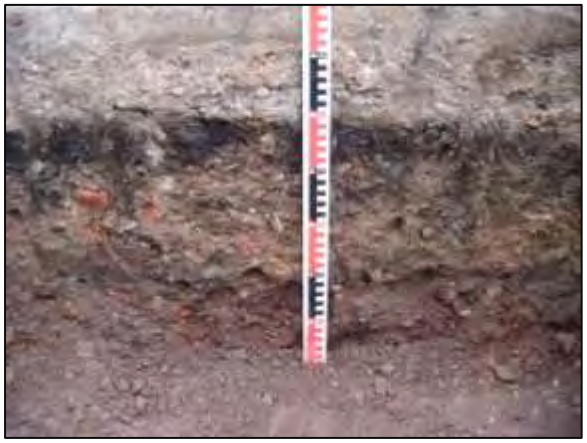
Figure 10. *Backfill of Test Bed 1 at 150mm layers using proprietary GSB Type 1*

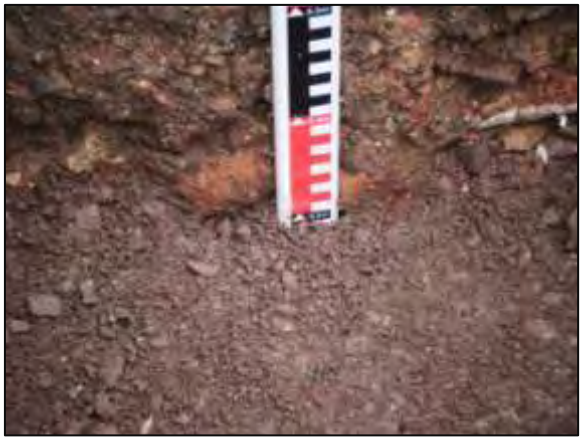


Test Bed 2 – GSB Type 1

Proprietary GSB Type 1 laid in 300mm compacted layers which will conflict with specified requirement of SROH, however, 8 passes of Vibrotamper were also applied to each layer. The following images will show the procedure as it progressed.

Figure 11. *Backfill of Test Bed 2 at 300mm layers using proprietary GSB Type 1*





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Research period: April 2012 to August 2012 Date: November 2012

Test Bed 3 – GSB Type 1

Proprietary GSB Type 1 laid in a single layer to full depth which will conflict with specified requirement of SROH. As per previous test beds there were 8 passes of Vibrotamper applied.

Figure 12. *Backfill of Test Bed 3 to full depth using proprietary GSB Type 1*

Test Bed 4 – Recycled Type 1 (Certified Graded Granular Material)

Recycled Type 1 laid in 150mm compacted layers as per Table A8.1 of the SROH with 8 passes of Vibrotamper applied for each layer.

Figure 13. *Backfill of Test Bed 4 at 150mm layers using recycled Type 1*

Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

Research period: April 2012 to August 2012 Date: November 2012

Test Bed 5 – Recycled Type 1 (Certified Graded Granular Material)

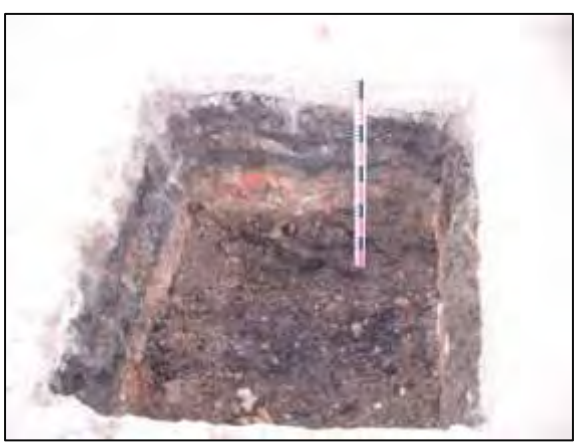
Recycled Type 1 laid in 300mm compacted layers which will conflict with specified requirement of SROH with 8 passes of Vibrotamper applied to each layer.

Figure 14. *Backfill of Test Bed 5 at 300mm layers using recycled Type 1*

Test Bed 6 – Recycled Type 1 (Certified Graded Granular Material)

Recycled Type 1 placed in a single layer to full depth which will conflict with specified requirement of SROH. As per previous test beds there were 8 passes of Vibrotamper applied.

Figure 15. *Backfill of Test Bed 6 to full depth using recycled Type 1*



Test Bed 7 – Hydraulically Bound Mixture (HBM)

Certified HBM material laid in 150mm compacted layers as per Table A8.1 of the SROH with 8 passes of Vibrotamper applied for each layer.

Figure 16. *Backfill of Test Bed 7 at 150mm layers using certified HBM material*

Test Bed 8 – Hydraulically Bound Mixture (HBM)

Certified HBM material laid in 300mm compacted layers which will conflict with specified requirement of SROH with 8 passes of Vibrotamper applied to each layer.

Figure 17. *Backfill of Test Bed 8 at 300mm layers using certified HBM material*

Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

Research period: April 2012 to August 2012 Date: November 2012

Test Bed 9 – Hydraulically Bound Mixture (HBM)

HBM material placed in a single layer to full depth which will conflict with specified requirement of SROH. There were 8 passes of Vibrotamper applied on the surface.

Figure 18. *Backfill of Test Bed 6 to full depth using certified HBM material*

4.1 Compaction of Backfill – Laboratory testing

Once all backfilled Test beds were completed to relevant requirement, the procedure allowed for a UKAS accredited method for test of compaction efforts for each material was applied.

It was decided that such testing would be undertaken when extracting core samples from first selected bituminous material.

This was by employing the Variable Energy Input Dynamic Cone Penetrometer otherwise known as Panda2 which is a fully accredited UKAS method.

This identified values for ground resistance and density for each material and relevant layer method used.

Figure 19. *Panda 2 Penetrometer being used to measure compaction efforts*

The Penetrographs and Strike Tables included within this report will be provided for all 9 test beds and identifies where failure has occurred as a result of poor or insufficient compaction.
This procedure also provides scientific data to determine if minimum requirements were achieved when considering non-standard layer depths which is especially relevant when measuring performance criteria of HBM materials.

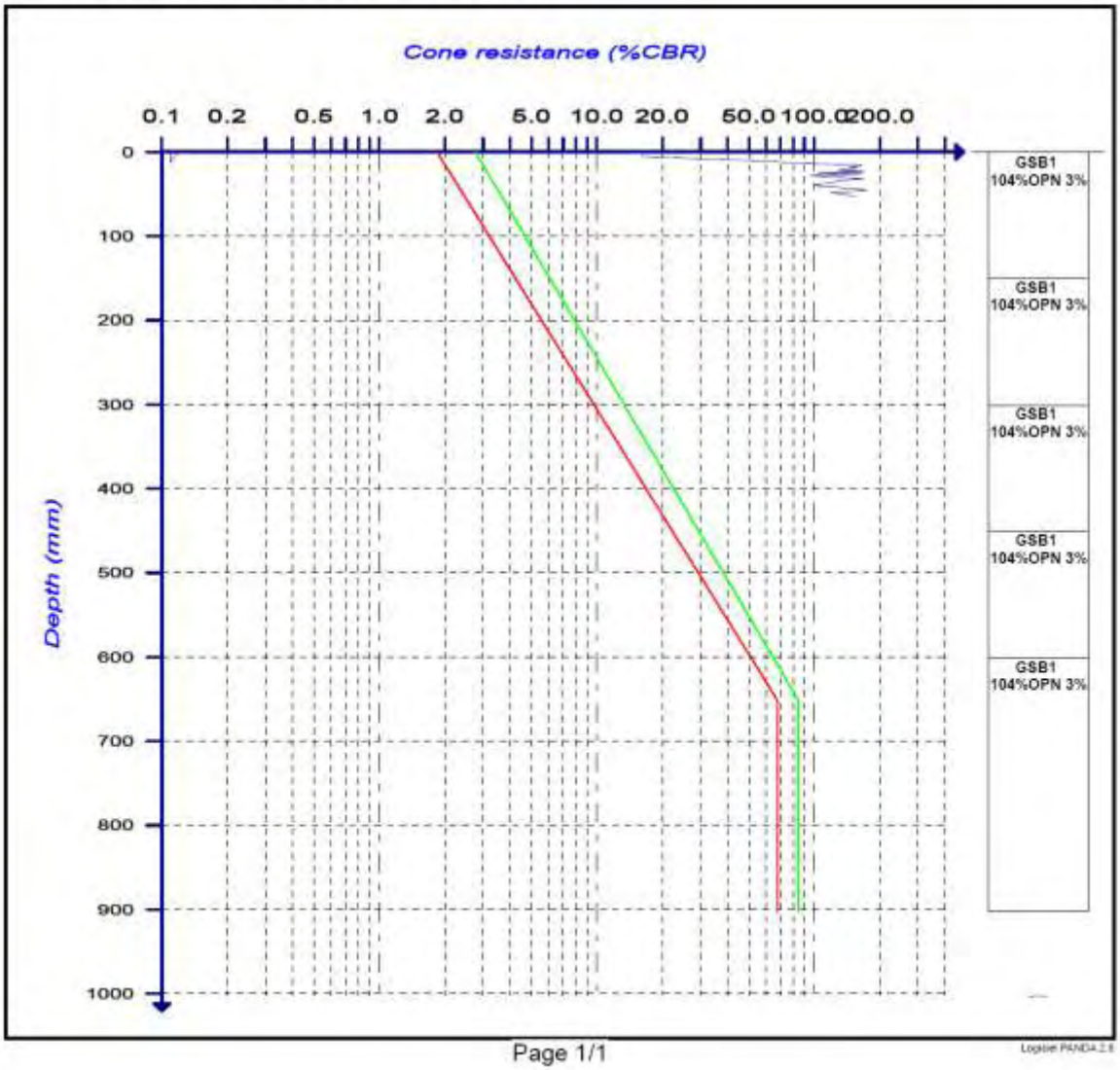
Compaction Testing Test Bed 1 – GSB Type 1

Penetrograph 1 - Laid at 150mm layers at 8 passes of Vibrotamper

Compaction control with variable energy dynamic penetrometer

Document : S:\Test Beds\Backfill\Pandas.pd2			
Site : Scratchwood Test Beds			
Sounding : Test Bed 1			
Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 07:20:00
Operator : L Brockhouse		Company : Veolia Water	

Comments :
GSB TYPE 1
150mm compacted layers
50kg Vibrotamper - 8 Passes per layer
Unable to achieve 1m depth due to extremely high resistance



Page 1/1

Strike Table for Test Bed 1 (measured in CBR% values)

Sounding cone resistance data table

Document : S:\Test Beds\Backfill\Pandas.pd2			
Site : Scratchwood Test Beds			
Sounding : Test Bed 1			
Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 07:20:00
Operator : L Brockhouse		Company : Veolia Water	

Comments :
GSB TYPE 1
150mm compacted layers
50kg Vibrotamper - 8 Passes per layer
Unable to achieve 1m depth due to extremely high resistance

Index Measure	*Depth (mm)*	*Resist. (%CBR)*
1	5	16.11
2	9	33.64
3	11	63.14
4	13	73.32
5	14	110.06
6	15	160.69
7	16	166.04
8	18	146.11
9	19	155.76
10	20	134.91
11	22	129.64
12	23	171.48
13	25	104.13
14	26	166.38
15	28	96.17
16	30	116.62
17	31	144.02
18	32	170.11
19	34	135.38
20	35	125.04
21	37	119.56
22	39	99.63
23	40	106.62
24	42	129.64
25	43	148.46
26	44	169.77
27	46	173.20
28	48	119.53
29	51	142.80
30	53	154.35

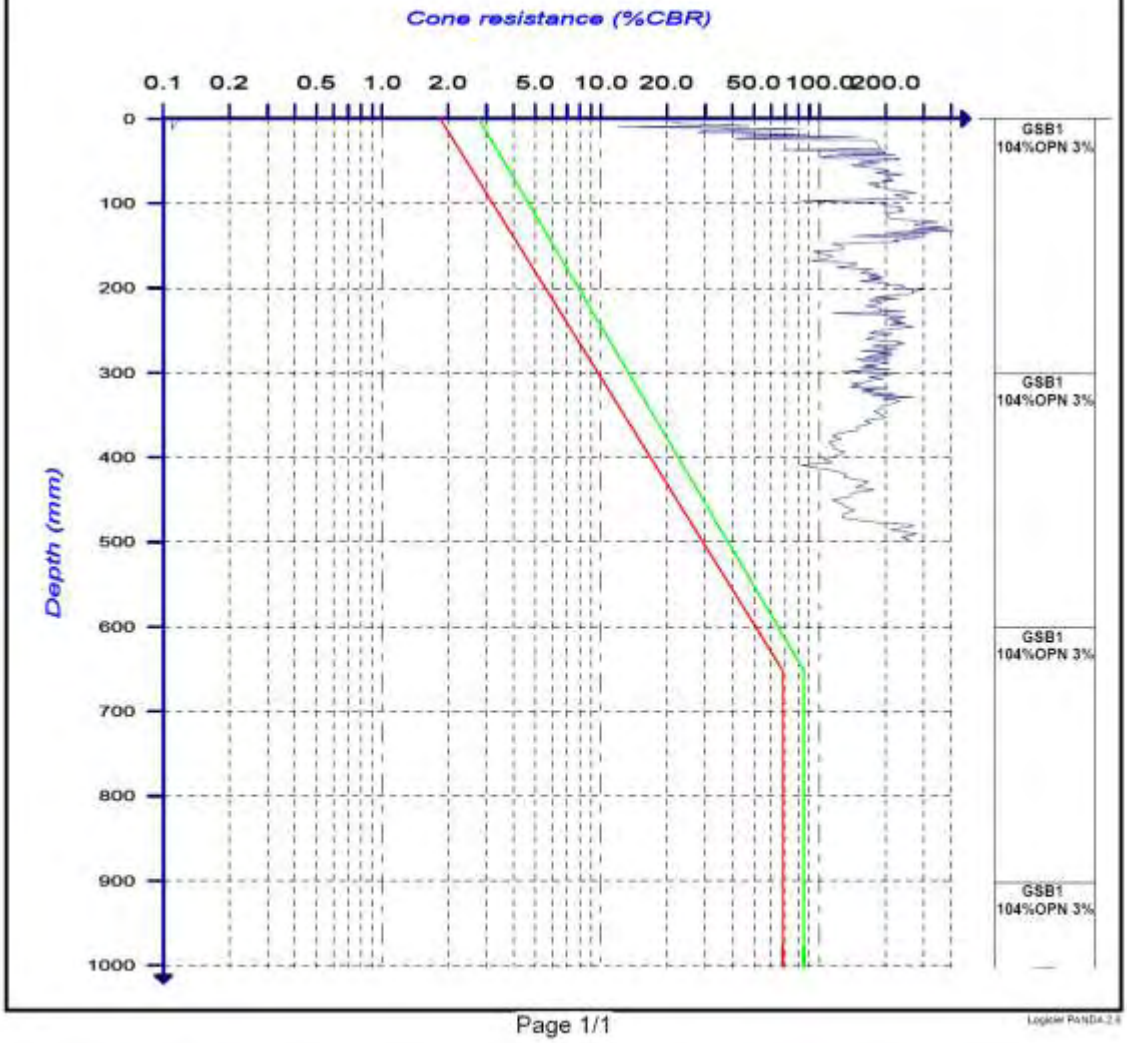
Page 1/1

Compaction Testing Test Bed 2 – GSB Type 1

Penetrograph 1 - Laid at 300mm layers at 8 passes of Vibrotamper

Compaction control with variable energy dynamic penetrometer

Document : S:\Test Beds\Backfill\Pandas.pd2			
Site : Scratchwood Test Beds			
Sounding : Test Bed 2			
Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 07:25:00
Operator : L Brockhouse		Company : Veolia Water	
Comments : GSB TYPE 1 300mm compacted layers 50kg Vibrotamper - 8 Passes per layer Unable to achieve 1m depth due to extremely high resistance			



Page 1/1

Strike Table for Test Bed 2 (measured in CBR% values)

Sounding cone resistance data table

Document : S:\Test Beds\Backfill\Pandas.pd2

Site : Scratchwood Test Beds

Sounding : Test Bed 2

Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 07:25:00
Operator : L Brockhouse		Company : Veolia Water	

Comments :
GSB TYPE 1
300mm compacted layers
50kg Vibrotamper - 8 Passes per layer
Unable to achieve 1m depth due to extremely high resistance

Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)
1	3	20.84	51	97	82.38	101	200	228.51	151	281	162.64
2	6	22.83	52	99	205.75	102	201	301.36	152	282	211.97
3	8	47.55	53	102	194.23	103	202	264.34	153	284	147.49
4	10	12.09	54	104	239.40	104	206	269.41	154	286	169.44
5	12	81.52	55	107	230.45	105	211	178.01	155	287	207.15
6	14	29.59	56	109	243.08	106	212	230.92	156	289	186.95
7	16	27.95	57	112	198.04	107	214	168.49	157	290	161.08
8	17	53.26	58	114	205.68	108	215	178.98	158	292	182.91
9	19	87.19	59	117	203.35	109	217	194.10	159	294	152.42
10	20	41.91	60	119	228.21	110	218	182.19	160	295	210.05
11	21	151.85	61	120	286.82	111	219	179.29	161	296	172.28
12	22	78.35	62	122	348.58	112	221	161.79	162	298	128.49
13	24	41.37	63	123	324.50	113	222	180.76	163	299	176.00
14	26	179.65	64	124	270.38	114	224	190.65	164	301	218.39
15	34	187.49	65	127	302.65	115	226	187.24	165	303	187.17
16	36	190.06	66	128	383.01	116	227	246.76	166	305	167.49
17	37	67.46	67	130	269.63	117	229	114.47	167	306	195.45
18	38	191.14	68	132	427.37	118	231	203.84	168	308	172.60
19	40	201.87	69	134	206.15	119	232	222.66	169	310	163.77
20	41	122.13	70	136	319.74	120	234	248.05	170	312	139.80
21	43	223.48	71	138	140.37	121	235	199.71	171	314	152.79
22	44	109.46	72	140	289.96	122	237	232.71	172	316	137.44
23	46	101.00	73	141	272.01	123	238	235.24	173	317	207.00
24	47	230.96	74	143	218.64	124	239	216.49	174	319	154.99
25	48	232.26	75	145	231.02	125	241	246.76	175	320	178.22
26	50	165.88	76	148	113.97	126	242	209.36	176	322	154.71
27	51	151.08	77	151	129.26	127	243	215.32	177	323	208.79
28	53	186.85	78	155	128.59	128	245	270.26	178	325	222.35
29	54	139.96	79	156	93.83	129	246	244.39	179	326	173.39
30	56	148.72	80	159	102.26	130	250	181.67	180	328	271.57
31	58	182.22	81	162	114.84	131	252	169.29	181	330	194.09
32	60	198.14	82	165	108.12	132	253	215.56	182	331	221.90
33	62	208.88	83	167	91.31	133	255	198.29	183	333	231.65
34	64	178.26	84	170	146.83	134	256	183.46	184	336	217.13
35	66	243.00	85	173	146.83	135	258	168.48	185	339	192.34
36	67	199.18	86	175	119.24	136	260	163.62	186	342	191.42
37	71	214.58	87	177	174.83	137	261	193.96	187	345	177.95
38	73	194.41	88	179	160.31	138	263	231.19	188	349	191.34
39	74	217.27	89	182	154.09	139	264	227.71	189	352	200.14
40	75	176.14	90	183	185.54	140	265	247.17	190	356	160.38
41	77	166.73	91	185	165.91	141	266	206.08	191	359	172.36
42	79	187.19	92	187	192.95	142	268	172.95	192	363	148.43
43	80	178.39	93	189	188.76	143	269	190.82	193	367	150.26
44	82	202.14	94	190	196.81	144	271	226.47	194	371	121.49
45	83	202.14	95	191	152.44	145	272	194.35	195	374	113.78
46	85	243.21	96	193	176.52	146	274	155.71	196	377	125.86
47	87	274.28	97	194	207.16	147	275	213.58	197	381	110.46
48	90	219.77	98	196	201.29	148	276	182.15	198	385	116.07
49	92	249.89	99	197	243.18	149	278	219.49	199	389	115.75
50	94	253.07	100	199	244.47	150	279	176.27	200	392	129.67

Page 1/2

Logiciel PANDA 2.8

Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

Research period: April 2012 to August 2012 Date: November 2012

(Cont'd) Strike Table for Test Bed 2 (measured in CBR% values)

Document : S:\Test Beds\Backfill\Pandas.pd2			
Site : Scratchwood Test Beds			
Sounding : Test Bed 2			
Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 07:25:00
Operator : L Brockhouse		Company : Veolia Water	

Comments :
GSB TYPE 1
300mm compacted layers
50kg Vibrotamper - 8 Passes per layer
Unable to achieve 1m depth due to extremely high resistance

Index Measure	*Depth (mm)*	*Resist. (%CBR)*
201	397	120.66
202	401	104.47
203	405	114.26
204	408	82.69
205	412	97.59
206	415	118.70
207	419	132.68
208	422	128.32
209	425	141.15
210	428	166.06
211	431	159.23
212	434	146.32
213	437	178.96
214	441	140.73
215	445	138.69
216	449	114.05
217	453	126.35
218	458	132.57
219	461	144.02
220	466	128.61
221	470	127.93
222	474	157.33
223	476	191.90
224	478	259.04
225	480	271.02
226	482	253.11
227	484	211.96
228	486	232.22
229	488	276.98
230	491	267.26
231	493	237.28
232	495	254.94
233	498	237.75

Page 2/2

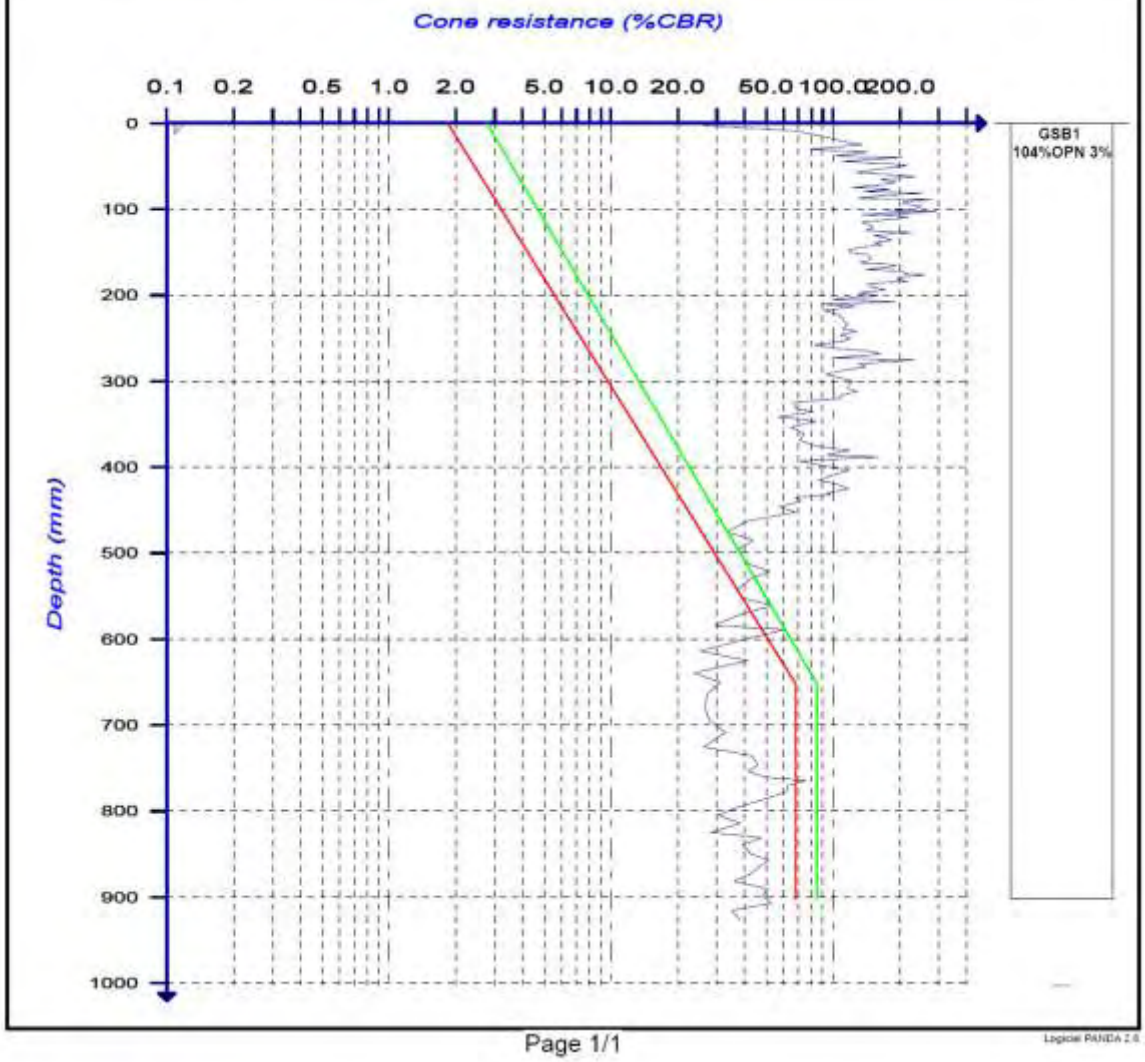
Logiciel PANDA 2.5

Compaction Testing Test Bed 3 – GSB Type 1

Penetrograph 3 - Laid at to full depth with 8 passes of Vibrotamper

Compaction control with variable energy dynamic penetrometer

Document : S:\Test Beds\Backfill\Pandas.pd2			
Site : Scratchwood Test Beds			
Sounding : Test Bed 3			
Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 07:32:00
Operator : L Brockhouse		Company : Veolia Water	
Comments : GSB type 1 900mm compacted layer - Full Depth 50kg Vibrotamper - 8 Passes Compaction fails to meet requirements			



Page 1/1

Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

Research period: April 2012 to August 2012 Date: November 2012

Strike Table for Test Bed 3 (measured in CBR% values)

Sounding cone resistance data table

Document : S:\Test Beds\Backfill\Pandas.pd2			
Site : Scratchwood Test Beds			
Sounding : Test Bed 3			
Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 07:32:00
Operator : L Brockhouse		Company : Veolia Water	
Comments : GSB type 1 900mm compacted layer - Full Depth 50kg Vibrotamper - 8 Passes Compaction fails to meet requirements			

Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)
1	2	26.32	51	150	118.45	101	324	66.73	151	744	45.86
2	6	45.58	52	152	142.42	102	331	67.53	152	752	41.47
3	9	68.43	53	155	147.94	103	335	81.39	153	758	49.14
4	14	83.81	54	158	147.94	104	341	56.77	154	763	75.36
5	18	97.86	55	162	131.97	105	345	84.11	155	768	62.54
6	22	115.87	56	164	191.84	106	353	64.82	156	775	62.11
7	25	135.94	57	167	181.16	107	360	74.22	157	784	49.63
8	30	79.03	58	170	139.43	108	368	70.82	158	793	37.16
9	33	143.58	59	172	207.36	109	375	85.07	159	803	30.50
10	38	102.63	60	174	210.28	110	380	118.55	160	812	38.27
11	40	205.07	61	176	259.54	111	385	93.32	161	823	28.21
12	44	109.83	62	178	206.29	112	387	160.56	162	829	47.69
13	47	179.30	63	181	193.62	113	392	71.52	163	837	39.18
14	49	215.24	64	183	216.37	114	398	92.04	164	848	42.75
15	53	164.17	65	186	143.56	115	403	118.19	165	855	51.21
16	57	127.11	66	190	149.41	116	408	99.97	166	862	47.21
17	60	194.80	67	193	171.16	117	414	86.96	167	871	42.42
18	62	234.85	68	197	130.93	118	419	106.15	168	879	35.88
19	65	163.71	69	200	159.83	119	424	117.18	169	888	50.49
20	68	191.55	70	204	98.92	120	429	94.25	170	896	48.41
21	71	174.55	71	207	191.24	121	431	97.56	171	905	52.47
22	74	121.00	72	210	89.11	122	434	67.54	172	913	34.93
23	76	180.69	73	212	125.90	123	439	71.67	173	924	38.24
24	79	137.70	74	217	90.81	124	445	57.43			
25	81	254.23	75	222	104.64	125	451	67.91			
26	83	175.10	76	226	110.20	126	462	40.87			
27	87	128.20	77	230	112.35	127	474	33.34			
28	89	278.26	78	234	116.24	128	484	43.68			
29	91	207.50	79	238	110.43	129	495	37.23			
30	93	207.18	80	241	126.97	130	504	38.87			
31	96	250.16	81	246	108.10	131	512	42.44			
32	98	246.71	82	250	119.61	132	520	52.06			
33	100	226.69	83	253	111.77	133	529	42.12			
34	101	175.06	84	257	82.91	134	540	37.16			
35	103	289.52	85	261	103.94	135	551	38.98			
36	106	133.90	86	265	147.58	136	559	53.12			
37	108	218.25	87	268	164.22	137	571	37.02			
38	111	187.13	88	272	98.71	138	583	29.25			
39	115	135.12	89	275	230.17	139	587	60.79			
40	118	145.68	90	279	130.10	140	598	40.78			
41	121	151.70	91	283	140.67	141	612	25.30			
42	125	141.30	92	287	109.57	142	623	41.42			
43	127	226.99	93	291	93.30	143	638	23.75			
44	130	152.61	94	295	104.33	144	649	30.95			
45	133	170.60	95	299	123.18	145	662	27.13			
46	136	183.38	96	303	118.45	146	676	26.50			
47	139	153.14	97	308	116.51	147	692	27.72			
48	141	166.22	98	311	128.16	148	707	32.79			
49	144	135.79	99	316	108.28	149	724	26.15			
50	147	117.19	100	319	107.10	150	734	43.04			

Page 1/1

Logiciel PANDA 2.6

Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

Research period: April 2012 to August 2012 Date: November 2012

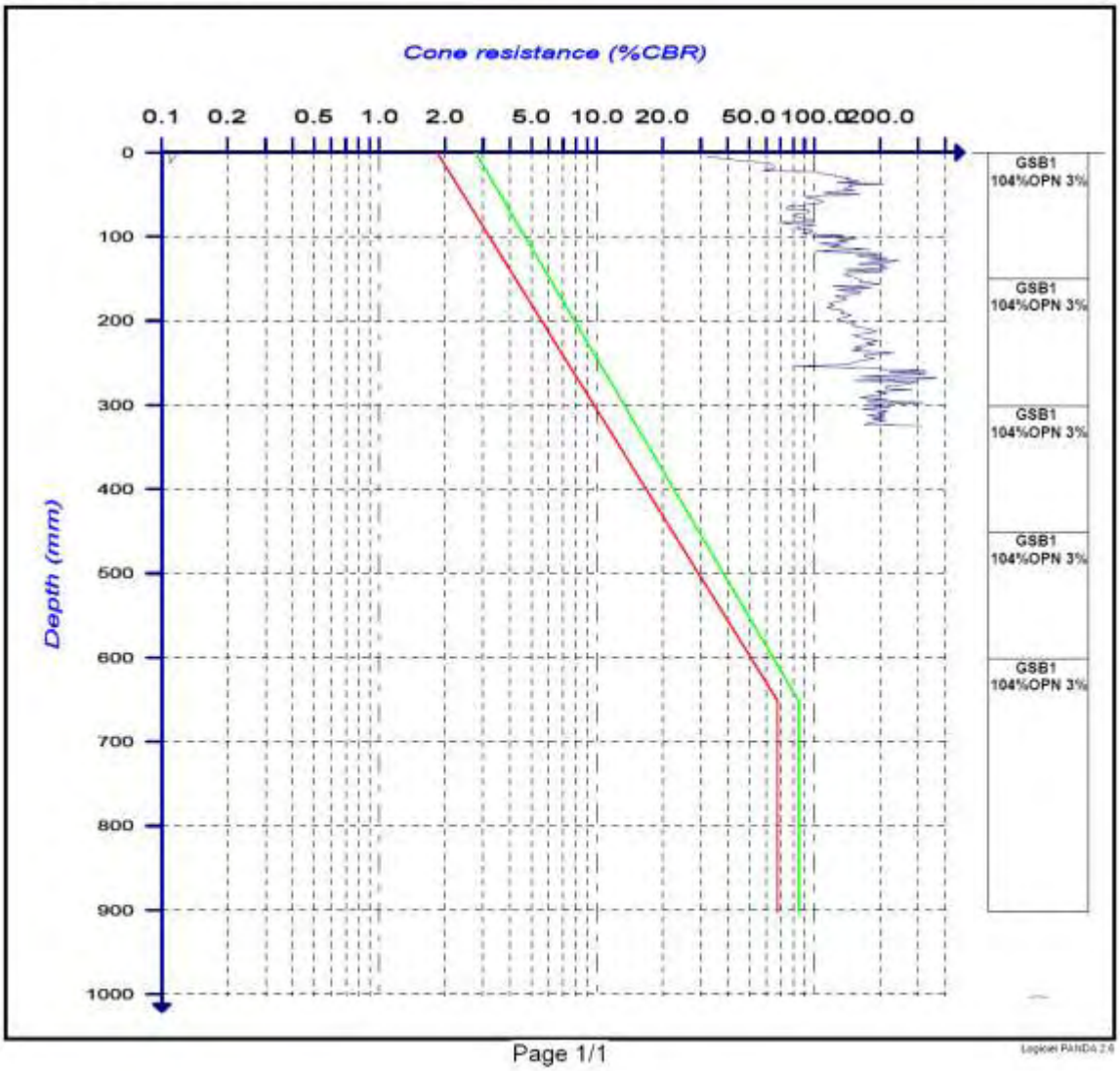
Compaction Testing Test Bed 4 – Recycled Type 1

Penetrograph 4 - Laid at 150mm layers at 8 passes of Vibrotamper

Compaction control with variable energy dynamic penetrometer

Document : S:\Test Beds\Backfill\Pandas.pd2			
Site : Scratchwood Test Beds			
Sounding : Test Bed 4			
Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 07:55:00
Operator : L Brockhouse		Company : Veolia Water	

Comments :
RECYCLED TYPE 1
150mm compacted layers
50kg Vibrotamper - 8 Passes per layer
Unable to achieve 1m depth due to extremely high resistance



Page 1/1

Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

Research period: April 2012 to August 2012 Date: November 2012

Strike Table for Test Bed 4 (measured in CBR% values)

Sounding cone resistance data table

Document : S:\Test Beds\Backfill\Pandas.pd2

Site : Scratchwood Test Beds

Sounding : Test Bed 4

Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 07:55:00
Operator : L Brockhouse		Company : Veolia Water	

Comments :
RECYCLED TYPE 1
150mm compacted layers
50kg Vibrotamper - 8 Passes per layer
Unable to achieve 1m depth due to extremely high resistance

Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)
1	5	32.13	51	108	104.50	101	214	175.28	151	312	175.73
2	9	43.28	52	110	132.40	102	216	151.31	152	314	209.00
3	13	60.82	53	112	117.48	103	218	153.38	153	316	184.16
4	16	65.60	54	113	139.78	104	221	174.38	154	317	213.24
5	19	65.50	55	115	179.83	105	223	196.22	155	319	199.29
6	21	58.09	56	117	100.84	106	226	172.17	156	320	180.22
7	23	101.82	57	119	152.66	107	228	189.24	157	322	168.97
8	25	109.85	58	120	203.82	108	229	159.21	158	324	313.04
9	27	125.26	59	122	156.19	109	231	152.91			
10	29	124.78	60	124	172.13	110	233	165.06			
11	30	146.19	61	125	217.55	111	235	150.16			
12	32	138.91	62	127	177.81	112	236	196.85			
13	33	156.33	63	128	242.29	113	238	234.72			
14	35	160.00	64	130	215.59	114	240	170.08			
15	36	126.97	65	132	158.38	115	242	169.59			
16	37	207.97	66	133	207.92	116	244	189.75			
17	39	143.84	67	135	203.55	117	247	161.83			
18	40	149.59	68	137	218.11	118	249	151.35			
19	42	139.68	69	139	138.08	119	252	133.26			
20	44	136.72	70	141	210.23	120	253	79.87			
21	45	154.31	71	143	136.57	121	256	189.49			
22	46	128.80	72	145	137.94	122	257	213.78			
23	48	109.98	73	147	149.82	123	259	329.60			
24	50	160.99	74	149	157.17	124	260	220.43			
25	51	108.91	75	151	165.20	125	262	329.66			
26	53	90.56	76	154	161.61	126	263	302.22			
27	55	100.24	77	155	201.27	127	266	161.02			
28	57	107.65	78	157	183.19	128	267	366.26			
29	59	109.12	79	159	120.80	129	268	350.12			
30	61	99.58	80	161	181.48	130	271	153.98			
31	64	75.93	81	163	128.27	131	272	294.97			
32	67	73.76	82	166	163.27	132	273	282.26			
33	69	95.19	83	168	158.02	133	276	244.87			
34	71	93.55	84	170	124.71	134	278	210.28			
35	74	79.99	85	173	140.63	135	280	216.61			
36	77	83.53	86	176	133.12	136	281	282.07			
37	79	95.45	87	179	117.00	137	283	191.10			
38	81	99.75	88	182	122.94	138	286	215.15			
39	83	88.93	89	184	114.29	139	291	161.81			
40	86	101.74	90	187	136.47	140	292	217.33			
41	88	84.74	91	190	131.47	141	294	174.89			
42	90	82.61	92	193	147.54	142	295	245.26			
43	92	97.94	93	195	136.79	143	296	318.28			
44	94	94.33	94	198	127.00	144	298	178.32			
45	96	87.99	95	200	131.25	145	300	192.04			
46	98	134.34	96	202	152.88	146	302	223.49			
47	100	100.43	97	205	149.38	147	304	165.75			
48	102	156.08	98	207	160.28	148	307	217.34			
49	104	128.07	99	210	181.87	149	309	194.03			
50	106	144.26	100	212	193.42	150	310	212.56			

Page 1/1

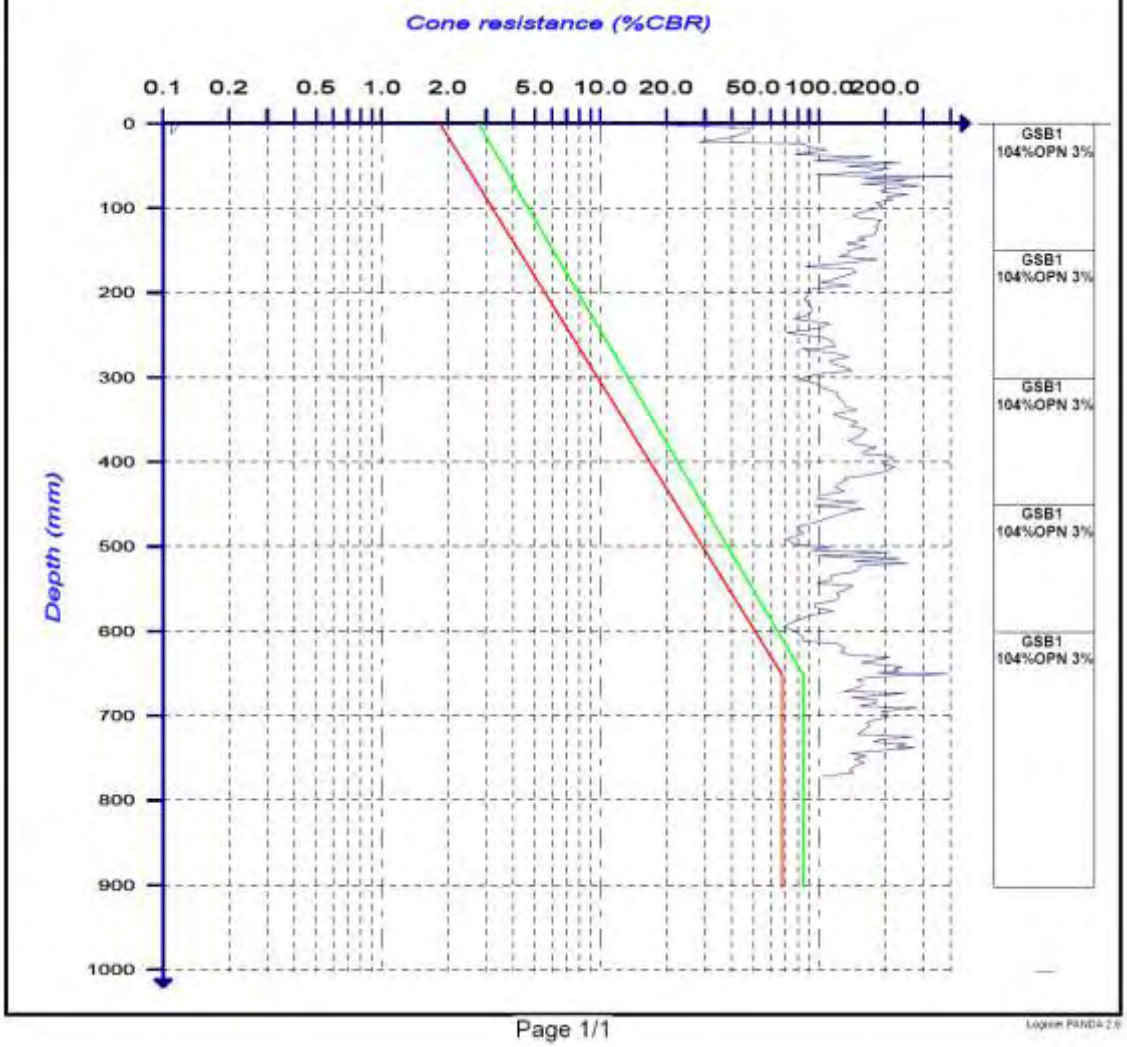
Logpel PANDA 2.0

Compaction Testing Test Bed 5 – Recycled Type 1

Penetrograph 5 - Laid at 300mm layers at 8 passes of Vibrotamper

Compaction control with variable energy dynamic penetrometer

Document : S:\Test Beds\Backfill\Pandas.pd2			
Site : Scratchwood Test Beds			
Sounding : Test Bed 5			
Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 08:02:00
Operator : L Brockhouse		Company : Veolia Water	
Comments : RECYCLED TYPE 1 300mm compacted layers 50kg Vibrotamper - 8 Passes per layer Compaction meets requirements			



Page 1/1

Strike Table for Test Bed 5 (measured in CBR% values)

Sounding cone resistance data table

Document : S:\Test Beds\Backfill\Pandas.pd2

Site : Scratchwood Test Beds

Sounding : Test Bed 5

Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 08:02:00
Operator : L Brockhouse		Company : Veolia Water	

Comments :
RECYCLED TYPE 1
300mm compacted layers
50kg Vibrotamper - 8 Passes per layer
Compaction meets requirements

Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)
1	1	17.05	51	172	142.45	101	402	195.41	151	616	127.28
2	5	48.49	52	175	147.28	102	404	220.64	152	620	131.27
3	10	47.73	53	179	131.53	103	407	211.96	153	623	124.51
4	17	37.69	54	184	117.95	104	411	197.43	154	627	139.28
5	22	27.96	55	187	101.67	105	415	162.47	155	629	211.05
6	24	85.06	56	191	138.53	106	418	130.58	156	632	184.32
7	27	88.21	57	195	90.55	107	421	132.89	157	635	155.42
8	31	108.75	58	202	89.36	108	425	122.65	158	638	196.03
9	37	77.45	59	208	85.73	109	429	119.09	159	641	241.83
10	39	172.96	60	213	90.38	110	434	130.44	160	643	221.67
11	44	94.42	61	219	93.31	111	438	102.10	161	645	232.75
12	46	236.75	62	226	89.45	112	443	97.41	162	648	183.20
13	50	133.47	63	231	76.64	113	446	149.61	163	649	385.88
14	53	209.88	64	236	112.20	114	451	95.12	164	652	183.79
15	57	173.71	65	241	101.43	115	454	159.82	165	655	149.16
16	61	96.92	66	247	71.04	116	458	134.65	166	659	157.74
17	62	406.67	67	253	106.23	117	463	117.48	167	663	155.76
18	65	160.34	68	258	116.19	118	469	98.29	168	667	142.21
19	68	250.36	69	264	118.05	119	476	79.05	169	670	129.27
20	71	155.28	70	268	83.30	120	483	84.95	170	672	248.41
21	73	290.33	71	271	117.57	121	490	71.05	171	677	140.46
22	76	225.77	72	275	136.09	122	496	76.77	172	680	183.47
23	79	193.03	73	280	112.47	123	500	112.29	173	683	181.30
24	81	193.53	74	284	116.75	124	503	92.06	174	687	153.72
25	84	255.53	75	287	131.35	125	506	210.23	175	689	280.45
26	87	202.14	76	291	140.83	126	510	96.40	176	693	192.24
27	90	214.78	77	296	95.72	127	512	234.70	177	696	203.54
28	93	180.44	78	302	81.97	128	516	144.34	178	699	209.41
29	97	194.03	79	307	98.50	129	518	252.94	179	703	181.11
30	101	181.06	80	313	105.87	130	521	153.51	180	706	165.04
31	105	156.02	81	317	121.43	131	525	151.47	181	710	170.94
32	108	142.63	82	323	122.22	132	528	150.12	182	713	162.55
33	111	149.90	83	328	130.12	133	533	113.23	183	717	155.12
34	114	192.64	84	334	132.05	134	538	114.23	184	720	150.96
35	117	186.44	85	338	148.96	135	542	97.70	185	723	269.09
36	119	186.97	86	343	115.63	136	545	143.37	186	726	190.23
37	122	180.41	87	348	132.04	137	549	134.71	187	729	178.37
38	125	187.02	88	352	149.97	138	553	120.77	188	732	250.89
39	128	180.89	89	357	139.32	139	558	123.61	189	735	224.41
40	131	179.09	90	360	165.16	140	562	121.92	190	738	273.95
41	134	151.69	91	365	157.89	141	567	94.48	191	738	207.38
42	138	161.68	92	369	152.03	142	571	96.39	192	742	138.88
43	141	133.68	93	374	136.53	143	575	116.44	193	746	163.86
44	145	164.98	94	378	147.17	144	580	92.00	194	749	145.53
45	150	136.08	95	382	183.04	145	586	78.98	195	753	160.81
46	153	136.34	96	386	162.80	146	593	68.53	196	757	146.76
47	157	123.45	97	389	157.51	147	600	78.95	197	761	137.53
48	160	186.09	98	392	218.01	148	606	84.47	198	765	144.29
49	164	138.80	99	395	218.04	149	611	84.60	199	770	103.76
50	169	86.03	100	398	199.42	150	613	120.85			

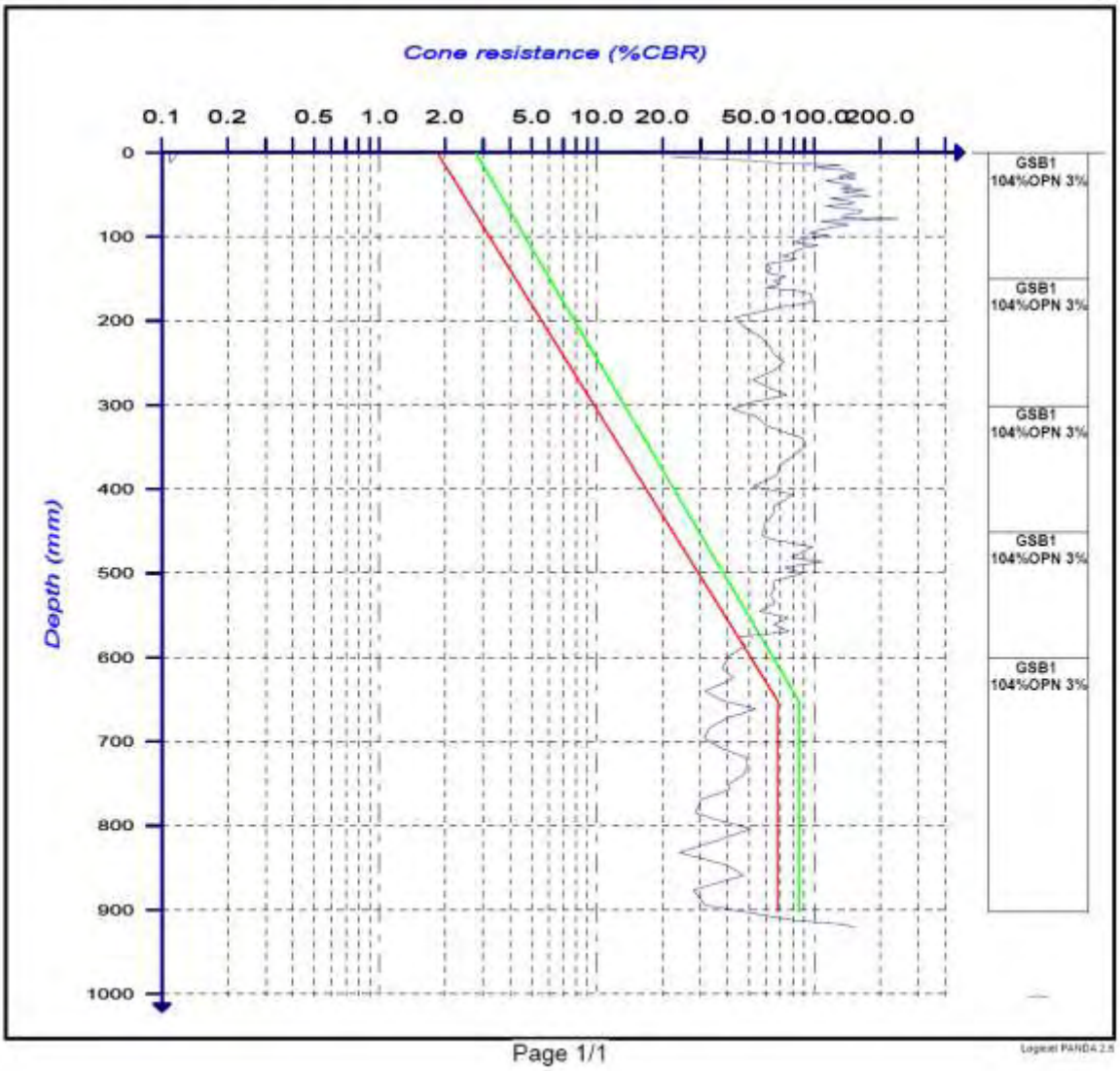
Page 1/1

Compaction Testing Test Bed 6 – GSB Type 1

Penetrograph 6 - Laid at to full depth with 8 passes of Vibrotamper

Compaction control with variable energy dynamic penetrometer

Document : S:\Test Beds\Backfill\Pandas.pd2			
Site : Scratchwood Test Beds			
Sounding : Test Bed 6			
Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 08:09:00
Operator : L Brockhouse		Company : Veolia Water	
Comments : RECYCLED TYPE 1 900mm compacted layer - Full depth 50kg Vibrotamper - 8 Passes Compaction fails to meet requirements			



Page 1/1

Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

Research period: April 2012 to August 2012 Date: November 2012

Strike Table for Test Bed 6 (measured in CBR% values)

Sounding cone resistance data table

Document : S:\Test Beds\Backfill\Pandas.pd2

Site : Scratchwood Test Beds

Sounding : Test Bed 6

Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 08:09:00
Operator : L Brockhouse		Company : Veolia Water	

Comments :
RECYCLED TYPE 1
900mm compacted layer - Full depth
50kg Vibrotamper - 8 Passes
Compaction fails to meet requirements

Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)
1	5	22.40	51	152	65.09	101	575	44.27
2	9	46.65	52	157	68.88	102	584	48.18
3	13	69.11	53	160	59.86	103	597	40.79
4	15	131.56	54	164	84.20	104	611	37.68
5	18	101.56	55	168	96.90	105	623	42.48
6	21	137.07	56	172	95.87	106	638	31.46
7	23	141.46	57	177	99.86	107	649	36.88
8	26	154.94	58	184	69.15	108	660	53.99
9	28	129.39	59	196	43.04	109	670	40.11
10	30	155.33	60	207	47.68	110	682	32.73
11	33	112.47	61	219	56.81	111	694	31.15
12	35	123.63	62	230	62.29	112	706	37.32
13	38	142.77	63	239	65.15	113	717	48.58
14	40	147.14	64	248	72.33	114	727	49.09
15	42	132.14	65	257	66.10	115	737	47.44
16	44	171.33	66	269	52.17	116	748	40.51
17	46	134.49	67	279	62.48	117	755	40.29
18	48	154.20	68	287	74.79	118	767	30.10
19	50	160.65	69	296	52.39	119	783	28.36
20	52	178.70	70	304	41.74	120	793	37.98
21	54	118.42	71	313	54.43	121	801	50.97
22	57	132.78	72	322	58.90	122	811	40.30
23	59	151.48	73	331	71.52	123	830	23.82
24	61	148.82	74	338	88.38	124	844	39.42
25	63	112.13	75	348	91.03	125	857	47.40
26	66	132.84	76	358	81.14	126	874	27.74
27	68	159.88	77	371	69.22	127	892	31.35
28	70	166.12	78	383	66.92	128	904	58.61
29	72	158.05	79	395	52.31	129	911	82.42
30	74	137.39	80	406	79.98	130	915	135.41
31	77	134.14	81	419	65.00	131	919	153.94
32	78	241.77	82	429	64.86			
33	81	106.12	83	440	59.27			
34	84	124.14	84	454	57.47			
35	86	143.42	85	459	63.70			
36	88	123.06	86	463	79.35			
37	92	105.70	87	467	97.93			
38	95	94.66	88	474	87.83			
39	98	116.47	89	480	78.44			
40	102	88.82	90	485	108.39			
41	107	80.99	91	492	73.14			
42	110	104.52	92	499	88.31			
43	114	86.71	93	508	64.73			
44	118	80.90	94	518	65.11			
45	122	71.37	95	525	62.79			
46	127	62.59	96	534	65.90			
47	132	60.54	97	544	55.67			
48	137	63.34	98	551	75.84			
49	143	60.02	99	560	65.15			
50	147	73.71	100	568	78.35			

Page 1/1

Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

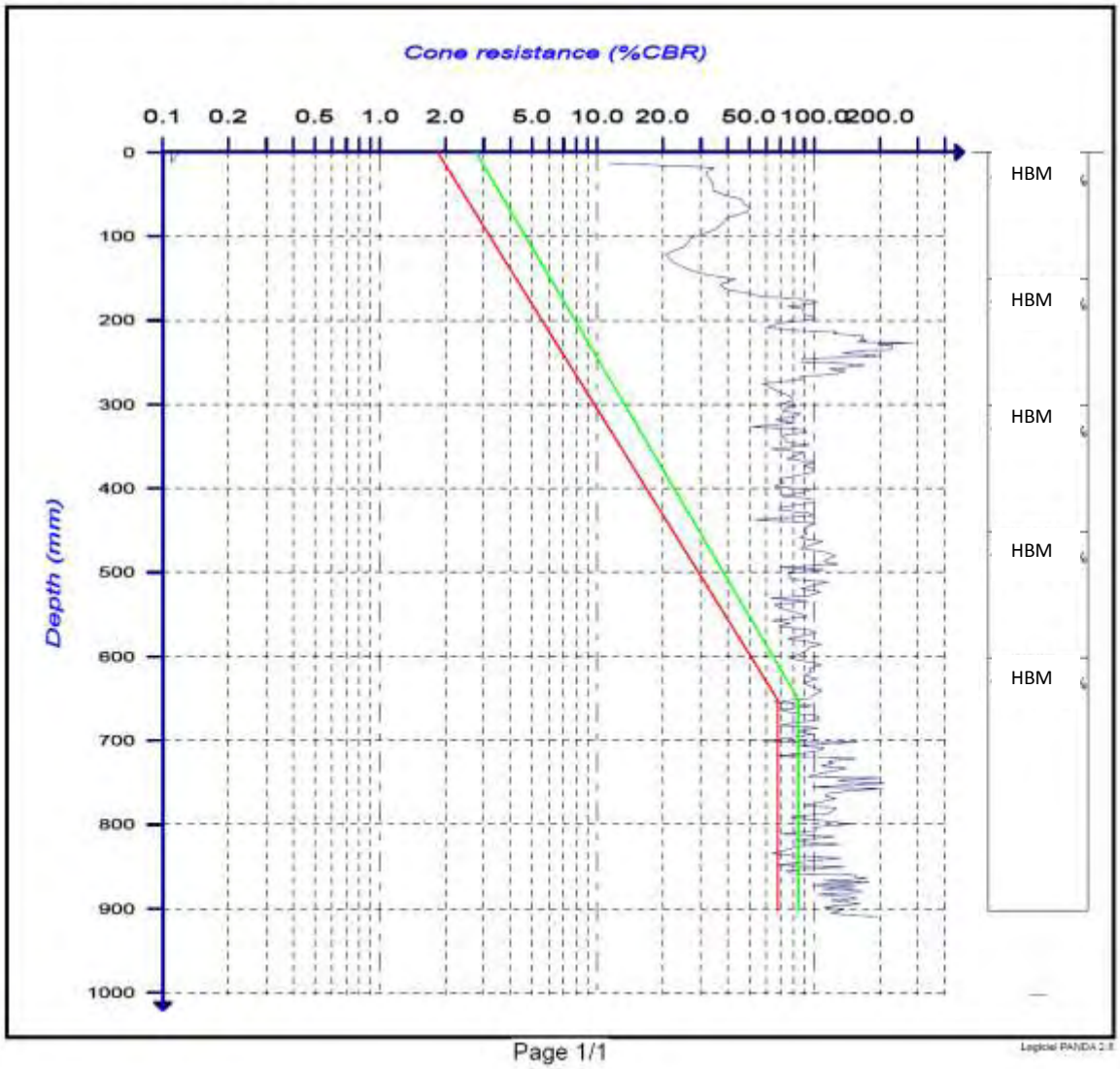
Research period: April 2012 to August 2012 Date: November 2012

Compaction Testing Test Bed 7 – Hydraulically Bound Mixture

Penetrograph 7 - Laid at 150mm layers at 8 passes of Vibrotamper

Compaction control with variable energy dynamic penetrometer

Document : S:\Test Beds\Backfill\Pandas.pd2			
Site : Scratchwood Test Beds			
Sounding : Test Bed 7			
Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 08:25:00
Operator : L Brockhouse		Company : Veolia Water	
Comments : HBM MATERIAL 150mm compacted layers 50kg Vibrotamper - 8 Passes per layer Compaction meets requirements			



Page 1/1

Strike Table for Test Bed 7 (measured in CBR% values)

Sounding cone resistance data table

Document : S:\Test Beds\Backfill\Pandas.pd2

Site : Scratchwood Test Beds

Sounding : Test Bed 7

Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 08:25:00
Operator : L Brockhouse		Company : Veolia Water	

Comments :
HBM MATERIAL
150mm compacted layers
50kg Vibrotamper - 8 Passes per layer
Compaction meets requirements

Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)
1	13	11.47	51	239	134.55	101	421	70.91	151	617	97.36
2	18	34.55	52	240	177.06	102	425	68.44	152	621	89.14
3	24	31.67	53	242	198.88	103	428	94.17	153	625	103.16
4	31	33.03	54	245	88.12	104	431	98.45	154	630	88.70
5	39	34.32	55	249	87.10	105	436	53.19	155	634	98.23
6	46	34.30	56	251	139.02	106	440	101.58	156	639	108.42
7	51	38.84	57	253	170.14	107	445	91.37	157	643	100.35
8	56	46.34	58	255	148.81	108	449	90.86	158	648	95.31
9	61	47.16	59	257	117.32	109	453	92.30	159	652	65.08
10	66	50.57	60	260	138.70	110	457	86.09	160	657	97.40
11	71	48.80	61	263	125.08	111	462	109.78	161	662	68.69
12	78	39.53	62	266	85.61	112	466	95.73	162	665	80.83
13	85	37.83	63	270	88.09	113	470	86.13	163	669	103.38
14	92	34.71	64	275	57.61	114	474	112.55	164	673	105.95
15	102	27.23	65	279	62.79	115	479	124.53	165	677	85.20
16	112	25.29	66	285	69.13	116	483	115.33	166	680	69.13
17	121	20.68	67	289	76.72	117	486	111.11	167	683	103.99
18	131	22.34	68	295	79.86	118	489	129.15	168	688	83.20
19	139	26.07	69	298	71.02	119	493	69.63	169	691	98.09
20	146	31.85	70	301	82.94	120	496	110.92	170	694	80.68
21	151	43.20	71	303	74.76	121	500	76.25	171	699	57.99
22	157	36.92	72	307	71.15	122	503	77.58	172	700	157.81
23	162	38.67	73	310	86.39	123	507	76.87	173	704	85.26
24	167	48.54	74	314	80.73	124	510	116.23	174	707	110.86
25	171	56.48	75	317	66.04	125	515	97.12	175	710	104.68
26	175	86.99	76	321	80.47	126	518	86.62	176	714	86.76
27	177	102.67	77	326	51.14	127	522	106.57	177	717	67.00
28	180	96.21	78	329	89.71	128	526	94.60	178	718	135.96
29	183	75.59	79	332	92.17	129	529	62.95	179	720	155.40
30	186	89.54	80	336	69.91	130	533	93.65	180	723	116.41
31	190	88.75	81	340	73.67	131	537	65.49	181	725	121.77
32	193	90.93	82	344	74.15	132	541	70.24	182	728	107.43
33	196	100.59	83	348	95.35	133	547	82.94	183	731	141.03
34	199	97.30	84	352	63.52	134	551	92.87	184	733	127.50
35	203	68.69	85	356	89.50	135	556	63.48	185	736	111.17
36	208	60.99	86	360	81.44	136	559	77.40	186	741	92.99
37	211	74.32	87	364	74.51	137	562	68.22	187	743	197.81
38	213	126.50	88	368	100.66	138	567	94.96	188	745	127.72
39	216	122.18	89	372	89.17	139	570	101.74	189	748	148.08
40	217	166.60	90	376	100.15	140	574	88.86	190	749	211.93
41	219	187.72	91	379	99.23	141	577	75.30	191	754	96.89
42	222	163.29	92	385	78.99	142	581	94.05	192	755	206.30
43	223	174.51	93	388	69.90	143	584	107.52	193	758	141.81
44	225	156.54	94	392	72.36	144	588	94.22	194	761	114.17
45	226	288.13	95	397	65.33	145	592	92.42	195	764	112.36
46	228	196.93	96	400	96.66	146	596	85.22	196	767	125.90
47	229	229.14	97	404	88.62	147	600	77.36	197	771	109.94
48	233	227.73	98	408	70.75	148	605	95.47	198	775	89.82
49	234	226.11	99	412	99.13	149	608	107.62	199	778	125.87
50	236	157.25	100	416	100.19	150	613	94.60	200	781	121.73

Page 1/2

Logiciel PANDA 2.0

Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

Research period: April 2012 to August 2012 Date: November 2012

(Cont'd) - Strike Table for Test Bed 7 (measured in CBR% values)

Document : S:\Test Beds\Backfill\Pandas.pd2

Site : Scratchwood Test Beds

Sounding : Test Bed 7

Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 08:25:00
Operator : L Brockhouse		Company : Veolia Water	

Comments :
HBM MATERIAL
150mm compacted layers
50kg Vibrotamper - 8 Passes per layer
Compaction meets requirements

Index Measure	Depth (mm)	Resist. (%CBR)
201	785	116.92
202	789	77.56
203	792	97.94
204	795	123.25
205	797	148.39
206	801	99.23
207	805	102.28
208	809	70.87
209	812	124.08
210	816	81.43
211	819	95.02
212	821	131.78
213	824	84.24
214	827	75.05
215	832	63.70
216	835	84.56
217	838	131.33
218	841	94.51
219	846	66.70
220	848	138.35
221	853	73.81
222	856	79.22
223	858	155.16
224	860	153.67
225	862	175.31
226	865	110.05
227	867	179.39
228	870	97.47
229	872	155.12
230	874	108.47
231	876	165.86
232	878	161.57
233	881	104.32
234	883	140.48
235	886	156.39
236	888	119.47
237	890	144.94
238	892	161.46
239	896	110.84
240	899	135.65
241	902	119.00
242	905	138.34
243	907	194.72

Page 2/2

Logiciel PANDA 2.6

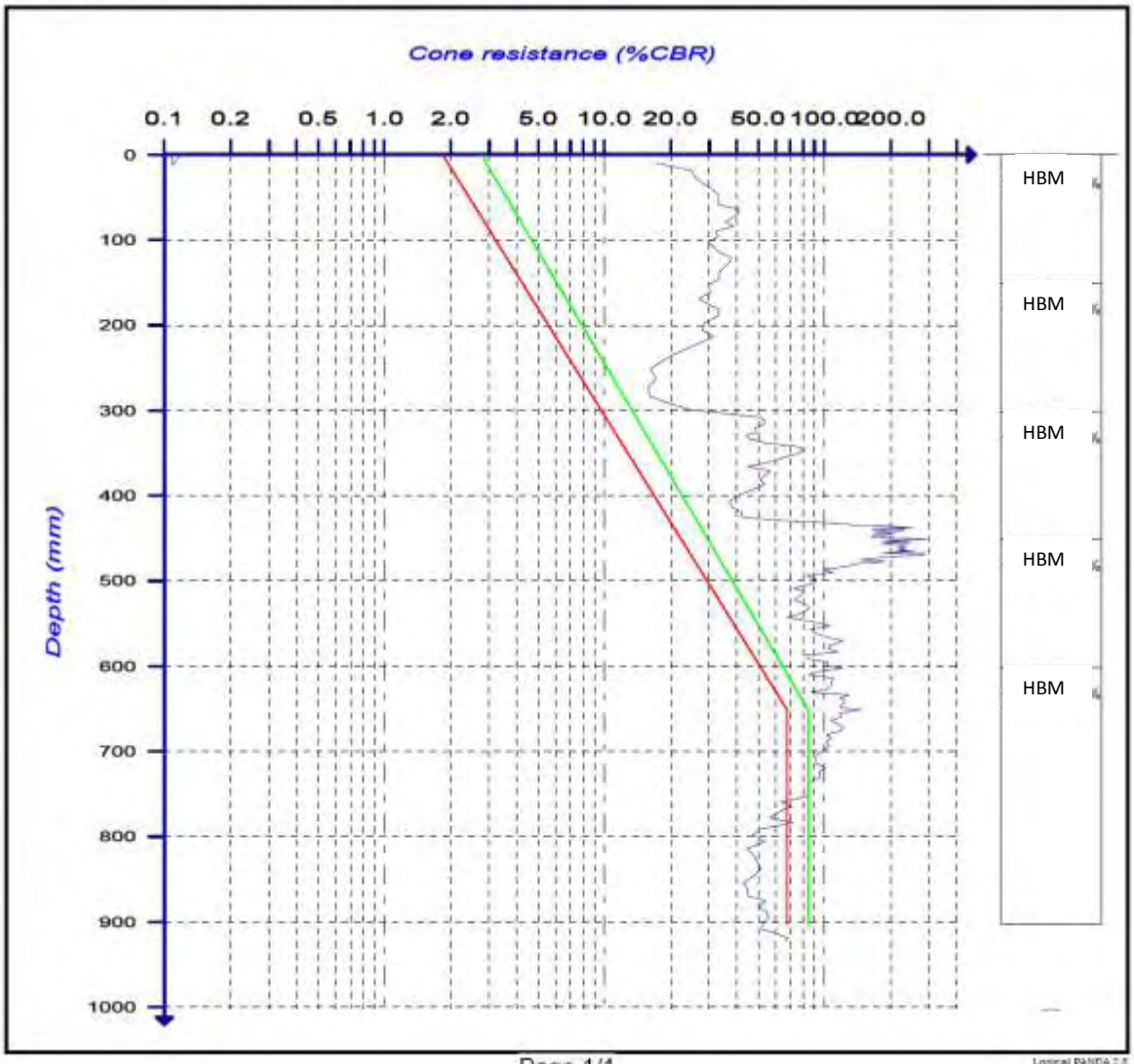
Compaction Testing Test Bed 8 – Hydraulically Bound Mixture

Penetrograph 8 - Laid at 300mm layers at 8 passes of Vibrotamper

Compaction control with variable energy dynamic penetrometer

Document : S:\Test Beds\Backfill\Pandas.pd2			
Site : Scratchwood Test Beds			
Sounding : Test Bed 8			
Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 08:37:00
Operator : L Brockhouse		Company : Veolia Water	

Comments :
HBM MATERIAL
300mm compacted layers
50kg Vibrotamper - 8 passes per layer
Compaction fails to meet requirements



Page 1/1

Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

Research period: April 2012 to August 2012 Date: November 2012

Strike Table for Test Bed 8 (measured in CBR% values)

Sounding cone resistance data table

Document : S:\Test Beds\Backfill\Pandas.pd2			
Site : Scratchwood Test Beds			
Sounding : Test Bed 8			
Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 08:37:00
Operator : L Brockhouse		Company : Veolia Water	

Comments :
HBM MATERIAL
300mm compacted layers
50kg Vibrotamper - 8 passes per layer
Compaction fails to meet requirements

Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)	Index Measure	Depth (mm)	Resist. (%CBR)
1	10	17.28	51	345	80.24	101	497	92.20	151	707	91.45
2	18	24.83	52	349	77.20	102	502	88.21	152	712	91.46
3	26	25.80	53	353	66.85	103	507	72.67	153	717	100.95
4	34	28.34	54	358	58.85	104	512	80.84	154	722	94.68
5	40	30.93	55	365	44.58	105	516	77.32	155	728	96.07
6	47	32.94	56	370	56.90	106	522	72.92	156	734	85.32
7	53	32.79	57	376	53.39	107	526	81.87	157	739	85.54
8	59	33.15	58	381	51.16	108	531	85.52	158	744	85.37
9	63	40.64	59	386	53.70	109	536	80.18	159	749	85.46
10	68	40.67	60	391	47.80	110	542	68.04	160	753	78.36
11	74	38.10	61	399	40.52	111	547	89.73	161	758	63.72
12	79	35.53	62	406	37.05	112	551	106.34	162	763	71.10
13	84	38.64	63	412	38.29	113	556	86.41	163	769	62.19
14	90	32.04	64	418	42.03	114	560	91.54	164	775	56.59
15	96	32.85	65	424	41.75	115	565	103.88	165	782	71.90
16	102	29.60	66	428	62.09	116	569	122.06	166	789	50.99
17	109	31.75	67	430	88.44	117	572	113.77	167	796	47.19
18	115	33.43	68	432	122.09	118	575	105.93	168	804	53.96
19	120	37.64	69	434	137.39	119	578	103.98	169	812	44.59
20	126	37.15	70	435	207.38	120	582	115.30	170	821	47.93
21	132	34.82	71	436	251.46	121	586	82.71	171	829	50.05
22	138	33.12	72	438	165.75	122	590	84.29	172	836	51.38
23	145	33.32	73	439	232.86	123	594	102.94	173	844	48.01
24	152	29.77	74	440	219.61	124	598	102.83	174	852	42.77
25	160	30.20	75	442	165.91	125	601	120.77	175	859	45.01
26	169	26.92	76	444	207.67	126	605	92.98	176	867	44.83
27	176	29.97	77	446	168.32	127	608	85.04	177	873	54.08
28	182	33.43	78	448	164.01	128	613	109.75	178	880	50.25
29	189	32.69	79	449	239.37	129	617	108.26	179	886	54.65
30	196	28.52	80	450	291.65	130	621	106.80	180	893	55.83
31	205	27.82	81	452	184.31	131	625	102.94	181	900	52.48
32	213	31.43	82	453	247.52	132	629	86.87	182	906	51.76
33	222	25.92	83	455	180.11	133	632	128.87	183	912	61.43
34	237	19.61	84	457	234.07	134	636	117.49	184	917	68.39
35	251	16.18	85	458	232.62	135	640	124.16	185	920	66.37
36	262	17.18	86	460	217.13	136	644	120.07			
37	273	15.78	87	461	234.31	137	647	117.72			
38	283	16.11	88	463	214.22	138	650	145.86			
39	291	19.80	89	464	258.68	139	654	117.16			
40	298	24.58	90	466	183.58	140	658	119.99			
41	303	36.09	91	467	287.11	141	662	106.74			
42	307	51.16	92	469	275.37	142	666	113.95			
43	312	53.91	93	470	201.50	143	670	121.73			
44	316	52.89	94	474	146.03	144	674	118.44			
45	320	48.38	95	476	187.70	145	679	101.90			
46	325	49.17	96	479	138.50	146	682	106.97			
47	328	44.15	97	482	127.40	147	687	101.97			
48	333	46.06	98	485	98.95	148	692	105.61			
49	337	54.28	99	489	109.41	149	697	99.28			
50	341	75.38	100	493	82.98	150	702	92.48			

Page 1/1

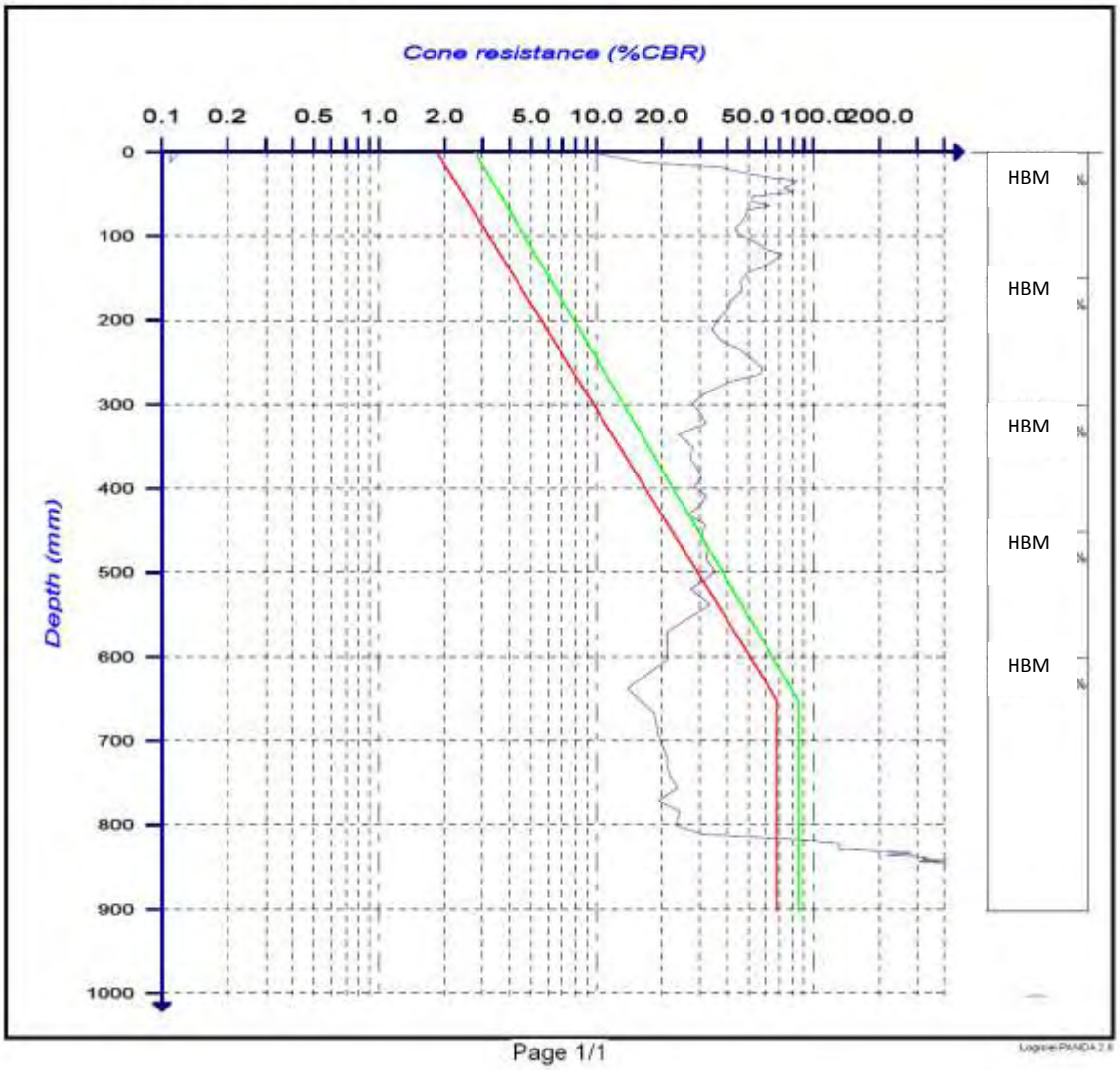
Logiciel PANDA 2.0

Compaction Testing Test Bed 9 – Hydraulically Bound Mixture

Penetrograph 9 - Laid to full depth with at 8 passes of Vibrotamper

Compaction control with variable energy dynamic penetrometer

Document : S:\Test Beds\Backfill\Pandas.pd2			
Site : Scratchwood Test Beds			
Sounding : Test Bed 9			
Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 08:45:00
Operator : L Brockhouse		Company : Veolia Water	
Comments : HBM MATERIAL 900mm compacted layer - Full Depth 50kg Vibrotamper - 8 Passes Compaction fails to meet requirements			



Page 1/1

Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

Research period: April 2012 to August 2012 Date: November 2012

Strike Table for Test Bed 9 (measured in CBR% values)

Sounding cone resistance data table

Document : S:\Test Beds\Backfill\Pandas.pd2			
Site : Scratchwood Test Beds			
Sounding : Test Bed 9			
Tarmac : 0.00 mm	Pre-sounding depth : 0 mm	Area : 2 cm²	Water table : Indefinite
Weight : Panda 2 hammer	Breaking cond. : Temporary	Date : 22/05/2012	Hour : 08:45:00
Operator : L Brockhouse		Company : Veolia Water	

Comments :
HBM MATERIAL
900mm compacted layer - Full Depth
50kg Vibrotamper - 8 Passes
Compaction fails to meet requirements

Index Measure	Depth (mm)	Resist. (%CBR)
1	1	10.03
2	12	16.01
3	17	36.58
4	24	46.40
5	30	62.73
6	33	83.32
7	39	79.33
8	42	73.05
9	48	80.61
10	53	51.99
11	59	51.91
12	63	63.13
13	68	49.40
14	76	48.43
15	84	46.13
16	91	43.71
17	99	45.37
18	104	51.32
19	110	56.90
20	115	59.50
21	121	71.67
22	127	67.85
23	134	60.57
24	144	49.27
25	154	45.99
26	164	47.00
27	175	41.63
28	187	40.10
29	199	36.28
30	211	33.84
31	223	37.55
32	234	45.55
33	243	50.21
34	251	54.77
35	257	58.27
36	263	56.28
37	273	40.47
38	286	31.72
39	298	27.58
40	311	30.32
41	321	31.83
42	335	23.89
43	350	27.69
44	364	27.09
45	378	29.46
46	387	30.24
47	397	28.22
48	407	32.16
49	419	29.94
50	431	26.36
51	441	31.54
52	451	30.82
53	463	30.99
54	470	32.68
55	482	31.86
56	498	35.26
57	518	27.25
58	537	33.30
59	569	21.09
60	602	21.12
61	636	13.89
62	666	18.53
63	692	19.28
64	718	21.24
65	725	20.95
66	740	21.83
67	754	23.64
68	769	19.26
69	782	24.07
70	799	23.38
71	809	30.85
72	812	53.94
73	815	92.85
74	819	129.67
75	823	130.69
76	826	129.63
77	829	198.15
78	831	282.75
79	833	215.12
80	835	288.78
81	837	331.52
82	839	315.68
83	840	498.41
84	842	304.24
85	843	410.84
86	844	437.70

Page 1/1

4.2 Analysis of backfill compaction results

Test Bed 1 (See 2.1)
GSB Type 1 was backfilled in 150mm compacted layers with 8 passes of vibrotamper for each.
When this test bed was subjected to Penetrometer testing it was found that the device alarmed due to the extreme high resistivity of the compacted material at a depth of 154mm which would coincide with the top of the subsequent compacted layer when measured from the surface.
This will confirm that the test bed has been compacted to an extremely high standard and would be very unlikely to subside when subjected to dynamic load bearing forces applied by subsequent traffic.

Test Bed 2 (See 2.2)
GSB Type 1 was backfilled in 300mm compacted layers with 8 passes of vibrotamper for each.
In this case the penetrometer had proceeded to a depth at approx 500mm from surface of backfill where alarm sounded. The penetrograph and strike table also confirms that an increase in density was occurring from depth 478mm which verifies the approach to the next compacted layer.
This result provides evidence of sufficient compaction being achieved for this material based on the number of passes being employed. It should be noted that layer values are not as recommended for this material within the SROH, but compliance has been achieved and therefore would pass when employing UKAS compaction test method.
It should also be noted that such results are only achievable when correct equipment and sufficient passes are applied.

Test Bed 3 (See 2.3)
GSB Type 1 was backfilled to full depth with 8 passes of vibrotamper on surface once levelled.
The penetrograph for this test bed will show that the compaction requirement for this material has failed at depth approximately 550mm from surface. It also proves that dissipation of force relating to selected equipment has a significant bearing on compaction values at lower levels.
This will confirm that in most cases subsidence will be as a direct result of poor attention to layers and compaction efforts made through the backfill process. It is highly likely to manifest over time through “settling” of underlying materials when subjected to dynamic loading as a result of traffic travelling over the finished surface.

Test Bed 4 (See 2.4)
Recycled Type 1 placed in 150mm compacted layers with 8 passes of vibrotamper for each layer.
The penetrometer travelled to a depth of 324mm from surface of backfill where it alarmed at an extremely high reading of 313%CBR which would coincide with the surface of the second layer from top. As with Test Bed 1, the method prescribed within the SROH for both material and equipment provides a robust reinstatement foundation with very little likelihood of subsidence.

Even though the penetrograph trace is demonstrating high resistance the compacted layers are easily identified from both the graphic output and the strike readings.

Test Bed 5 (See 2.5)
Recycled Type 1 placed in 300mm compacted layers with 8 passes of vibrotamper for each layer.
The penetrometer reached a depth approaching 800mm from surface where test ceased as a result of device alarm.
As mentioned in description for Test Bed 2 the applied method in this case moves away from recommended layer depths prescribed within SROH of 150mm but maintains the requirement of 8 passes when using the vibropamper.
However, when looking at the test result it is apparent that sufficient compaction has been achieved on both the penetrograph and the strike table with average readings in excess of 130%CBR.
Again, it should also be noted that such results are only achievable when correct equipment and sufficient passes are applied.

Test Bed 6 (See 2.6)
As with Test Bed 3, the backfill was introduced to full depth with 8 passes of vibrotamper on the surface.
What is most apparent is the direct comparison with Test Bed 3 where the compaction requirement fails at almost exactly the same depth which provides evidence of repeatability of test results.
This also highlights the requirement to ensure individual layers are sufficiently compacted and monitored.
The penetrograph will show that an impact test on top of backfill (Clegg Test or Dynamic Plate Test) would provide a good result for surface modulus but could not identify the underlying problem for lack of compaction below.

Test Bed 7 (See 2.7)
A certified hydraulically bound mixture was backfilled in 150mm compacted layers with 8 passes of vibrotamper for each.
As with the WRAP Technical Report on compaction trials it is found that HBM materials have a consistent resistance when compacted using the correct method and manner.
They also have the added benefit of increasing in resistance as the stabilise over a a short period of time. However, until that time has elapsed, they are required to meet performance criteria for compaction requirements to allow reinstatement to conform to minimum standards on job completion.
The penetrograph will show that a consistent average resistance is identified in the region of 110%CBR and has exceeded required compliance in this case. It also highlights that HBM materials should be compacted and monitored to ensure compliance is achieved at time of completion to ensure subsequent dynamic loading will not affect stability.

Test Bed 8 (See 2.8)
Certified hydraulically bound mixture was backfilled in 300mm compacted layers with 8 passes of vibrotamper for each.
As can be seen from the penetrograph and strike table the efforts applied for compaction of 300mm layers may not be sufficient to provide a compliant reinstatement of backfill.
What was evident when monitoring the method was how the compaction equipment had sunk into the material rather than travel along its surface.
It should also be noted that operative had mentioned it is extremely difficult to manipulate compaction equipment in comparison with 150mm layers.
The penetrograph and strike table will show that this method fails to achieve requirement for compaction at depth 750mm from surface.

Test Bed 9 (See 2.9)
A certified hydraulically bound mixture was backfilled to full depth with 8 passes of vibrotamper.
The penetrograph and strike table will show that HBM material should not be backfilled unless in compacted layers to ensure compliance is achieved.
This particular Test Bed failed compaction requirement at depth of 500mm and would most certainly be subjected to subsidence following completion of reinstatement and dynamic loading from traffic.

4.3 Summary - Backfill

It is imperative that all materials selected for purpose of this trial should be backfilled in layers with sufficient number of passes from relevant equipment.
Proprietary and recycled type 1 granular materials should be laid as per prescribed method laid out in Appendix A2 of the Specification for Reinstatement of Openings in Highways to ensure that minimum compaction requirements are achievable. The correct equipment should be applied in all cases as vibrating frequencies have a considerable impact of compaction conformance.
This trial will also highlight that proprietary and recycled type 1 materials achieved conformance with 8 passes of vibrotamper at 300mm layer thickness but have not provided the density range achieved at 150mm layers (Test Beds 1 & 4). However, based on results from this trial, it should also be noted that observing layer thickness greater than 150mm does not imply that compaction requirement has not been achieved and should be verified through recognised UKAS test methods if in dispute.
Subsidence in more likely to occur as a direct result of insufficient attention to compacted layer depths along with correct application of the selected equipment through required passes.
Bearing in mind this trial was undertaken under controlled conditions, emphasis should be applied to training and monitoring of personnel tasked with undertaking these works.
The ability to select and apply the correct method and equipment will greatly reduce the likelihood of subsequent defective reinstatement through subsidence at a later time. This may allow for a scheme to clearly define what applications each

compaction device is suited for and a means for operatives to easily identify that the correct equipment has been selected.

5.0 BITUMINOUS MATERIALS

Test beds for bituminous materials were prepared as per 2.11 to 2.19 of this document with storage and rolling temperatures recorded for each layer as it was placed.
The probe thermometer was also verified twice each day to show that it had been functioning in the correct manner with results being available in *Table 1* of this report.

All documentation in relation to supply or delivery has been retained for each material and is included for verification purposes. Once all 9 test beds were completed for each product it was allowed to reach ambient temperature overnight whereupon core sample extraction was undertaken to allow laboratory measurement and advanced testing.

When core samples had been extracted the remainder of the material was removed and the test beds were prepared to receive the next allocated bituminous product using the prescribed method for each.

The first selected material was 6mm ACDSC which also allowed for retrieval of laboratory compaction test results once core samples had been extracted. It had been agreed that this was directly related to current practice employed when undertaking laboratory testing under usual conditions.

All equipment had been fully inspected and checked to ensure that it was suitable for purpose prior to introduction of any bituminous material. Personnel selected were fully qualified and conversant with the methodology applicable for each material and equipment.

Each test bed was identified and provided a laminated identification card to ensure all operatives were constantly aware of the requirement for each material and method used. These cards were only placed immediately prior to introduction of materials and were used to identify all digital imaging taken for temperature and compacted lift thickness. Once each test bed was completed the card was removed and stored in order not to cause conflict or issue with subsequent test beds.

All subsequent testing in relation to methods and materials are all fully accredited to UKAS procedures and conform to requirements as prescribed in S2 of the SROH (Specification for the Reinstatement of Openings in the Highway) along with specific national or international standards for each test employed.

Each extracted core sample was placed in a vinyl sealable bag which in turn was sealed within a protective tube along a plastic identification card displaying the samples unique reference number. The protective tube was also labelled clearly with the same unique reference number to ensure traceability and process was also recorded through digital imaging.

As mentioned above, continuous monitoring ensured that all materials had been laid to the required method for each test bed along with temperature readings for each applied layer.

Due to the huge amount of imaging and data recorded, the following is a randomly selected test bed and material to provide a representation of method. The material selected for this purpose will be 10mm ACCSC and will be outlined hereafter. All bituminous materials were subjected to exactly the same methods and procedures when applying the following requirements of Specification for the Reinstatement of Openings in Highways (Version 3 - April 2010).

- A2.6.1 Bituminous Mixtures (Table A2.1 Compacted Lift Thickness)
- A2.7 Bituminous Laying Temperatures (Tables A2.3 & A2.4)
- A8.3 Bituminous Mixtures (Compaction)
- NG A8.3 Bituminous Mixtures (Table NG A8.3 Compaction requirements)

Test Bed 1 – 10mm ACCSC (See 2.11)
This test bed had been designated as requiring two compacted layers using both the 50kg vibrotamper and the 1800m kg/m² vibrating plate. Once the material temperature was verified as suitable when introduced to the test bed the lower layer was subjected to 6 passes of the vibrotamper across the whole area of the product. What was apparent was the distinct change in the action and sound of the device when the final layer was being compacted and no observational movement could be seen. The top surface of the layer was also very close to causing distress of the aggregate as no further compaction could be achieved and the vibrotamper was essentially “bouncing off” the material.
Once complete, the material was introduced for the second and final layer and after the temperature had been recorded the vibrating plate was used to complete in 5 passes with each in linear opposition to the previous. This has a far higher vibrating frequency than the vibrotamper with a less obvious impaction force and from observation it appeared to have a milder effect on the material appearing to provide a greater texture depth or “open” appearance. It should be highlighted that each layer was at the maximum recommended compacted lift thickness for 10mm ACCSC as prescribed in Table A2.1 of the SROH

Test Bed 2 – 10mm ACCSC (See 2.12)
The second test bed comprised of two layers using the vibrotamper with the third and final layer being compacted using the vibrating plate. As the material was introduced for each layer a temperature reading was taken to verify it complied to requirements of Table A2.3 of SROH.
The first layer was introduced at to compacted thickness of approx 35mm after being subjected to 5 passes of the vibrotamper with each suite of passes at righ angles to previous. A second layer of material was then introduced following exactly the same method and process. When completing both layers it was apparent that the material was at its limit of compaction as the vibrotamper was proving more difficult to manage due to the high resistivity of the material.
The vibrating plate was introduced to complete the third and final layer which demonstrated a similar observational result as test bed 1 by providing an open textured surface when complete. This layer was subjected to three passes of the

vibrating plate as per recommended method as prescribed in Table NG A8.3 for a 30mm compacted lift layer. The layers in this test bed fall within recommended criteria for nominal compacted lift thickness for 10mm ACCSC as prescribed under Table A2.1 of the SROH

Test Bed 3 – 10mm ACCSC (See 2.13)
This was the third and final test bed using the combination of vibrotamper and vibrating plate and was constructed using four compacted lift thickness layers each being subjected to minimum requirements of SROH as previously described. As with previous test beds the material was subjected to temperature reading prior to application of compaction equipment for each layer. In this case there were three compacted layers of approximately 25mm using the vibrotamper with the final layer being compacted using the vibrating plate.
As outlined in Table NG A8.3 the required number of passes for use of the 50kg vibrotamper is the same as the previous test bed which requires 5 passes for each compacted layer up to 40mm. The requirement for vibrating plate is also the same as the previous test bed where 3 passes are recommended for compacted layer up to 40mm.
The first three layers all demonstrated an extremely high resistance to compaction efforts of the vibrotamper as there was evidence of some aggregate distress on the surface of each layer after 5 passes, also the device appeared that failure could occur any moment due to such high impact resistance from material. The fourth and final layer was introduced and compacted with vibrating plate with no discernible difference to surface appearance from previous two test beds. Each layer was at the minimum recommended compacted lift thickness for 10mm ACCSC as prescribed in Table A2.1 of the SROH.

Test Bed 4 – 10mm ACCSC (See2.14)
The selection of equipment has changed from previous test beds which now allows for combination of vibrotamper and single drum vibrating roller as outlined in section 3 of this document.
This test bed mimics the layer requirement for Test Bed 1 and was designated as requiring two compacted layers of 50mm thickness using both the 50kg vibrotamper and the single drum vibrating roller.
As with previous methods the temperature of the material was verified as suitable when introduced to the test bed and the lower layer was then subjected to 6 passes of the vibrotamper. Again this resulted in a noticeable increase in resistance from observation as both the material and the device were demonstrating evidence of stress similar to those as described in test bed 1above.
The second layer was then subjected to 12 passes of the vibrating roller as required under Table NG A8.3 of SROH, with each suite of passes being at right angles to previous to ensure maximum effectiveness.
From visual inspection of the completed test bed it again demonstrated an open surface but with less texture depth than previous test beds as the weight of the roller coupled with the vibrating frequency appeared to have a greater influence on the bituminous material.

Again, each layer was at the maximum recommended compacted lift thickness for 10mm ACCSC as prescribed in Table A2.1 of the SROH

Test Bed 5 – 10mm ACCSC (See2.15)
As with the second test bed this requirement comprised of two layers using the vibrotamper with the third and final layer being compacted using the single drum vibrating roller.
Once again the material was placed for each layer and had been subjected to temperature probe in each occasion and values recorded as per Table 3 (10mm ACCSC) of this document.
Three layers were required in this instance with the first two being approximately 35mm compacted lift thickness using vibrotamper with the third and final being approximately 30mm using the single drum vibrating roller.
Again, the first and second layers were compacted with 5 passes of the vibrotamper to conform to requirements of Tables A2.1 and NG A8.3 of the current version of Specification for the Reinstatement of Openings in the Highway.
The first and second layer still demonstrated similar attributes found in test bed 2 where applying use of the vibrotamper with the surface layer being laid using the single drum vibrating roller at 10 passes.
Once completed the material provided a finish similar to that of test bed 4 from visual inspection.
The layers in this test bed fall within recommended criteria for nominal compacted lift thickness for 10mm ACCSC as prescribed under Table A2.1 of the SROH.

Test Bed 6 – 10mm ACCSC (See 2.16)
The compacted layer values for this test bed were exactly the same as test bed 3 with the exception of the fourth and final layer being compacted using the single drum vibrating roller for 10 passes as described above.
As with previous test beds the material was subjected to temperature reading prior to application of compaction equipment for each layer. In this case there were three compacted layers of approximately 25mm using the vibrotamper with the final layer being compacted using the single drum vibrating roller.
Each layer was at the minimum recommended compacted lift thickness for 10mm ACCSC as prescribed in Table A2.1 of the SROH.

Test Bed 7 – 10mm ACCSC (See 2.17)
Rather than repeat criteria for test beds 1 and 4 this bed was reinstated in one compacted layer of 100mm using the 1800kg/m² vibrating plate at 8 passes as per requirement of Table NG A8.3 (SROH) for this device at 100mm compacted lift thickness.
However it should be noted that the maximum compacted lift thickness recommended for this material is 50mm as prescribed in Table A2.1 of the specification.
On completion of the 8 passes the material appeared to have a very open texture when compared to the previous test beds where the single drum vibrating roller had been employed.

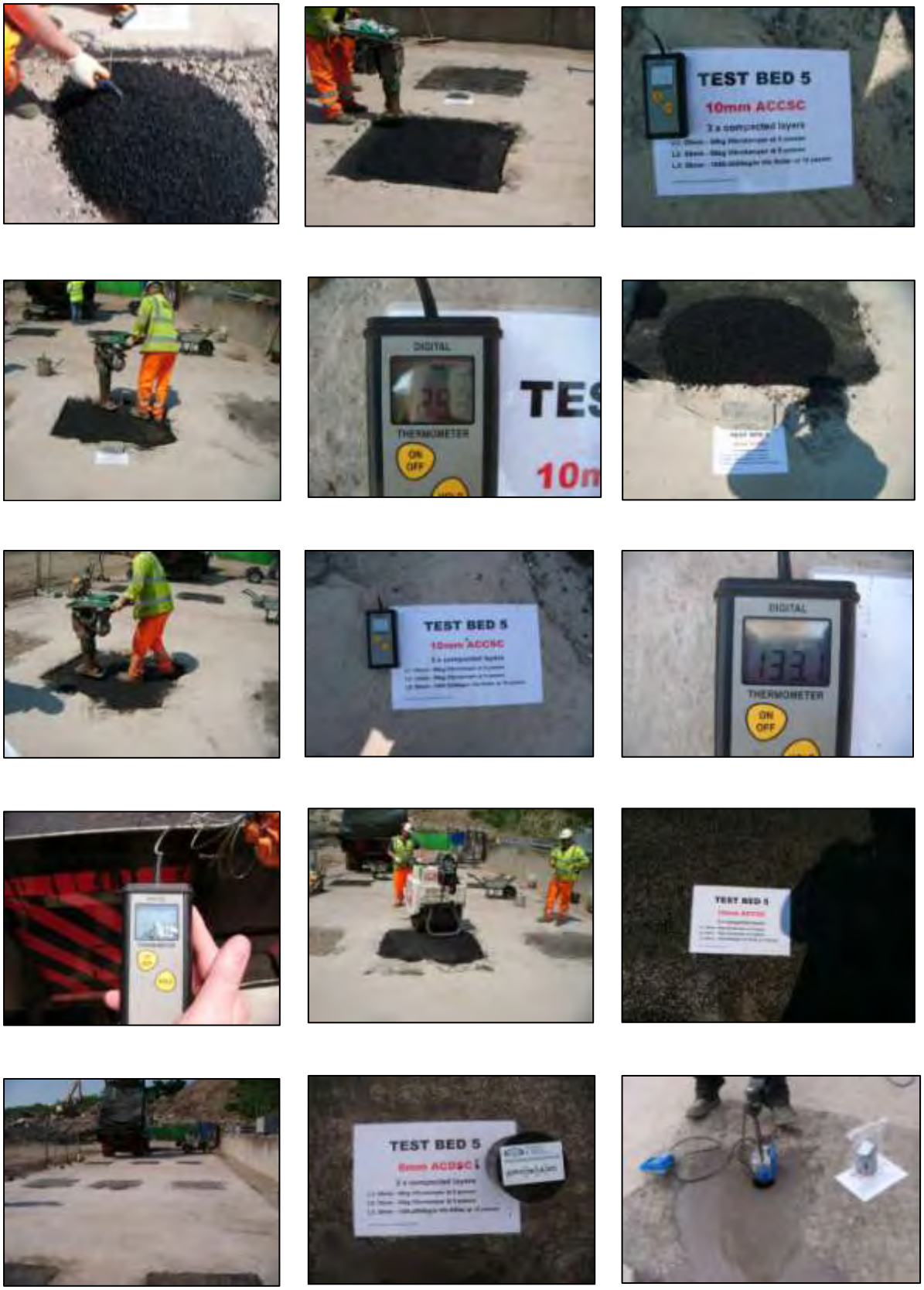
As such there may be confusion in relation to compacted lift applications when looking at the table relating to bituminous materials (Table A2.1 – SROH) as opposed to the table relating to equipment types and methods on bituminous materials (Table NG A8.3 – SROH) especially if and where operatives require clarification of compaction requirements.

Test Bed 8 – 10mm ACCSC (See 2.18)
This test bed was comprised of two compacted layers at approximately 50mm each using the 1800kg/m² vibrating plate.
As usual, both layers were subjected to thermometer testing immediately prior to commencement of compaction and the values can be found in Table 3 of this document which will confirm that material was within acceptable temperature range.
Each layer was subjected to 5 passes of the vibrating plate with each suite of passes being at right angles to the previous.
From observation the initial passes appeared to reach a point where no further compaction was achievable with this device where it appeared that the vibrating frequency had no further influence on this material. It was also observed that it appeared that further compaction could have been gained from the material for both layers but the device seemed incapable of applying sufficient force to achieve it when using recommended 5 passes as prescribed in Table NG A8.3 of the Specification for Reinstatement of Openings in Highways.

Test Bed 9 – 10mm ACCSC (See 2.19)
This is the final test bed used for this particular material and consisted of three layers as described in 2.19 of this document. Each layer was compacted using the 1800kg/m² vibrating plate with 3 passes required for each as per requirement of Table NG A8.3 of the SROH where individual compacted lift thickness was below 40mm.
Introduction of material for each layer had been subjected to usual temperature reading prior to commencement of compaction and all material layers were within required range as specified in Table A2.3 of the SROH and values can be found in Table 3 of this document.
Once again the material appeared to compact to a point where no further influence appeared to have resulted from prescribed use of the vibrating plate. This again resulted in an open texture from a visual perspective when compared to test beds 4, 5, and 6, where the material seemed to have a dense appearance by contrast.
When looking at test beds 7, 8, and 9 there is a marked difference in visual observation when compared with test beds compacted using the single drum vibrating roller.

Section 5.2 of this document will outline laboratory core extraction and test methods compliant with BS EN 12697 Parts 5 and 8 which are quoted within the SROH in relation to air voids testing. Table S10.1 (SROH) provides criteria for air voids allowance for individual bituminous materials.

Figure 20. *Representation of method employed for TB5 using 10mm ACCSC as prescribed.*



Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

Research period: April 2012 to August 2012 Date: November 2012

5.1 Bituminous Delivery and Temperatures

Table 2: **6mm ACDSC**

	On Delivery	Layer 1	Layer 2	Layer 3	Layer 4
Test Bed 1	150°C	109°C	116°C	-	-
Test Bed 2		105°C	104°C	116°C	-
Test Bed 3		110°C	104°C	108°C	109°C
Test Bed 4		123°C	121°C	-	-
Test Bed 5		118°C	120°C	115°C	-
Test Bed 6		108°C	106°C	132°C	110°C
Test Bed 7	160°C	98°C	-	-	-
Test Bed 8		104°C	103°C	-	-
Test Bed 9		106°C	105°C	106°C	-

Table 3: **10mm ACCSC**

	On Delivery	Layer 1	Layer 2	Layer 3	Layer 4
Test Bed 1	137°C	103C	99°C	-	-
Test Bed 2		104°C	107°C	113°C	-
Test Bed 3		111°C	103°C	107°C	108°C
Test Bed 4		118°C	115°C	-	-
Test Bed 5		130°C	133°C	120°C	N/a
Test Bed 6		112°C	103°C	106°C	107°C
Test Bed 7		106°C	-	-	-
Test Bed 8		104°C	101°C	-	-
Test Bed 9		106°C	102°C	103°C	-

Table 4: **10mm SMASC**

	On Delivery	Layer 1	Layer 2	Layer 3	Layer 4
Test Bed 1	153°C	112°C	113°C	-	-
Test Bed 2		121°C	122°C	118°C	-
Test Bed 3		115°C	124°C	131°C	127°C
Test Bed 4		128°C	122°C	-	-
Test Bed 5		123°C	115°C	116°C	-
Test Bed 6		110°C	109°C	111°C	115°C
Test Bed 7		116°C	-	-	-
Test Bed 8		117°C	113°C	-	-
Test Bed 9		111°C	108°C	108°C	-

Table 5: **30/14 HRASC**

	On Delivery	Layer 1	Layer 2	Layer 3	Layer 4
Test Bed 1	146°C	128°C	112°C	-	-
Test Bed 2		136°C	120°C	120°C	-
Test Bed 3		142°C	119°C	120°C	124°C
Test Bed 4		138°C	115°C	-	-
Test Bed 5		132°C	120°C	125°C	-
Test Bed 6		128°C	119°C	114°C	112°C
Test Bed 7		120°C	-	-	-
Test Bed 8		115°C	114°C	-	-
Test Bed 9		115°C	114°C	114°C	-

Table 6: **20mm ACBC**

	On Delivery	Layer 1	Layer 2	Layer 3	Layer 4
Test Bed 1	134°C	105°C	107°C	-	-
Test Bed 2		108°C	108°C	107°C	-
Test Bed 3		109°C	106°C	104°C	106°C
Test Bed 4		108°C	107°C	-	-
Test Bed 5		110°C	109°C	115°C	-
Test Bed 6		103°C	104°C	101°C	110°C
Test Bed 7		102°C	-	-	-
Test Bed 8		104°C	104°C	-	-
Test Bed 9		109°C	107°C	106°C	-

The temperatures taken from materials on delivery and at each layer introduction will show that conformity has been achieved in all cases when compared to appendix A2.7 of SROH.

All test beds for bituminous materials had been laid at relevant layers using the methods as described in items 2.12 to 2.20 of this document and utilising SROH A2.6.1 and NGA8.3 where applicable.

Bituminous materials were purchased by primary certified suppliers involved in Civil Engineering, Utilities, and road construction.

Delivery tickets or dockets have been recorded and will be included as part of this document to verify ordered product and dispatched materials.

Materials collected were retained in an insulated lorry with temperature check regularly taken from covered load throughout process.

Figure 21. *One of the regular temperature checks on rear of vehicle*

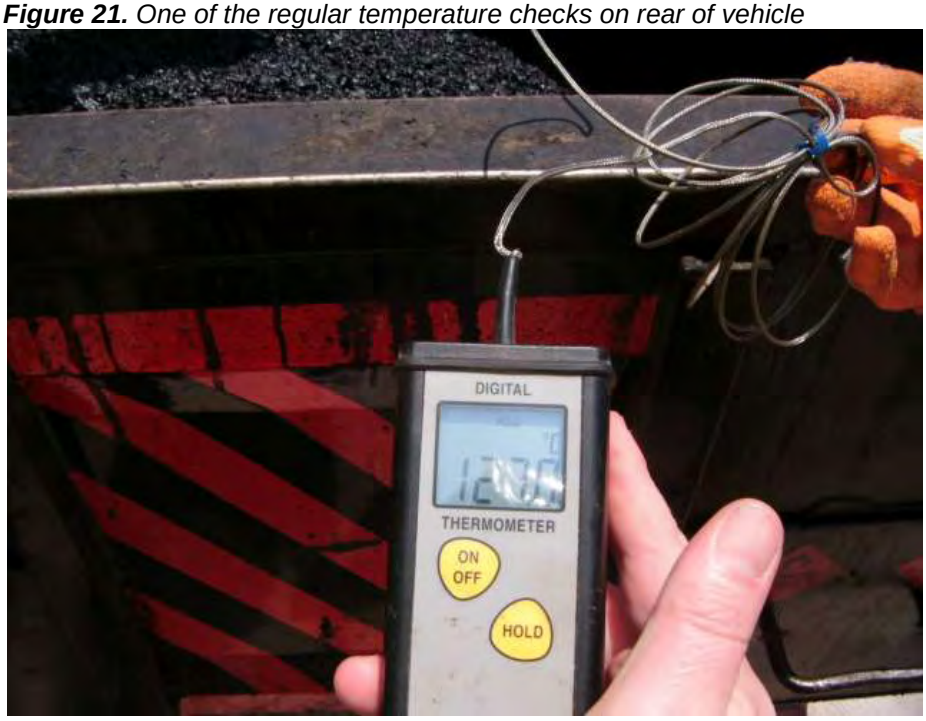


Figure 22. *Images showing copies of original bituminous conveyance receipts*

(i)

(ii)

(iii)

(iv)

(v)

(vi)

(i) 6mm ACDSC
(ii) 6mm ACDSC
(iii) 10mm ACCSC
(iv) 10mm SMASC
(v) 30/14 HRASC
(vi) 20mm ACDBC

5.2 Bituminous Core Extraction and Testing

As previously mentioned, a single core was extracted from each test bed 24 hours after reinstatement which were submitted for laboratory voids testing. Test bed 9 had 2 cores taken for each material with the second core being submitted for laboratory testing for materials analysis and grading.

Figure 23. *Images showing representation of core extraction procedure*

Document Reference: CHD-RR-1112-001vA – Report prepared by B Murtagh

Research period: April 2012 to August 2012 Date: November 2012

UKAS accredited layer measurement taken immediately after extraction to ensure dimensional value is less likely to be affected by mishandling, temperature, or transportation.

Samples were bagged and placed in tubular containers specifically manufactured to ensure no movement is allowed which may compromise condition of core.

Identification tags were placed within sealed bags along with sample which shows unique reference number for each core along with identification label placed on container.

This then allowed for samples to be transported safely to laboratory tasked with voids testing and materials analysis. All voids tests are UKAS and comply with requirement of SROH - S10.2.3

5.3 Core testing results and analysis

Table 7: 5.3.1 *Test Beds – 6mm ACDSC* (SROH requirement = Max 13% - Min 2%)

Location/Reference	Maximum Density Test Temperature (°C)	Bulk Density (kg/m³)	Maximum Density (kg/m³)	Insitu air void Content (%)	
TB1 6mm ACDSC 220512/TBT/LB/001	22.3	2083	2350	11.4	Pass
TB2 6mm ACDSC 220512/TBT/LB/002	22.3	2300	2401	4.2	Pass
TB3 6mm ACDSC 220512/TBT/LB/003	22.5	2158	2257	4.4	Pass
TB4 6mm ACDSC 220512/TBT/LB/004	23.1	2184	2388	8.5	Pass
TB5 6mm ACDSC 220512/TBT/LB/005	23.1	2225	2393	7.0	Pass
TB6 6mm ACDSC 220512/TBT/LB/006	22.3	2234	2441	8.5	Pass
TB7 6mm ACDSC 220512/TBT/LB/007	23.1	2198	2391	8.1	Pass
TB8 6mm ACDSC 220512/TBT/LB/008	22.3	2198	2449	10.2	Pass
TB9 6mm ACDSC 220512/TBT/LB/009	22.3	2144	2386	10.1	Pass

Determination of Bulk Density carried out in accordance with BS EN12697-6: 2003 + A1: 2007 Procedure C (Wax)
Determination of Maximum Density carried out in accordance with BS EN12697-5:2009: Procedure A (Water)
Determination of Void Characteristics carried out in accordance with BS EN12697-8: 2003

The above will show that all methods applied for laying 6mm ACDSC material have achieved requirements as shown in current version of SROH Table S10.1 as maximum 13% and minimum 2%.

Table 8: 5.3.2 *Test Beds – 10mm ACCSC* (SROH requirement = Max 11% - Min 2%)

Location/Reference	Maximum Density Test Temperature (°C)	Bulk Density (kg/m³)	Maximum Density (kg/m³)	Insitu air void Content (%)	
TB1 10mm ACCSC 230512/TBT/LB/001	23.1	2084	2429	14.2	Fail
TB2 10mm ACCSC 230512/TBT/LB/002	21.2	2070	2413	14.2	Fail
TB3 10mm ACCSC 230512/TBT/LB/003	23.1	2088	2401	13.0	Fail
TB4 10mm ACCSC 230512/TBT/LB/004	21.3	2185	2400	9.0	Pass
TB5 10mm ACCSC 230512/TBT/LB/005	21.2	2153	2381	9.6	Pass
TB6 10mm ACCSC 230512/TBT/LB/006	22.3	2220	2440	9.0	Pass
TB7 10mm ACCSC 230512/TBT/LB/007	23.1	2006	2387	16.0	Fail
TB8 10mm ACCSC 230512/TBT/LB/008	23.2	2025	2430	16.7	Fail
TB9 10mm ACCSC 230512/TBT/LB/009	23.1	1945	2401	19.0	Fail

Determination of Bulk Density carried out in accordance with BS EN12697-6: 2003 + A1: 2007 Procedure C (Wax)
Determination of Maximum Density carried out in accordance with BS EN12697-5:2009: Procedure A (Water)
Determination of Void Characteristics carried out in accordance with BS EN12697-8: 2003

The above voids test results will show that only methods used in Test beds 4, 5, and 6 have managed to achieve minimum requirements for SROH Table S10.1 which allows maximum air voids of 11% and 2% minimum.

The first three test beds (1 to 3) were placed using vibrotamper on lower courses with surface layer being applied using vibrating plate. Test beds 7, 8, & 9 were laid entirely using vibrating plate only, with each application consisting of differing layer scenarios (see section 2.18 to 2.20) and have also demonstrated significant failure in relation to voids content

As can be seen from Table 5.3.3 the specification criteria required in the SROH for voids content on this material is achieved in relation to test beds 4, 5, and 6 respectively.
These particular test beds are the only ones that have been subjected to use of vibrating roller on the surface layer and demonstrate that the vibrating plate cannot achieve minimum requirement for voids compliance, even when applying recommended passes as per Table NG8.3 of the SROH.

The results above suggest that it is difficult to ensure voids compliance when applying methods as prescribed in SROH when dealing with this particular material.

Table 9: 5.3.3 *Test Beds – 10mm SMASC* (SROH requirement = Max 8% - Min 2%)

Location/Reference	Maximum Density Test Temperature (°C)	Bulk Density (kg/m³)	Maximum Density (kg/m³)	Insitu air void Content (%)	
TB1 10mm SMA 240512/TPT/LB/001	22.1	2234	2446	8.7	Fail
TB2 10mm SMA 240512/TPT/LB/002	22.3	2201	2353	6.5	Pass
TB3 10mm SMA 240512/TPT/LB/003	22.2	2217	2349	5.6	Pass
TB4 10mm SMA 240512/TPT/LB/004	23.2	2290	2455	6.7	Pass
TB5 10mm SMA 240512/TPT/LB/005	22.1	2267	2397	5.4	Pass
TB6 10mm SMA 240512/TPT/LB/006	23.3	2266	2340	3.2	Pass
TB7 10mm SMA 240512/TPT/LB/007	22.1	2176	2337	6.9	Pass
TB8 10mm SMA 240512/TPT/LB/008	23.0	2131	2340	8.9	Fail
TB9 10mm SMA 240512/TPT/LB/009	21.9	2110	2348	10.1	Fail

Determination of Bulk Density carried out in accordance with BS EN12697-6: 2003 + A1: 2007 Procedure C (Wax)
Determination of Maximum Density carried out in accordance with BS EN12697-5:2009: Procedure A (Water)
Determination of Void Characteristics carried out in accordance with BS EN12697-8: 2003

When looking at the above results in relation to 10mm SMA material it is apparent that compliance has not been achieved in three cases out of the total 9 test beds.

Test bed 1 was laid in two layers of 50mm each with the lower layer (layer 1) being compacted with a trench rammer for 6 passes and the surface layer being compacted for 5 passes as per SROH requirement for lift thickness shown in Table NG A8.3 of the specification. However, Test beds 2 and 3 both achieve compliance for voids content when using both vibrotamper and vibrating plate in differing compacted layer scenarios as per 2.13 and 2.14 of this document.

Attention should be drawn to Test bed 7 where a single layer of 100mm was compacted using a vibrating plate (over 1800kg/m²) for 8 passes which is as quoted under Table NG A8.3 of the SROH.
This is particularly interesting as test beds 8 and 9 both failed to reach voids compliance even though they were subject to compacted layers as prescribed under the same SROH requirement (ie 2 x 50mm layers at 5 passes each) for test bed 8.

Test bed 9 was laid in three layers as follows:

(i) L1 - 35mm compacted with Vibrating Plate ≥ 1800kg/m² at three passes
(ii) L2 - 35mm compacted with Vibrating Plate ≥ 1800kg/m² at three passes
(iii) L3 - 30mm compacted with Vibrating Plate ≥ 1800kg/m² at three passes

This demonstrates the difficulty of achieving voids compliance when applying the prescribed method as laid out in SROH under controlled conditions. Also to show that 100mm compacted in a single layer can achieve compliance with suitable temperature and compaction.

Table 10: 5.3.4 *Test Beds –HRASC* (SROH requirement = Max 7% - Min 2%)

Location/Reference	Maximum Density Test Temperature (˚C)	Bulk Density (kg/m^3)	Maximum Density (kg/m^3)	Insitu air void Content (%)	
TB1 HRASC 30/14 280512/TBT/LB/001	22.3	2222	2479	10.4	Fail
TB2 HRASC 30/14 280512/TBT/LB/002	23.1	2198	2365	7.1	Fail
TB3 HRASC 30/14 280512/TBT/LB/003	22.3	2256	2344	3.8	Pass
TB4 HRASC 30/14 280512/TBT/LB/004	23.1	2279	2425	6.0	Pass
TB5 HRASC 30/14 280512/TBT/LB/005	23.1	2278	2363	3.6	Pass
TB6 HRASC 30/14 280512/TBT/LB/006	23.1	2276	2349	3.1	Pass
TB7 HRASC 30/14 280512/TBT/LB/007	23.1	2241	2403	6.7	Pass
TB8 HRASC 30/14 280512/TBT/LB/008	22.3	2237	2375	5.8	Pass
TB9 HRASC 30/14 280512/TBT/LB/009	23.1	2043	2346	12.9	Fail

Determination of Bulk Density carried out in accordance with BS EN12697-6: 2003 + A1: 2007 Procedure C (Wax)
Determination of Maximum Density carried out in accordance with BS EN12697-5:2009: Procedure A (Water)
Determination of Void Characteristics carried out in accordance with BS EN12697-8: 2003

When viewing Table 10 above it is apparent that there are three failures in relation to voids compliance for 30/14 HRASC used in carriageway construction.

As with previous material, test bed 1 has failed voids result when two layers of 50mm have been applied even though requirement of SROH Table NG A8.3 has been utilised for equipment type and number of passes for each.

Test bed 2 has also failed but may have benefitted from an additional pass on each layer as the void failure was only 0.1% over the required specified criteria of SROH Table S10.1

Test beds 3 to 8 have all passed voids requirement for HRASC material when used in carriageways.

Test bed 9 has failed as a void result of 12.9% had been returned from laboratory which again highlights that test bed 7 and 8 had both passed with fewer layers, but increased compaction passes.

This again highlights the issue in relation to recommended passes and lift thickness as quoted in NG A8.3 of the SROH.

Table 11: 5.3.5 *Test Beds –20mm ACDBC* (SROH requirement = Max 10% - Min 2%)

Location/Reference	Maximum Density Test Temperature (°C)	Bulk Density (kg/m³)	Maximum Density (kg/m³)	Insitu air void Content (%)	
TB1 20mm ACBC 250512/TBT/LB/001	23.1	2196	2317	5.2	Pass
TB2 20mm ACBC 250512/TBT/LB/002	23.1	2119	2424	12.6	Fail
TB3 20mm ACBC 250512/TBT/LB/003	23.1	2185	2387	8.5	Pass
TB4 20mm ACBC 250512/TBT/LB/004	22.3	2264	2402	5.7	Pass
TB5 20mm ACBC 250512/TBT/LB/005	21.4	2283	2410	5.3	Pass
TB6 20mm ACBC 250512/TBT/LB/006	22.3	2247	2340	4.0	Pass
TB7 20mm ACBC 250512/TBT/LB/007	22.3	2103	2380	11.6	Fail
TB8 20mm ACBC 250512/TBT/LB/008	23.1	2079	2348	11.5	Fail
TB9 20mm ACBC 250512/TBT/LB/009	23.1	2112	2426	12.9	Fail

Determination of Bulk Density carried out in accordance with BS EN12697-6: 2003 + A1: 2007 Procedure C (Wax)
Determination of Maximum Density carried out in accordance with BS EN12697-5:2009: Procedure A (Water)
Determination of Void Characteristics carried out in accordance with BS EN12697-8: 2003

The table above has been based on using a 20mm ACDBM on carriageway circumstance as Test beds 7 and 8 would pass SROH voids requirement if used on footway construction.

Test bed 1 allowed for two x 50mm layers with Layer 1 (lower layer) having been compacted in 6 passes of 50kg vibrotamper and the surface layer (layer 2) being compacted in 5 passes of 1800kg/m² vibrating plate.

The result is slightly unusual as the three previous materials have all failed minimum voids criteria when using exactly the same methods and equipment. However, when looking at Test bed 2 which has an additional compacted layer, the voids result is over twice the percentage value of that of the first test bed and also exceeds the specified criteria of maximum 12% allowance for this material.

Again, the compacted lift thickness requirements were adhered to when applying SROH Table NG A8.3 for selected equipment as prescribed in 2.13 of this document and are as follows:

2.13 TEST BED 2 (Temperature and photograph taken for each layer)

1. *35mm compacted layer using min 50kg vibrotamper at 5 passes*
2. *35mm compacted layer using min 50kg vibrotamper at 5 passes*
3. *30mm compacted layer using 1800kg/m² vibrating plate at 3 passes*

6.0 Bituminous Material analysis

In addition to air voids testing on bituminous materials there was a core sample retained for determination of binder content and aggregate grading as required under BS EN 12697-1:2005 which was carried out under specification requirements for BS EN 13108 and specifications shown below.

Each sample had been retrieved as prescribed in section 5.2 of this document and safely transported to laboratory for advanced testing.

The laboratory test specification for each material was as shown in Table 12 below.

Table 12: Bituminous Materials analysis

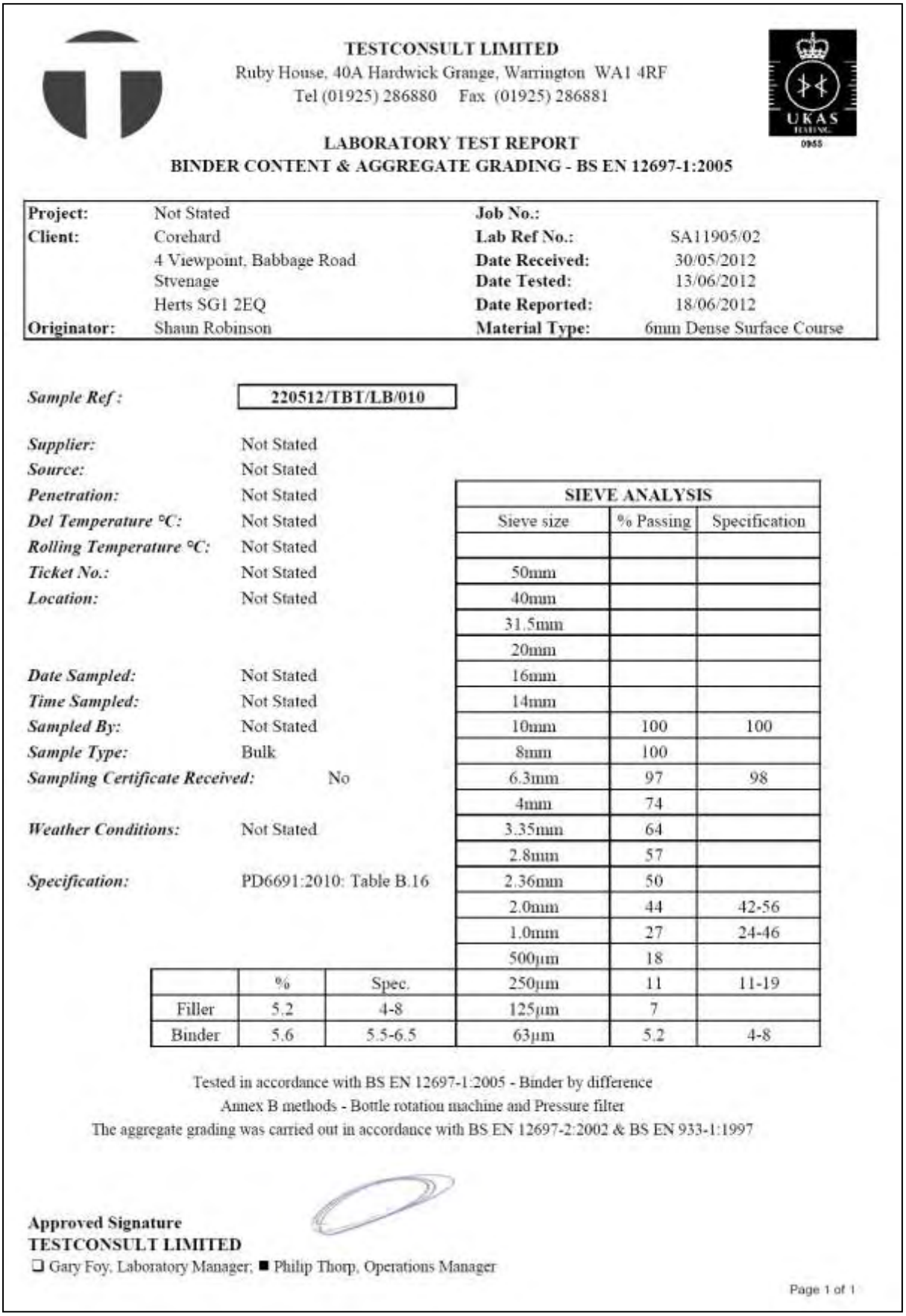
Material	***Specification***
6mm ACDSC	PD6691:2010: Table B.16
10mm ACCSC	PD6691:2010: Table B.14
10mm SMASC	PD6691:2010: Table D.1
30/14 HRASC	PD6691:2010: Table C.2A
20mm ACBC	PD6691:2010: Table B.11

Figure 24. *Image showing sample retained for binder & grading test*

The following certificates will demonstrate results in relation to each individual material and will show values against specification requirement for each.

It will be apparent that some materials have variation from the specification requirement.

Figure 25. *6mm ACDSC Binder Content & Aggregate Grading*



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UKAS TESTING 0955

LABORATORY TEST REPORT
BINDER CONTENT & AGGREGATE GRADING - BS EN 12697-1:2005

Project:	Not Stated	**Job No.:**	
Client:	Corehard	**Lab Ref No.:**	SA11905/02
	4 Viewpoint, Babbage Road	**Date Received:**	30/05/2012
	Stvenage	**Date Tested:**	13/06/2012
	Herts SG1 2EQ	**Date Reported:**	18/06/2012
Originator:	Shaun Robinson	**Material Type:**	6mm Dense Surface Course

Sample Ref : **220512/TBT/LB/010**

Supplier:	Not Stated
Source:	Not Stated
Penetration:	Not Stated
Del Temperature °C:	Not Stated
Rolling Temperature °C:	Not Stated
Ticket No.:	Not Stated
Location:	Not Stated
Date Sampled:	Not Stated
Time Sampled:	Not Stated
Sampled By:	Not Stated
Sample Type:	Bulk
Sampling Certificate Received:	No
Weather Conditions:	Not Stated
Specification:	PD6691:2010: Table B.16

	%	Spec.
Filler	5.2	4-8
Binder	5.6	5.5-6.5

SIEVE ANALYSIS

Sieve size	% Passing	Specification
50mm		
40mm		
31.5mm		
20mm		
16mm		
14mm		
10mm	100	100
8mm	100	
6.3mm	97	98
4mm	74	
3.35mm	64	
2.8mm	57	
2.36mm	50	
2.0mm	44	42-56
1.0mm	27	24-46
500µm	18	
250µm	11	11-19
125µm	7	
63µm	5.2	4-8

Tested in accordance with BS EN 12697-1:2005 - Binder by difference
Annex B methods - Bottle rotation machine and Pressure filter
The aggregate grading was carried out in accordance with BS EN 12697-2:2002 & BS EN 933-1:1997

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Figure 26. *10mm ACCSC Binder Content & Aggregate Grading*

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Project:	Not Stated	**Job No.:**	
Client:	Corehard	**Lab Ref No.:**	SA11905/03
	4 Viewpoint, Babbage Road	**Date Received:**	30/05/2012
	Stvenage	**Date Tested:**	13/06/2012
	Herts SG1 2EQ	**Date Reported:**	18/06/2012
Originator:	Shaun Robinson	**Material Type:**	AC10 Close Graded Surface Course

Sample Ref :	**230512/TBT/LB/010**
Supplier:	Not Stated
Source:	Not Stated
Penetration:	Not Stated
Del Temperature °C:	Not Stated
Rolling Temperature °C:	Not Stated
Ticket No.:	Not Stated
Location:	Not Stated
Date Sampled:	Not Stated
Time Sampled:	Not Stated
Sampled By:	Not Stated
Sample Type:	Bulk
Sampling Certificate Received:	No
Weather Conditions:	Not Stated
Specification:	PD6691:2010: Table B.14

	%	Spec.
Filler	7.2	4-8
Binder	4.8	4.7-5.7

SIEVE ANALYSIS		
Sieve size	% Passing	Specification
50mm		
40mm		
31.5mm		
20mm		
16mm		
14mm	99	100
10mm	97	100
8mm	91	
6.3mm	80	62-68
4mm	46	
3.35mm	39	
2.8mm	34	
2.36mm	32	
2.0mm	29	25-31
1.0mm	22	14-26
500µm	17	
250µm	13	
125µm	9	
63µm	7.2	4-8

Tested in accordance with BS EN 12697-1:2005 - Binder by difference
Annex B methods - Bottle rotation machine and Pressure filter
The aggregate grading was carried out in accordance with BS EN 12697-2:2002 & BS EN 933-1:1997

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Page 1 of 1

Figure 27. *10mm SMASC Binder Content & Aggregate Grading*

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LABORATORY TEST REPORT
BINDER CONTENT & AGGREGATE GRADING - BS EN 12697-1:2005

Project:	Not Stated	**Job No.:**	
Client:	Corehard	**Lab Ref No.:**	SA11905/01
	4 Viewpoint, Babbage Road	**Date Received:**	30/05/2012
	Stvenage	**Date Tested:**	13/06/2012
	Herts SG1 2EQ	**Date Reported:**	18/06/2012
Originator:	Shaun Robinson	**Material Type:**	10mm SMA

Sample Ref : **240512/TBT/LB/010**

Supplier:	Not Stated
Source:	Not Stated
Penetration:	Not Stated
Del Temperature °C:	Not Stated
Rolling Temperature °C:	Not Stated
Ticket No.:	Not Stated
Location:	Not Stated
Date Sampled:	Not Stated
Time Sampled:	Not Stated
Sampled By:	Not Stated
Sample Type:	Bulk
Sampling Certificate Received:	No
Weather Conditions:	Not Stated
Specification:	PD6691:2010: Table D.1

	%	Spec.
Filler	12.8	8-13
Binder	5.5	5.7-6.7

SIEVE ANALYSIS		
Sieve size	% Passing	Specification
50mm		
40mm		
31.5mm		
20mm		
16mm		
14mm	100	100
10mm	93	93-100
8mm	66	
6.3mm	48	28-52
4mm	34	
3.35mm	33	
2.8mm	31	
2.36mm	30	
2.0mm	28	20-32
1.0mm	25	
500µm	24	
250µm	22	
125µm	19	
63µm	12.8	8-13

Tested in accordance with BS EN 12697-1:2005 - Binder by difference
Annex B methods - Bottle rotation machine and Pressure filter
The aggregate grading was carried out in accordance with BS EN 12697-2:2002 & BS EN 933-1:1997

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Figure 28. *30/14 HRASC Binder Content & Aggregate Grading*

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Project:	Not Stated	**Job No.:**	
Client:	Corehard	**Lab Ref No.:**	SA11905/04
	4 Viewpoint, Babbage Road	**Date Received:**	30/05/2012
	Stvenage	**Date Tested:**	13/06/2012
	Herts SG1 2EQ	**Date Reported:**	18/06/2012
Originator:	Shaun Robinson	**Material Type:**	HRA30/14mm SC

Sample Ref : **280512/TBT/LB/010**

Supplier: Not Stated
Source: Not Stated
Penetration: Not Stated
Del Temperature °C: Not Stated
Rolling Temperature °C: Not Stated
Ticket No.: Not Stated
Location: Not Stated

Date Sampled: Not Stated
Time Sampled: Not Stated
Sampled By: Not Stated
Sample Type: Bulk
Sampling Certificate Received: No

Weather Conditions: Not Stated

Specification: PD6691:2010: Table C.2A

	%	Spec.
Filler	9.1	7-11
Binder	6.0	5.9-7.1

SIEVE ANALYSIS		
Sieve size	% Passing	Specification
50mm		
40mm		
31.5mm		
20mm	100	100
16mm	100	
14mm	99	93-100
10mm	84	67-83
8mm	74	
6.3mm	70	
4mm	68	
3.35mm	67	
2.8mm	67	
2.36mm	66	
2.0mm	66	60-70
1.0mm	63	
500µm	58	49-68
250µm	31	19-51
125µm	13	
63µm	9.1	7-11

Tested in accordance with BS EN 12697-1:2005 - Binder by difference
Annex B methods - Bottle rotation machine and Pressure filter
The aggregate grading was carried out in accordance with BS EN 12697-2:2002 & BS EN 933-1:1997

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Figure 29. *20mm ACBC Binder Content & Aggregate Grading*

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BINDER CONTENT & AGGREGATE GRADING - BS EN 12697-1:2005

Project:	Not Stated	**Job No.:**	
Client:	Corehard	**Lab Ref No.:**	SA11905/05
	4 Viewpoint, Babbage Road	**Date Received:**	30/05/2012
	Stvenage	**Date Tested:**	13/06/2012
	Herts SG1 2EQ	**Date Reported:**	18/06/2012
Originator:	Shaun Robinson	**Material Type:**	AC 20 BC

Sample Ref : **250512/TBT/LB/010**

Supplier:	Not Stated
Source:	Not Stated
Penetration:	Not Stated
Del Temperature °C:	Not Stated
Rolling Temperature °C:	Not Stated
Ticket No.:	Not Stated
Location:	Not Stated
Date Sampled:	Not Stated
Time Sampled:	Not Stated
Sampled By:	Not Stated
Sample Type:	Bulk
Sampling Certificate Received:	No
Weather Conditions:	Not Stated
Specification:	PD6691:2010: Table B.11

	%	Spec.
Filler	7.2	3-9
Binder	3.8	4.0-5.2

SIEVE ANALYSIS

Sieve size	% Passing	Specification
50mm		
40mm		
31.5mm	100	100
20mm	99	99-100
16mm	88	
14mm	78	
10mm	61	61-63
8mm	52	
6.3mm	47	47
4mm	40	
3.35mm	37	
2.8mm	34	
2.36mm	31	
2.0mm	29	27-33
1.0mm	21	
500µm	16	
250µm	12	11-15
125µm	10	
63µm	7.2	3-9

Tested in accordance with BS EN 12697-1:2005 - Binder by difference
Annex B methods - Bottle rotation machine and Pressure filter
The aggregate grading was carried out in accordance with BS EN 12697-2:2002 & BS EN 933-1:1997

Approved Signature
TESTCONSULT LIMITED
❑ Gary Foy, Laboratory Manager; ■ Philip Thorp, Operations Manager

Page 1 of 1

7.0 GENERAL OBSERVATIONS

The following observations were made in relation to materials, methodology, equipment, and working practices as a result of diligent monitoring and scrutiny related to these test bed trials.

7.1 Backfill

All backfill materials should be completed in layers as recommended within SROH document. However, consideration should be given to the type of equipment and materials used where conformance can be achieved and verified.
It was found that proprietary and recycled type 1 materials performed very well when applying the recommended methods as prescribed in the SROH with the correct equipment.

Particular attention should be made to selection of equipment as the impacting force of a vibrotamper appeared to provide a greater influence on the material than the vibrating plate.
This trial had found that sufficient passes of the vibrotamper at 300mm layers managed to reach compliance for compaction when subsequently tested under UKAS accredited means however it is not recommended that this method is adopted in the workplace and SROH layer recommendations are adhered to.
This also implies that issues arising from layer depth cannot be ascribed by visual representation only, and a robust method of verification should be employed.

Results and observations from this trial suggests that HBM materials should be laid in regular layers with adequate compaction as it was apparent that material was of a low density and provided considerable difficulty for operatives at greater layer depths. When using a vibrotamper the material had a propensity to allow the device to sink into the surface and hinder both forward and reciprocating motion of the equipment by enveloping the base plate.

The material proved to respond very well to compaction efforts of the vibrotamper when laid in compacted lift thickness of 150mm as can been observed from penetrograph results included within this document.

Due to the nature of production, generally HBM materials will further stabilise through time as chemical change occurs within the product but will require full attention to layers and compaction equipment used to ensure minimum performance criteria are achieved at time of opening to traffic.

7.2 Bituminous materials

As with backfill layers, all bituminous materials should be laid in accordance with requirements of the SROH as an absolute minimum. For the purpose of this trial all bituminous layers were applied and compacted as per the prescribed methods as detailed in 2.10 to 2.19 of this document.

A temperature reading was taken on all materials prior to compaction of each individual layer. This was to ensure that all materials were within specified working criteria and allowed for performance measurement of completed reinstatements to be related to selected compaction method and equipment.

As previously described, each material was laid across 9 test beds with differing methods and equipment and had been subjected to laboratory core extraction procedure to provide samples for voids testing.

All voids testing was undertaken independently through UKAS accredited laboratory holding current certification for these tests along with criteria specified in S10.2.3 of the SROH.

The results shown in section 5 of this document will show that failure has occurred in some instances where prescribed methods and equipment have been applied under controlled conditions within correct operating temperatures.

In all the tests that were undertaken, there were no results that voids had been found at minimum requirement (≤2%) across all selected materials.

With regards to this trial only, it can be noted that the vibrating plate provided good results across all relevant test beds when using 6mm ACDSC material but had not provided any such values when applying the exact same methods to 10mm ACCSC material and had varying degrees of success or failure on all other bituminous products when subjected to voids testing.

It was also observed that on two occasions, separation had occurred between compacted lifts where correct compaction requirement had been applied when working to prescribed method even though the subsequent layer had been placed within minutes of first with no contamination.
One such incident was where the 20mm ACBC material was laid at 50mm using trench rammer, with the top layer being compacted with vibrating roller.

As can be determined from the laboratory results shown above, there is considerable difference in results between 6mm ACDSC and 10mm ACCSC where all nine applications passed for the 6mm and only three passed for the 10mm material.

There is a difference in composition of materials but the methodology prescribed for compacted lift thickness and equipment is broadly similar in relation to methodology when applying requirements of SROH.
Training and competence checks will assist in reducing issues arising from lack of compaction in backfill and bituminous materials.

8.0 CONCLUSIONS & RECOMMENDATIONS

8.1 Backfill materials

This trial demonstrates that recommended methods for reinstatement of GSB Type 1 and recycled Type 1 should be applied as per requirement of SROH as a high level of compaction has been achieved as can be seen from the penetrographs from test beds 1 and 4.

Where these granular materials were laid in test beds 2 and 5 the compacted layer was increased to 300mm depth whilst still applying the same passes required for 150mm layers.
In both cases the materials had achieved compliance for compaction purposes when subjected to laboratory testing. However, both results had only marginally passed the penetrometer test and the correct SROH method should always be the preferred application. What is apparent is that compliance can only be measured by a recognised test method and visual observations will therefore require validation.

Hydraulically bound mixtures should only be laid at 150mm compacted layers in accordance with Table A9.1 (SROH) which allows for sufficient compaction to meet performance criteria when opening to traffic. Laboratory result from penetrometer for test bed 7 will demonstrate compliance has been achieved.

Test beds 3, 6, and 9 were backfilled to full depth applying considerable compaction efforts on material surface where it is apparent from corresponding laboratory tests that all have failed at lower levels due to dissipation of force from compaction equipment. Regardless of how much compaction effort is introduced the result will always fail for this reason. This is the primary cause for subsidence at a later time where natural settlement and dynamic loading from subsequent traffic movements will provide considerable contribution. Impact devices (ie. Clegg) will show good results for surface modulus but cannot verify compaction unless taken on each individual compacted lift.

As part of this trial a widely distributed selection of personnel were interviewed in relation to understanding of compaction requirements as provided in the SROH specification. Most had intimated that they had not seen a copy of the document since initial qualification and also highlighted that some had no recollection of relevant requirement for compaction but were aware that 150mm layers were to be applied.

It is recommended that operatives are fully aware of the methods and procedures within the SROH for each material and selected compaction equipment and have a clear understanding of why these have to be adhered to. Regular training and competence checks should be undertaken to ensure a full understanding requirements and capabilities for each material and equipment.

Further emphasis should be applied to researching a method to clearly identify compaction equipment and to which materials it can be successfully applied to. One suggestion is by a colour coding system which will allow operatives and inspectors to ensure correct equipment and method is applied.

8.2 Bituminous materials

Bituminous materials should be applied as per compacted lift thickness and methods as prescribed in SROH document but clarification of method is required when comparison is made between Table A2.1 and NG A8.3. This has provided considerable debate when discussed with operatives into application.

Samples had been taken from all materials and subjected to laboratory testing in relation to presence of air voids. Table S10.1(SROH) shows the voids content requirement for each material so as to achieve conformity. The results found that there may be further investigation required to ensure that conformity is achievable when utilising methods prescribed within Table NG A8.3 for compacted layer depth and passes required.

Consideration should be given time period after laying of materials to ensure dynamic loading due to traffic has not affected voids result in relation to minimum requirements. By definition, all bituminous materials are flexible and will be influenced by such loading as no voids failure was notated as below minimum values allowed for each material.

Further to this particular trial it is believed that considerable research is required to ensure that voids criteria are easily achieved when utilising methods and equipment as prescribed within current version of SROH for compaction of bituminous materials. Placing and compaction requirements for such materials is outlined in current version of Manual of Contract Documents for Highways Works (MCHW) which are broadly based around machine laying methods as prescribed in section 903 clauses 8 to 14 and relevant clauses quoted in section 929
As also mentioned in SHW the standard BS 94987 clause 9.5.1.2 also deals with air voids requirements based on large works where voids testing is generally applied to units of 5000m².

Such research would require a high level or repeatability to ensure that methods and procedures used are correct and will always achieve compliance when applied in the prescribed manner. The current voids criteria within the SROH may have been extracted from such a research project and reference to this would assist in providing additional training where required, otherwise the calculations for voids content may have been extracted from criteria shown within SHW 900 series which again is broadly based around machine lay methods for larger mats and is less descriptive in relation to small excavations and trenches.

Clarification of requirements with regard to application of compaction equipment as prescribed under SROH should also be sought as there appears to be an anomaly when taking into consideration Tables A2.1 (Bituminous compacted lift thickness) and NG A8.3 (Compaction requirements for bituminous materials). When looking at analysis of test beds for 10mm ACCSC material as shown in section 5 of this document where all recommended methods and procedures were applied in relation to compacted lift thickness and number of passes required (SROH Table NG A8.3), it is apparent that this particular material failed across 6 test beds.

9. References

Langton,DD, 1999. The Panda lightweight penetrometer for soil investigation and monitoring material compaction. Ground Engineering, Vol32.99.

Parsons AW, 1992. Compaction of soils and granular materials: A review of research performed at the Transport Research Laboratory. The Stationary Office, London.

WRAP, 2009. Recycled utility arisings in trench reinstatement: Compaction Trial. WRAP, J Edwards (Project MRF106)

AFNOR, P904-105 Quality control of compaction. Assocoation Française de Normalization

NRSWA 1991. New Roads & Street Works Act
Specification for Reinstatement of Openings in the Highway V3:2010

NRSWA 1991. New Roads & Street Works Act
Code of Practice for Inspections

MCHW Volume 1. Specification for Highways Works – Series 800 – Road Pavements Unbound – Cement & Other Hydraulically Bound Mixtures.

MCHW Volume 2. Specification for Highways Works – Series NG800 – Road Pavements Unbound – Cement & Other Hydraulically Bound Mixtures.

MCHW Volume 1. Specification for Highways Works – Series 900 – Road Pavements – Bituminous Bound Materials.

MCHW Volume 2. Specification for Highways Works – Series NG900 – Road Pavements – Bituminous Bound Materials.

BS EN 17025:2005 General requirements for the competence of testing and calibration laboratories

BS 1377-9:1990. Methods of test for Soils for civil engineering purposes – methods of in-situ tests

BS 594987:2010. Asphalt for Roads & other Paved Areas – Specification for Transport, laying, compaction, and type testing protocols.

BS EN 12697-27:2001. Bituminous mixtures – Test methods for hot mix asphalt – Part 27 Sampling

BS EN 12697-5:2009. Bituminous mixtures – Test methods for hot mix asphalt – Part 5 - Determination of the maximum density

BS EN 12697-8:2001. Bituminous mixtures – Test methods for hot mix asphalt – Part 8 – Determination of void characteristics of bituminous specimens.