TIM O'HARE ASSOCIATES

SOIL & LANDSCAPE CONSULTANCY

28th August 2007

Our Ref: TOHA/07/2303
Your Ref: ATS

RE: Amenity Tree Soil

We have completed the assessment of the Amenity Tree Soil (ATS) and enclose the findings and recommendations.

The purpose of the assessment was to assist with the development of a new product data sheet. This is to include up-to-date analysis, installation guidelines and details of tree pits and backfill materials. The function of this material is to provide a number of key properties, being principally:

- Growing medium for trees placed within paved areas.
- Engineering performance to support paving and traffic below paved areas around trees.

The following work has therefore been undertaken:

1. Laboratory analysis on a representative sample of ATS from the Retford Quarry. Tests included pH, salinity, nutrients, potential contaminants, permeability, CBR and grading.
2. Assessment of the material as a growing medium
3. Determination of compaction methods and equipment
4. Example tree pit detail, showing backfill materials, drainage layers and tree anchoring system
5. Installation guidelines

The laboratory results are presented on the attached and a summary of the findings is provided below. The tree pit detail and installation guidelines are also attached.

Growing Medium Assessment

From the laboratory analysis undertaken, the sample can be described as an alkaline, non-saline LOAMY SAND with a single grain structure and very low stone content. The material is deficient in organic matter, nitrogen, phosphorus and potassium and free from significant contamination, with respect to the parameters determined.

The grading of the sand indicates a narrow particle size distribution and a predominance of medium sand (0.25-0.5mm) and fine sand (0.15-0.25mm). This is ideal for 'structural soils' as sufficient porosity levels are maintained in a compacted state and the risk of particle interpacking is minimised.

The pH of the sample was alkaline (pH 7.9), at a level considered acceptable for the vast majority of tree species grown in the UK. The exceptions to this would be calcifuge species, such as Pin Oak (*Quercus palustris*) or Red Oak (*Quercus rubra*), which require acidic soils.

The salinity levels were low, indicating no risk from soluble salts. Contamination levels were very low so there should be no restrictions for site operatives handling the soil or for using the soil in areas of sensitive end-use, such as housing schemes or high groundwater.

The organic matter content and fertility status were low for a growing medium, so these will need to be supplemented by the incorporation of a suitable slow-release, compound fertiliser. An organic-based fertiliser would be preferable, which could also inoculate the sand with beneficial soil microbes.

Determination of Compaction Methods and Equipment

In order to identify the appropriate compaction method, we have compared the test data on the material against the requirements from The Manual of Contract Documents for Highway Works, Specifications for Highway Works [SHW]: Volume 1: Table 6/1, 6/2 and 6/4.

From reference to the results of the grading analysis and SHW Table 6/2, the closest grading classification of the material would be as either a **Class 1B** uniformly graded general fill, or a **Class 6D** starter layer. From reference to SHW Table 6/1, the appropriate method of compaction is given as Table 6/4 Method 3 for Class 1B and Method 4 for Class 6d. Method compaction allows the selection of a variety of compaction plant which by trial have been proven to be acceptable to compact the specific soil type. The key compaction criteria for these soils is that they should achieve a minimum of 95% of the appropriate Maximum Dry Density so long as the methodology listed in Table 6/4 is strictly adhered to. Due to the variety of the different compaction equipment listed within SHW Table 6/4 only compaction plant suitable for Method 3 and 4 have been recorded and for ease of reference the data has been reproduced below in Table 1.

From a further assessment of the results of the grading analysis and associated engineering testing, it is suggested that unless the grading of the parent material changes and becomes both coarser and more single-sized in nature, then **Method 4** compaction should be selected in preference to Method 3.

Given the restricted access to the material when it is being placed and compacted within the tree pits, it is considered likely that only the **Vibro Tamper** will prove to be suitable, and as such reference to the mass of the equipment should be used in order to determine the maximum depth of layer, and minimum number of passes.

It is understood that the nominal mass of a typical Vibro Tamper this would be over 75kg and less than 100kg. As such and from reference to Table 1 above, Vibro Tamper ref no 3, the maximum depth of layer should be 175mm with a minimum number of 3 passes. This compaction should be equivalent to the use of the 2.5kg rammer within the laboratory and in turn should return similar densities to samples at the same moisture content.

Table 1 – Summary of Compaction as per SHW Table 6/4 Method 3 and Method 4

Type of Compaction Plant	Ref. No.	Category	Method 3		Method 4	
			Depth of Layer [mm]	Minimum no of Passes	Depth of Layer [mm]	Minimum no of Passes
Smooth wheeled roller [or vibratory roller operating without vibration]		Mass per metre width of roll:				
	1	Over 2100kg up to 2700kg	125	10	175	4
	2	Over 2700kg up to 5400kg	125	8	200	4
Grid Roller		Mass per m width of roller:				
	1	Over 2700kg up to 5400kg	150	10	250	4
Deadweight tamping roller		Mass per metre width of roll:				
	1	Over 4000kg up to 6000kg	250	4	350	4
	2	Over 6000kg	300	3	400	4
Pneumatic-tyred roller		Mass per wheel:				
	1	Over 1000kg up to 1500kg	150	10	240	4
Vibratory tamping roller		Mass per metre width of a vibrating roll:				
	1	Over 700kg up to 1300kg	150	12	100	10
	2	Over 1800kg up to 1800kg	175	12	175	8
Vibratory roller		Mass per metre width of a vibratory roll:				
	3	Over 700kg up to 1300kg	150	6	125	10
	4	Over 1300kg up to 1800kg	200	10	175	4
Vibrating plate compactor		Mass per m² of base plate:				
	2	Over 1100kg up to 1200kg	100	6	75	10
	3	Over 1200kg to 1400kg	150	6	150	8
Vibro tamper		Mass:				
	1	Over 50kg up to 65kg	150	3	125	3
	2	Over 65kg up to 75kg	200	3	150	3
	3	Over 75kg up to 100kg	225	3	175	3
	4	Over 100kg	225	3	250	3

As part of the previous engineering testing undertaken on samples of this material, a re-compacted California Bearing Ratio [CBR] was completed. The sample was re-compacted using the 2.5kg rammer at the as received moisture content and returned a minimum CBR of 57%. Given that the method selected from Table 1 should provide similar levels of compaction to that of the 2.5kg rammer, the in-situ performance of the material should it be compacted at the same moisture content, should also be in excess of 50%. Using this CBR value, it is possible to determine a number of other engineering characteristics which can be used in pavement design, such as the modulus of sub-grade reaction [k] based on a 760mm plate. From this correlation, it is anticipated that the modulus of sub-grade reaction for this soil, when compacted at the same moisture content, would be in excess of 100MN/m²/m.

As the performance of the soil will be linked to the moisture content at time of compaction, further work may be required in order to correlate the change in engineering performance of the material over the range of moisture contents at which the soil is likely to be placed and compacted.

At this stage, we recommend a more conservative approach with the performance of the material, and as opposed to a CBR of 50%, we would quote "should achieve a CBR in excess of 5%..." The 5% CBR is important as this is the upper limit for the sub-grade for the minimum construction thickness.

Compaction Assessment

Assessment of the compacted soil after vibro-tamping can be carried out using a *Mexe Probe* (Cone Penetrometer), which measures it directly as a CBR. A cone is pushed into the ground and a reading taken on the resistance of the ground.

Hand-held Mexe Probe

Other installation guidelines, such as Urban Soils, refer to the use of a 'penetograph' and a measurement in Mega Pascals (MPa). The penetograph is also an assessment tool used on site to check specifically topsoil/subsoil materials, but it is not widely used in the UK. I have not been able to source a UK supplier of it. It appears to be very similar in operation to a mexe probe, however with the penetrograph, it appears to read in MPa, hence the reference in the previous document to the MPa, then corrected to an equivalent CBR. Based on the tests undertaken, with the compaction method identified, the results for ATS are significantly better than for the other soil.

As an explanation of what a CBR is, at 2.5mm penetration @ rate of 1mm per minute of a flat circular plunger of end-area 1935mm^2, 100% CBR = 13.2kN. For the same equipment but at 5mm penetration, 100% CBR = 20kN. By converting this to MPa [i.e. MN/m^2], 100% CBR = 6.8 MPa [@ 2.5mm] or10.3 MPa [@5mm] but this relates to the force required to achieve a rate of 1mm per minute. As the penetrograph is a cone, the results of one test cannot be used to make a direct correlation. Therefore without the actual equipment to do our own correlation between the penetrograph and the CBR, we can only rely on the information from the other source, which suggests that their soil had a lower CBR to your soil.

Product Data Sheet

To put together a Product Data Sheet, it may not be necessary to present all the results of analysis, but instead select the most important parameters. If required, the full tests certificates can be provided if a customer requests further information.

The following parameters are recommended:

⇒ pH

⇒ Grading (5 sand fractions, silt and clay)

⇒ Compacted Bulk Density

⇒ Moisture Content

⇒ Permeability

⇒ CBR Value

The nutrient and organic matter levels could also be displayed, but these are not positive features of the product as they are so low.

It may also be prudent to offer 'typical values' or 'typical ranges' as the composition of the product will vary slightly within each batch and each quarry. For example, the text could read:

pH Range	7.0 – 8.0
CBR Value	>5%

I hope the work meets with your approval. Please call me if you wish to talk through the findings and recommendations.

Yours sincerely

Tim O'Hare
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Principal Consultant

For and on behalf of Tim O'Hare Associates LLP

Encl: Certificates of Analysis
Example Tree Pit Detail
Installation Guidelines

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Client:
Project: **Amenity Tree Soil Analysis**
Date: **August 2007**
Job Ref No: **TOHA/07/2303**

Sample Reference		ATS Retford
Sample Description		Brown Sand
Depth		--
pH Value (1:2.5 water extract)	units	7.9
Electrical Conductivity (1:2.5 water extract)	uS/cm	144
Electrical Conductivity (1:2 CaSO4 extract)	uS/cm	1952
Organic Matter (Walkley Black)	%	0.5
Total Nitrogen (Dumas)	%	0.03
Extractable Phosphorus	mg/l	17
Extractable Potassium	mg/l	37
Extractable Magnesium	mg/l	80
Total Arsenic (As)	mg/kg	3
Total Cadmium (Cd)	mg/kg	0.3
Total Chromium (Cr)	mg/kg	10
Total Copper (Cu)	mg/kg	11
Total Lead (Pb)	mg/kg	13
Total Mercury (Hg)	mg/kg	<0.02
Total Nickel (Ni)	mg/kg	11
Total Selenium (Se)	mg/kg	0.2
Total Zinc (Zn)	mg/kg	69
Water Soluble Boron (B)	mg/kg	0.3
Total Cyanide (CN)	mg/kg	<1
Total (mono) Phenols	mg/kg	<1
Elemental Sulphur (S)	mg/kg	<20
Acid Volatile Sulphide (S)	mg/kg	<1
Water Soluble Sulphate (SO4)	g/l	1.2
TPH by GCMS Broadscan	mg/kg	<50
Naphthalene	mg/kg	<0.1
Acenaphthylene	mg/kg	<0.1
Acenaphthene	mg/kg	<0.1
Fluorene	mg/kg	0.1
Phenanthrene	mg/kg	0.5
Anthracene	mg/kg	<0.1
Fluoranthene	mg/kg	<0.1
Pyrene	mg/kg	<0.1
Benzo(a)anthracene	mg/kg	<0.1
Chrysene	mg/kg	<0.1
Benzo(b)fluoranthene	mg/kg	0.1
Benzo(k)fluoranthene	mg/kg	<0.1
Benzo(a)pyrene	mg/kg	<0.1
Indeno(1,2,3-cd)pyrene	mg/kg	<0.1
Dibenzo(a,h)anthracene	mg/kg	<0.1
Benzo(g,h,i)perylene	mg/kg	<0.1
Total PAHs (sum USEPA16)	mg/kg	<2.0

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Client:
Project: **Amenity Tree Soil Analysis**
Date: **August 2007**
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Sample Reference		ATS Retford
Sample Description		Brown Sand
Depth		--
Clay (<0.002mm)	%	7
Silt (0.002-0.063mm)	%	5
Very Fine Sand (0.05-0.15mm)	%	9
Fine Sand (0.15-0.25mm)	%	20
Medium Sand (0.25-0.50mm)	%	44
Coarse Sand (0.50-1.0mm)	%	14
Very Coarse Sand (1.0-2.0mm)	%	1
Texture Class (UK Classification)	--	LOAMY SAND
Stones (2-20mm)	% DW	1
Stones (20-50mm)	% DW	0
Stones (>50mm)	% DW	0

Determination of Permeability (K H Volume 10.7 method)

Initial Height	mm	113.0
Initial Diameter	mm	105.0
Particle Density	Mg/m3	2.66
Initial Bulk Density	Mg/m3	1.98
Final Bulk Density	Mg/m3	2.00
Initial Moisture Content	%	13.6
Final Moisture Content	%	17.8
Initial Dry Density	Mg/m3	1.74
Final Dry Density	Mg/m3	1.70
Permeability	m/s	2.08x10-4

Notes
Material recompacted at the 'as-received' moisture with a 2.5kg rammer
Sample is assumed to be fully saturated when a sate of steady flow is achieved
Permeability is determined when sample achieved a state of steady flow

Determination of California Bearing Ratio (BS 1377-4:1990:Method 7.4)

Moisture Content (Initial)	%	14
Moisture Content (Top)	%	13
Moisture Content (Base)	%	13
Moisture Content (Mean)	%	13
Initial Bulk Density	Mg/m3	1.67
Initial Dry Density	Mg/m3	1.47
CBR Top	%	57.0
CBR Base	%	71.0

Notes
Material recompacted at the 'as-received' moisture with a 2.5kg rammer
Sample tested in an unsoaked condition
Applied Seating Load (top) : 6N
Applied Seating Load (base) : 7N
Applied Surcharge : 12.0kg