Deep Soil Mix (DSM) techniques

The properties of DSM treated columns are influenced by the type and proportion of the cementing agent and soil properties, the mixing technique and mixing energy have strong influence on the strength and stiffness of the DSM columns. The greater the ability to break-down the soil mass into smaller aggregates and if a more uniform mix can be achieved (either by higher mixing energy and/or better mixing tool), the resulting strength and stiffness of the DSM are likely to be greater. This is one of the reasons why the dry mix method is able to achieve high strength in Scandinavian quick clay which liquefies when disturbed.

The attached Table 1 presents a brief comparison of different DSM techniques that are currently available in the Australia and New Zealand region. It can be seen from Table 1 that a large range of DSM column strengths can be achieved depending on the method of installation and the proportion of cementing agent adopted (need to add range of additive content to table).

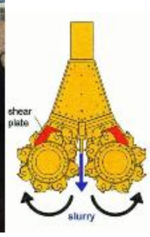
Established design methods (SGF, 1977 and Eurocode, 2005) for DSM are currently limited to relatively compressible and low to moderate strength columns due to concerns regarding brittle failure, tensile or flexural failure behaviour of rigid columns. The writers believe that more rigid and higher strength columns could be adopted provided the type, size and spacing of the DSM columns are chosen such that lateral ground movements are controlled to limits that are compatible with the stiffness and strength of the columns used. For example, quadruple augers that form columns up to about 1.35m “square” shaped columns or Cutter Soil Mixing (CSM) that forms 2.4m x 0.55m rectangular columns would have greater lateral resistance and flexural capacity than single columns that are generally limited to about 0.8m diameter. Detailed soil-structure interaction analysis have been applied successfully in recent projects in New Zealand (Finlan et al, 2004) and Queensland (Wagstaff, 2006) using high strength wet mix techniques.

References:

Finlan, S., Quickfall, G., and Terzaghi, S (2004) *Innovation in Slip and Settlement Remedials: the Soil Mixing Option*, Proc. 9th ANZ Conference on Geomechanics, Auckland, Vol 1, 405-411

Wagstaff (2006) *Private communications* during CSM design carried out by Coffey on behalf of Wagstaff for a tank project in Townsville, QLD, Australia

Table 1 - Brief Comparison of Various DSM Techniques

1. Dry Soil Mixing with Single Auger/Mixer	2. Wet Soil Mixing with Multiple Augers	3. Wet Soil Mixing using Cutter Soil Mixing (CSM)
		 
Advantages • Relatively small rig implies easy access onto soft ground (Note: for the CSM method described in Column 3, a substantial working platform is required to support the 85 tonne rig employed). • Size of column varies typically from 0.6m to 0.8m diameter.	• More uniform mix is possible due to action of multiple augers • Size of column varies with auger arrangement (for example, quadruple 750mm diameter augers creates DSM columns having a cross sectional area of 1.75m^2)	• Uniform mix can be achieved • Large treated column size (2.4m x 0.55m) means fewer columns required • By rotating the mixing tool near ground surface, a column head size of 3.6m x 1.7m can be achieved to provide good load transfer to enable relatively large spacing to be adopted. • The column can be oriented with the long direction across the embankment to improve stability, reducing the need to interlock columns for embankment stability.
Strength 75kPa to 250kPa shear strength but typically limited to a design strength of 100kPa to 150kPa	UCS of 1500kPa (shear strength of 750kPa approximately) has been achieved, but effective strength parameters of c’= 300 to 500kPa and ϕ’ = 25^o to 35^o may be more appropriate to allow for potential brittle behaviour under lateral loading/bending.	With high cement content in the slurry mix, UCS in excess of 1 to 4 MPa has been achieved in marine clays in Queensland. Potential brittle behaviour may also need to be considered although size of column is more resistant to lateral loading/bending.