AustStab Construction Tip

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Achieving density in stabilised materials using static compaction

1 Introduction

The thorough compaction of pavement materials, such as granular, asphalt, concrete and stabilised, is essential to achieve the design strength and stiffness. Various studies have shown lower compaction levels leads to lower modulus and strength, and subsequently early distress of the pavement layer.

For many years, the use of the vibratory padfoot and smooth drum rollers were common for all stabilisation contracts. In recent years, heavier rollers have also been available providing the opportunity to successfully use static compaction to achieve density compliance for layers up to 300 mm in thickness. The avoidance of dynamic compaction has been important during night time construction when contractors need to use construction techniques that minimise environmental noise and vibration.

In some road construction contracts, the primary civil contractor may subcontract the 'spread and mix' operations to a specialist stabilisation contractor with the primary contractor carrying out the compaction and trimming activities. AustStab prefers that the 'spread, mix, compaction and trimming' stages are carried out by the specialist contractor to ensure the operations are effectively balanced around the construction resources on site.

Australian Standards and many road authorities set guidelines for the maximum level of ground vibration at building sites and bridges. Whilst the vibration level can be monitored with specialist equipment, it is a significant cost to the contractor and is rarely carried out.

2 Compaction methods

Table 1 lists the three common compaction methods used in road construction, with static, dynamic and impact compaction the most common methods.

Table 1 Compaction methods used for road construction (see Figures 1 to 3).

Type	Description	Examples
Static	Uses mass of machine to apply pressure on the upper surface. The roller may have the capacity to increase its mass by the addition of steel weights or water.	Three wheeled (or point) rollers, soil compactors, self propelled smooth drum / padfoot rollers and pneumatic multi-tyred rollers
Dynamic	A rapid succession of impacts against the surface. This machine achieves higher compaction levels compared to static compaction of similar mass.	Single and tandem smooth drum/padfoot rollers
Impact	Higher but less rapid impact compaction. Impact rollers must operate at significantly higher speeds than static or vibratory compactors.	Self propelled tandem and towed impact rollers, and hand held compactors for around services.

3 Compaction equipment

Accredited contractors will choose a range of compaction equipment to meet the following site conditions:

- Insitu subgrade strength
- Pavement or subgrade materials
- Size of the compacted area
- Pavement layer thickness
- Proximity and condition of existing underground utilities
- Location and condition of adjacent buildings
- Ride quality requirements

Figure 1 Self propelled vibrating (or static) 27 t padfoot roller (left) and soil compactor.

Figure 2 Self propelled vibrating (or static) smooth drum 15 t roller (left) and pneumatic multi-tyred roller.

Grid rollers (see Figure 3) have been used for road stabilisation projects to assist with the breakdown of large macadam material into smaller particles to improve the overall grading. At some sites, the macadam is raised to the surface from the subbase during the first mixing pass and the grid roller would be used during this stage of construction.

4 Compaction requirements for materials

For typical pavement materials consisting of coarse sands to gravels, most contractors will add water to increase the moisture content to just below the Optimum Moisture Content (OMC). When using cementitious binders, water will be required to assist in the hydration of the binder and the contractor has to take this into consideration when adjusting the water content during the mixing operations. If the moisture content of pavement material is too dry, substantial compaction effort is required. On the other hand, if the moisture content is more than the OMC, dry back will be required before sealing the surface (Austroads, 2003).

Figure 3 Typical three wheeled/point roller (left) and towed grid rollers are commonly used to break up macadam stones that have been incorporated in the stabilised base layer.

One of the underlying benefits of using reclaimers and stabilisers, is that moisture is introduced into the mixing chamber which results in the uniform application of moisture with depth, assisting to achieve uniform compaction of the layer (AustStab, 2000). For subgrade materials, the mixing action can also distribute wet surface material throughout the pavement layer resulting in consistent moisture content and therefore uniform compaction.

Clay subgrade materials require a relatively higher compactive effort than granular materials. Whilst it has been traditional to use vibratory rollers to compact clay, by using lime stabilisation (AustStab, 2006), the clay will dry and become easier to compact, and in most instances a heavy static compaction roller (eg. CAT 815 type compactor or a 27 tonne self propelled padfoot roller used statically) can therefore be used inlieu of lighter (ie 15 tonne) vibratory padfoot rollers.

Foamed bitumen materials generally require less compactive effort than a granular pavement to achieve a similar level of compaction, due to the increased 'lubrication' provided by the bitumen. Compaction can therefore be easily carried out in one layer for pavement depths of up to 300 mm.

Compaction of the material in the pavement is best carried out immediately so that final trimming can be achieved within the working time of the binder. The slower setting characteristics of foamed bitumen stabilised materials allows more flexibility with compaction times. In colder climates, a 'cool' material may slow the setting, although this can be offset somewhat by the use of a better supplementary binder. Specific project circumstances should be taken into consideration at the design stage of works.

Some materials like sandstone and scoria are known to breakdown under heavy compactive effort. The reduction in particle size changes the PSD[1] and typically results in a less dense material. Practitioners have been known to spread hard coarse gravel to improve the final PSD of the stabilised material after mixing.

5 Building vibration limits

Over the last ten years, research on vibration limits has been focused on human or whole body vibration. Current vibration limits for buildings from road construction have either been based on DIN 4150 or experience, and the only recent published work[2] found on this topic is by Mayfield (1994). Mayfield noted that most road authorities limit the peak particle velocity to 2 mm/s and 5 mm/s for minimal complaints and maximum potential to damage respectively.

[1] PSD refers to particle size distribution.
[2] Relating to road construction sites.

6 Comparison of passes by static versus vibratory compaction

In road stabilisation, a single pass of a roller is defined as the travel from the start to the end of the mixing run. Tables 2 and 3 provide examples of equivalent static and vibratory roller passes used on various road sites. Note that these passes are dependent on subgrade strength and the material to be stabilised and cannot be relied on for all sites of equivalent depth. In Tables 2 and 3 a high speed pass refers to the roller speed of between 6 to 12 kph, whereas a low speed pass is typically less than 6 kph.

Table 2 Guide to compacting stabilised base materials 150 mm in depth.

Static compaction	Vibratory compaction
Initial Compaction: 8 high speed passes of a 18 t padfoot roller (no vibration) keeping pavement surface near OMC to 'walk the padfoot out' Post Trimming Compaction: 6 passes of a 9 t multi or 12 t three point roller	Initial Compaction: 4 low speed passes of a 15 t smooth drum roller on high vibration followed by 4 passes on low vibration. Post Trimming Compaction: 2 passes of a 15 t smooth drum roller on low vibration followed by 2 passes with no vibration (static)

Table 3 Guide to compacting stabilised base materials 300 mm in depth.

Static compaction	Vibratory compaction
Initial Compaction: 10 high speed passes of a 27 t padfoot roller (no vibration) keeping pavement surface near OMC to 'walk the padfoot out' Post Trimming Compaction: 6 passes of a 18 t multi or 8 passes of a 12 t three point roller	Initial Compaction: 4 low speed passes of a 27 t padfoot roller on high vibration followed by 4 passes on low vibration followed by 2 high speed passes static to 'walk the padfoot out' Post Trimming Compaction: 4 (up to) passes of a 15 t smooth drum roller on low vibration followed by 2 passes with no vibration (static)

It is noted that final trimming in preparation for sprayed seal running surface should be carried out as per standard practice for stabilised pavements using a water cart, grader and multi tyre roller.

7 Examples of static compaction

Table 4 lists the results of compliance testing on several road stabilisation projects using different binders and only static compaction. The relative compaction results from a NATA laboratory confirm that satisfactory results can be obtained from using static rolling techniques inlieu of vibratory compaction. The relative compaction in the table is a ratio of the insitu density measured using a NDG[3] and the reference density is a laboratory sample compacted using standard compactive effort.

Table 4 Typical range of density compliance results from use of static only compaction for various urban projects with different binders and layer thickness.

Pavement material	Binder (s)	Compacted depth (mm)	Relative compaction (%)
Crushed recycled concrete	GB cement	300	100.0 to 106.0
Clayey gravel & AC	Foamed bitumen & lime	200	101.0 to 107.0
Existing gravel & AC	GB cement	200	102.0 to 105.0

[3] NDG refers to Nuclear Density Gauge

8 Conclusion

This construction tip provides initial guidance for the selection of static rollers inlieu of vibratory rollers to achieve compaction compliance for stabilised layers. Not only is it important to get the best combination of rollers, but to maintain an appropriate moisture content to allow the hydration of cemented material[4] and to not exceed the OMC for the pavement material.

AustStab also recommends that accredited contractors are used for road stabilisation to meet all the compliance measures set out in specifications.

References and bibliography

Austroads (2003) *Controlling Moisture in Pavements* Technical Note 13, Austroads, Sydney, NSW

Austroads (2006) *Guide to Pavement Technology Part 4(e): Stabilised Materials* Austroads Project No: TP1089, Sydney, NSW.

AustStab (2000) *Profilers versus stabiliser* AustStab Construction Tip No.1, Chatswood.

AustStab (2006) *Lime Stabilisation Practice* AustStab Technical Guideline, Australian Stabilisation Industry Association, Chatswood, NSW.

DIN 4150 (1999) *Part 3, Structural vibration - Effects of vibration on structures*

Mayfield, M, Symons, MG and Collins, JR (1994) *Guide to the selection of vibratory rollers for road construction* Structural Materials and Assemblies Group, University of South Australia, Adelaide, SA.

Svedala Dynapac (2000) *Compaction and paving – Theory and practice* Dowell/Stubbs, Sweden

Tynan, AE (1973) *Ground vibrations – Damaging effects to buildings* Special Report No.1 Australian Road Research Board, South Vermont, Victoria.

Web Sites

The following websites provides more information on road stabilisation and compaction:
http://www.auststab.com.au
http://www.conplant.com.au
http://www.dynapac.com

For more information about the Association, please write to the Executive Director, AustStab, 14/29 Bertram Street, Chatswood NSW 2067 or email: inquiry@auststab.com.au or visit the web site at **www.auststab.com.au**

[4] When using cement and slow-setting binders.