Technical Guide: Designing with GRT Polymer Cement Modifier (PCM)

Document Title	**Technical Guide: Designing with GRT Polymer Cement Modifier (PCM)**
Version	**1.0**
Description	**First version and release of a Technical Guide in Designing with GRT Polymer Cement Modifier (PCM). The target audience for this Guide are Engineers, Pavement Designers and users of GRT products**

Disclaimer:
This guide is general in nature only and assumes engineering expertise by the user regarding the assessment of sub-grade design conditions, traffic loading, material characterisation, pavement rehabilitation and design application as well as ongoing maintenance. The guide focuses on the structural design of pavements rather than structural detailing or design detailing.

This guide refers to both new pavements and recycling or reuse of existing ones. The pavement thickness design principles apply equally to in-situ stabilisation and plant mixed material. It is the pavement designer's responsibility to satisfy themselves that the ground support conditions below the stabilised pavements are sufficient to allow proper compaction to occur and that sub-grade volumetric change associated with environmental effects has been appropriately considered.

The use of this design guide is only applicable to GRT PCM and is not compatible with other polymer modified additives produced from suppliers other than GRT.

Due to differences between design inputs and whole-of-life actualities (e.g. traffic growth, enforcement of, and changes to legislation relating to heavy vehicle loading, variability in construction, accuracy of design models, environmental considerations and ongoing maintenance and rehabilitation) the guidance contained in this document can provide only an indication of future pavement performance.

A global and integrated approach is required if high levels of pavement performance are to be achieved. It is emphasised that pavement design is only one aspect associated with the achievement of sound pavement performance. Sound pavement performance depends on a number of factors as illustrated below:

This document will be reviewed from time to time as the need arises and in response to improvement suggestions by users.

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BACKGROUND INFORMATION

Global Road Technology (GRT) polymer modified cemented materials may be described as a combination of a cementitious binder, GRT polymer, water and granular material which is mixed together and compacted in the early stages of the hydration process to form a pavement layer that is subsequently cured.

The curing process for GRT modified cement blends is different to that of conventional cement stabilised materials as outlined in GRT's construction specification.

The cementitious binder may consist of a combination of pozzolanic material that is compatible with the GRT polymer as determined by laboratory testing.

Commonly used cement blends normally used in conventional operations are suitable along with other blends which have an increased percentage of pozzolan waste by-product. The binder should be added in sufficient quantity to balance both strength and shrinkage requirements to produce a bound or modified material with significant tensile strength that does not exhibit the same shrinkage crack propensity as cemented materials when used alone. Typically, cementitious contents for GRT polymer mix designs are limited to 2 to 4% by weight.

Control does need to be exercised during construction over the water/cement and cement/polymer ratio as determined by GRT for each specific project.

The GRT polymer is a substance composed of nanoparticles which bond to form larger molecules. The simple molecules are known as monomers, and the reaction that merges them is called polymerization. The GRT polymer is a copolymer where two or more monomers are polymerized. The exact formulation is covered by a patent and has been developed by specialist polymer chemists and cement technologists.

Why use GRT Polymer modified cementitious blends?

Composite materials using polymer binders are widely used as structural chemically resistant, vibration and impact proof materials for industrial construction and chemical industry for over 20 years and are proven in other civil engineering fields.

Developed from the proven use of polymers in specialised structural concrete, GRT have developed polymers to be used in pozzolanic stablisation of pavement materials to overcome some of the current shortcomings associated with the use of cement alone including shrinkage cracking and curing times; and improve on properties of using cementitious materials alone.

The GRT polymer is a non-hazardous substance and requires minimal handling and environmental precautions. It is both environmentally and OHS friendly.

Some of the other advantages of GRT polymer modified pozzolanic blends when compared to conventional cement stabilised or treated pavements are detailed below:

1. • Significantly reduced or eliminated shrinkage cracking
2. • Improved curing at ambient temperatures
3. • Higher tensile, flexural and compressive strengths for equivalent cement content
4. • Improved vibration dampening
5. • Improved adhesion to most surfacings
6. • Improved long-term durability with respect to freeze and thaw cycles
7. • Lower permeability to water
8. • Improved chemical resistance
9. • Improved workability and requires less compactive effort for a given depth of compaction and can be compacted in greater single lifts

Whilst the GRT polymer does introduce improved toughness and fatigue life, at this stage of the products development, conventional cement materials fatigue characteristics are used in design.

Applications for the use of GRT Polymer Modified Pozzolanic Blends

- Potential suitable applications of GPMP blends include:
- Rehabilitation and strengthening of existing granular pavement
- Recycling/re-stabilisation of existing cement stabilised pavements which are exhibiting extensive shrinkage cracking
- Construction of pavements and/or working platforms in limited or constrained construction times or simply where reduced construction time frames deliver project efficiencies or benefits such reduced temporary traffic barrier hire
- Where design and construction efficiencies can be gained by increasing the depth of a single compacted cemented material layer
- In areas susceptible to high rainfall or inundation
- Working platforms - particularly in areas where the use of unbound materials may be susceptible to degree of saturation issues and the need for rework
- Over soft ground conditions where stiff bridging layers are required to compact overlying materials
- In other situations where improved support to overlying materials are required; in the case of an asphalt surfacing this may lead to longer asphalt fatigue life

- Where temporary trafficking of the pavement may be required during different stages of construction. (Depending on traffic volumes and environmental conditions at the time, GRT polymer modified pozzolanic blend pavements can generally be trafficked immediately after final compaction)
- Maximising use of locally won materials and for rendering marginal pavement gravels suitable or fit for purpose
- Modification or improvement of non-organic sub-grade condition
- Where construction water availability is limited – GRT polymer, when used with cement, reduces construction water requirements. Depending on the water quality, the GRT polymer may enable the use of non-potable water

Typical results achieved with the use of GRT Polymer modified Pozzolanic Blends

The results of flexural beam breaking testing for samples prepared using a TMR Type 2.1 gravel below show the benefits of the addition of GRT PCM compared to results produced from cement alone. Testing has shown at least a 30% increase in flexural strength.

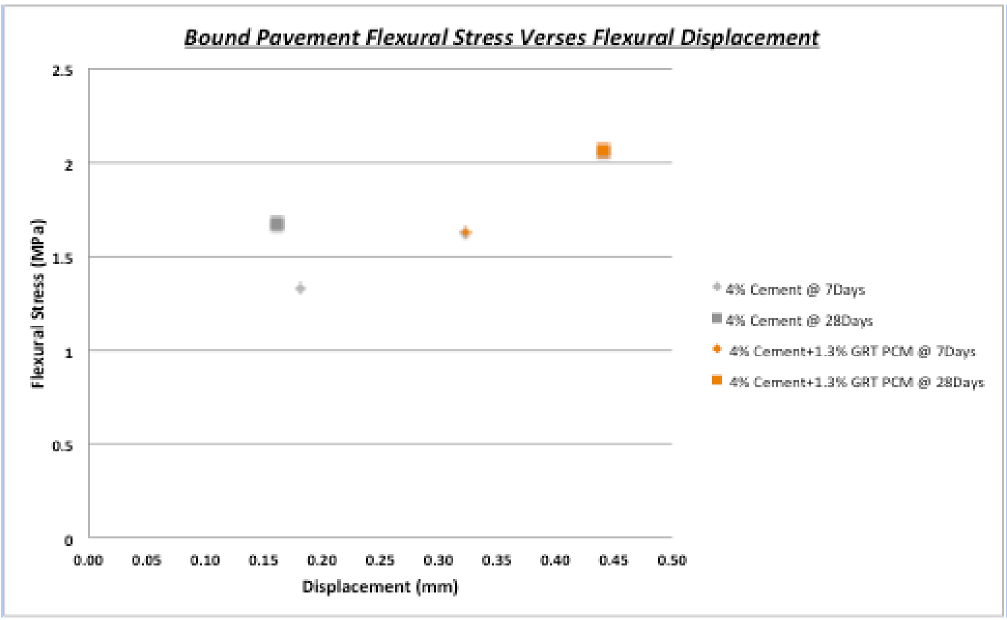


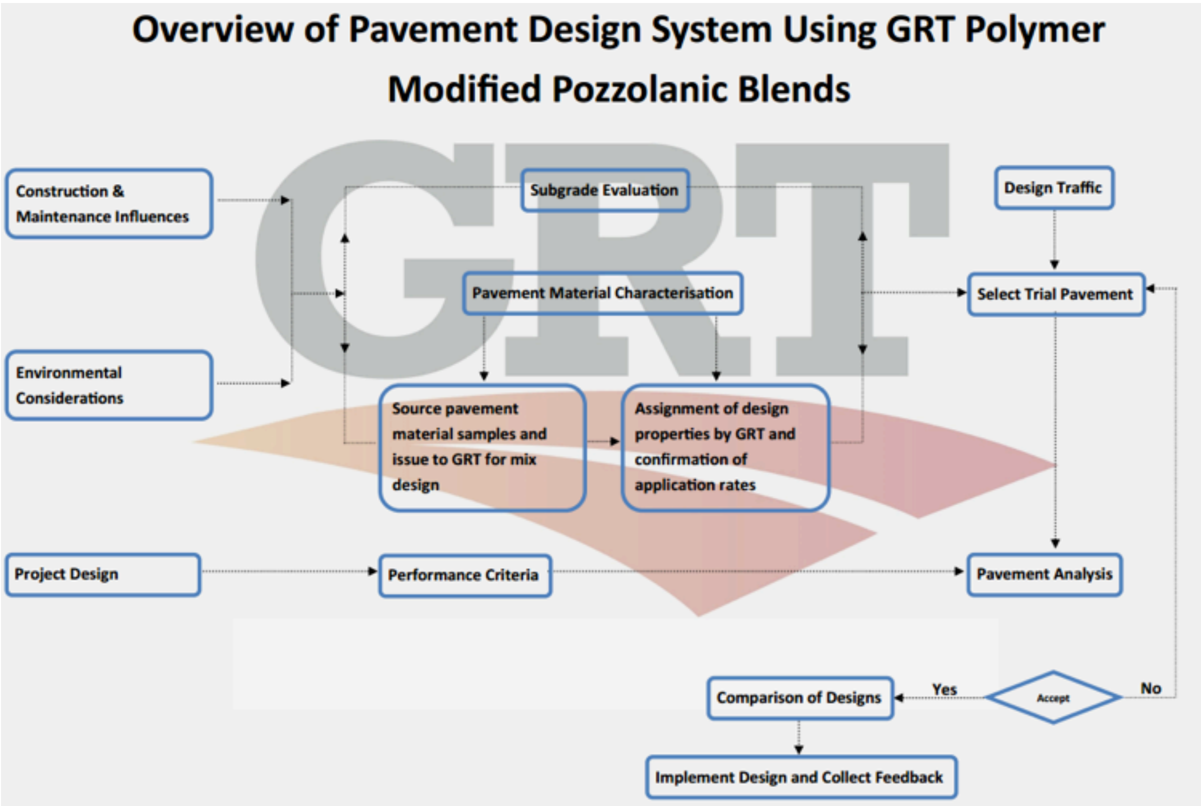
Figure 1 - Flexural Beam Break test on Modified TMR Type 2.1 Road Base

This testing was undertaken in according with "Third Point Break Test" to test method ASTM D1635/D1635M -12 and the results presented above are the average of three individual test results.

Overview of Pavement Design System using GRT Polymer Modified Cementitious Blends

This design guide aims to be compliment to established pavement design procedures and practices as recognised by relevant authorities. The guide is primarily based on Austroads pavement design practices.

The design flow chart described in this guide is summarised Below in Figure 2.



Design Traffic Loading (in accordance to Austroads Guide to Pavement Technology)

The design traffic loading shall be calculated in accordance with Section 7 of Austroads Guide to Pavement Technology Part 2: Pavement Structural Design 2012 together with locally endorsed practices which may be part of the clients design requirements (this may include but not limited to development guidelines, state road authority pavement design supplements, local council practices or project specific specifications).

Where available, Weigh-in-Motion (WIM) data specific to the subject road section should be used in the design traffic loading calculation. For the design of the GRT polymer modified cementitious layer, the same load damage exponent as that used for cement stabilised material alone is considered a good guide for use in design traffic calculations.

Empirical Thickness Design

In so far as employing empirical designs, the following empirical designs reproduced from National AustStab Guidelines, Pavement Design Guide for a Cement Stabilised base Layer for Light Traffic (Version B – 31 July 2012) may also be adopted.

Street Type [1]	IDT[2] (DESAs)	Cemented base layer thickness (mm)[5]				
		Design subgrade strength (CBR)				
		<3%	3% - 5%	6% - 10%	11% - 15%	>15%
Minor with single lane traffic	3×10^3	200	175	150	150	150
Minor with two lane traffic	4×10^3	200	175	150	150	150
Car park with no delivery vehicle	8×10^3	225	200	175	150	150
Local access with no buses	4×10^4	225	200	175	150	150
Local access with buses	8×10^4	250	225	200	175	150
Local access in industrial area	1.5×10^5	275[3]	250[4]	225	200	175
Collector with no buses	4×10^5	300[3]	275[4]	250	225	200
Collector with buses	8×10^5	325[3]	300[4]	275	250	225

Notes:

1. Street type as defined in Austroads pavement design guide.
2. Indicative design traffic in DESAs based on work by Austroads.
3. In the dark shaded region, it is recommended to stabilise the subgrade.
4. In the light shaded region it is suggested to stabilise the subgrade.
5. In some regions in Australia the minimum thickness is 200mm (values in italics).

The thickness of the stabilised layer shown in the table above is based on a cemented material tested in the laboratory to meet the unconfined compressive strength range (UCS) of 1 to 2 MPa at 7 days, prepared and tested to the following conditions:

- Sample size - 115.5 x 105 mm diameter cylinder
- Compaction at 100% standard or 98% modified
- 7-day curing at a 90% or more humidity and 23°C and precondition sample prior to testing with 4-hour soak (applicable for GP & GB cements)

- 7-day curing at 65°C and precondition sample prior to testing with 4-hour soak (applicable for slow setting cementitious binders, for example lime/slag and lime/fly ash blends)
- Refer to GRT for laboratory curing conditions that should apply with the use of PCM.
- UCS testing to AS1141.51

Mechanistic Thickness Design

In so far as providing guidance to suitability qualified persons wishing to produce customised designs using Circly, the recommended design process is the same as that adopted for conventional cemented gravel materials.

The fatigue relationship is as defined in Section 6.4.5 of Austroads Guide to Pavement Technology Part 2 : Pavement Structural Design is as repeated below.

$N = RF\,[\,(113000/E^{0.804} + 191)/\mu\varepsilon]^{12}$

Where

N = Allowable number of repetitions of the load

με = load-induced tensile strain at the base of the GRT polymer modified cemented material (mircrostrain)

E = GRT polymer modified cemented material flexural modulus (MPa)

RF = reliability factor for cemented materials fatigue defined by Table 6.8 of Austroads Guide to Pavement Technology Part 2: Pavement Structural Design is as repeated below for ease of use:

Desired Project Reliability				
80%	85%	90%	95%	97.5%
4.7	3.3	2.0	1.0	0.5

With future development of the GRT polymer modified cementitious blend fatigue relationship, it is likely that shift factors or a modified fatigue relationship may be applied to cater for the improved toughness and fatigue resistance that is attributable to the use of the GRT polymer. It is suggested current practice however to adopt the more conservative approach to thickness design.

Allowance of Pre and Post Cracking in Design

Where the pavement incorporates a GRT Polymer Modified Cementitious sub-base layer, the sub-base layer may consider a post-cracking phase of the design life if cracking from the fatigued GRT Polymer Modified Cementitious layer does not reflect through to the surface. To reduce the risk of reflective cracking the pavement should provide a minimum cover equivalent to 175 mm of bound material. Gravel material can be used as cover either solely (i.e. any spray sealed or thin asphalt surfacing is not considered to be part of the cover), or in conjunction with asphalt, subject to the following criteria:

(0.75 x thickness of granular material cover) + (thickness of asphalt cover) ≥ 175 mm

The cracked GRT Polymer Modified Cementitious material should be modeled as a cross-anisotropic material with a vertical modulus of 500 MPa, and a Poisson's ratio of 0.35. No sub-layering of the material is required.

Example Design Thickness Charts

A primary application of this document is the provision of a basis for developing design charts for specific circumstances. As an example of this, a number of charts for pavements are presented below. The charts have been developed using the mechanistic procedure. These charts must not be used for detailed design thickness design. They serve as an illustration of the application of mechanistic design procedures for GRT polymer modified cementitious layers and may be useful in selecting a trial pavement configuration. Trail pavements selected using the charts below are appropriate for design CBR's of between 3 and 15% and should not be projected beyond these limits.

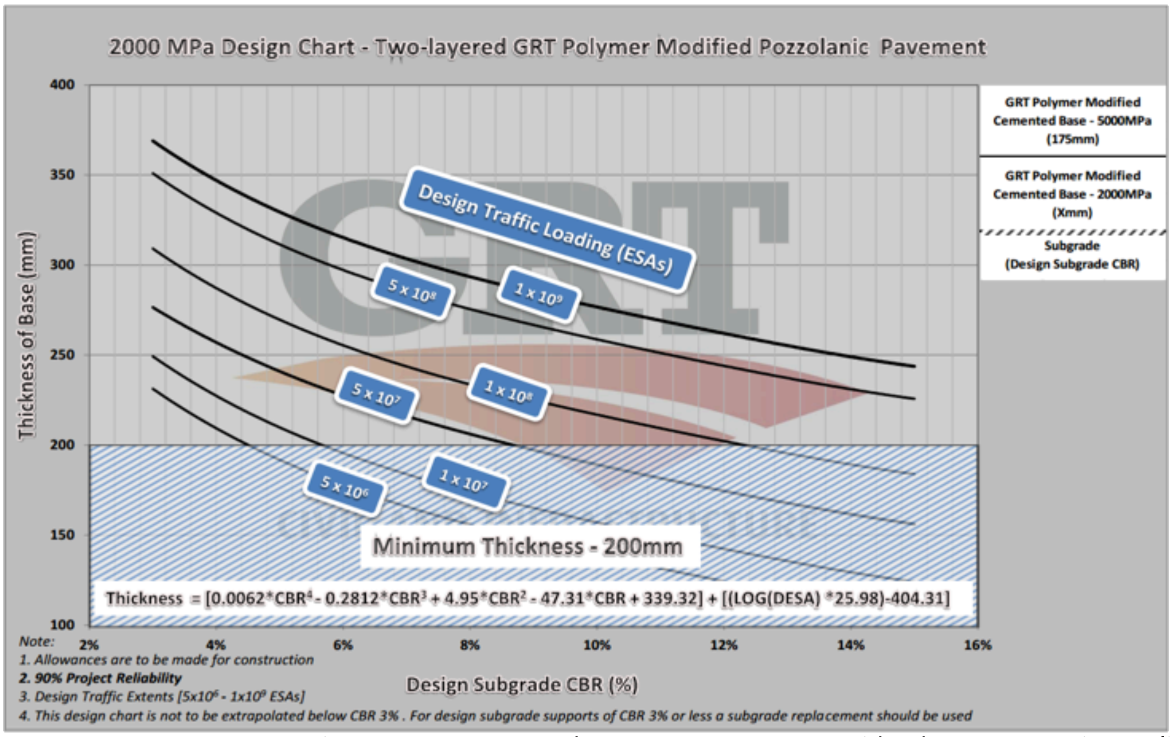


Figure 3 – Two Layered GRT PCM Pavement Guide Chart (90% Project Reliability)

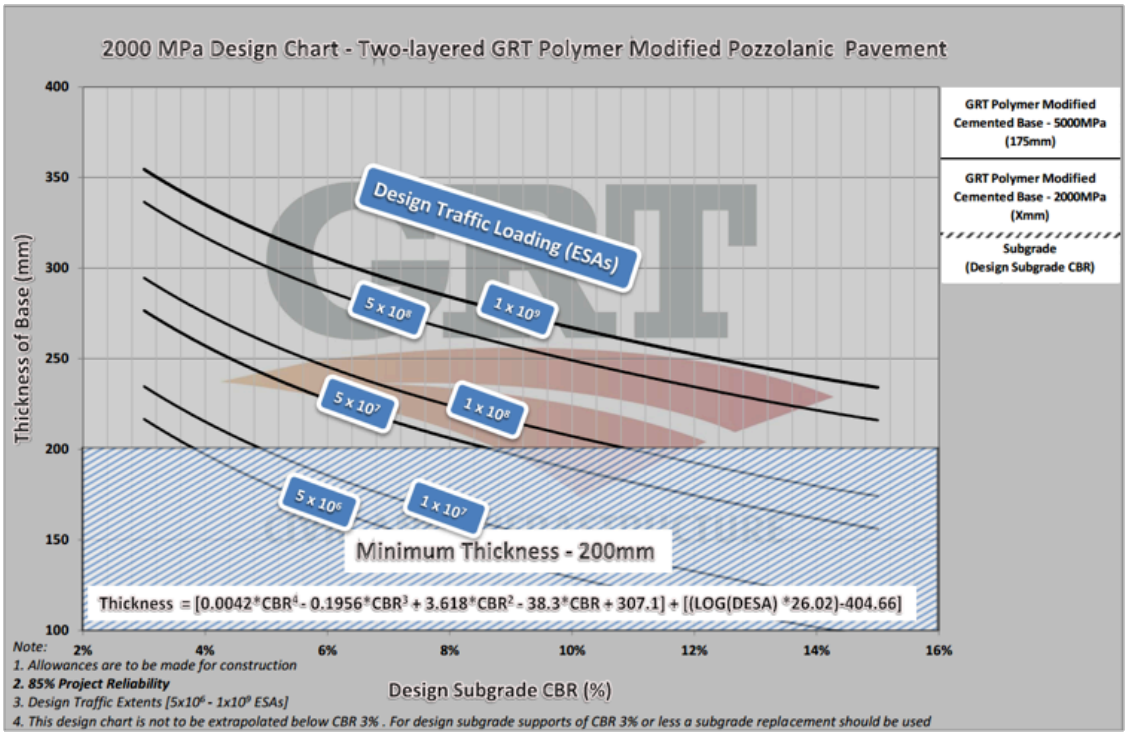


Figure 4 – Two Layered GRT PCM Pavement Guide Chart (95% Project Reliability)

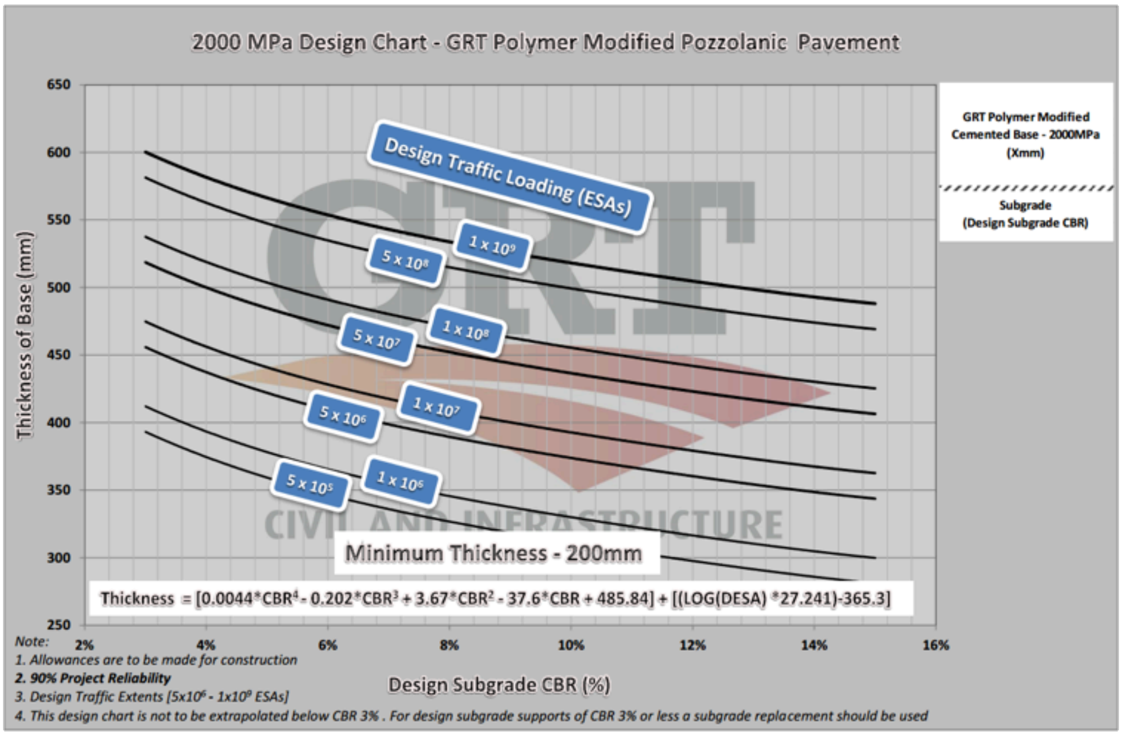


Figure 5 – GRT PCM Pavement Guide Chart (2000 MPa)

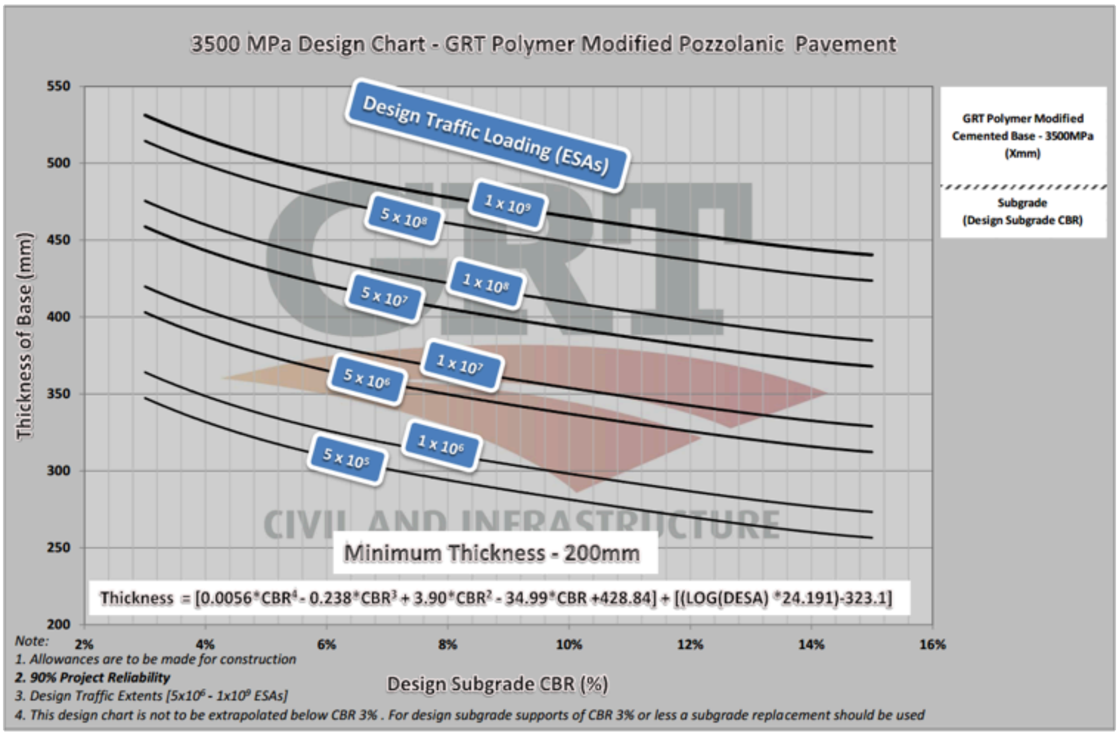


Figure 6 – GRT PCM Pavement Guide Chart (3500 MPa)

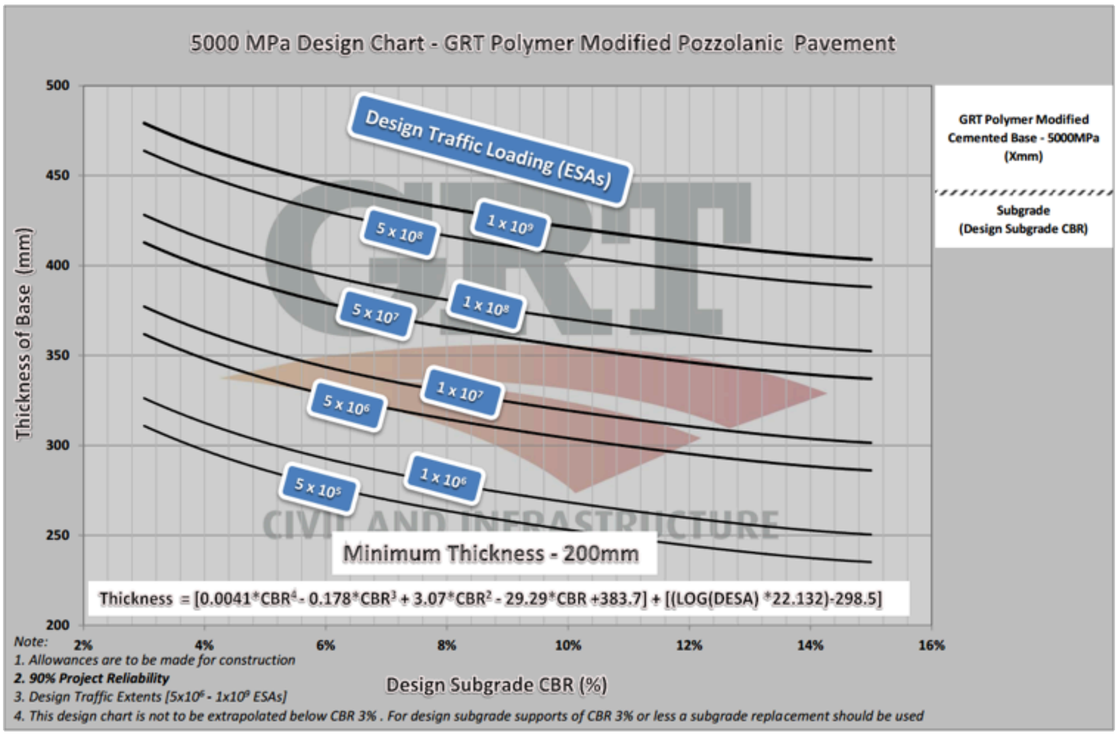


Figure 7 – GRT PCM Pavement Guide Chart (5000 MPa)

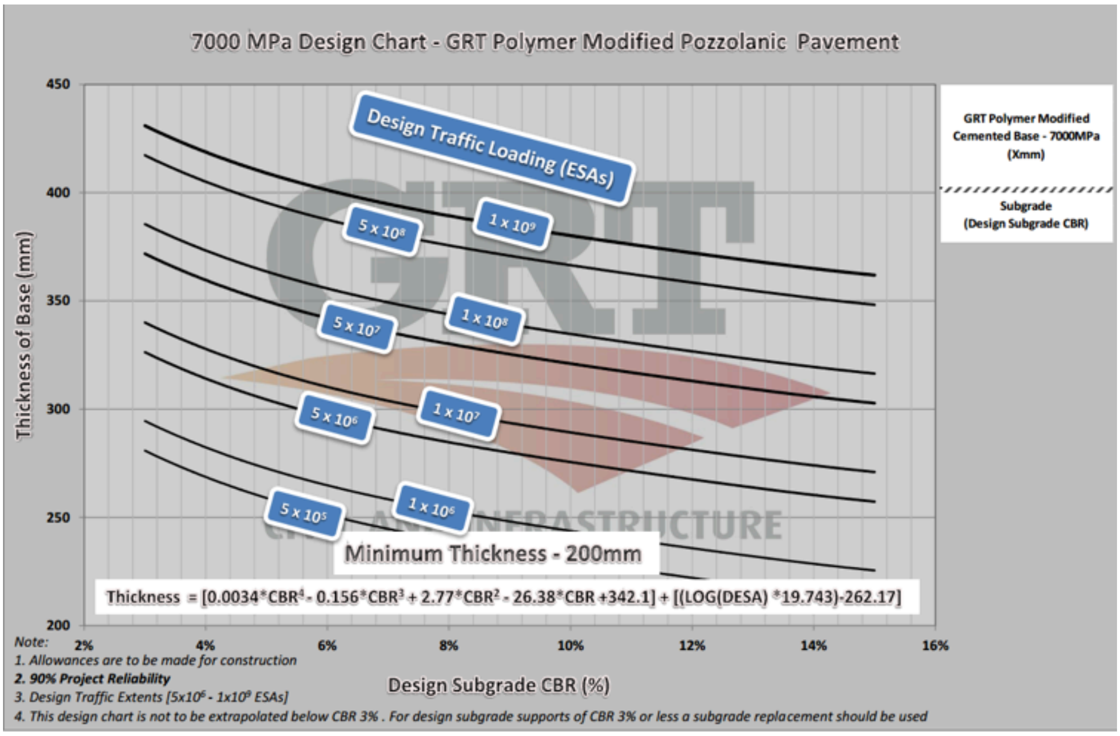


Figure 8 – GRT PCM Pavement Guide Chart (7000 MPa)

Heavy Duty Pavement Design

Heavy duty pavements relate to those pavements which carry wheel loads in excess of those carried by conventional roads and highways. They include airports, ports, container stacking areas and haul roads, all of which are typically subjected to significant wheel loads.

Many aspects of the design methods for highway/road pavements such as those presented in the new Austroads Pavement Design Guide (2012) are not appropriate for designing heavy duty flexible pavements for these applications.

Traditionally, heavy duty pavements have been designed using chart-based, empirical processes such as the British Ports Association method.

In more recent times, designers have used mechanistic analysis using Circly based design software such as HIPAV (Heavy Industrial Pavement Design) and APSDS (Airport Pavement Structural Design System).

For pavement designs completed using empirical based methods, the use of Material Equivalency Factors such as that outlined in the British Ports Association Method are suggested. In the case of those procedures that incorporate cemented gravels material characteristics such as UCS and resilient modulus using GRT PCM should be matched to the properties required by cemented materials alone.

For pavement designs completed using mechanistic design methodology, the same methodology as that adopted for cemented materials alone shall is suggested.

Determination of Binder Dosages

A number of factors affect the field performance of cementitious pavements in general, including but not limited to; weather conditions at and around the time of construction and water table levels.

Laboratory testing of mix designs are required to validate binder dosages required giving due consideration to potential risk factors for both design and construction. So as to optimise the cementitious and GRT binder application rates, an iterative process is recommended.

A construction tolerance of 0.5% for the Cementitious binder application rate and 0.2% for the GRT polymer are recommended to allow for construction variability.

Binder dosages for both Cementitious and GRT polymer binder are calculated as shown below:

- Cementitious binder application rate in kg/m² = Design thickness in mm x Design dosage plus 0.5% construction tolerance expressed as a decimal x compacted density of material being stabilised in t/m³
- GRT polymer binder application rate L/m² = Design thickness in mm x Design dosage plus 0.2% construction tolerance expressed as a decimal x compacted density of material being stabilised in t/m³

As an example, if laboratory testing identified the optimum binder dosage of 2% Cementitious binder and 0.3% GRT binder, for a material with a compacted density of 2.3 t/m³ and a pavement design thickness of 200 mm, the following field application rates may be adopted:

- Cementitious binder application rate = 200 x ((2+0.5)/100) x 2.3 = 11.5 kg/m²
- GRT polymer binder application rate = 200 x ((0.5+0.2)/100) x 2.3 = 3.22 L/m²

A Guide to Typical Binder Dosage

The thickness design of the stabilised layer is based on UCS test results achieved by laboratory testing. If local knowledge is not available, the following application rates by mass may be used as a guide only for a laboratory test program to target a 28 day UCS result of at least 2 MPa. Finalised dosages will vary depending on several factors including but not limited to the chemical composition of fine grained materials, Atterberg limits and fines ratio of granular materials being tested. The addition of lime is recommended for PI's > 20.

Particle Size	More than 25% passing 0.425 sieve			Less than 25% Passing 0.425mm sieve		
Plasticity Index	PI ≤ 10	10 <PI <20	PI ≥ 20	PI ≤ 6 WPI ≤ 60	PI ≤ 10	PI ≥ 10
Cementitious Dosage (% by weight)	3 to 4	3 to 5	3 to 7	2 to 3	2 to 3	3 to 5
GRT Polymer Dosage (% by Weight)	0.5 to 1.5	0.5 to 1.5	1 to 1.5	0.5 to 1.5	0.5 to 1.5	0.5 to 1.5
Lime Dosage	n/a	n/a	3 to 5	n/a	n/a	n/a

Typical Production Rates

Typical production rates vary depending on construction logistics and site conditions. Typically for small non-continuous areas, production rates may be < 2000 m² per day whereas for large continuous areas, construction rate of up to 5000 m² per day or more may be achieved.

References

Austroads Guide to Pavement Technology Part 2: Structural Design, 2012

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Austroads Guide to Pavement Technology Part 4 (d): Stabilised Materials, 2006

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