# Do Dry Powdered Polymers Work?

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## ABSTRACT

Rehabilitation of existing roads by stabilising with cementitious and bituminous binders has been well-documented and proven to be a successful process. Recently, an Australian developed 'Dry Powdered Polymer' (DPP) has found wide acceptance within the road industry. DPP expands the range of pavement materials and situations for which stabilisation is suitable. DPP was first incorporated into pavements in 1988 and has since been extensively used in National and State Highways in Australia and parts of Asia.

The Australian Stabilisation Industry Association (AustStab) has defined Dry Powdered Polymer as 'a dry powdered road stabilising binder consisting of an insoluble polymer thermally bound to a very fine carrier such as fly ash'. This comprehensive definition avoids confusion with water-soluble binders that are sometimes referred to as polymers.

Most road gravels have adequate strength to resist typical traffic stresses when dry but dramatically lose strength when wetted up. When wet clay fines within gravels become 'greasy', they lubricate the larger particles resulting in plastic deformation.

The aim of DPPs is to preserve the 'adequate' dry strength of water-susceptible gravels by a process of 'internal' waterproofing of fine grained particles. This involves creating a hydrophobic soil matrix between the particles which limits water ingress. The typical softening and lubricating effect of any moisture that enters the gravel is also significantly reduced.

Since DPP stabilisation does not involve a cementitious chemical reaction, gravels incorporating DPP remain flexible and therefore are not susceptible to shrinkage, racking or premature fatigue load failure.

The process used to establish the suitability of DPP stabilisation requires basic soil parameters to be determined, such as maximum dry density, optimum moisture content, particle distribution and Atterberg limits. Once these parameters have been established, the correct DPP binder type can be chosen to then carry out CBR testing, and capillary rise and swell as per Australian Standard AS 1141.53 – 1996.

Laboratory results conducted over the last ten years by several state and local government authorities has consistently shown a considerable increase in soaked CBR strength when mixed with DPP for moderate to poor quality gravels. Performance in the field during the same period has seen minimal to no change to the 'as-built' formation shape and condition, and without failure or repair expenditure attributed to DPP binders to date.

Many DPP stabilised pavements have already experienced traffic loadings in excess of 2.0E+07 equivalent standard axles (ESAs) per lane. Their current shape and excellent condition strongly suggests that many more maintenance free years will continue, therefore ensuring highly competitive whole-of-life costs.

This paper documents much of the hundreds of kilometres of roadway constructed using DPPs and presents guidelines for their use.

# 1. INTRODUCTION

Since the beginning of the 1990's, large stabilising equipment became readily available in Australia. Large stabilisers such as CMI and Wirtgen were found to successfully and uniformly mix existing road formations up to depths of 400mm. Road authorities were quick to realise that insitu stabilisation could provide considerable economic savings when compared to funding traditional granular overlay projects.

The majority of insitu stabilisation incorporated cementitious binders that strengthened pavements by producing significant tensile strength (bound pavements). However, shrinkage cracking often accompanied the 'cementing' process which required sealing of cracks to avoid or minimise pumping of fines and premature block cracking. While most bound pavements perform well in their early service life, when correctly designed and constructed, the demand for diligent crack surveillance and progressive heavy patching repairs increases with age.

Slow-setting cementitious binders such as slag/lime, slag/lime/flyash and GB cement were found to delay the progression of micro-cracking to macro-cracking. However, bound pavements are significantly more sensitive to vehicle overloads and localised deficiencies in thickness and layer stiffness.

For medium to high trafficked roads, treatment depths for bound pavements needed to be in excess of 300mm. Many such pavements were commonly up to 370mm thick. Alternatively, bound subbase treatment depths of up to 250mm have been constructed with either 200mm or more of unbound granular overlay or up to 175mm of asphalt overlay.

However, insitu bound pavements are not always feasible due to the deficiency in thickness of existing pavement material. Notwithstanding the increasing environmental concerns and difficulty to obtain new raw materials, the cost to import granular overlay material is often inhibitive when considering the highly competitive needs within any given road network.

For unbound granular pavement designs, overlay thicknesses can often mean importing 200mm to 400mm of gravel to satisfy current design guidelines for a twenty plus year design life on high volume roads. Based on complying with current pavement design guidelines, the cost to rehabilitate and provide conforming pavement structures is not regularly afforded within the maintenance and upkeep budget of most road networks.

Within the current pavement design guidelines, all efforts are directed towards minimising surface rutting by limiting the vertical compression strain at the top of the subgrade i.e.: increased rut resistance and protection of the subgrade is only achieved by significantly increasing the stiffness of a stabilised layer or a significant increase in depth of unbound granular overlay. Specifically, the design method can not factor in the benefits of reduced plastic deformation of a layer or the benefits of waterproofing produced by a Dry Powdered Polymer (DPP) binder. As a result, pavement designers must currently rely on the accumulated field evidence to assess the effectiveness of DPP stabilisation.

## 1.1 What is a dry powdered polymer?

Within the local road industry, only brief descriptions of polymers are provided in stabilisation literature. The Austroads Guide to Stabilisation in Roadworks (Austroads, 1998) deals briefly with polymers in Sections 8.3.1, Polymer in Dry Powder Form, and 9.8.2.3, Powdered Polymer Stabilisation. The Australian Stabilising Industry Association (AustStab) (1998) has defined the material as, *'A dry powdered road stabilising binder consisting of an insoluble polymer thermally bound to a very fine carrier such as fly ash'*. This comprehensive definition avoids confusion with water-soluble stabilisers that are sometimes referred to as polymers.

The DPP consists of an insoluble polymer thermally bound to an 'inert fine carrier', which is then added to small percentages of hydrated lime. The lime is not coated with polymer. The lime's function is only to flocculate and prepare clay particles for adhesion to the polymer rather than generate pozzolanic reactions that produce cementitious bonds.

There are three DPP products available, Polyroad PR100, PR21L and PR11L. PR100 consists of 100% polymer-coated fine carrier spread at a rate of 1% by weight and is targeted at non-plastic gravels. PR21L consists of a mixture of 67% polymer-coated fine carrier and 33% hydrated lime spread at a total rate of 1.5% by weight for gravels having a Plasticity Index (PI) of 12% and below. PR11L consists of a mixture of 50% polymer-coated fine carrier and 50% hydrated lime spread at a rate of 2% by weight for gravels having a PI of 12% to 20%. Through extensive research and development, and early field trials, 1% by weight of DPP is sufficient to coat all fine grained particles and provide the desired waterproofing effects.

Polyroad's DPP has been scientifically evaluated by CSIRO (Melbourne) using an electron microscope on several occasions during the last twelve years. Samples of DPP stabilised pavement have been examined and shown that the DPP has not degraded in the field.

### 1.2 How dry powdered polymers work?

Most road gravels have sufficient strength to resist typical traffic stresses when dry however, they dramatically lose strength when wetted up. When wet clay and silt fines within gravels become 'greasy' they lubricate the larger aggregates resulting in permanent plastic deformation.

DPPs act to preserve the 'adequate' dry strength of water-susceptible gravels by a process of 'internal' waterproofing. This involves creating a hydrophobic soil matrix between the aggregates which reduces permeability and limits water ingress. The typical softening and lubricating effect of any moisture that enters a granular pavement is also significantly reduced ('internal' waterproofing).

Because DPP stabilisation does not involve a cementitious chemical reaction, the incorporation of DPP is not associated with a time constraint during mixing and achieving compaction as occurs with other binders.

## 2. GUIDELINES FOR THE ASSESSMENT AND USE OF DRY POWDERED POLYMERS

### 2.1 Assessing material suitability

The process used to establish the suitability of DPP stabilisation requires basic soil parameters to be determined, such as maximum dry density, optimum moisture content, particle distribution and Atterberg limits. Once these parameters have been established, the correct DPP binder type can be chosen to then carry out CBR testing, and capillary rise and swell as per Australian Standard (AS 1141.53 – 1996).

#### 2.1.1 *Particle distribution*

An assessment of particle distribution is required to ensure sufficient fine grained particles are present within the gravel to provide satisfactory 'internal' waterproofing i.e., a dense graded matrix. From extensive laboratory results and performance in the field, it is recommended there be a minimum of 35% of material passing the 2.36mm sieve. For example, the recommended minimum percentage passing the 2.36mm sieve is similarly required in the Roads and Traffic Authority's Materials QA specification for unbound and modified base and subbase materials (RTA QA Specification 3051).

While base and subbase gravel specifications also limit the percentage passing 2.36mm (typically not more than 55%) DPP stabilisation is enhanced with moderately high percentages passing the 2.36mm sieve (refer capillary rise and swell).

### 2.1.2 *Plasticity Index*

Gravels need to be tested for PI to ensure the correct DPP binder type PR21L or PR11L is chosen i.e., extent of hydrated lime required to enable complete polymer-coating of clay plates or alternatively PR100 for non-plastic gravels.

For gravels having a PI in excess of 20%, pre-treatment with hydrated lime or quicklime is required. Laboratory testing should be carried out to ensure the desired PI range after pre-treatment is achieved relative to the binder type proposed.

### 2.1.3 *Capillary rise and swell*

Capillary rise and swell testing as per AS 1141.53 is highly recommended to provide visual evidence of compatibility and integrity of the DPP treated sample. It should be remembered that this test method is designed to represent free subgrade moisture. In reality, very wet subgrades typically will not support construction plant irrespective of pavement treatment proposed and therefore would require pre-treatment of the subgrade.

For gravel samples with a high percentage of fines passing the 2.36mm sieve eg; 50% or more, only minor capillary rise is observed, typically 20% to 30% maximum.

For gravel samples with the minimum recommended percentage of fines passing the 2.36mm sieve, up to 100% capillary rise may be observed. However, the compacted sample will not deteriorate nor will it impact upon soaked CBR strength results. At the same time of observing high capillary rise, it is common that the sample will measure 0% swell. Because the clays and silts within the gravel sample have been physically coated by the DPP, water cannot successfully penetrate to the fine grained particles to cause detrimental affects upon swell or strength.

### 2.1.4 *CBR testing*

CBR testing is strongly recommended particularly when comparing the raw parent gravel against the DPP treated sample. Moderate to poor quality gravels record the greatest strength increases. Table 1 is indicative of the range of CBR strength increases that occurs after DPP stabilisation.

Minor strength increases usually occur with high quality crushed rock base gravels. However, these gravels are significantly less moisture sensitive when stabilised with the DPP due to the polymer coating and subsequent protection from moisture of clays and silts after stabilisation.

## 2.2 Design considerations

Guidelines for DPP stabilisation have been published in;

- AUSTROADS APRG Technical Note 14
- AustStab Technical Note No. 3
- GeoPave Technical Note No. 53
- RTA Towards Best Practice, Modification of base course materials using Polyroad, Reference: 2003/02

**Table 1** Example of CBR % strength increases after DPP stabilisation.

| Project Location | 4 Day Soaked CBR % of Existing Pavement Material | 4 Day Soaked CBR % after DPP Stabilisation |
|---|---|---|
| Pacific Highway at Cooperabung, NSW | | |
| Lot B1 | 15 | 110 |
| Lot B2 | 40 | 80 |
| Lot B3 | 20 | 60 |
| Lot BP5 | 30 | 120 |
| Lot BP8 | 60 | 120 |
| Oxley Highway 5km west of Port Macquarie, NSW | | |
| Lot B1 | 25 | 50 (9 day soak) |
| Lot B2 | 25 | 45 (10 day soak) |
| New England Highway 31km south of Tamworth, NSW | | |
| Sample P5 | 50 | 150 |
| Sample P6 | 100 | 120 |
| Kulgera Pit, Northern Territory | | |
| Sample 420 | 68 | 140 |
| RTA South West Region NSW, State and National Highways projects that incorporate Prior Stream gravels – typical range of past results | 5 to 40 (10 day soak) | 45 to 80 (10 day soak) |
| Note: All Lots/Samples in NSW tests consist of a blend of quarry and ridge gravels. Prior Stream gravels are clayey/silty sands. | | |

The benefits that DPP's provide by way protection of fine grained granular particles and reduced permanent plastic deformation of pavement materials is not directly modelled in current pavement design procedures. Whereas the mechanistic design model in the Austroads guide assumes the subgrade will fail due to subgrade rutting, increasing vehicle loads and tyre pressures increase the potential of granular pavements to rut before the subgrade. In the absence of a suitable estimate of pavement life in this scenario, the design of DPP stabilisation is based on accumulating field evidence over the last 10 years involving State and National Highways, and Local Government Roads.

Additionally, information provided in the following section regarding performance of DPPs in the field contains many examples of varying traffic regimes, existing pavement profiles and indicative subgrade strengths. The field examples are indicative of the successful performance for all rehabilitation projects carried out to date.

# 3. PERFORMANCE OF DRY POWDERED POLYMER STABILISATION

## 3.1 Overview

The earliest documented example of DPP stabilisation took place in 1988 in a section of Taree airfield runway, NSW (Polymix Industries, 1998). Since 1998, DPP stabilisation has been used by New South Wales, Victorian, Queensland and Tasmanian State Road Authorities, numerous Local Government Authorities in NSW and Victoria and overseas in Brunei and Papua New Guinea.

Stabilisation depths of 200mm are most common but depths of 150mm and 300mm to 325mm have been carried out. The majority of DPP stabilisation has occurred on National and State Highways within NSW carrying 20 year design traffic loadings between 106 and low 108 equivalent standard axles (ESAs).

In accordance with Austroads Guide to the Structural Design of Road Pavements, Figure 8.4 (Austroads, 1992), many of the pavements stabilised from the early nineties should have theoretically failed by now (low subgrade CBR strengths and considerably less pavement thickness than required). Their ongoing ability to perform without pavement misshape or maintenance repair to date, is predominantly a result of no plastic deformation occurring within the pavement because of the 'internal' waterproofing of fine grained particles that DPPs provide.

### 3.2 Performance in the field

To understand and appreciate the performance of DPPs, the following table summarises some of the National and State Highways in NSW which have incorporated DPP stabilisation. Indicative twenty year design life, available pavement depths, actual stabilised depths and theoretical pavement thicknesses required are outlined.

**Table 2** Overview of design parameters and available pavement thicknesses.

| Description | Indicative 20 year design life (ESAs) | Approximate thickness of granular pavement required[1] | Depth of existing pavement in the field[2] | Actual depth of DPP stabilised layer |
|---|---|---|---|---|
| Newell Highway - National (Tocumwal to Marsden) | High $10^7$ To Low $10^8$ | 600mm on CBR 5% 450mm on CBR 8% | 150mm to 350mm | 150mm to 300mm, commonly 200mm |
| Sturt Highway - National (Wagga to Wentworth) | Mid to High $10^7$ | 575mm on CBR 5% 425mm on CBR 8% | 130mm to 200mm | 150mm to 325mm, commonly 200mm |
| Riverina Highway - State (Corowa to Deniliquin) | Mid to High $10^6$ | 475mm on CBR 5% 375mm on CBR 8% | 150mm to 200mm | 200mm |
| Main Road 57 – State (Junee to West Wyalong) | High $10^6$ to Low $10^7$ | 500mm on CBR 5% 400mm on CBR 8% | 150mm to 200mm | 200mm |
| Note: 1. Thickness based on Figure 8.4 from Austroads pavement design guide (1992) and CBR values based on 10-day laboratory soaked conditions. 2. Pavement materials in the field includes base and subbase (mostly one material source only), and is directly upon the subgrade. | | | | |

In Table 2, the typical depth of existing granular pavement and resultant DPP stabilised depth are considerably less than theoretically required to provide a twenty year design life. As shown in the above table, some of the DPP stabilised pavements have in fact incorporated part of the subgrade (material blend tested prior to construction approval).

The subgrade CBR strengths listed above are indicative of known test results through extensive geotechnical investigation over the last fifteen years. It should also be noted that many of the existing pavement materials prior to stabilisation do not have high elastic modulus values (vertical MPa). Whereas Austroads Table 6.4 (Austroads, 1992) suggests a subbase gravel over granular material may have a presumptive modulus of 250 to 300 MPa, many of the sites have base materials (Prior Stream gravels) of less than 200MPa. When wetted up, Prior Stream gravels perform extremely poorly due to its high percentage of fine grained particles.

While road authorities have been encouraged to establish correct control sections to compare Polyroad DPPs against other treatments, little has been established until recently. However, the following examples are in close proximity to other base and subbase stabilisation treatments and full depth pavement construction in accordance with Austroads pavement design guidelines (Austroads, 1992).

It should be noted that for considerable lengths at a time along many of the State and National Highway examples provided there is consistency in pavement materials, subgrade conditions, traffic regimes and environment. Only Polyroad DPP stabilised pavements have performed without pavement distress, misshape or maintenance expenditure since constructed.

Examples of specific site details and recent photographic records for locations listed in Table 2 are provided.


**Figure 1** Newell Highway 35 km north of West Wyalong (photographed Dec 2002).

Site Details (for Figure 1):

- AADT = 3500 vehicles per day
- Indicative 20 year design life ESAs = high $10^7$ to low $10^8$
- Constructed Jun 1996
- Expansive black soil subgrade
- Retained formation shape
- No shoulder deformation
- Percentage heavy vehicles = 45%
- Estimated back-calculated ESAs to date = $2X10^7$ per lane (RTA Vehicle Usage Survey, 2001)
- Stabilised 200mm deep with Polyroad PR21L (1.5% spread rate)
- Conventional cutback bitumen seals
- No wheelpath rutting


**Figure 2** Newell Highway 42 km north of Jerilderie (photographed Dec 2002).

Site Details (for Figure 2):

- AADT = 3300 vehicles per day
- Indicative 20 year design life ESAs = high $10^7$ to low $10^8$
- Constructed May 1996
- Conventional cutback bitumen seals
- No wheelpath rutting
- Percentage heavy vehicles = 50%
- Estimated back-calculated ESAs to date = $2X10^7$ per lane (RTA Vehicle Usage Survey, 2001)
- Stabilised 200mm deep with Polyroad PR21L (1.5% spread rate)
- Retained formation shape
- No shoulder deformation


**Figure 3** Sturt Highway 60Km west of Wagga Wagga (photographed Dec 2002).

Site Details (for Figure 3):

- AADT = 2700 vehicles per day
- Indicative 20 year design life ESAs = mid to high 107
- Stabilised 200mm deep with Polyroad PR21L (1.5% spread rate)
- Floodway included in stabilisation
- Less than 2mm wheelpath rutting
- Percentage heavy vehicles = 35%
- Constructed Feb 1996
- Conventional cutback bitumen seals
- Retained formation shape
- No shoulder deformation

**Figure 4** Riverina Highway 22 km west of Finley (photographed 2002).

Site Details (for Figure 4):

- AADT = 1500 vehicles per day
- Indicative 20 year design life ESAs = mid to high $10^6$
- Stabilised 200mm deep with Polyroad PR11L (2% spread rate)
- High water table and constant head of capillary rise
- Retained formation shape
- No shoulder deformation
- Percentage commercial vehicles = 25%
- Constructed Sep 2000
- Adjacent to Mulwala Irrigation Canal – largest canal within Murray Irrigation Area
- Conventional cutback bitumen seals
- Less than 2mm wheelpath rutting

**Figure 5** Main Road 57 (State Highway) Temora Township (photographed Dec 2002).

Site Details (for Figure 5):

- AADT = 1750 vehicles per day
- Indicative 20 year design life ESAs = high $10^6$ to low $10^7$
- Stabilised 200mm deep with Polyroad PR21L (1.5% spread rate)
- Retained formation shape
- No shoulder deformation
- Percentage heavy vehicles = 35%
- Constructed Apr 2000
- Conventional cutback bitumen seals
- No wheelpath rutting

### 3.3 Actual performance versus theoretical pavement life

The following table provides an indicative comparison of performance to date versus theoretical pavement life based on the traffic regime, pavement profile and design subgrade qualities of some of the above examples.

Table 3 is indicative of what has been measured in the field to date. The inclusion of an optimistic subgrade value of CBR 12% is merely for comparison purposes. Under normal seasonal conditions many of the locations listed in Tables 2 and 3 do not regularly achieve moderate to high subgrade strengths.

**Table 3** Sample of actual performance versus theoretical pavement life.

| Location | Pavement Profile - Best Case[1] | Const Date | Age (Yrs) | Approx ESAs to Date | Life Expectancy[2] (ESA) CBR 8% | Life Expectancy[2] (ESA) CBR 12% | Approx Theoretical Failure [3] |
|---|---|---|---|---|---|---|---|
| Newell Highway 35km north of West Wyalong | 200mm DPP over 100mm remaining gravel | Jun '96 | 7.5 | $2 \times 10^7$ | $8 \times 10^5$ | $1 \times 10^7$ | Late 1996 for Subgrade CBR 8%, or Early 2000 for Subgrade CBR 12% |
| Newell Highway 42km north of Jerilderie | 200mm DPP over 50mm remaining gravel | May '96 | 7.5 | $2 \times 10^7$ | $1 \times 10^5$ | $1 \times 10^6$ | Mid 1996 for Subgrade CBR 8%, or Early 1997 for Subgrade CBR 12% |
| Sturt Highway 60km west of Wagga Wagga | 200mm DPP over 50mm remaining gravel | Feb '96 | 7.75 | $5 \times 10^6$ | $1 \times 10^5$ | $1 \times 10^6$ | Mid 1996 for Subgrade CBR 8%, or Late 1997 for Subgrade CBR 12% |

Note: 1. Existing pavement in the field includes base and subbase (mostly one material source only), and is directly upon the subgrade.
2. Life Expectancy in ESA is based on pavement profile & design subgrade CBR of 8% or 12%, and using Figure 8.4 from Austroads pavement design guide (1992).
3. CBR based on 4 day soaked.

The ongoing ability of DPP to perform without pavement misshape or maintenance to date is predominantly a result of no plastic deformation occurring within the stabilised pavement because of the 'internal' waterproofing of fine grained particles. As has been historically recognised within the road industry, pavements that have managed to remain 'dry' have delivered a service well in excess of their estimated design life.

# 4. ENVIRONMENTAL INFLUENCES

## 4.1 Local experience

The following two examples explain further the attributes of DPP stabilisation in difficult environmental situations.

Figure 7 shows typical environmental cracking resulting from expansive subgrade and variable moisture regimes. When gravels are stabilised with DPPs, moisture movement is significantly inhibited therefore maintaining equilibrium for significant periods at a time. As a result, environmental cracking does not occur after DPP stabilisation. The subgrade material at this location is equivalent to the subgrades underlying the pavements in Figures 4 and 5 above which have been stabilised with DPP.

**Figure 7** Sturt Highway approximately 70km west of Wagga Wagga (NSW).

**Figure 8** Sturt Highway approximately 100km west of Narrandera (NSW).

For the same principle as explained above, DPP stabilisation controls moisture regimes such as severe dry-back during drought periods. While cracking due to drought may be observed within the surrounding terrain and up the embankment formation, once the cracking intercepts the edge of DPP stabilisation, cracking then only travels longitudinally and does not propagate across the stabilised pavement. Drought conditions have only occurred for the last two years.

It should be noted that the pavement thickness at Figure 8 conforms to the current mechanistic design model in the Austroads guide. However, several locations of DPP stabilised pavements occur within a few kilometres either side of Figure 8 project site and which do not conform to Austroads pavement thickness guidelines. Observations to date of the DPP stabilised pavements indicate there is no pavement distress as a result of drought conditions.

## 4.2 Freeze-thaw testing

Polyroad's ability to significantly control moisture ingress has recently been confirmed yet again during testing in Finland. The Institute of Structural Engineering at Tampere University (Tampere University of Technology, 2003) has confirmed Polyroad's ability to also withstand frost heave and prevent permanent axial deformation as a result of repeated load triaxial testing.

The University tested two local materials commonly used in their road pavements (Lillby and Emet crushed aggregates). Different binders were incorporated with these materials and tested for dielectricity and resilient modulus. The University advised that Polyroad DPP is treatment agent D as shown in the following graphical results contained within their report.

Based on past experience by the University, a good quality base course material has a lower dielectricity value than 10. Poor quality material have dielectricity values greater than 16.

Figure 9 and 10 demonstrates Polyroad DPP has achieved the desired result (dielectricity value less than 10) after stabilisation with both crushed aggregate material sources.

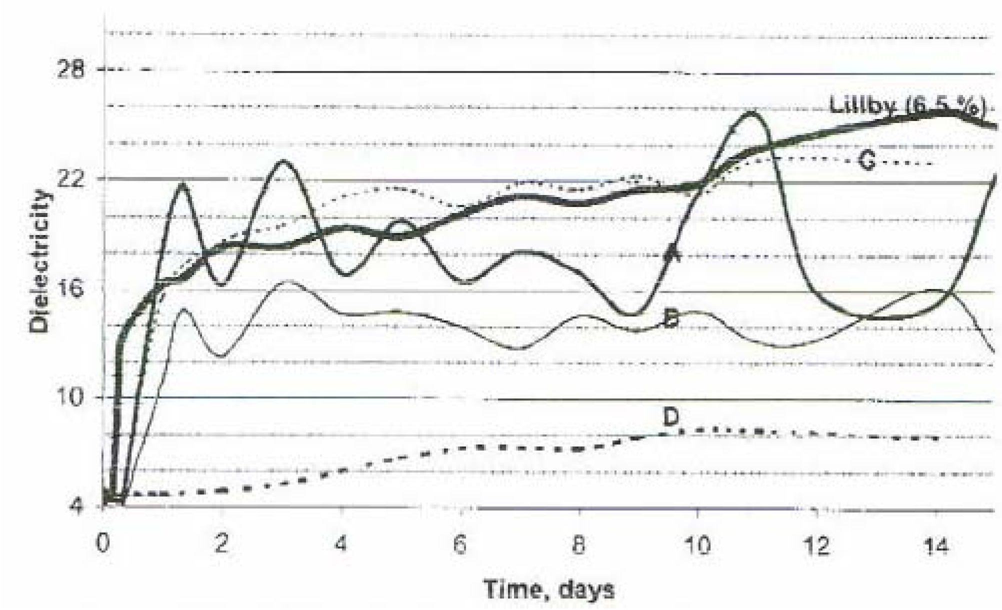


**Figure 9** Dielectricity results for Lillby crushed aggregate.
(NOTE: *Dielectricity curves of Tube* Suction *Test for the original Lillby aggregate compared to the samples mixed with different treatment agents.)*

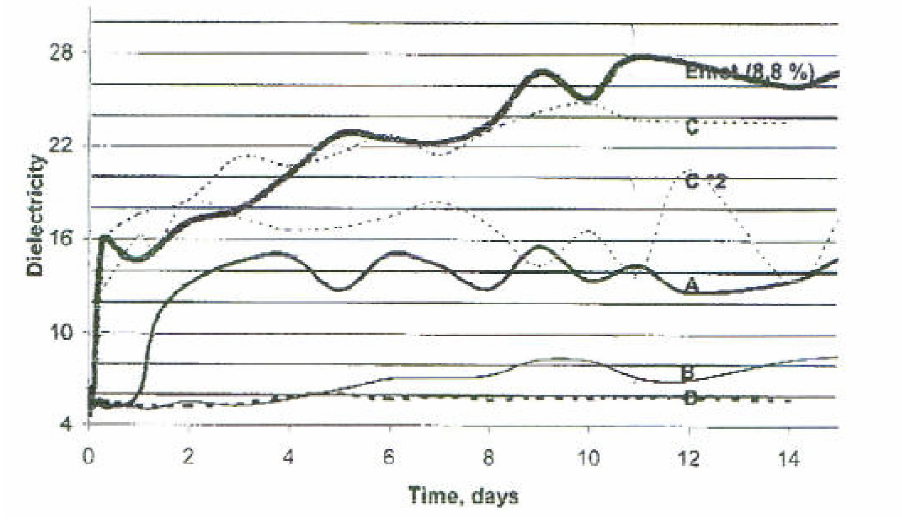


**Figure 10** Dielectricity results for Emet crushed aggregate.
(NOTE: *Dielectricity curves of Tube Suction Test for the original Emet aggregate compared to the samples mixed with different treatment agents.*

Figure 11 compares the resilient modulus values of the Lillby samples based on repeated load triaxial testing. It indicates the resilient modulus of the Lillby material containing up 32mm particle size is acceptable as a base course material while the same material containing a maximum particle size of 20mm is not considered suitable as base course material. When Polyroad DPP (treatment D) was mixed with Lillby 0 - 20mm aggregate, the resilient modulus increased considerably during for all three conditions of dry, water absorbed and after freeze-thaw.


**Figure 11** Resilient modulus values when tested dry, water absorbed and after freeze-thaw cycle.
(NOTE: The values are determined at a stress level corresponding to a sum of principal stresses 200 kPa.)

The Institute of Structural Engineering at Tampere University has advised they intend to carry out field trials with Polyroad DPP in the coming months.

## 5. CONCLUSION

Many hundreds of kilometres of Polyroad DPP stabilisation have been successfully carried out to date and without failure or reactive maintenance repair. DPP stabilisation is especially suited for treating moderate to poor quality gravels that lose considerable strength when wetted up. They also have particular application to regions of high water tables, periodic flooding of pavements and even during prolonged drought periods.

The mechanistic pavement design method is not well suited to DPP stabilisation which improves granular material behaviour in ways other than increasing material stiffness. The field performance of DPP stabilised pavements has shown to increase pavement rut resistance (less moisture sensitive) for granular materials that historically were highly sensitive to moisture. The subgrade is also further protected because there is minimal to no deformation of the stabilised pavement itself. It is important for a stabilised pavement to function as an 'impermeable' protection of the subgrade to improve its volume stability.

Because DPP stabilisation does not involve chemical reactions, the stabilised pavement does not suffer shrinkage cracking or premature load-induced cracking.  This is because access of surface water through cracks to the subgrade does not occur and there are no granular pavement cracks to reflect into overlying thin surfacings. DPP stabilised pavements have reduced deformability and functions as a low permeability protective barrier to the subgrade.

The author has had many years experience in managing road networks, in particular, managing large rehabilitation programs and annual maintenance programs. He can confirm the absence of reactive maintenance expenditure for DPP stabilised pavements since being introduced to the industry which in turn has provided a highly competitive and cost-effective long term solution for pavement rehabilitation.

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