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# SUSTAINABLE SOLUTION TO EXPANSIVE SUBGRADE AND EXISTING PAVEMENT USING GEOCONFINEMENT SYSTEM

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**ABSTRACT:** The Darling Downs region, located over 100 km west of Brisbane, comprises predominately fertile black soil. Black soil found across the region has characteristics that are extremely problematic to civil engineers and have caused significant damage to the road infrastructure in the region. The black soil in the region has a high shrink/ swell characteristic which has caused substantial pavement damage through rutting, shoving, washouts and settlement issues. Many pavement rehabilitation techniques, such as lime stabilization and foamed bitumen, have been used to minimize the damage caused by moisture infiltration. However, the issues remain. The Department of Transport and Main Roads developed ten innovative rehabilitation methods as a trial using geocells and geosynthetics along a 1km section of the main highway in the region. The Gore Highway had been identified as the ideal location as previous rehabilitation methods achieved limited benefits in reducing pavement failures, which posed safety concerns.

*Keywords: Expansive soil, Geocells, Geocomposite and Geogrid*

## 1. INTRODUCTION

The Darling Downs region consists of roads that link the national highways which predominately are used by the tourism and the transport industry for transporting goods across the nation. The characteristics of the soils pose a greater threat as the region is also susceptible to large scale flooding. Most of the area in Toowoomba, soils are formed from basalt rock and weathered rock. There are two types of soils that can be found around the region which are 'red soil and 'black soil'[11]. Most of the roads are built on the black soil, which is sensitive to water. Black soil comprises both alluvial and residual soils, which formed across the low laying areas around the region [3]. The black soils around the region are highly fertile, comprising high water-absorption, liquid limits, and plasticity. These characteristics pose significant concerns for engineers as the black soils absorb significant water content, resulting in high expansive properties whilst also shrinking significant when drying out.

This creates serious issues for engineers when designing and building major road infrastructure in the region. The expansive soils around the Darling Downs have caused significant damage to the road networks mainly causing large cracking, shoving, and rutting along throughout roads across the region. The swelling of the soil during the wet season and the shrinkage during the dry season of the black soil generates additional strain to the pavement which leads to the majority failure of the pavement around the Darling Downs District [20]. As a result, the road industries look for an economical treatment to maintain the road for end users. The aim is to provide safer and reliable transport infrastructure across the regions and utilise the fund effectively to deliver rehabilitation works.

Most of the part on Gore Highway consists of black soil which is a highly expansive soil. Black Soil swells when absorb water and shrink during the dry season [13]. As the expansive soil is highly sensitive to the moisture which cause distress to the infrastructure build on it [14]. In past various treatments such as Foam Bitumen, Lime and cement stabilization were carried out to bridge the expansive subsoil. Those treatments were successful where the sugrade has been treated prior to the base layer. Further mechanical, chemical, geogrid material produced locally and polymer [16] subgrade stabilisation have been shown improvement on the structure, however those treatments requires more resources, materials, time consuming and additional funds [15].

Constructing roads on expansive soils, without the appropriate technological and innovative engineering practice in place, means these materials would fail and impact the highways rideability resulting in not achieving its intended pavement life. Consequently, Geocells (geoconfinement system), polymeric materials and geocomposites recommended for the trials, were used to provide the rigorousness and resistance needed to stabilize roads on poor subgrades [17]. These materials have been used in various application including in past where the soil is subject to influence by climate factors. [19]. These materials will contribute towards preventing shrinkage and cracking of the pavement formation, mitigating lateral strain and dispersion, and reinforcing highly expansive subgrades.

The purpose of the trail was to identify the type of treatment to be applied for the future rehabilitation works to treat subgrade instead of stabilisation. The Department of Transport and Main Roads (TMR), Western Queenstland Standards [3] was the major reference on the classification of the alluvial and residual soil. Table 1 shows the Engineering properties of the various types of the soil. Further this paper address the treatments carried out on site to identify the economical solution to reduce the damage for the road network.

## 2. RESEARCH SIGNIFICANCE

Building major road infrastructure on expansive soil is ongoing challenge for the construction industry. Over the years, Department of Transport and Main Roads (TMR) and state agencies have undertaken various research and trials to counter the properties of the soils by using different stabilising agents. Some of these techniques include lime stabilisation, cement with the fly ash content stablisation, and foam bitumen stabilisation. Even though it has been proved the stabilising techniques are effective for full depth pavement construction with suitable subgrade treatment, these types of treatment methods are still major challenge for the rehabilitation works espicaaly on the highly reactive subgrade. Therefore, TMR invested on Research and Development to identify better solution for rehabilitation works when the agencies have limitation on funding and bounded by the rehabilitation guideline.

## 3. BACKGROUND

The Department of Transport and Main Roads (TMR) undertook an innovative rehabilitation trial along the Gore Highway 28A. The rehabilitation trials were carried out to address pavements where failing due to the reactive subgrade and climate change on the Condamine River flood plain [23]. With the trials the department aimed to achieve innovative pavement repair methods, improve the road safety with the good rideability including uninterrupted freight route and robust and sustainable treatment on highly reactive soil [23].The trial comprised of 10 various trials over a 1km section of the Gore highway. Each trial was undertaken over a 100m section using different innovative techniques, most of which had never been used in Queensland.

The project site was located 57 km west of Toowoomba between the suburbs of Pampas to Brookstead.The section was previously stabilised using foamed bitumen and lime stabilisation, however, because of the significant rainfall and flooding events the region had experienced, significant pavement damage had occurred. The 1km section chosen for the trial posed a safety concern for traffic because of the degradation of the existing pavement. Significant rutting, shoving, wash outs and cracking were observed over the selected area. This study discusses the various trials carried out on site and the structural performance which is aimed to apply for the future rehabilitation treatments.

## 4. EXPANSIVE SOIL PROPERTY

Black soil is a cohesive soil, which is sometimes referred to as black cotton soil [12]. The typical characteristics of black soil include its colour, which is typically black or dark grey . The soil is usually soft to very soft when wet and has high plasticity and liquid limits, which may cause significant swelling as it has a high-water retention capability. Its ability to retain water results from the high clay content present within the soil.When drying the soil experiences significant shrinkage, resulting in cracking as the water molecules evaporate from the bonding matrix. Black soils have low bearing capacity and low shear strength [7].

Black soils make up about one third of the area of the state of Queensland [13]. There are three types of black soils found in the Darling Downs region, all of which have similar qualities, however, were formed geologically differently. Black soil from alluvial origin, was derived from weathering produced from the Rolling Downs Group, which was transported along with sediments from the Tertiary age [3].

Residual black soil was formed directly over the weathered sedimentary rock of the Rolling Downs group during the Cretaceous age. The black soil type found in the region was formed on the Tertiary basalt deposits which has been classed as Residual on Basalt [3]. The engineering properties of these soils are summarised below.

Table 1: Engineering properties for black soils [3]

| Property | Alluvial | Residual on Cretaceous | Residual on Basalt |
|---|---|---|---|
| Liquid Limit | 40 – 60 | 40 -70 | 60 -90 |
| Plastic Index | 25 – 35 | 25 - 35 | 40 – 60 |
| Linear Shrinkage | 12 -18 | 15 - 20 | 15 – 25 |
| USC | CL -CH | CL - CH | CH |

### 4.1 Geogrids and Geosynthetics

Geogrids and geosynthetics have been used across the world for many years with various engineering applications[18]. TMR were required to find alternative solutions to the ever-growing problem of pavement rehabilitation in the region. Various trials and stabilisation techniques, such as lime and foamed bitumen, were used across the region with various degrees of success.

TMR began investigating alternative solutions and began trialing geocells and geosynthetics on a section of the Gore Highway. Using geo-cells on the Gore Highway was a first for the state of Queensland, as these had only been trailed in other states in Australia with different soil conditions.

The trial involved stabilising a 1km length of road along the Gore Highway 28A, between Pampas and Brookstead approximately 57km west of Toowoomba. The trial involved using 10 different geogrids each over a 100m length.

The project, along with the procedures, was developed between consultation with technical experts and TMR.

### 4.2 Geocells and Geosynthetics

Geosynthetic reinforcement has been used for subgrade improvement as well base reinforcement for over 40 years around the world [6]. However, in Queensland, geocells had not been used despite the vast areas of weak expansive soils. Geocells and geosynthetics are used to achieve five functions which assist with improving the durability of a road. The five key functions they are designed for include providing reinforcement, stiffness, improved drainage, filtration, and separation [2].

Because of the above, geocells and geosynthetics help with mitigating reflective cracking in asphalt, separate, lateral restraints. Geosynthetics can be used both as a subbase treatment and a subgrade treatment. Some other using geocells include limiting the use of lime or foam bitumen and using recycled material, thus significantly reducing the cost of construction and maintenance and as well as providing an environmentally friendly alternative solution.

Figure 1 shows the benefits of using geogrids. Load distribution of the axle force and shear stresses are distributed over a larger area therefore resulting in reducing the impact on the pavement. The geosynthetic absorb the forces and remain in tensile stress [2].

Research was carried out at the University of Kansas to investigate the vertical stresses and impact of permanent deformation because of using geocells in recycled asphalt pavement (RAP) with weak subgrade material under cyclic plate loading. The experiment involved using test samples with and without geocells in a geotechnical test box applying cyclic loading replicating a single wheel load force of 40kN. The subgrade material used in the experiment had a CBR value of 2%, a plastic limit of 22% and a liquid limit of 30%. During the cyclic loading, the surface deformation and vertical stresses and strains were monitored, and the results indicated using geocells improved the life of the pavement by a factor of up to 19% compared with not using geocells. The data also indicated using geocells improved the resilient deformation whilst reducing plasticity properties [5].

Other research using geocells in unpaved roads with fill material also indicated a reduction in permanent deformation and an increase in stress distribution angles when using geocells compared [6]. Research into the benefits of using geocells over planar geosynthetics indicated using geocells was more effective in increasing the strength, bearing capacity, and reducing settlements in various engineering applications [8].

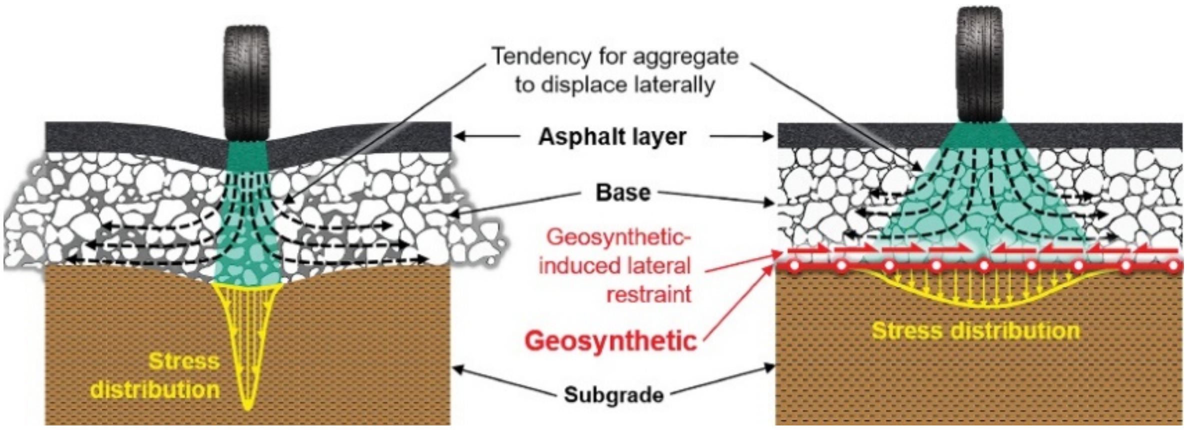


Fig.1 Stress distribution with and without geo-grid in stabilised roads [2]

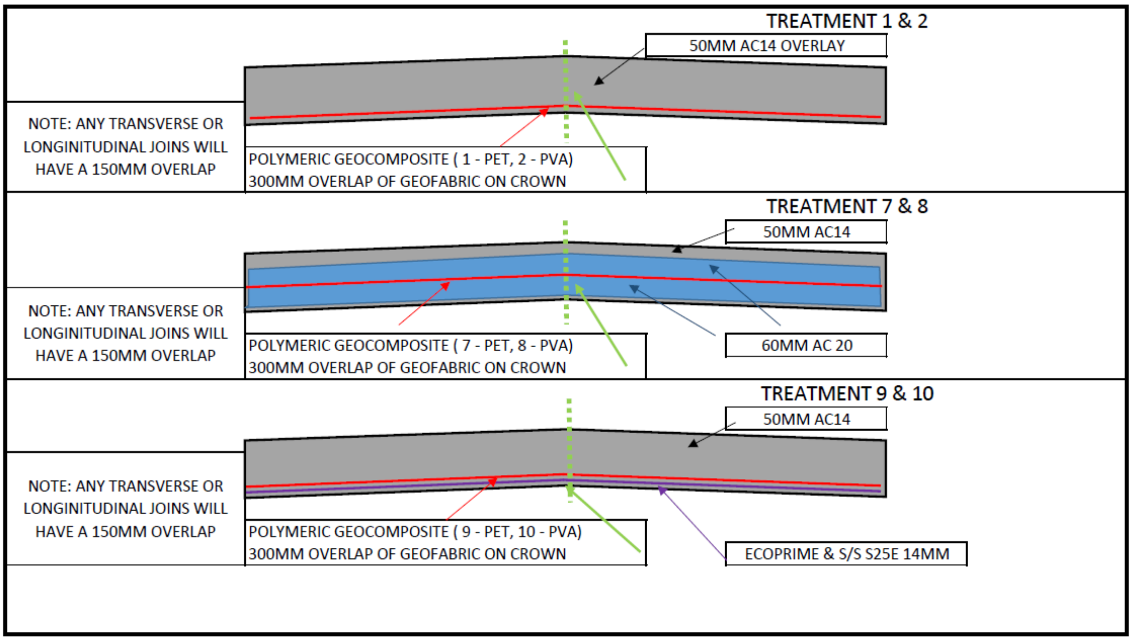


Fig. 2 Trial techniques used on Gore Highway

## 5. TRIAL

The trial involved using different geocells and geosynthetics in various ways to treat the subgrade and base along the Gore Highway. The figure below shows how each trial was undertaken.

### 5.1 Application of Polymeric – PET and HaTelit XP geosynthetic (Trial 1 and 2)

Trials 1 involved adding the polymeric-PET (HaTelit C) geosynthetic over the full 10m width. The process involved brooming and cleaning the existing pavement surface before adding a tack coat to assist with binding the existing layer with the Hateltic C. The Hatelitic C polymer was laid using a forklift with a modified frame to lay the product. Once the product was laid over the subgrade, AC20 was laid over it**.**

HaTelit C is made from reinforced mesh comprising of high-modulus polyester yarn. It is made by combining ultra-light non-woven fabric with the polyester yarn. Some advantages of using this product include minimal loss of strength, high resistance to pavement damage and resistance to permanent dynamic traffic loads by absorbing and distributing tensile stress. [4, 10].

In Trial 2, a HaTelit XP geosynthetic was used. This product is made from polyvinyl alcohol (PVA), which is known for having good resistance to reflection cracking, high resistance to pavement damage and traffic loads and can be used on asphalt surfaces [9].

Fig. 3 Trial 1 using Hatelitic C

### 5.2 Application of Geotextile and HSS2 Seal (Trial 3 and Trial 4)

These trials were focused on treating the base layers. The trials involved cleaning the existing surface to remove dust and loose stones, allowing the tack coat to bind better with the surface. Once the tack coat was placed, the geotextile was laid respectively over the trial areas.

Geocomposite chip seal grids were used as they are easy to use, durable, provide high resistance, through flexibility and rupture resistance which helps prevent crack propagation [4]. Once the geotextiles were laid, hot bitumen crack treatment and HSS2 seal were placed over a 10m width.

Fig. 4 Geotextile on tack coat

Fig. 5 HSS2 Seal

**5.3 Application of Geogrid (Trial 5)**

The rest of the trials comprised subgrade treatment trials. Trial 5 involved profiling/ milling out approximately 400mm of unsuitable material. Class A MRTS04 material was used to replace soft areas, allowing for the Hilf test to achieve a minimum of 97% compaction. A basetrac duo geocomposite (Basetrac Duo PET 50 B15) was placed over the layer to prevent penetration of moisture to the subgrade. Basetrac Duo was another geocomposite used made from polypropylene, polyester, or polyvinyl alcohol. The manufacturer states the product has a biaxial tensile strength of up to 75kN/m whilst providing the ability to interlock with granular material to prevent fine soil particles from segregation [4].

The geocells Fortrac 80MDT was placed over the geocomposite and stretched out and nailed to the edges of the existing pavement surrounding the trial area. This allowed the geocells to remain in a state of tension. Fortrac geogrids were also used as they are easy to use because of the flexibility of the product. This product also provides high tensile strength made from low-creep synthetic materials [4].

Fig. 6 Placing Geogrids on Geofabric

Type 4.1 material was used to fill in around the geocells before being compacted using a smooth drum, before being sealed off using spray seal

Fig. 7 Placing material and fill voids

**5.4 Trial 6: Application of Geocomposite and Foreac 80 MD**

This trial involved removing 250mm of existing material before the Bastrac Duo PET 50 B15 layer was placed over 5m X 100m area. Type 4.1 was then laid over the geocomposite before the Fortac 80 MDT was laid. Type 2.1 material was laid and compacted to 250mm before the primar10mm seal was placed.

Fig. 8 Placing Geocomposite

Fig. 9 Placing Foreac 80 MD on Geocomposite

### 5.5 Trial 7 and 8 : Application of Geosynthetic Material

These trials involved milling 150mm of the existing surface and placing a geosynthetic material (HaTelit XP and C respectfully). A tack coat was placed over the geosynthetic before AC20 was placed and compacted.

Fig. 10 Placing Geosynthetic Material (Trial 7 and 8)

### 5.6 Trials 9 and 10 : Application of Polymeric-PET and Polymeric-PVA

These trials involved milling out approximately 60mm of the existing pavement before being primed and then the geocomposites were placed.

HaTelit material used in this trial. HaTelit C is a reinforcement mesh made of high modulus polyster yarns combined with an ultra-light non-wovan fabric [9]. The previous studies shows that the HaTelit material is higher resistance to paving damage and delay of reflection of any crack failure. The advantage of using Trail 9 had a polymeric-PET HaTelit C geosynthetic placed and trial 10 had a polymeric-PVA HaTelit XP placed. Once these were laid, A/C 20mm was placed and compacted.

Fig. 11 Placing Polymeric-PET and Polymeric-PVA (Trial 9 & 10)

## 6. LIMITATIONS

Although research has been undertaken using geocells and geosynthetics as reinforcements by subgrades and bases, the research is limited to laboratory testing trying to simulate real world scenarios.

Due to time, weather and budget constraints, the trials were limited to 100m length sections, which may limit the true reflection of performance of each geocell and geosynthetic product. Prior pavement rehabilitation techniques, such as subgrade treatment (lime and foamed bitumen) may also hinder the true performance of the products. Likewise, any prior water infiltration or subgrade damage may not have been identified at the time of construction and may influence the performance of the products.

## 7. CONCLUSIONS

The trials undertaken along the Gore Highway provided a much needed alterative to a problem that has caused a significant impact to the road network in the Southern Downs region. Finding a long-term solution to countering the highly expansive soils in a region suffering both from severe drought and largescale flooding could have substantial economic impacts for not only the region but also for the state of Queensland.

Geoconfinement systems, polymeric and geocomposite products are becoming more widespread having potentials replacing the standard subgrade treatments and pavement reconstruction. Geocells and geosynthetics could be an alternative engineering solution to a widespread problem in the Southern Downs region. Although limited research is available on the impacts of these products on black soils, the research suggests these products could solve a problem that has plagued the region.

Some of the expected benefits of using these products include minimizing the ability for moisture to penetrate through to the subgrade whilst also improving and increase the strength of the pavement. Geocells can transfer the shear stresses caused by axle loading to a larger area of the base and subgrade, therefore reducing the impact and stress on those areas. As a result, reducing the potential for damaging the structural integrity of the pavement.

The results from the trial proved that various Road Authorities have got more options in the industry when it comes to the rehabilitation works. However, those optioned need to be carefully selected to the type of failure. To better understand the true impact on the performance of these products, further analysis is required of the trialed section of the Gore Highway.

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