# Geofoam—20 Years of Experience and Commonly Adopted Practices in NSW, Australia

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**Abstract** For 20 years, Expanded Polystyrene (EPS), known in civil applications as Geofoam, has been used in New South Wales, Australia as a lightweight fill material for various applications. Pioneered in Norway in the 1970s as a lightweight construction material to minimise settlement, Geofoam was first utilised in NSW for a highway widening on steep ground in 2002. Since then, Geofoam has been used as a lightweight fill to minimise vertical loads on soft ground where excessive settlement was predicted, for emergency and planned slope rehabilitation, as a way of reducing horizontal loading on bridge abutments, and for various other applications. There are several advantages to using Geofoam in construction. It can be more cost-effective than traditional ground improvement techniques; its use can lead to reduced construction time where earthworks' compaction is needed and can reduce the vertical impact on services. Geofoam can be installed by smaller work crews utilising lighter plant and can minimise the excavation footprints for slope remediations. These examples are just some of the demonstrated advantages showcased as part of the case studies explored. Case study examples will illustrate where and in what capacity Geofoam has been utilised in NSW, practical experiences on how and why they have implemented at each location, observations on performance over time, and the process for wider acceptance in road construction projects.

**Keywords** Geofoam · Slope remediation · Lightweight fill

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# 1 Introduction

## 1.1 A Brief History of Geofoam—Norway to Narooma

Expanded Polystyrene (EPS), Geofoam as it is referred to in civil applications was first utilised as a lightweight fill in 1972 in Oslo, Norway [1]. Excessive settlements of 20 cm/year of an embankment approaching Flom Bridge outside of Oslo caused the Norwegian Road Research Laboratory to determine a solution to minimise the settlement. It was decided to replace 1 m of embankment fill with two 0.5 m layers of EPS blocks. Settlement was immediately reduced with effectively no additional settlement recorded from 1979 [1].

By the end of the 1970s, the use of Geofoam as a lightweight fill had increased, being applied by European Countries such as Sweden, Finland, and Italy for minimising settlement in embankments and bridge approaches, and for building over shallow pipes. By the mid-1980s, Japan had adopted Geofoam as a lightweight fill with the USA, South Korea, and Australia (Melbourne City Link in Victoria, Australia) adopting Geofoam for slope stability works, highway embankment and bridge abutment construction by the 1990s.

Geofoam was first utilised in New South Wales (NSW) by the South Region of the then Roads and Traffic Authority (RTA) now Transport for NSW (TfNSW) in 2002 for a slip remediation north of Narooma on the south coast of New South Wales, 350 km south of Sydney.

## 1.2 Geofoam Properties and Specification

As the use of Geofoam increased in many countries, several research projects into the properties required for civil applications including dynamic loading, tensile strength behaviour, block size and shapes, effects of varying densities were conducted [2].

Geofoam has 1% the density of general earthworks however also has adequate strength and solidity with excellent durability [3]. The blocks have negligible creep, are resistant to weather, alkali, acids, salt water, are reusable, and have a 100-year design life when correctly constructed and protected. Geofoam manufactures supply blocks in various densities, shapes, and sizes. For projects completed in NSW, Class M blocks with densities $\rho = 20$ kg/m$^3$ are typically used for lightweight fill applications. Design parameters used compressive strength at 1% of 50 kPa, Elastic modulus of 5 MPa, and a cohesion of 30 kPa.

## 2 Geofoam Applications in NSW

The international applications for Geofoam have been widely presented in various papers and case studies as a lightweight fill, for load reduction, and energy absorption as examples [1, 2, 4]. Over the past 20 years in NSW, Geofoam has been used for slope failure remediations, as lightweight fill for widening on steep or marginal slopes, reconstruction of a failed 100-year-old bridge abutment, as a void filler to adsorb lateral pressures on a bridge abutments from expanding fills, for preventative slope remediation works, over pipes and other lightweight applications on soft ground.

"Why?" and "What's the Benefit?" Utilising Geofoam is not a replacement for other traditional construction methods, however, there can be significant advantages in its applications [5, 6].

- Slope Remediations:
  - Reduced timeframes compared with conventional methods, resulting in a reduction in the duration of road or lane closures, which is a significant benefit to the road users and local communities and businesses.
  - WHS and Environmental advantages—Less need for large, specialised plant such as piling rigs or heavy earthwork equipment on unstable slopes. Blocks are light and can be moved into place by two workers rather than craning materials to site.
  - Less lead time on supply of Geofoam blocks compared to steel products in the current economic climate (2023).
  - Cost savings—compared to more conventional treatments such as soldier piles.

- Soft soils—Minimise settlement. With generally 1%, the load of conventional earthworks settlements can be minimised, reducing the need for expensive ground stabilisation techniques.
- Earthworks
  - Substitute for importing general fill material—can be a cost saving when taking into account importing low-quality material that requires conditioning and compaction, against a uniform imported Geofoam block.
  - Pipe construction—minimise the load on and around pipes.
  - Reduce lateral loadings on abutments with Geofoam.
  - Sustainability—Geofoam blocks can be reused with examples in USA and Norway at Løkkeberg Bridge [4].

## 3 Case Studies from NSW

The following are a few examples of how Geofoam has been utilised in various ways in NSW by TfNSW South Region.


**Fig. 1** Cross-section design and construction photo

## *3.1 Mt Ousley Road Widening, Wollongong—2002*

Mt Ousley Road, Wollongong, is an important freight route between Wollongong and Sydney with the port at Port Kembla significant for Coal exports from the Illawarra. With an AADT in 2002 of ~35,000 and 12% heavy vehicles, a northbound climbing lane to widen the steep incline of the northbound carriageway to three lanes was planned.

Widening over a gully section encountered a number of limitations including the inability to widen the batter conventionally due to a 104 m long large corroded steel pipe in need of replacement, with the site also known to have existing stability issues due to adjacent landslides and subsidence.

Optioneering ruled out widening with reinforced soil or a short retaining wall, due to the increased load on the pipe and slope and the excavation required to accommodate reinforced strapping. Time was also a critical factor as to widen in any case would require the northbound carriageway to be reduced to one lane.

Geofoam was selected as the preferred option as it would achieve a net load reduction on the slope, was the quickest construction option, would allow for any potential creep movements in the slope and ended up being the lowest cost option, Fig. 1 shows the design which included a stepped excavation to a depth of 2.4 m and the placement of three 600 mm thick layers of Geofoam with an anchored rolled concrete protection load distribution slab and 450 mm of heavy duty pavement. Note the outside vertical face was shotcreted to encapsulate the Geofoam.

Having now been in service for 21 years, the Geofoam section has shown no signs of movement or distress.

## *3.2 Scarborough Slip Reconstruction, Lawrence Hargraves Drive North of Wollongong—2005*

A step formed along the guard rail on Lawrence Hargraves Drive near the suburb of Scarborough after a significant storm in mid-2003. The slope was investigated with a conventional soil nail solution design selected. Works were programmed to


**Fig. 2** Left the step in the pavement on the guardrail. Right slope location above cliff

**Fig. 3** Left the stabilised excavation with horizontal drain connected to a trench drain. Right the Geofoam remediation prior to shotcreting

be completed before the grand opening of Sea Cliff Bridge in 2005, however, after commencing the drilling of the top row of soil nails a large tension crack opened up under the excavator. The tension crack approximately 3 m back from the proposed face lined up with the interface between the in-situ weathered sandstone and the embankment fill constructed when the road was built. The existing soil nail design was insufficient to achieve the required FoS and the slope needed to be stabilised urgently to coincide with the bridge opening (Fig. 2).

The revised remediation consisted of excavating behind the tension crack and applying the same soil nail design to stabilise the excavation face. The resulting 5 m wide void was constructed with Geofoam Blocks. The presence of groundwater seepage from the excavation required the installation of horizontal drains that were connected into drainage trench as shown in Fig. 3.

Post 2022 natural disaster rain events, the original slip reactivated to the south of the Geofoam remediation, however, the Geofoam block has not shown any movement with the southern limb of the crack continued to progress through 2022.

### *3.3 Bridge Abutment Reconstruction, Victoria Bridge Picton—2007*

Movement of a timber wing wall caused the collapse of a section of the northern bridge abutment in 2007 (Fig. 4). Built in 1897, Victoria Bridge is a heritage timber truss bridge, with hand placed drystone embankment facing. The failure proposed a difficult question, how to remediate the bridge abutment while maintaining the heritage value.

Conventional earthworks, which would have required a significant amount of further excavation to accommodate benching, was rulled out, as was bored pile options, due to stability and access issues. As the wing walls need to be replaced, it was decided to over-excavate a wedge of the abutment as shown in Fig. 4 (right), and to rebuild it with Geofoam. This also allowed space for bridge bracing and repairs to occur concurrently.

Once the wing wall was rebuilt, the Geofoam was placed as backfill as shown in Fig. 5. A significant success of this remediation was the ability to reuse all the pre-existing drystone blocks as facing once the Geofoam had been shotcreted to reinstate the heritage look (Fig. 5 (right)).


**Fig. 4** Left the extent of the collapsed wing wall and drystone wall. Right the excavation and site preparation of placing the Geofoam blocks

**Fig. 5** The Geofoam blocks placed prior to shotcrete, and the final remediation with the original drystone blocks reused

**Fig. 6** Construction stages of the Geofoam construction for the acceleration lane

## *3.4 Widening of the M1 Princes Motorway from Picton Road to Accommodate a Northbound Acceleration Lane—2010–2012*

In 2010, it was proposed to improve the intersection of Piton Road with the Princes Motorway North of Wollongong, buy providing a 1.4 km northbound climbing acceleration lane from Picton Road to aid heavy vehicles. The concept design considered various options with conventional earthworks or a Gabion retaining structure as the preferred options. The location of the widening was constrained by Sydney Water catchment and the embankment to be widened had questionable stability with periodic monitoring taking place. Detailed design reviewed the widening options, with either reinforcing the existing batter prior to widening or constructing a lightweight Geofoam structure, with the Geofoam being the most cost-effective.

As part of the design process, incorporation of a ridged barrier was required due to the steep grade of the alignment. This resulted in structural "I" beams, with 2–3 m piles as the vertical supports, which were to be incorporated into the structural elements of the concrete slab and the extruded rigid barrier. In this case, the Geofoam blocks were used as a lightweight fill to offset load of the widened pavement and barrier system. As with previous projects, a net reduction in load was achieved. Figure 6 shows the construction stages, left at the top of the Geofoam, and right at the final construction.

## *3.5 Slope Remediation, MR261 Nowra Road, Barrengarry Mountain—2015*

In August 2015, a natural disaster rain event occurred at Barrengarry Mountain 35 km northwest of Nowra, where the recorded August rainfall was 378, 115 mm of which fell on 2 August, resulting in a number of slope failures. Two significant slips


**Fig. 7** Two significant slips on Barrengarry Mountain 2015

occurred towards the top of the escarpment (Fig. 7). The upper slip was 260 m long, with a meandering open crack with vertical displacements of 35 mm increasing to 60 mm after 10 days. The second slip 150 m downhill at the hairpin was 30 m long and had a 150 mm vertical displacement that increased to 180 mm. The road was closed while investigations, monitoring, and options assessments were conducted.

Investigations showed that the underlying colluvial and residual material was of low strength with numerous voids. Rock, where encountered, was highly weathered with very low strength. Options became limited as the slope was still actively creeping. Heavy plant was to be avoided, reconstruction with earth or rock fill would require a large excavation, and the steep slope below the failure were all limitations. Keeping one lane open during the works was also a major limitation. The solution adopted was to progressively excavate and stabilise the excavation from the centreline to a depth of 3.5 m and then rebuild the affected lanes with Geofoam constructed with a vertical shotcreted face.

This remediation was the largest Geofoam slope remediation completed as emergency restoration by the then Roads and Maritime Services (RMS) now TfNSW, with approximately 4000 m$^3$ of Geofoam used in the upper slope. Although successful the project highlighted challenges with many learnings that have been incorporated into our current design approach, such as a free draining bedding layer for the Geofoam support, block level consistency on a steep alignment (at what grade is it needed to bench longitudinally?) concrete protection slab versus hydrocarbon resistant protection membranes, size and shape of blocks used and slab anchoring options.

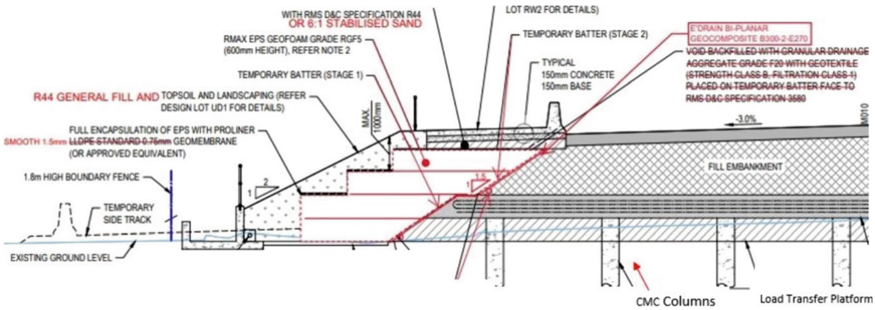


**Fig. 8** Cross-section detail for the lightweight fill at Batemans Bay

### *3.6 Settlement Minimisation of an Embankment at Batemans Bay Bridge—2021*

The first site where Geofoam was utilised specifically to minimise settlement was on the New Batemans Bay Bridge project in 2021. Adjacent to the main alignment, a shared path was part of the final construction staging at the southern approach to the bridge. There had been significant ground stabilisation works conducted for the southern bridge embankment consisting of CMC's with a load transfer platform. The shared path foundations could not undergo the same treatment as the area was used for traffic staging while the main alignment was constructed. To minimise settlement and drawdown damage to the load transfer platform, a 2.4 m thick Geofoam fill encapsulated in a 1.5 mm Geomembrane and topsoil landscaping was constructed as shown in Fig. 8.

Construction challenges encountered on this project included a thicker geomembrane of 1.5 mm being used (if used it is usually 0.75 mm), as it is stiffer it was difficult in shaping around the blocks. Fully encapsulating the Geofoam also caused construction difficulties as water from rain during construction collected on the base of the membrane. The membrane also has almost no friction so was an issue keeping blocks in their placed positions on the sloped back face.

### *3.7 Alpine Way, Slope Remediations—2020 and 2023*

Two embankment slopes were remediated in 2020 and 2023 on the Alpine Way Southeast of Thredbo. Both slopes were high-risk slopes as rated by the TfNSW slope risk assessments and were monitored by inclinometers and piezometers with data loggers to allow pre-emptive remediation works to be planned. Slope ID:10043 (2020) had two failures apparent, a shallow slip circle of the outer 3 m and a secondary larger slip across both lanes. Slope ID:10019 (2023) main failure was a slip circle that extended from the centre line and was causing a depression along the centre line.

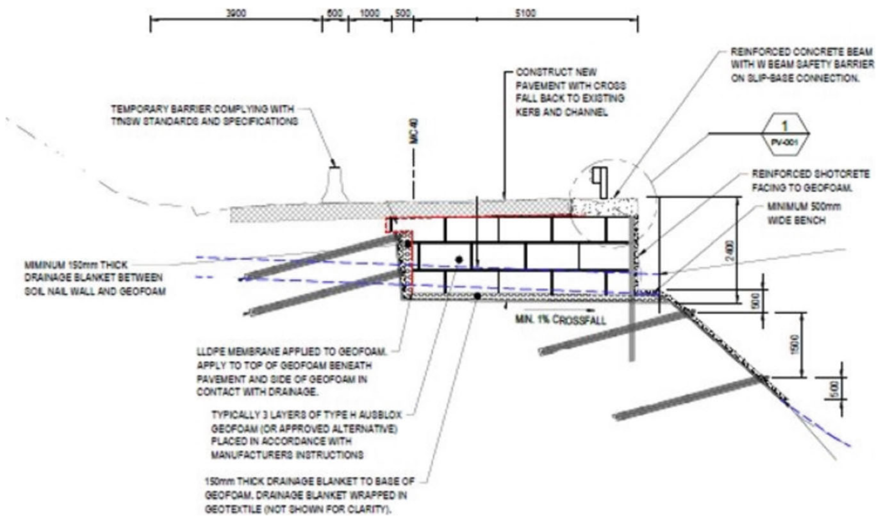


**Fig. 9** Remediation design for Alpine Way slope 10019

Slope ID:10019 also had a ~30–40-year-old 1.8 m wall consisting of geogrid with a folded mesh facing, however, the reinforcing straps did not extend to the failure plane.

The remediation methodology follows the current Geofoam design practice adopted by TfNSW South Region for slope remediations required to the centre line. Slope stability target FoS is achieved through a combination of removal of a large portion of the failed or failing material, stabilising the excavation with soil nails typically 6 m long, and rebuilding the excavation with Geofoam blocks. This approach aims to reduce the net load of the slope, resulting in a reduction in the number of and length of soil nails required. As a comparison, for slope ID:10019, the final design shown in Fig. 9 has two rows of 6 m nails supporting the excavation and two rows of 8 m nails stabilising below the Geofoam. The soil nail only option required five rows of soil nails (three 12 m and two 15 m long), which are difficult and more expensive to drill, with the added access issues in a National Park.

## 4 Evolved Design Considerations

The design process has been a continuous evolution over the past 20 years of Geofoam projects in NSW. For the first era of projects 2002–2006, the load-carrying capacity pavement construction and hydrocarbon protection were the key considerations. From 2007, experience through other applications such as void filler to alleviate expansive embankments, to major slope failure remediations. From 2016 to the present, there is a well-evolved understanding of the design considerations to incorporate into Geofoam design applications including:

- A well-defined ground model—including geotechnical investigations, survey, geological mapping, understanding the groundwater, monitoring where required such as inclinometers, piezometers and surface monitoring.
- Intended use—Lightweight fill to minimise settlement effects, slope remediations to attain a net reduction in the loading, earthworks construction.
- Grade of Geofoam Block—Grade M ($\rho = 20$ kg/m$^3$) is now the standard used block type.
- Geofoam block dimensions—generally 600 mm thick, 1200 mm wide with lengths determined to best accommodate the dimensions of the area required.
- Geometry of the project—for slope remediations how high is the vertical wall, this influences the need to fix support posts or provide inter-layer load distribution layers.
- Geofoam block placement—Blocks should always be placed perpendicular to the layer below, with an offset of the joint between blocks.
- Groundwater and drainage—how will this be managed, is it well understood? Current practice is to incorporate a drainage layer as the bedding for the Geofoam blocks. This allows any intercepted water to be able to escape the system. Horizontal drains installed in the stepped or stabilised back face can also be run under the block through this layer allowing observations of water flows. Gaps at the back of the Geofoam blocks should be kept to a maximum of 200 mm and backfilled with free draining aggregate for each block layer.
- Safety barriers—where required how they will be integrated. There has been a tendency to mount standard "W" beam ontop of a concrete plinth with shear plates rather that incorporating a zone of earthfill where posts can be driven into.
- Risks and design considerations:
  - Damage from hydrocarbons—what level of protection is required? Current slope remediation approach is to extend the concrete protection slab a minimum 300 mm past the back of the Geofoam to minimise potential ingress of hydrocarbon that may spill onto the pavement. The pavement layers then extend past the slab as a further precaution. The need for a Geomembrane protection layer is a case by case and should be considered for highly trafficked roads and major freight routes.
  - Geomembrane protection layers—these protection layers introduce construction risks as they are smooth and frictionless. When used consideration needs to be given as to their constructability.
  - Flammable risk—Geofoam blocks are manufactured with fire retardant properties where they can self-extinguish if ignited, however in bushfire prone areas long-term protection needs to be considered, and risk management on site during construction. There have been some documented fires ignited on site by other activities on sight such as hot welding or angle grinding, and in urban areas vandalism, however, none on any TfNSW sites. In the 2019/20 bushfires, two sites where geofoam was utilised for widening with shotcrete protection

were in severe fire zones, neither of which has shown any issues related to the fires.
– Wind—the blocks are relatively light and need to be tied down while stockpiled in high wind areas.

## 5 Conclusion

The use of Geofoam over the past 20 years in NSW has been found to be a time and cost effective solution for slope remediations and lightweight fill applications. The methodology has evolved to incorporate many of the lessons learned from previous projects and overseas experiences. Geofoam systems are not intended to replace traditional remediation systems, however, they have shown that they can be included as part of the options discussion, or part of hybrid designs to reduce costs and time. Monitoring and inspections of sites where Geofoam has been utilised show no adverse issues, no settlement has been observed, and sites effected by bushfires have shown no exposure issues.

The lessons learned and presented in this paper need to be considered for incorporation as guide notes for other practitioners interested in utilising Geofoam. To quote the Norwegian Geofoam moto; "Be Bright, Think light and Do it right" [4].

## References

1. Alfheim S, Flaate K, Refsdal G et al (2011) The first EPS Geoblock road embankment—1972. In: Paper presented at the 4th international conference on geofoam blocks in construction applications—EPS 2011, Lillestrøm, Norway
2. Aabøe R, Bartlett S F, Duškov M, Frydenlund T E, Mandal J N, Negussey D, Tolga Özer A, Tsukamoto H, Vaslestad J (2018) Geofoam blocks in civil engineering. In: Paper presented at the 5th international conference on geofoam blocks in construction applications—EPS'18, Kyrenia–Northern Cyprus
3. Miki G Ten Year History of EPS method in Japan and its future challengers. In: Proceedings of international symposium on EPS construction method (EPS Tokyo '96), pp 394–411
4. Aabøe R The Norwegian public roads administration, Frydenlund T E—40 Years of experience with the use of EPS Geofoam Blocks in Road Construction
5. Brown RG Repairing road embankments in mountainous terrain with polystyrene, GeoPave, VicRoads, Australia
6. Boyer M, Chew K, Look B (2014) Case study—use of expanded polystyrene blocks in landslide remedial works. In: Fourth international conference on geotechnique, construction materials and environment, Brisbane, Australia