THE UK AGGREGATE LEVY AND ITS IMPLICATIONS TO GEOSYNHTETICS

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Abstract: Within Europe the Aggregate Levy is unique to the United Kingdom and this paper will look at the implications this tax has had on the geosynthetic market and how industry and government regulators have adapted and used geosynthetics under this new regime. This tax is designed to reduce the quantity of aggregate extracted and promote recycling within the construction industry. Geogrids and woven geotextiles when used in basal reinforcement reduce the amount of aggregate used and can improve the performance of recycled aggregates which are contaminated by fines etc. Geodrains can replace aggregate where drainage is required, the Highways Agency have now approved a geodrain for drainage behind bridge abutments on motorway widening projects and has now been used on the M25. In the waste management industry the cost of a leachate drainage layer which complies with the European Landfill Directive has increased considerably, discussions between the industry and the Environment Agency have resulted in changes to the requirements for the drainage stone involving geodrains and filter geotextiles. The Environment Agency has also allowed tyres to be used as a recycled drainage media, but a geogrid and/or filter geotextile must be used to stabilise the drainage layer. This paper will also look at the first site trials that were carried out before the new guidance came into force.

Keywords: bridge abutments, drainage.

INTRODUCTION

In April 2002 the UK Government brought in the Aggregates Levy, a primary aggregate tax. This was aimed at reducing the use of primary, quarried, aggregates and increase the use of recycled materials. The incentive was that the introduction of the £1.60 per Tonne tax to compensate for additional costs of selecting and sorting recycled materials. The main aggregate producers and many small recycling companies were quickly able to change over to selecting and crushing suitable wastes and, whilst the government assumed that there could be significant savings using recycled materials, the reality was that prices immediately rose to be just below primary aggregate.

As always there were huge variations in quality at the start with some suppliers producing rather variable materials and obviously a producer using merchant material from dozens of mixed small contracts in the market place will inevitably have more problems than one crushing material from a large section of motorway or a runway. There was a need for modifying existing specifications to provide realistic minimum requirements to allow the small quantities of other remnant materials such as plastic into specifications etc, and the British Standards Institute, the Highways Agency and other similar bodies developed alternate specifications.

The change instigated a relook at the issues and problems anew by both specifiers and contractors and in particular geosynthetics alternatives. This paper looks at some of the ways the specification of materials has changed and the uses to which geosynthetics have replaced the use of aggregates or compensate for the slightly poorer specifications of some recycled materials.

BASAL REINFORCEMENT

The use of stone in granular layers to increase bearing capacity under foundations, roadways, railways etc in combination with geosynthetics is not new but the use has grown significantly since the introduction of the Aggregate Levy and the inevitable rise in costs of aggregates and close scrutiny to reduce costs. The use of any geotextile separator between a soft subgrade and a stone fill has advantages in reducing the loss of stone punching into the underlying soft soil, i.e. a separation function, whilst the use of a high strength woven geotextile or a geogrid can significantly reduce the thickness of the layer, i.e. a reinforcement function.

Simple aggregate layers work by distributing loads over a wider area that is dictated by their load distribution angle (Figure1). The introduction of a geosynthetic improves the situation by providing both separation and reinforcing functions. The separation function reduces loss of material into the sub-grade but the reinforcement increases this load distribution angle therefore allowing any load on the top of the layer to be spread over a greater area of the subgrade and so reduce the necessary thickness of the layer.

Whilst geotextiles, usually woven ones, act as excellent separators and spread the load on the basal interface and reduce loss of material into the soft sub-grade, the use of a geogrid has added advantages as the stone interlocks with the grid. Vehicular loads applied to the road surface create a lateral spreading motion of the aggregate. Tensile lateral strains are created at the interface subgrade/geogrid as the aggregate moves down and sideways due to the applied load. Through shear interaction of the base aggregate with the geogrid, the aggregate is laterally restrained and tensile forces are transmitted from the aggregate to the geogrid. The interaction between geogrid and base aggregate increases the shear strength and thus the load distribution capacity of the used base course material. This correlation enables the reduction of reinforced aggregate thicknesses in comparison to un-reinforced aggregate layers (Figure 1).

Diverse field studies subject to different boundary conditions show that apart from the minimum tensile strength of the reinforcement element the structure and inherent stiffness of the geogrid increases the value of the soil modulus. Reinforcing elements with pre-stressed and firm joints, that is to say geogrids, achieve a far greater increase in modulus compared with flexible reinforcement such as normal woven geotextiles. Also the stiffer the bars of the grid the less the strain permitted under a given load and the higher the modulus. There are therefore significant potential gains in using strong geogrids.

There are of course products available which bond together both geogrids and geotextiles to get the best of both reinforcement and separation functions and these are of particular benefit where the stone fill is poorer quality in terms of lower particle strength and may start to break up or contain more fines. Such materials have started to be used in much larger quantities in the last few years.

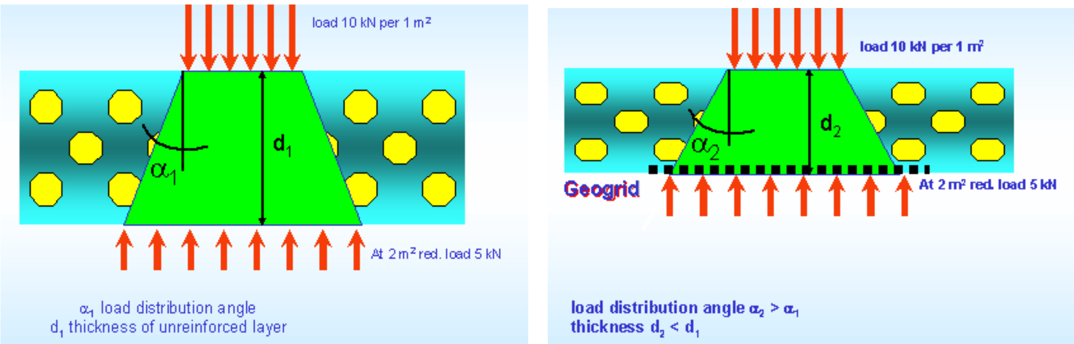

Figure 1. Reinforcement of the base spreads the load more effectively allowing a thinner layer

Table 1. Different aggregate material depths required to achieve a CBR of 15%

CBR Subsoil (%)	Rounded Material/Sand		Crushed Rock Aggregate	
	Un-reinforced depth of material (mm)	Geogrid reinforced depth of material (mm)	Un-reinforced depth of material (mm)	Geogrid reinforced depth of material (mm)
3	500	330	400	280
4	400	270	310	210

A very topical example of where geogrids have recently become important in reducing the amount of aggregate used is the construction of windfarms. The turbines cannot be too close together to ensure that the turbulence generated by one turbine does not affect adjacent ones. One such windfarm being constructed in the United Kingdom at the present time has 85km of access road. If all the aggregate had to be imported then assuming the CBR of the subgrade was 2% the use of geogrids has reduced the requirement for aggregate by 30%, this equates to 142,800m^3 of aggregate, which equates to circa 6,000 trucks of aggregate. Whilst these sites try to win as much aggregate onsite to avoid tax the use of geogrids has become a norm rather then an exception purely as cost saving exercise.

GEODRAINS

For years now it has been common practice in Europe and elsewhere to use geodrains/fin drains/geocomposite drains at the back of retaining walls and bridge abutments. In Germany they have a drainage specification, WAS7, which requires vertical drainage between the structure and the backfill to have a flow rate of > 0.3 l/s*m under the relevant earth pressure. In the UK both the industry and the Highways Agency are actively looking at more cost effective and sustainable alternatives to granular backfill as a result of the Aggregate Levy.

The Specification for Highways Works Clause 513 gives the following options for back of wall drainage:

- Minimum 300 mm thickness of granular drainage material
- Minimum 225 mm thickness of porous no fines concrete
- Precast hollow concrete blocks

For the M25 Widening Project the use of a proprietary geosynthetic drainage medium was proposed, limited to back of retaining wall use but not for drainage around other structures. The geocomposite drainage material was not proposed for use behind integral bridges as the behaviour of integral bridges and the affect of thermal movement on backfill is not yet considered to be fully understood in the UK.

Figure 1. A geodrain being installed on the B529 Herford Bypass, Germany

Figure 2. Geodrain at the back of an Earth Retaining Structure on the M25 London, UK

Technical Justification

Permeability

The proposed proprietary geosynthetic drainage medium had good drainage flow capacity and can be compared with the conventional option of 300 mm of granular material. This was demonstrated by equivalence calculation using laboratory test data.

With a maximum applied active earth pressure of 65 kN/m^2 (based on a maximum retained height of 4 m and a 20 kN/m^2 surcharge) the short term drainage capacity of the proposed drainage material upon installation is Q = 0.67 l/m/s, potentially reducing to $Q_{longterm}$ = 0.30 l/m/s after 120 years (with a hydraulic gradient of I = 1.0). This is comparable to the upper end of flow capacity for the conventional 300 mm thick granular drainage layer, which is between Q = 0.05 to 0.50 l/m/s (with I = 1.0) (TRL Contractor Report 324).

The flow capacity of the proposed material also exceeded the minimum flow capacity for such materials set down by the German Standard DIN4095 'Planning, Design and Installation of Drainage Systems Protecting Structures Against Water in the Ground', which is 0.31 l/m/s.

Durability

The proposed geosynthetic drainage material was constructed from non-biodegradable polypropylene, and is chemically inert to most common soil types (including the proposed retaining wall back fill). And will therefore not degrade over the lifetime of the structure.

Filtration Properties of the Geotextile

Notes for Guidance Series 500, NG 514 Fin Drains gives a criteria for selecting a geotextile filter compatible with the adjacent soil to prevent the occurrence of piping.

The uniformity coefficient (d_{60}/d_{10}) of the Class 6P wall backfill is in excess of 11 (from laboratory testing conducted on site to date). The O_{90} (90% pore size) of the proposed geotextile was 0.12 mm. The table below gives details of the compatibility of the geotextile to prevent piping based on NG 514.

Table 2. Compatibility of Geotextile filter against piping of fines

Uniformity Coefficient of Soil (d_{60}/d_{10})	**D_{50} Range of Class 6P fill mm**	**D_{90} Range of Class 6P fill mm**	**Geotextile O_{90} mm**	**Compatibility of Needle Punched Geotextiles (from NG 514)**	**Geotextile compatible with Class 6P backfill?**
>5	2.0 to 10.0	20.0 to 37.5	0.14	O_{90}/d_{50} <1.8 or:	Yes
				O_{90}/d_{50} <6	Yes

The methodology available in NG 514 the geotextile prevents the potential for piping of fines from the backfill There was a significant saving in the quantity of granular drainage material to be imported if this method were used. But what of the risks?

The potential for clogging of pores with fine soil particles or through chemical or biological deposition is present for all back of wall drainage media and depends upon the filtration capabilities of the filter medium, the chemical composition of the drainage medium, backfill and the groundwater chemistry and other environmental aspects such as average temperature. It is considered that the potential for clogging of pores and consequential reduction in permeability of the geosynthetic drainage medium is low, and no greater than any of the other conventional methods of back of wall drainage.

Earth pressures from the backfill will cause limited crushing of the geosynthetic through creep, however the physical structure of the geosynthetic means that permeability will be retained even at high applied loads. Long term creep tests at various loads are available for most geosynthetic drainage composites.

The proposed proprietary back of wall drainage material was constructed out of non-biodegradable polypropylene. This is highly resistant to chemicals found in all common soils and groundwater. The retaining wall backfill is also specified as being an inert material. The risk of degradation of the geosynthetic is considered to be negligible.

The performance of the geosynthetic drainage material may be affected by certain industrial chemicals or concentrated liquid hydrocarbons. It is considered that the risk to the back of wall drainage material from accidental spillage of chemicals or liquid hydrocarbons onto the carriageway is minimal. The M25 verges in these areas are hard verges and measures to drain the highway surface (slot drains for example) will channel spilled liquids away before they percolate into the groundwater system and reach the geosynthetic. The proposed polypropylene back of wall drainage is resistant to low concentrations of hydrocarbons that may be found in the groundwater beneath a highway.

There are no unusual hazards associated with this proposal. The use of a composite geosynthetic drainage material removes the hazards related to the labour intensive manual handling of hollow concrete blocks, and reduces the exposure to the hazards associated with pouring no fines concrete if this were used as back of wall drainage. The increased speed of installation and the installation occurring in one go reduces the exposure of workmen to site hazards.

Benefits

- Easier, more rapid installation compared with methods given in the specification, resulting in improvements to the programme.
- Removes labour intensive manual handling involved with hollow blockwork.
- Reduction in onsite concrete pour compared to use of no fines concrete drainage medium.
- Full height installation occurs in one go, resulting in an unhindered backfilling operation and less exposure of personnel to hazards.
- Higher quality control as product is factory manufactured offsite.
- Material has uniform properties despite site conditions. Granular drainage material or no fines concrete is difficult to place at an even thickness and is more likely to be variable in composition or permeability. Removes the potential for laitance in no fines porous concrete
- Reduction in the volume of granular drainage fill imported to site when compared to specified granular material option.
- Chemically inert and non-biodegradable.
- Geotextile filters prevent piping within the retaining wall backfill.
- Long term drainage capacity comparable to upper limit drainage capacity of 300 mm thick granular drainage layer.
- Sustainability improved as less transport needed for delivery.

Use of this geosynthetic material as a back of wall drainage layer (for retaining walls only), should provide both economic and programme benefits, compared to the three Specification for Highway Works Clause 513 material options. It also has potential Health and Safety benefits compared to the manual handling of precast hollow concrete blocks and concrete pours.

LANDFILL DRAINAGE

The Landfill Regulations (2002) are the UK enactment of the EU Landfill Directive. Within both documents there is a requirement for the drainage collection layer in all Hazardous and Non-Hazardous landfills and the required specification is for the layer to be 500mm thick. This is a totally unsatisfactory engineering specification as it does not address the required performance in terms of defining particle grading, permeability, gradients, any included collection pipework etc. However, in recognition of this omission the Landfill Regulations do allow the relevant sub-paragraph to be reduced to “an appropriate extent” on the basis of an assessment of environmental risks. On the basis of this most landfill designers have attempted to justify a lower thickness, typically the 300mm that was previously commonly used. However, there is little rational methodology for the design of landfill drainage and the only realistic way would be to use an “equivalence “ method. Unfortunately the Environment Agency has never stated what the default design is to which we can design an equivalent system and furthermore have studiously avoided the issue. The recently convened Landfill Regulation Group, a joint Environment Agency/Industry forum to resolve issues in landfill, have a Landfill Engineering Sub-Group which was tasked with resolving this problem and creating a set of criteria that, if met, could be relied upon without resorting to unjustified, and often incorrect equivalence calculations. This guidance has been issued and is to remain in place whilst more detailed research is undertaken and so is an interim position.

The committee concluded that the efficiency of the drainage blanket can be improved by the installation of a robust and well engineered slotted / perforated pipe drainage network to operate in conjunction with the granular leachate drainage layer. In such cases, a drainage system utilising a slotted / perforated pipe network within a thinner granular layer may fully meet the requirements of the Groundwater Regulations and the Landfill Regulations within certain criteria. They state:

> *A 300mm thick granular aggregate leachate drainage blanket in combination with a robust and well engineered slotted / perforated pipework system is acceptable to meet the requirements of Schedule 2 paragraph 3(6) of the Landfill (England and Wales) Regulations 2002 as long as various minimum design and installation criteria are met.*

These criteria include minimum basal gradient, specification of stone size (BS 13242:2002) with a realistic increase in fines recognising testing after placement will generate more fines; ten percent fines value for the stone for robustness; and the design method for the pipes against crushing.

The hydraulic conductivity of an aggregate drainage blanket is important in both the initial phase and the long term and is related to the grading of the material used. The committee accepted that a 20/40mm stone would be adequate but some members of the group were concerned that in some areas this material was not available or would entail unsustainable long haulage distances. They argued that the reduction of a layer thickness from 500 to 300mm of 10/20mm size stone could clog with fines prematurely and reduce the flow within the layer. Whilst no absolute evidence of this is available there is much observational evidence that using a geosynthetic filter between the waste and the drainage layer significantly reduces the collection of fines within a leachate liner from work carried out in Canada (McIssac and Rowe 2006) and (Fleming *et al* 1999). A compromise decision was made that a 300mm thick layer of 10/20mm stone would be acceptable as long as a geotextile filter was placed between the waste and the drainage media, a methodology promoted and supported by some of us for some years.

The task was then to specify a suitable range of filter geotextiles for this purpose. As with all landfill leachate drainage design there is no valid design methodology for designing such a filter. Normal particle/filter ratios could be used but what is the particle size we wish to filter out? After correspondence with many of the academics who have published on related topics and operators there was only conflicting no and no-one has any firm evidence of the particles at the base of a landfill mass. It was therefore decided that silt particle size was realistic particle to filter out and that finer particles would be allowed to pass through remaining in suspension within the leachate.

The evidence from McIssacs 2006 and Fleming et al 1999 is that non-woven needle-punched/mechanically bonded construction is by far the best to avoid clogging and so was adopted as an essential part of the specification. Polypropylene was specified as a robust polymer in the chemical conditions of the vast majority of landfills. Initially a proposal was put forward that came from the heart of filtration theory using fibre diameter and the number of constrictions. On consultation, and despite the fact that the calculations were very simple, these criteria confused most specifiers, users and regulators and had to be changed. As a wide a range of potential products was desirable it was decided to use a filtration specification from Germany (GRK) as a basis because most major manufacturers produced a suitable products.

When considering the properties for such a use some are important and some not. For instance it was decided not to specify tensile strength, elongation at maximum load as allowing a non-woven filter geotextile to distort over the top of a drainage layer rather than come under tension and perhaps tear was considered the better alternative. The static puncture value would in itself ensure a reasonably robust product and that was considered to be a far more relevant property to specify. The acceptance requirement to be “within manufacturers published parameters” was used for these parameters to ensure prime product is supplied rather than product that may have failed some QC tests.

This Specification has been used for a few months and does appear to be allowing a wide range of broadly suitable products to be used. As it is an interim methodology it can be developed and changed as necessary, and no doubt will.

Of course this interim position still does not help in the design of proper geocomposite drainage systems that are used in many other countries. These must be designed by equivalence to some standard design that has still not been defined here by the Environment Agency.

The Environment Agency has also issued guidance on the use of rubber tyres as a landfill drainage media. This could also be considered to be a form of geodrain. The guidance given is for both shredded tyres and whole tyres. If using shredded tyres then a filter geotextile as discussed above must be used. However if whole tyres are used the filter geotextile may not be required. The problem remains on the compressibility of the tyres; therefore it has been proposed to use a geogrid over them to help alleviate the potential differential settlement that may occur in the tyres. This has been successfully carried out on at least two sites that the authors are aware of, one of which was a trial prior to issuing the guidance.

Table 3. Filter Geotextile Specification

Property	**Test**	**Acceptance**
Polymer		Polypropylene
Geotextile Construction		Non-woven - mechanically bonded
Marked		CE
Tensile strength	EN ISO 10319	Within manufacturers published parameters
Elongation at max load	EN ISO 10319	Within manufacturers published parameters
Static puncture (CBR)	EN ISO 12236	3300 N min.
Dynamic perforation resistance (Cone Drop)	EN ISO 918	Within manufacturers published parameters
Characteristic opening size O_{90}	EN ISO 12956	50 to 120 µm
Water permeability normal to plane	EN ISO 11058	>40 l/m^2s
Thickness	EN 964-1	>1.5 mm
Mass per unit area	EN 965	>300 g/m^2
Durability	See Annex B of EN13252 OR German robustness class (GRK) 5	
Resistance to weathering (UV)	EN 12224	> 1 month
Resistance to chemical ageing	EN ISO 12960, EV ISO 3438 or ENV 12447	Within manufacturers published parameters
Resistance to microbiological degradation	EN 12225	Within manufacturers published parameters

CONCLUSION

The Primary Aggregate tax has been one of the driving forces for the UK construction industry to reconsider traditional tried and tested construction methods. The result of this has been the proposal and acceptance of geosynthetics across the board to replace other materials. This is a welcome trend that should see the acceptance and use of geosynthetics continue to grow both in the short and long term.

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