TECHNICAL NOTE: SUBSOIL DRAINS

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This technical note has been prepared to assist in the understanding of subsoil drainage design and the related geotechnical issues. Subsoil drains are also sometimes referred to as 'seepage drains', 'subsurface drains', 'trench drains', 'rubble drains', 'Ag drains' or 'agricultural drains'.

1 SUBSOIL DRAINAGE GENERALLY

As the design of many engineering structures necessitates the removal of subsurface water from the ground close to, or under the structure to be constructed, it is *firstly* important to consider the potential effects of an intermittent, or permanent reduction of the soil moisture content, or groundwater level. In this regard, it is to be noted that a lowering of the moisture content in soils that have a clay content exceeding 20% can cause shrinkage of the clay soil foundation with consequent damage to the structure.

Note: Additional information on the effects of drying out a clay foundation to a structure are contained in the CSIRO 'Homeowners Guide' [CSIRO 2003].

Secondly, the nature of the soil within which the drain is to be installed is of paramount importance to the design of the drain. This is because whilst sandy and coarser-grained soils can usually be effectively drained by subsoil drainage, clay soils are usually too impermeable to be drained. Further, the installation of a subsoil drain in a clay soil can have the effect of introducing water into the soil [e.g. from surface drainage or pipe leakage], rather than removing water from the soil [Marshall 1959 pp17, Malaysian Department of Irrigation & Drainage clauses 44.2.2 & 44.5.1].

Note: Clay soils with a moisture level less than the plastic limit typically exhibit 'soil suction' [i.e. the soil takes up water from any available water source]. Additional information on soil suction and the relationships between water and soil are provided in Marshall 1959.

Thirdly, as seepage from a soil is often confined to a localised 'seepage path' [or aquifer], it is important to ensure that the subsoil drain is designed to capture water from the seepage path, and then effectively remove the seepage water to an appropriate efflux [Shirley 1977]. Further, it is very important that both the base of the subsoil drain itself, and any pipe located within it, be the subject of a detailed hydraulic design with all pits, invert levels, etc., being specified prior to commencement of construction.

Note: In some cases, the water flows from a localised aquifer can be significant.

Fourthly, whilst the use of geosynthetics in the construction of a subsoil drain can be a very cost-effective approach to the design / construction of a subsoil drain, the author's experience with the use of these materials has indicated that these materials have significant limitations on their use, and may have the opposite effect to that intended by the subsoil drain designer [see Section 3].

It is also important that any subsoil drainage installation be carefully designed, and then properly constructed in accordance with the design.

Additional notes on the above issues are provided in the following sub-sections.

1.1 DESIGN CONSIDERATIONS

In addition to the information contained in the Australian Standard on Earth Retaining Structures [AS4678, Section 3 & Appendix G], the author considers that the following are also important:

a) The subsoil drainage system design should be 'site specific', with the design providing not only details of the materials to be used in the subsoil drain trench itself, but also details of how any seepage collected by the subsoil drain is to be conveyed to a suitable efflux point.
b) It is important that surface water / stormwater run-off does not enter the subsoil drain; thus, an impervious cap, or seal [e.g. compacted clay] should always be provided over the subsoil drain to ensure that surface waters do not enter the subsoil drain [Shirley 1977]. Consideration should also be given to the redirection of surface water flows from buildings, road pavements, paved surfaces, etc., away from the location of the subsoil drain.
c) The design should be based on the predicted 'long-term' condition of the drainage system, rather than the expected performance of the system immediately after installation, including the assumption that there may be a failure, or partial failure of the subsoil drainage system in the future.

d) Any perforated pipes within the subsoil drain should be in accordance with AS2439 Part 1, and laid so that the invert of the pipe is at the base of the trench.

Notes:

1. It is not necessary for a subsoil drain to have a perforated pipe; only where significant flows within the drain are anticipated should a pipe be provided.
2. A subsoil drain without a pipe is sometimes termed a 'rubble drain'.

e) On some installations, it may be preferable to use a slotted uPVC pipe rather than a corrugated perforated pipe due to the larger capacity of the uPVC and its greater crush strength.

Note: The smoothbore of a uPVC pipe is also advantageous from both flow and cleaning / maintenance aspects.

f) As corrugated perforated subsoil pipes come in a variety of 'strength classes', an important consideration for the design is the pressures to which the pipes may be subjected in the future [AS2439, Part 1].

Note: The author has observed number of subsoil drain failures due to the crushing of the subsoil pipe.

g) Where a subsoil drain incorporates a pipe or geocomposite equivalent, flushing points and clean-out pits / sumps should be provided to enable the removal of any silt, and / or bacterial growth that may develop over time within the pipe, or geocomposite equivalent of the subsoil drain.

Notes:

1. Where feasible, it is preferable for flushing points to also provide ventilation to the drain, and extend above the ground surface.
2. In some cases, it may be necessary to provide for the injection of an appropriate gas [e.g. nitrogen dioxide] to destroy bacterial growth within a subsoil drain.

h) On some installations [e.g. in landslide control and / or localised groundwater control], it may be necessary to provide for monitoring of the water levels within the subsoil drain by the installation of monitoring wells and / or piezometers [Shirley 1977].

Note: In some cases, the provision of a remote monitoring system for the piezometers can prove cost-effective.

i) Typical filter / backfill materials for a subsoil drain consist of natural clean washed sands and gravels of adequate permeability. The particle size of filter / backfill materials should also be such that it will not enter the perforations in the pipe. In addition, it is preferable that:
   - sand materials have less than 5% passing a 75 µm sieve;
   - screened crushed rock not be too 'angular', and have minimal fines / crusher dust.

j) Where a geotextile is provided on the sides of the subsoil drain trench to prevent / minimise the migration of fine particles into the filter / backfill material, it is often necessary to provide a natural sand filter between the geotextile and the natural ground / fill material to promote the development of a natural soil filter within the ground / fill outside of the geotextile associated with the subsoil drain trench.

Note: It is important that a designer of a subsoil drain recognise that the inability of a geotextile to 'wick' soil moisture across the plane of the geotextile can create the situation in which the geotextile actually diverts seepage, and prevents the localised seepage / aquifer from entering the subsoil drain [see Section 3, items f) & g)].

k) Mixtures of brick bats, concrete rubble, etc., are usually unsuitable for use in the subsoil drainage system because such materials can become clogged over time, with silt and fine materials rendering the drain ineffective. Further, such materials can puncture thin geotextiles easily because of their sharp and ragged edges, with the result that the geotextile barrier is ineffective.

Note: Should it be desired to use such materials for construction of the subsoil drain, then special consideration should be given to the geotextile design, and its puncture and tear strength in particular [see Section 3].

l) Where the pipe 'bedding' is a different material to the trench filter / backfill material within the subsoil drain, the 'bedding' should be more pervious [e.g. coarser grained] than the filter / backfill material.

m) Where a subsoil drain pipe, or equivalent geocomposite drain connects to a pit, or pump-out sump:
- suitable access should be provided to enable monitoring of the performance of the subsoil pipe or equivalent geocomposite drain;
- the invert level of the subsoil pipe / subsoil drain should be sufficiently above the base of the pit / pump-out sump to minimise the risk of backflow occurring into the subsoil drain.

n) Subsoil drains should be constructed with the base of the trench at an even slope, and so that the trench can act as a 'rubble drain' even if the pipe, or equivalent geocomposite drain, within the trench becomes blocked. Any subsoil pipe / equivalent geocomposite used in the drain should also be laid on the base of the trench.

Note: It is not necessary for an effective subsoil drain to include a pipe; rather, some of the drains that perform the best over the long-term are ones which do not include a pipe, and rely on the porosity of the filter materials within the drain to convey the seepage / water flows to the efflux point.

o) As the purpose of a pipe within a subsoil drain is primarily to create an 'open void' within the porous trench backfill materials to promote more rapid drainage, it is important that the pipe have an even and continuous grade of not less than 1% [and preferably 2%] to the point of efflux, with any localised 'high' points being avoided.

Notes:
1. Where the site topography permits, steeper gradients of the subsoil pipe are usually beneficial.
2. Corrugated subsoil pipes typically require a gradient of at least twice a smoothbore pipe to operate effectively.

p) The author generally recommends against the use of a geotextile 'sock' around the subsoil pipe; this is because the fine crusher dust from gravel materials, or the remnant fines within a 'washed sand' have been observed to 'clog' such filter socks over time, with adverse consequences on the performance of the subsoil drain.

Note: It is also generally technically unnecessary to have a 'sock' over a perforated pipe within a subsoil drain unless the subsoil drain filter / backfill material is a fine to medium grained sand.

q) An important part of subsoil drainage design is the connections between the pipework and / or geocomposites; in this regard, it is essential to provide a proper hydraulic connection between the various sections of pipework and / or geocomposite.

Note: The author has observed a number of instances where a failure to properly hydraulically connect the geocomposite used as a vertical strip drain behind a building basement wall, has resulted in serious dampness and seepage issues in the basement.

1.2 CONSTRUCTION AND MAINTENANCE

As with all drainage systems, it is very important that subsoil drains are constructed in accordance with the design and in a manner that will permit maintenance. In addition, where the drainage of subsoil water is critical to the performance of a structure, the author also recommends the installation of appropriate piezometers that can be remotely monitored.

The author also suggests the following:

a) To ensure compliance of the subsoil drainage system with the design intent, it is important that the construction be reviewed by an appropriately experienced engineer.

Note: The author has encountered many occasions on which persons with little knowledge as to the appropriate construction of subsoil drainage have caused serious problems, with these problems including damage to building structures and initiation of localised landslides.

b) The subsoil drainage system be flushed with water on completion of the installation to ensure:
- the adequacy of the 'as built' gradient of the subsoil drain, as well as;
- the removal of any debris that may become lodged in the system during the course of construction.

c) The monitoring points and pits associated with the subsoil drain should be checked at least annually, and any debris within the pipes removed by suitable flushing.

2 GEOSYNTHETICS - GEOTEXTILES & GEOCOMPOSITES

As there are many types of geosynthetics, with each of the various geosynthetic materials exhibiting particular properties, it is very important that the specific details of the geosynthetic material required for a particular installation be carefully specified. In addition, where a particular contractor wishes to use a geosynthetic material different to that specified, the approval of the design engineer should always be sought prior to substitution of one material for another.

In this regard, the following are noted:

a) Geosynthetics is the generic term that includes geotextiles, geogrids, geomembranes and geocomposites.

   Note: The term Geofabrics is a tradename for particular types of geosynthetic.

b) An important consideration in the design of a geotextile or geocomposite associated with a subsoil drain is the angularity & sharpness of the particles for the filter / backfill material; in this regard, the thickness / grade of the geotextile [particularly puncture & tear strength] should be considered in the geotextile design.

c) Although the use of geotextiles & geocomposites has become widespread in subsoil drainage construction, the author's experience indicates that whilst such materials are usually very effective in the shorter term, there is limited evidence of their long-term efficacy in subsoil drainage.

   Note: The author's exhumation of a number of subsoil drains that have not performed adequately revealed that the geotextiles had become clogged with fine soil particles.

d) The permeability of geotextiles used in subsoil drains should be greater than that of the surrounding soil; it is also desirable that the permeability of any geotextile used be at least 10 times that of the surrounding soil.

e) Geotextiles can become clogged in some locations [e.g. where iron salts are present, etc.], due to oxidation and biologically related actions which cause plate-like deposits of ferruginous particles to form on filter surfaces. In addition, as geotextile design usually relies on the formation of a natural filter between the soil and the geotextile, it is important that the design incorporate a methodology for the natural filter to develop.

f) Both woven and needle-punched geotextiles are generally hydrophobic [i.e. they repel water] and do not 'wick' water across the geotextile, with the typical 'surface tension' effect [i.e. hydrophobia] exhibited by such materials only being overcome by a water pressure 'head' of 50 to 100 mm. In other words, until the surface tension effect is overcome and the geotextile is saturated with water, the geotextile acts as a **barrier** against seepage [Koener pp 271].

   Note: Whilst this hydrophobic property of the usual geotextile does not present a problem in many cases, where the object of the design is to provide seepage control [e.g. for minor leaks & seepage within a basement excavation, the control of a landslide where the seepage path lies at a particular geological interface], then special forms of geocomposite [or other drainage methods] are required to ensure that the seepage is appropriately controlled.

g) Although all geotextiles possess some 'in-plane' drainage capability, with the thicker needle punched geotextiles exhibiting significant 'in-plane' drainage capability, there is no 'wicking action' across the plane of a geotextile [Koener pp 264].

   Notes:

   1. Because polyester and polypropylene both repel water, geotextiles do not 'wick' water in the way in which the 'wick' of a candle transfers molten wax to the flame.
   2. Where significant 'in plane' drainage capacity is required, it is preferable to use a 'flow net' geocomposite [i.e. a polypropylene 'geogrid like' material encapsulated in geotextile].

3 RETAINING WALL DRAINAGE

The author's experience has shown that a common cause of failure of many walls is a lack of suitable drainage behind the wall. In this regard, the following are noted:

1. The design of a retaining structure should consider the drainage aspects of the site, including the short and long-term subsurface hydrological conditions. In addition, as the lowering of groundwater by retaining wall construction may have an adverse effect on the adjoining property / ground, it is important to consider the impact of groundwater lowering, both the short and long-term, in the retaining wall design process.

   Note: It is a specific requirement of the Australian Standard on Earth retaining structures to consider *"the possible adverse effect on the adjacent land or structures of the construction of an earth retaining structure."* [AS4678, clause 3.7].

2. The provision of effective drainage behind a wall is very important as a lack of proper drainage can increase the load on the wall by about 1½ to 2 times. Further, even where water does not come in direct contact with the retaining wall, increased pressures can occur on the retaining wall due to an elevated phreatic [water] surface level within the potential failure wedge behind the structure.
3. Surface water should be directed away from the top of a retaining wall, and not allowed to pond behind the top of the retaining wall. The surface drainage should also be designed so that it does not permit surface water to enter the subsoil drainage system [e.g. from surface run-off during rainfall].
4. The build up of water behind a retaining wall, and / or faulty subsoil drainage, can cause softening of the retaining wall foundation, with resultant wall instability [either overturning or sliding].
5. Where possible, weepholes should be provided through the retaining wall at regular intervals.
6. If the subsoil drain has an inadequate fall, or localised areas where water can pond / build up within the drain, concrete / masonry walls without adequate waterproofing on the rear face can result in the retaining wall becoming damp / wet on the inside face. As such, it is the author's preference for retaining walls, and similar structures, to be isolated from the 'habitable' or 'dry' areas of houses / buildings.

4 REFERENCES

CSIRO BTF 2003 *"Foundation Maintenance and Footing Performance: A Homeowner's Guide"*.

Koener, Robert M 3rd Edition 1994 *"Designing with Geosynthetics",* Prentice Hall.

Marshall T J – *"Relations between Water and Soil"* 1959 – CSIRO Technical Communication No. 50.

Standards Australia – AS4678-2002: *"Earth retaining structures".*

Standards Australia – AS2439 Part 1 - 2007: "Perforated drainage pipe and associated fittings".

Malaysian Department of Irrigation and Drainage: ch 44 [1st edition 2000] - *"Urban Stormwater Management Manual"*. https://www.water.gov.my/index.php/pages/view/887.

Shirley, A F & Francis, K W *'Techniques of Landslide Control Using Drainage'* March, 1977 - Annual Engineering Conference of the Institution of Engineers, Australia.