Sodicity and dispersion relations in some Darling Downs subsoils

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Abstract
An investigation was undertaken into the likelihood of problems associated with exposed soil as part of planned construction of powerline towers on the southern Darling Downs, Queensland, Australia. Soils were investigated at selected sites using 50 mm undisturbed cores to a maximum depth of 2 m. Cores were described, and strategically sampled in 10 cm sections for further analysis. Samples were assessed using the Emerson dispersion test and conventional laboratory analyses – pH, EC, Cl and cations. Dispersion scores were amalgamated to produce a Loveday-Pyle score (between 0-16). When plotted against Exchangeable Sodium Percentage (ESP) and grouped by dispersion index, four obvious groups of soils became evident: those that fully dispersed; those that unless compacted or disturbed remained relatively stable; those containing calcium carbonate; and those that failed to disperse. Dispersion was greatest where ESP values were between 16 and 50. Aggregates containing calcium carbonate (Dispersion class of 4) failed to disperse even with ESP values of up to 11.8. Aggregates, which dispersed and once re-moulded (Dispersion class of 3a or 3b), possessed ESP values as low as 0.9. The selection of ESP and Emerson tests to assess erodibility of soil material aimed to cover both the theoretical chemical stability of the soils (as determined using ESP) coupled with a test more representative of field conditions (Emerson test). Strongly to extremely sodic subsoils were a common feature of the landscapes in the transect, requiring conservative practices to manage both construction and site rehabilitation.

Key Words
Dispersion, sodic, ESP, subsoil, stability, erosion.

Introduction
A major power line has been proposed to connect the Millmerran power station with the city of Toowoomba. This area spans a range of land types, primarily on sandstones, basalts and alluvial parent materials. Based on existing land resource mapping for the area (Harris *et al* 1999), it was expected that there would be a strong likelihood of intercepting both texture contrast and uniform soils, possessing sodic to extremely sodic clay subsoils throughout the transect. Management of sodic spoil from construction processes was deemed a significant issue in preliminary assessments for the project.

Methodology
Soil investigations were undertaken at selected proposed tower sites using standard soil survey methodology as defined in Gunn *et al.* (1988) and McDonald *et al*. (1990). At each of 23 sites, a 50 mm diameter undisturbed core was taken to a maximum depth of 2 m or rock, whichever came first.
A minimum of one, and a maximum of four samples were taken per site. At all sites, a further sample was taken from the top of the clayey B horizon (where present), as existing chemical data for soils of the area (Harris *et al.* 1999) indicated that maximum exchangeable sodium percentage (ESP) was often encountered at this point. All of these samples were 10 cm sections.

All samples were air dried (40°C) for at least 24 hrs, and then assessed using the Emerson dispersion test (Figure 1) as defined in Emerson (2002). Based on the results from the dispersion tests, selected samples were analysed for pH, EC, Cl, exchangeable cations (Ca, Mg, Na, K) and cation exchange capacity (CEC) by NRM&E laboratories. ESP was calculated from exchangeable Na*100/CEC.

Dispersion was scored from 0-4, depending upon the degree of dispersion, for both time intervals of 2 and 20 hours. Since soil has a tendency to behave differently once disturbed, aggregates which were noted to not disperse at all, or only slightly, were worked and remoulded into 5 mm balls at field capacity water content (as described by Emerson 2002) and re-tested for dispersion. Those aggregates that dispersed either moderately or severely were assumed to disperse fully after remoulding and were not treated any further. These were automatically given scores of 4 for both remoulded time intervals of 2 hours and 20 hours. Dispersion was assessed and recorded after 2 hours and 20 hours for the remoulded samples.

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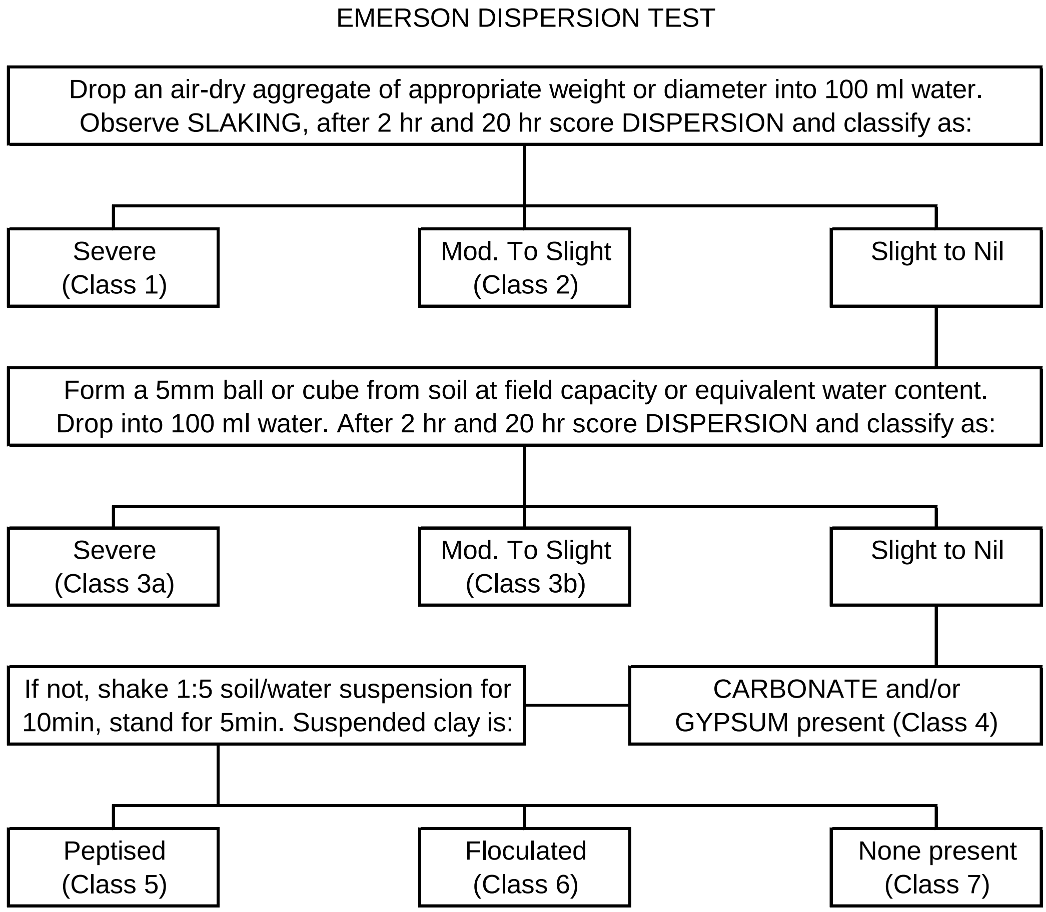

Figure 1. Emerson dispersion test flowchart.

Results

Soils identified fell into three main classification (Isbell 1996) groups– uniform sandy soils (Tenosols) found on sandstones, texture contrast soils (Sodosols) formed on alluvia or sandstones and uniform cracking soils (Vertosols) formed on alluvia. Sodosols varied from thin surfaced types found on alluvia to those with thicker, sandier A horizons found on sandstones.

In general, all soil materials with clay textures were dispersive. All four dispersion scores were added to give the Loveday-Pyle dispersion index, as described by Emerson (2002). When plotted against exchangeable sodium percentage (ESP) and grouped by dispersion class (Figure 2), the differences between each dispersion class become more evident. For a Loveday-Pyle score to be greater than 9, a significant amount of dispersion must take place, i.e. scores of 3 or 4 for each sample. Only dispersion classes of 1 and 2 have Loveday-Pyle scores greater than 9.

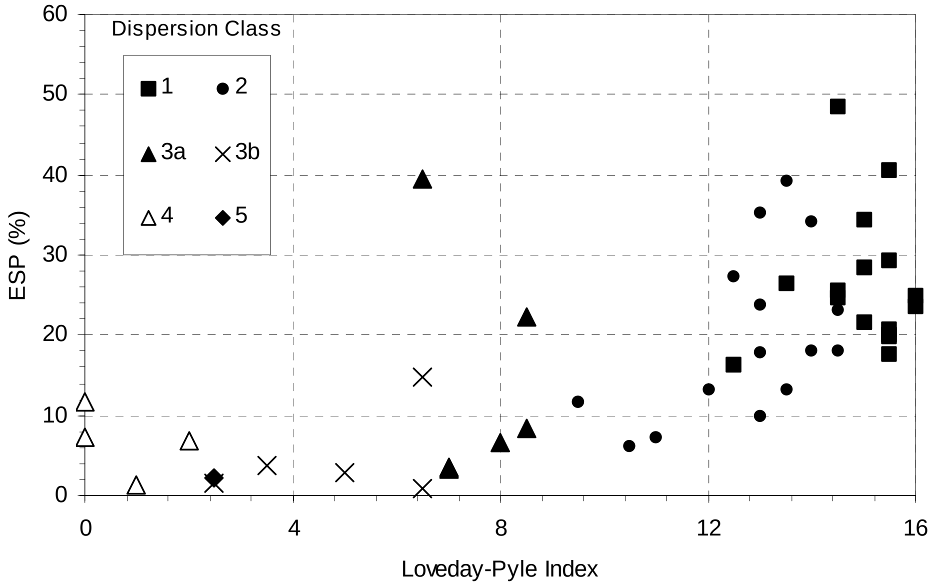

Figure 2. Loveday-Pyle Index *vs* ESP (dispersion classes indicated).

Figure 2 also illustrates the relationship of ESP values against the Loveday-Pyle dispersion index. In order for an air-dried soil aggregate to disperse readily (i.e. Dispersion class of 1 or 2) there is a minimum required ESP value of about 6. Figure 2 also shows that dispersion was greatest (i.e. class 1) with ESP values between 16 and 50. Those aggregates containing calcium carbonate (Dispersion class of 4) failed to disperse even with ESP values of up to 11.8. It is also evident from these results that those aggregates, which dispersed once remoulded (Dispersion class of 3a or 3b), possessed ESP values as low as 0.9.

Discussion

Strongly to extremely sodic subsoils were a common feature of the landscapes in the transect. Many of the soils were also magnesic (Ca:Mg ratio <1). Magnesic conditions can exacerbate sodic properties. Four main dispersion-based soil groups were distinguished for the purposes of this study and are detailed here.

> *Group 1* Profiles with dispersive subsoils (dispersion class 1 and 2)
> *Group 2* Profiles with relatively stable subsoils unless disturbed and compacted (dispersion class 3a and 3b)
> *Group 3* Profiles containing (highly likely) calcium carbonate (dispersion class 4)
> *Group 4* Profiles that are non-dispersive (dispersion class 5)

Group 1

These soil profiles described had a relatively stable surface horizon, usually very thin, but had extremely dispersive subsoils (B horizons) with dispersion classes of 1 or 2. These soils have a high probability of forming pipe or tunnel erosion if water is able to make its way through the hard setting surface and move laterally through the profile. If the surface soil is removed by water erosion or other physical disturbance, the exposed highly dispersive subsoil can quickly erode and develop rills and gullies. Material stockpiled to excessive heights from these soils will suffer such dispersion/erosion problems. Group 1 soils were mostly Sodosols.

Group 2

These soils were found to be relatively stable under natural conditions unless disturbed and either compacted or moulded, in which case they became very unstable. These sites had dispersion classes of either 3a or 3b through some or most of the subsoil. Group 2 soils were Sodosols, Chromosols and Kurosols.

Group 3

A percentage of the soils contained variable amounts of calcium carbonate at depth, stabilising the clay to some degree, even after disturbance. Calcium cations, being physically smaller than sodium cations, will reduce the distance between clay particles, which in turn increase the clay particle attraction and reduce

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dispersion. These soils have a Dispersion class of 4. At two sites the calcium carbonate had accumulated near the top of the subsoil, which usually coincided with a long-term wetting front. In most cases, immediately below these calcium carbonate layers are highly dispersible clay horizons. Soil profiles at two other sites had calcium carbonate throughout. It is possible that when such material is brought to the surface, the calcium carbonate will be leached out, causing the soil to become less stable. Group 3 soils were Sodosols.

Group 4
There was only one profile in this group – a uniform sand (Tenosol). The soil had a dispersion class of 5, which was to be expected given the lack of clay in the soil. This soil type was not common within the study area.

Management Considerations
The selection of ESP and Emerson tests to assess erodibility of soil material aimed to cover both the theoretical chemical stability of the soils (as determined using ESP) coupled with a test more representative of field conditions (Emerson test).

It is important to note that once subsoil material is excavated and stockpiled, its chemical attributes will change. Leaching of readily mobile ions such as carbonates and chloride can cause significant changes (usually negative) in stability of material, and therefore an assessment should always consider a worst-case scenario.

At nearly all sites located on hillslopes of sandstone, hardsetting soils were found. On those soils rainfall run-off maybe excessive, but soil loss will not always be high, due to the tendency of the soils to become "armoured", unless flow is concentrated enough to initiate gully erosion. Disturbance to the hard surface e.g. construction traffic, can cause the rate of soil loss to increase. Soils with clay texture surfaces typically possessed surfaces that crusted and cracked when dry. Soil loss from surface erosion of these soils can be high in sloping lands, although the sites investigated were flat, hence surface erosion is not likely to be a problem on these soils unless overland flow is concentrated.

Where a dispersive subsoil exists, the nature and thickness of the A horizon will be a critical factor in determining the degree of disturbance that may result in a significant erosion problem. Obviously soils with thicker A horizons are less likely to develop subsoil erosion as a result of disturbance of the soil surface. They will also possess a greater amount of material available for capping stockpiles. Application of ameliorants such as gypsum ($CaSO_4.H_2O$) may be useful for treating stockpiles, particularly when low volumes of stable material are available for capping.

Attention should also be focused towards preventing tunnel erosion at the concrete-soil interface. Evidence within southern inland Queensland suggests a high incidence of dispersion at the concrete/soil interface when structures are placed in highly sodic materials. Most evidence comes from disturbed and re-compacted materials rather than *in situ* constructions, but significant consideration should be applied to the matter given the highly sodic nature of the materials in the transect area.

Conclusions
In general, the landscape through which the proposed transmission line runs is dominated by soils with dispersive subsoils (either sodic and/or magnesic). Exposure of the subsoil material during construction will lead to erosion in a variety of potential forms, in particular gullying and tunnelling. Stockpiled subsoil material (spoil from construction of pylon stubs) will require specific management techniques. Management options include treating the material *in situ* or removing it from the site. If subsoil ESP is greater than 15, removal of material would be an easier solution than attempting to rehabilitate on-site. At a number of sites, partitioning of the profile, and treating of the upper layer on-site is feasible, but from a construction perspective, it may be easier to remove the whole profile. If treating *in situ*, application of gypsum, and capping the stockpile with topsoil (with application of appropriate seed and mulch) would be the most effective treatment method.

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