Sandplain hardpan: a different dam construction material

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Before 1980, the Department of Agriculture did not believe that suitable farm dam materials could be found in light land soils. However Beacon earthmoving contractor, V. J. Pavlinovich, has demonstrated that where suitable cemented subsoils or 'hardpan' existed, a successful dam site could be found.

This material should not be confused with compaction or traffic hardpans which are dense layers of soil found near the surface. Traffic hardpans result from the compaction of soil materials with the passage of vehicles and farm machinery. Rather, the hardpan referred to here is a natural subsoil layer that has been cemented by silica and exists at depths greater than one metre below the surface. This hardpan has been locally described as 'rock' or 'sandstone'.

As about half the north-eastern wheatbelt is mapped as being sandplain, this opens a new prospect for potential dam sites where suitable hardpan exists. The potential may apply to extensive areas of similar soils elsewhere in the agricultural area.
Properties of sandplain hardpan material

The major feature that sets sandplain hardpan dam material apart from most other conventional dam material is the degree of subsoil hardness. Although cemented pallid zone exists in parts of the north-eastern wheatbelt it is not often present in large distinct layers as is the hardpan material. Sparks and smoke are often created as the bulldozer ripper tyne uses considerable effort to break up the dense hardpan. The hard nature of the hardpan can be realised by comparing its density to quartz (a very hard substance) and uncemented pallid zone. The hardpan has an average calculated bulk density (air and solid components) of 2.3 tonnes per cubic metre, which is significantly greater than an average of 1.7 tonnes per cubic metre for uncemented pallid zone and approaching the 2.65 tonnes per cubic metre density of quartz.

Farm dams constructed in hardpan material usually retain water very successfully. A seepage rate of less than two millimetres a day is generally regarded as representing successful water storage in the north-eastern wheatbelt. From the most recent (January, 1985) seepage records for 11 sandplain hardpan dams, the maximum seepage rate was only 1.7 mm/day. This represents one of the most successful types of farm dams in the area. Only one of these dams had a significantly greater initial seepage rate of 10 mm/day and it sealed itself within several years. However, pallid zone dams in the area may have seepage rates as high as 100 mm/day and may not 'take-up' or seal for many years.

Although the seepage rates for hardpan dams are usually low, soil pores several millimetres in diameter can be seen with the naked eye in some hardpan materials (Figures 1,B and 2). This fact, in addition to the very coarse or gritty texture of some drilled hardpan material, would suggest that it might be highly porous and leak. To explain this apparent contradiction of low seepage but porous appearance, sandplain hardpan dam material was investigated for its physical, mineralogical, and chemical properties.

The sandplain hardpan profile shown in Figure 3 includes a number of forms of hardpan which are not always all present in the same profile. The dominant type of hardpan is the grey, coarse-textured hardpan which is mottled (stained) orange-red (Figures 1,C and 3,E). When not stained it is called grey hardpan. Within the mottled or grey hardpan, veins of a finer textured grey material described as conchoidal hardpan may occur (Figure 1,A). This material has sharp edges when broken, with a smooth and sometimes glossy surface appearance. Above the mottled or grey hardpan, a grey to reddish-brown laminated hardpan may exist with horizontal planes of weakness (Figure 3,D).
Particle size distribution

One of the standard tests for determining the suitability of soil material for dam construction is an examination of the particle size distribution. This is important because soil ‘fines’ or silt (particles between 0.02 and 0.002 mm diameter) plus clay (particles less than 0.002 mm diameter) can bind larger grains and aggregates together. Dispersion of the soil fines provides material that may fill porous channels, thus limiting seepage from farm dams. Although there is no precise value for the minimum percentage of silt and clay necessary to seal a dam, a figure of 15 to 20 per cent is believed by most authorities to be appropriate.

Sandplain hardpan dams are often composed of the massive hardpan in the lower levels of the dam. The loose excavated hardpan on the batters usually forms a layer over the shallower surface soil material. The fact that these dams hold water when full indicates that both the massive hardpan and batter material successfully retain water.

Sandplain hardpan contains quartz, kaolin, and goethite (iron oxide). Mineralogy (x-ray diffraction) and chemical (x-ray fluorescence) testing techniques were used to determine what percentage of kaolin plus goethite minerals are present in the hardpan material. These minerals have small particle diameters and can fill porous channels. An estimate of their abundance will determine how much material might be available to limit seepage.

Mineralogical and chemical tests both showed that an average of 46 per cent (range 32 to 60 per cent) of the sandplain hardpan is kaolin plus goethite. Although this percentage appears sufficient to seal dam material, a siliceous cement that is bonding the hardpan together is preventing the dispersion of most of the minerals.

When particle size percentages were determined by physically crushing the hardpan and mechanically mixing it to produce a hardpan material similar to those of existing dam batters, only an average of 8 per cent of silt plus clay (range 3 to 13 per cent) and 4 per cent clay material (range 1 to 8 per cent) result. Uncemented pallid zone material, by comparison and using the same technique, has at least 30 per cent silt plus clay and 20 per cent clay material.

The low percentages of silt plus clay for hardpan, using the crushing and mixing technique, result because much of the material was not dispersed. Thus the silt and clay minerals including kaolin plus goethite, remained within hardpan aggregates. The percentages of kaolin plus goethite for hardpan were significantly greater, using both the mineralogical and chemical tests, because...
these two methods did not rely on the dispersion of the hardpan material. Thus, although these two tests show that a considerable percentage of fine material exists in the massive hardpan, the hardpan cement is limiting dispersion and allowing the release of only a third of the fine material in the dam batter. The amount of dispersed silt and clay is well below the accepted minimum value of 15 to 20 per cent desired for limiting seepage from farm dams. If the hardpan batter material is a sealing layer then other factors besides the amount of soil fines in the hardpan batter material appear responsible for its low permeability. The role of cements (silica and iron oxides) and non-hardpan material in the sealing mechanism is being investigated.

**Hardpan porosity**

Water generally flows through large pores faster than through small pores. Therefore the proportion of large pores to small pores in a soil material can influence the rate of seepage (permeability). The volume of soil not occupied by solid material defines the volume of soil pores. This volume comprises cracks and root channels (preferred pathways or macropores) and smaller internal pores (micropores). The ability of massive hardpan to successfully retain water was investigated by examining its porosity characteristics. Soil moisture retention tests showed that about 25 per cent of the total sample volume (range 20 to 34 per cent) was pore space. Uncemented pallid zone material by comparison contains about 50 per cent total pore space. In addition to the small volume of connecting pores in hardpan material, more than half the pores were less than 0.003 mm diameter. These are very fine pores that severely restrict water movement. Another reason for the relative impermeability of the hardpan material is the general lack of cracks or large root channels in the hardpan (Figure 3) which are found in some pallid zone materials (Figures 3 and 4) and which may cause excessive dam water seepage.

The fact that the massive hardpan contained an average of 46 per cent kaolin plus goethite minerals (as determined by mineralogical and chemical tests) would imply a considerably greater total pore volume than the 25 per cent total volume determined. However, it is believed that the siliceous cementing agent present in hardpan material has filled most of the porous cavities and thereby reduced the total volume of pores.

Sandplain hardpan material therefore has different properties compared to some pallid zone material. The sandplain hardpan is very hard and needs a lot of cross-ripping during dam excavation. The densities are much greater than some pallid zone material, and the total porosities are considerably lower. The siliceous cement present, and the relative lack of preferred pathways for water movement, contribute to make the massive sandplain hardpan a successful material for farm dams.

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Further reading
