introduction

The author has been involved with the performance of concrete drain tile for over thirty-five years. While it is unfortunate that much of this involvement has been related to the investigation of the cause(s) of failures, it is an integral part of engineering that we learn and advance our knowledge by the investigation and back analysis of such events.

The potential causes of the failures investigated have been identified as including one or more of the following:

- under strength tile
- higher than anticipated earth loads on the tile
- poor construction practices which apply significant additional loads to the tile
- loss of sidewall support

Back analysis of failures requires an adequate knowledge of the tile materials supplied, soil types and groundwater conditions, trenching and tile installation procedures and post installation traffic over the trench. Frequently, not all of this information is available. It is also of interest to note that, when drain tile failures are investigated, the extent of the problem with cracked and deformed tile is usually much greater than the immediate area where the initial collapse was observed.

It has been the author's observation that tile failures are more commonly associated with larger diameters, more deeply buried installation or installation subject to significant live loads.

trench conditions

Concrete drain tile are usually installed in less than ideal soil and groundwater conditions, primarily as a result of the location of the drain in low lying areas. The soil conditions can vary from coarse granular materials to fine grained clayey materials or soft organic materials and the water conditions can vary from dry to heavy seepage. The extremes of these conditions, excluding organics, are outlined on Figure 1 which shows typical trench conditions for a dry clay soil and a wet sandy soil. The dry clay trench is characterized by neatly cut vertical or near vertical wall which provides the minimum width specified to install the tile. By contrast, the wet sandy trench has much flatter and irregular side walls and a broader base. Under these conditions, it is frequently difficult to control the trench geometry due to groundwater inflows and sloughing of the sidewalls. To address these problems, it is common practice to use clear stone to stabilize the base of the trench. However, where fine grained sands or silts are present, the use of clear stone may create additional problems if a separation geotextile is not provided.
Trench Backfill

The potential variation in trench condition is mirrored in the backfill condition which will impact on the magnitude and rate of transfer of the earth loads to the tile. Typically, wet soils with high water contents will have higher unit weights than drier soils.

Loosely placed dry, lumpy backfill which receives only surficial compaction will be slower to transfer both dead and live loads to the tile.

bedding conditions

Typical bedding conditions for rigid circular pipe are shown on Figure 2 which has been reproduced from the Concrete Pipe Design Manual. These bedding conditions are commonly used for reinforced concrete sewer pipe and, normally, the shaped subgrade Class C bedding and flat subgrade Class D bedding are not permitted.

Concrete drain tiles have traditionally been installed in conditions which approach the flat subgrade Class D condition. While it is common to make an effort to shape the subgrade somewhat, it is unlikely that, even under the best conditions that a bedding condition better than Class D is achieved. Concrete drain tile is a truly rigid pipe and since it is non-reinforced, any discernible deformation results in cracking and total loss of strength.

calculation of loads

Earth loads (dead loads) on concrete drain tile can be estimated from any one of a number of references such as Spangler* or the Concrete Pipe Design Manual. In the case of rigid concrete drain tile with relatively compressible side fills, it is reasonable to assume that all of the earth load is transferred to the tile. The dead loads should be calculated based on total unit weight of soil in the order of 7.0 megagrams per cubic metre (Mg/m³) and should include soil mounding over the trench, where applicable.

Referring to the trench conditions outlined above and shown on Figure 3, it should be noted that the earth load on the tile is related to the square of the trench width, thus emphasizing the critical need for trench width control. Excessively wide trenches actually result in an embankment loading condition on the tile.

In the author's experience, live loads on concrete drain tile have been largely ignored. However, with the increasing size and weight of both the construction equipment used to install the drains and the farm equipment which will subsequently cross over or along the drain, then loads must be considered.

A typical distribution of live loads with depth is shown on Figure 4 and the resultant distribution on the typical trench conditions are shown on Figure 5.

Potential live loads expressed as the load on the concrete drain tile at a normal depth of cover are provided in Table I for a depth of cover of 1.5 times the tile diameter. The units referenced are typically in the larger categories of equipment utilized today, particularly in the case of the agricultural equipment.

**drain tile selection**

Specifications for concrete drain tile are provided in American Society for Testing and Materials (ASTM) C412. Unfortunately, this document is typical of "product specifications" and while it provides only the criteria to meet certain standards, it does not provide any guidance on the methodology or analyses required to assess the drain tile strength actually required for a specific installation.

For comparison purposes, the crushing strength and potential dead and live loads for tile diameters of 525 and 750 millimetres with a cover depth of 1.5 times the tile diameter are given in Table II for a normal installation. By inspection of Table II, it is clear that tile conforming to the minimum requirements of Extra Quality Concrete Drain tile have at best, adequate strength to support the dead loads with no reserve for live loads. By moving to Heavy Duty Extra Quality concrete drain tile, at least some reserve for live loads is provided.

How much reserve capacity is required for dead loads? This is a question that must be answered by the drain designer - most appropriately in consultation with the affected land owners/farm operators.

Today, the production of concrete drain tile is a sophisticated manufacturing process and is, or should be, subject to continuous Quality Control checks. The manufacturer should carry out routine Quality Control testing which should be made available to the product purchaser. In addition, it is the author's opinion that routine Quality Assurance testing of selected tile should be carried out during shipping and delivery of the tile to the work area. This process clearly documents the strength of the drain tile manufactured and delivered to the work site.
deformation of concrete drain tile

The performance of concrete drain tile installed in the ground is subject to many variables. These include:

- the strength of the tile when installed and potential future strength gains;
- the dead loads applied during installation;
- increases in dead load due to changes in backfill properties;
- the application of live loads due to i) construction equipment and ii) agricultural equipment.

As noted previously, where a catastrophic collapse of a drain is observed and investigated, it frequently reveals that, while the total collapse of concrete drain tile(s) occurred in a relatively localized area, many, if not all of the adjacent tiles were cracked, severely deformed and near collapse.

summary

In summary, the following parts should be noted:

- Historically, traditional methods of drain tile design, specification and installation have generally proven to be economic and successful. However, there have been failures and economic consequences to the affected parties.
- In the author's experience, the frequency/severity of such failures is related to:
  
  i) increasing tile diameters  
  ii) depth of bury 
  iii) increasing live loads

- Refining/updating design procedures, improving drain tile manufacturing Quality Control and Quality Assurance, enhanced site supervision should result in fewer failures.

While it is not necessarily the author's wish to reduce his income from investigating failures and related problems, it is his wish that such events occur much less frequently to the benefit of his clients, drain designers, contractors and owners.
### TABLE I

**POTENTIAL LIVE LOADS**

<table>
<thead>
<tr>
<th>UNIT</th>
<th>LIVE LOAD (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction Equipment</td>
<td></td>
</tr>
<tr>
<td>Bulldozers</td>
<td>12 to 36</td>
</tr>
<tr>
<td>Backhoes</td>
<td>15 to 33</td>
</tr>
<tr>
<td>Tiling Machines</td>
<td>8</td>
</tr>
<tr>
<td>Haul Trucks</td>
<td>18</td>
</tr>
<tr>
<td>Agricultural Equipment</td>
<td></td>
</tr>
<tr>
<td>Tractors</td>
<td>18 to 25</td>
</tr>
<tr>
<td>Combines</td>
<td>20 to 40</td>
</tr>
<tr>
<td>Grain Buggies</td>
<td>22 to 43</td>
</tr>
</tbody>
</table>
### TABLE II

COMPARISON OF DRAIN TILE CRUSHING STRENGTHS AND TYPICAL LOADS

<table>
<thead>
<tr>
<th>TILE DIAMETER (mm)</th>
<th>CRUSHING STRENGTH (kN/m)*</th>
<th>APPLIED LOADS (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Extra Quality</td>
<td>Heavy Duty Extra Quality</td>
</tr>
<tr>
<td>525</td>
<td>20.5</td>
<td>38.3</td>
</tr>
<tr>
<td>750</td>
<td>29.0</td>
<td>54.5</td>
</tr>
</tbody>
</table>

TRENCH CONDITIONS

Figure 1
TRENCH BEDDINGS
Circular Pipe

CLASS A
Reinforced $A_r = 1.0$, $L_f = 4.8$
Reinforced $A_r = 0.4$, $L_f = 3.4$
Plain $L_f = 2.8$

CLASS B
$A_r = 1.9$

CLASS C
$A_r = 1.5$

CLASS D
$A_r = 1.1$

Legend
$B_o =$ outside diameter
$H =$ backfill cover above top of pipe
$D =$ inside diameter
$d =$ depth of bedding material below pipe
$A_w =$ area of transverse steel in the cradle or arch expressed as a percent of area of concrete

Depth of Bedding Material Below Pipe

<table>
<thead>
<tr>
<th>$D$</th>
<th>$d$ (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22&quot; &amp; smaller</td>
<td>3&quot;</td>
</tr>
<tr>
<td>30&quot; to 60&quot;</td>
<td>4&quot;</td>
</tr>
<tr>
<td>65&quot; &amp; larger</td>
<td>6&quot;</td>
</tr>
</tbody>
</table>

NOTE: For rock or other incompressible material, the bedding shall be overlaid with 6" of granular material.

FROM CONCRETE PIPE DESIGN MANUAL

Figure 2
TRENCH CONDITIONS
DEAD LOADS

Figure 3

WET SANDS

CLAY
Limiting Load Distribution for Typical Dual Tire Truck Loading

Figure 4
TRENCH CONDITIONS
LIVE LOAD EFFECTS

Figure 5