Geology and Geotechnical Considerations of the SSC Site in Texas:

Texas TBM Tunneling Experience

Priscilla Nelson
Geotechnical Engineering Program
The University of Texas at Austin

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MASTER SYMBOL

For marl, marly claystone data only:

- SAN-ANTONIO RIVER
- SAN-ANTONIO RIVER WEATHERED
- SAN-PEDRO CREEK
- SAN-PEDRO CREEK WEATHERED

For marly claystone and chalk data:

- GOVALLE-LATE-CLAYSTONE
- GOVALLE-LATE-CHALKY CLAYSTONE
- GOVALLE-EARLY
- SSC-S.W.L.
- SSC-M.J.A.
- SSC-EARLY
- ONION CREEK IV
- ONION CREEK II

For chalk and limestone data:

- DART-PLANO LINE
- SLAUGHTER CREEK
- WALLER CREEK
- BRUSHY CREEK
FIG. NUMBER OF SPECIMEN VS WATER CONTENT FOR MARLY CLAYSTONE.
FIG. MARLY CLAYSTONE'S UNIAXIAL COMPRESSION STRENGTH VS WATER CONTENT
DIFFERENT WATER CONTENT RANGE FOR MARLY CLAYSTONE

FIG. THE DISTRIBUTION OF UNIAXIAL COMPRESSIVE STRENGTH AT

PSI

UNIAXIAL COMPRESSIVE STRENGTH

W.C.=23.3
W.C.=11.9
W.C.=10.1
W.C.=6.9
W.C.=2.2
FIG. UNIAXIAL COMPRESSIVE STRENGTH, IN PSI, VS NUMBER OF SPECIMEN AT DIFFERENT WATER CONTENT RANGE FOR MARLY CLAYSTONE
FIG. $E_{t,50}$ VS UNIAXIAL COMPRESSIVE STRENGTH FOR MARLY CLAYSTONE

$\frac{E_{t,50}}{\text{UCS}} \approx 214$
FIG. 2: STRENGTH OF MARLY CLAYSTONE AT DIFFERENT WATER CONTENT RANGES
Fig. Shear Stress vs Normal Stress at Failure Plane

NORMAL STRESS, PSI

SHEAR STRESS, PSI

- Residual Unwoven
- Peak Unwoven
- Peak Transverse
- Peak Unwoven Residual

φ (degrees)
<table>
<thead>
<tr>
<th>Rock Type:</th>
<th>TAYLOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock Quality:</td>
<td>GOOD</td>
</tr>
<tr>
<td>Rock Type:</td>
<td>POOR</td>
</tr>
</tbody>
</table>

### Rock Mass Classification Schemes

<table>
<thead>
<tr>
<th>RSR</th>
<th>RMR</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>94-100/38-52</td>
<td>69/38</td>
<td>22/1-3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rating</th>
<th>Stand-up Time</th>
<th>Cohesion (psi)</th>
<th>Friction Angle</th>
<th>Load on Lining (ksf)</th>
<th>Support Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt;5 yrs/1 day</td>
<td>50/30</td>
<td>40/25</td>
<td>0/0.8</td>
<td>0/None-2.0</td>
</tr>
</tbody>
</table>

- **Support Requirements**
  - NONE/None
  - NONE/None to
  - B@3' + 2"S
Figure 6.4. Geomechanics Classification of rock masses: output for mining and tunneling; ○ = case histories of roof falls in mining; □ = tunneling roof falls; contour lines = limits of applicability.
Lovat TBM in Taylor Marl

Ave. Penetration Rate Per Day (ft/hr)

Station (ft)
% DRY Weight Loss on Acid Reaction
Lovat TBM in Taylor Marl

Station (ft)

0 7500 12500 17500 22500 27500

Advance Rate Per Day (ft/hr)

0 5 10 15

Overall 0.9

m/z 8:2
Pizza Lovat

Running Average Daily Penetration Rate (ft/TBM/hr)

Working Days
Pizza Lovat

Running Average Daily Advance Rate (ft/hr)

Working Days
Combined Lovats in Taylor Marl

Running Average Daily Utilization (%)
Combined Lovats in Taylor Marl

![Graph showing running average daily advance rate (ft/shift hr) vs. working days. The graph plots an upward trend with a peak around 140 working days and a subsequent decrease.]
## Lovat TBM Performance

<table>
<thead>
<tr>
<th>Material</th>
<th>U%</th>
<th>PR St/TBM HR</th>
<th>AR St/Shi5+HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marl</td>
<td>23.7</td>
<td>32.3</td>
<td>7.6</td>
</tr>
<tr>
<td>Chalk</td>
<td>31.9</td>
<td>11.4</td>
<td>3.6</td>
</tr>
<tr>
<td>Whole Job</td>
<td>25.3</td>
<td>27.2</td>
<td>6.9</td>
</tr>
</tbody>
</table>
Geology:

ck: chert
cl ck: clays, chalk
c: claystone
ccl co: clayey claystone
b: black fault
f: fault

L: lateral tunnel intersection

Initial Support

AAL: ribs and lagging
B3L: rock bolts, straps (chimneys)
OB: plywood lagging
OB5: occasional rock bolts
OB5: occasional rock bolts and straps

Rivar in Concrete liner

ck ck: clays, chalk
c: claystone
ccl: clayey claystone
b: black fault
f: fault
L: lateral tunnel intersection
Robbins TBM in Austin Chalk

Advance Rate Per Day (ft/hr)
Robbins TBM in Austin Chalk

Station (ft)

Cumulative Shift Hours
<table>
<thead>
<tr>
<th></th>
<th>U 8</th>
<th>PR ft/TBM HR</th>
<th>AR ft/Shift HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start/Chalk/Hagg/Und Cars</td>
<td>16.2</td>
<td>13.5</td>
<td>2.2</td>
</tr>
<tr>
<td>Chalk/Marl Train</td>
<td>18.2</td>
<td>20.4</td>
<td>3.7</td>
</tr>
<tr>
<td>Chalk/Train</td>
<td>33.9</td>
<td>21.5</td>
<td>7.3</td>
</tr>
<tr>
<td>Whole Job</td>
<td>22.9</td>
<td>19.3</td>
<td>4.4</td>
</tr>
</tbody>
</table>
GOVALLE
MAJOR DOWNTIME

LOVAT MOTORS
LOVAT CUTTER WEAR (CHALK)

MUCK BOUND - BOTH
DERAILS - BOTH

Robbins Ground Support
<table>
<thead>
<tr>
<th></th>
<th>Govale Project</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>PR (6h/8m/hr)</td>
<td>AR (6h/24 hr/shift/day)</td>
</tr>
<tr>
<td>Lowat in Marl</td>
<td>241</td>
<td>32</td>
<td>183</td>
</tr>
<tr>
<td>Lowat in Chalk</td>
<td>32</td>
<td>11</td>
<td>87</td>
</tr>
<tr>
<td>Robbins in Marl</td>
<td>18</td>
<td>20</td>
<td>89</td>
</tr>
<tr>
<td>Robbins in Chalk</td>
<td>34</td>
<td>22</td>
<td>175</td>
</tr>
</tbody>
</table>
Robbins TBM in Austin Chalk

Penetration Rate (ft/TFMhr)

Total Amps
Information to Date (3/8/88)  
for the Govalle Tunnel Project - Robbins TBM

7/1/87 to 3/8/88 Total Project to Date  
(Including shifts required for trailing floor installation, 
Haglund car switch out and crane muck system relocation to a forward shaft)

14114 feet in 432 shifts  
32.7 ft/shift  
98.0 ft/24 hour day

7/1/87 to 11/2/87 Haglund Car Mucking System  
(Including shifts required for trailing floor installation)

3297 feet in 170 shifts  
19.4 ft/shift  
58.2 ft/24 hour day

11/13/87 to 3/8/88 Crane Mucking System  
(Including shifts required for crane muck system relocation to a forward shaft)

10817 feet in 234 shifts  
46.2 ft/shift  
138.7 ft/24 hour day

For Crane Mucking System Operations:

11/16/87 to 12/31/87  2597 ft in 30 working days = 87 ft/day
1/4/88 to 3/8/88  8256 ft in 44 working days = 188 ft/day
For Crane Operations Shifts with Fairly Complete PBQD Records:

10285 feet
1744.5 shifted hours

5.9 ft/hour average advance rate
141 ft/day average daily advance rate

Instantaneous Penetration Rate at 1500 to 1800 psi thrust system pressure averaging about 3.5 to 4.5 in./min or 0.28 to 0.36 in./cutterhead revolution, at cutterhead assumed rpm=12.63.

Average Utilization = 54 %
Average Downtime = 46 %

Note: Per Records, regrip time and time waiting for trains to return is not explicitly included in downtime. Some of each source of time is probably included in both utilization and downtime categories.

Downtime Distribution:

- Rail/Rail Repair/Derailments: 13 %
- Utilities/Install and Repair: 7 %
- Conveyor Repair/TBM and Backup: 6 %
- Ground Support and Gripper Cribbing: 5 %
- Laser and Survey: 3 %
- TBM Hydraulics Repair: 3 %
- Bolt Drill Repair: 2 %
- Electrical Systems Repair/Power: 1 %
- Repair Crane at Shaft: 1 %
- Cutter Replacement: 1 %

Most Frequent Causes of Downtime:

- Derailments and Rail Breakage
- Clogged Buckets and Main Beam/TBM Conveyor
- Water Accumulation at Heading
- Taylor Slack Outfall
- Gripper Slippage
- Ventilation - Smoke and Dust