IRRIGATION TUNNELING IN ANCIENT INDONESIA
(HISTORICAL PERSPECTIVE)
By:
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PRESENTATION OUTLINE
I. Introductory Background;
II. General Tunneling Practice;
III. Basic Philosophy;
IV. Tools and Equipments;
V. Planning, Designing & Sizing;
VI. Construction (Excavation);
VII. Operation and Maintenance;
VIII. Conclusion.

INTRODUCTION
IRRIGATION TUNNEL: Historically, Irrigation in Indonesia related with lowland paddies.
However, no evidence had been indicating the exact time it was initially practiced. So did the irrigation tunnel.
The relief of Borobudur temple showing the farming activities for pest control.

Ancient Stone Relief

TRADITIONAL IRRIGATION

The simpler the approach the easier the farmer to participate and adopt the techniques and more sustainable would be the irrigated agriculture.

Traditional irrigation in Indonesia since the ancient time: Subak in Bali; Keujreun Blang in Aceh; Tuo Banda in West Sumatra; Raja Bondar in Northern Sumatra; Mitra Cai in West Java; Dharma Tirto in Central Java; Tudang Sipulung in South Sulawesi; Mantri Siring in South Sumatra; Il-i-ili in Lampung; etc.
These include: traditional technique on measurement devices (environmentally friendly) agriculture and “Traditional Tunneling Technique”.
Generally, the tunnel in Bali, Lombok, Java & Sumatra Islands are on arid & semi arid zones, undulating, hilly, and frequently suffered from water scarcity.
BASIC PHILOSOPHY
The is the ability to regulate the suitable techniques, time, space and environment with "harmonious-togetherness" principle.

BASIC PHILOSOPHY
The tunnel designer and construction executor, are experts by experience and by heritage, often referred to by them as “witch engineer” (irrational, but successful).

BASIC MEASUREMENT AND EQUIPMENT

PHYSICAL MEASUREMENT
Non exact measurement standard as we used today

EQUIPMENTS, TOOLS & FACILITIES
Traditional tools that are used by tunnel builders during the ancient time, (tool for design, land surveying, tunnel excavation, & operation and maintenance).
<table>
<thead>
<tr>
<th>No.</th>
<th>Tools</th>
<th>Number</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Chisel</td>
<td>4</td>
<td>These tools are actually required for the undagi to make traditional</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>survey equipment</td>
</tr>
<tr>
<td>2.</td>
<td>Small saw</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Small plane</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Ruler (seleran)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Pincers</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Knife</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Grinder</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Pencil</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Sand paper</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

EQUIPMENTS, TOOLS & FACILITIES (for survey and staking out)

EQUIPMENTS, TOOLS & FACILITIES (for making & calibrating survey equipment)

EQUIPMENTS, TOOLS & FACILITIES (for survey and staking out)
Design and Tunnel Sizing

Determination of Size

Three categories: (1) crawl type; (2) squat type; and (3) standing type, taking into the size of human body to work freely in side of the tunnel.

Determination of Aeration Hole

For air circulation and disposal of excavation material, they make horizontal aeration hole (calung). They also make vertical aeration hole (bindu).
DETERMINATION OF AERATION HOLE

Slope depending upon the soil material, water discharge and the sediment transport. Based on experience, they have standard like supercritical, critical and laminar flow.

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of flow category</th>
<th>Slope</th>
<th>Brief Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Jaran Ngarong</td>
<td>0.01 &lt; I &lt; 0.015</td>
<td>No sediment deposit</td>
</tr>
<tr>
<td>2.</td>
<td>Buaya mangap (similar to wild crocodile)</td>
<td>0.005 &lt; I ≤ 0.01</td>
<td>Small gravel can settle as deposit</td>
</tr>
<tr>
<td>3.</td>
<td>Sikep Ngimbang</td>
<td>0.0025 &lt; I ≤ 0.005</td>
<td>Sand is potentially deposited</td>
</tr>
<tr>
<td>4.</td>
<td>Mebulun jangkrik (similar to the fibration of cricket wing)</td>
<td>I ≤ 0.0025</td>
<td>The case of water fall either on natural flow or at the diversion</td>
</tr>
<tr>
<td>5.</td>
<td>Banyu Langse</td>
<td>Vertical</td>
<td></td>
</tr>
</tbody>
</table>

DOCUMENTATION

Documentation is always made to communicate the feature of the tunnel to others, for O&M, as well as for future rehabilitation or for reconstruction purposes.
All equipment and facilities for tunneling consist of simple traditional tools. No supporting materials like scaffolding or supporting structure for the ceiling, nor for preventing the land slides.
Routine Monitoring the excavation work, the use of equipment, the groundwater flow as well as soil crack, and the need for immediate action if necessary.

Based upon experience, the medium sized tunnel with a group of 12 workers would have to be excavated at about 3 years for one km length.
PROBLEMS ON EXCAVATION

The general problems:
(1) Boulders at the tunnel alignment;
(2) The axis of tunnel is not consistent;
(3) Tunnel excavation along the soft soil;
(4) The soil cracking, etc.

OPERATION AND MAINTENANCE

PROBLEMS ON EXCAVATION

Oversized but easy to inspect

SUSTAINABILITY

- Operations of the tunnel are mostly under the sustainable condition;
- So far, there is no record where the tunnels reported damaged, even for the case of huge earthquake.

PROBLEMS OF O&M

The O&M problems, are related to sedimentation; water distribution during the season of scarcity; excessive percolation; and water losses at the tunnel along the porous soil.
PROBLEMS OF O&M

The O&M of irrigation networks are becoming more and more difficult due to the expansion of irrigation area with limited O&M budget as well as personnels.

COMMUNITY LEADERS (WUA'S)

For instance, Bali w/ the total area of 100,000 ha, the total tunnel of about 100 km (1979); 300 km (2009), currently under the scarcity of personnel & resources allocation.

TUNNEL MAINTENANCE

Irrigation Tunneling in Indonesia has been practiced since the ancient time, but, no evidence indicating the time. Technique: simple measurement devices, traditional environmentally friendly; The location: are on arid & semi arid zones, undulating, hilly, frequently suffered from water scarcity.

CONCLUDING REMARKS
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- Sustainable approach: the easier the farmer to participate and adopt the techniques and the more sustainable of the practices;
- The ability to regulate the suitable techniques, time, space & environment ("harmonious-togetherness");
- The general problems: (1) Boulders at the tunnel alignment; (2) The axis is not consistent; (3) Excavation along the soft soil; (4) The excavation w/ soil cracking, etc.

CONCLUDING REMARKS

- Traditional Irrigation tunnel had been developed & maintained with strong support of traditional organization;
- It has been sustained for hundreds of years, however, the spirit of integrated & participatory is disappearing through intervention of modernization.

CONCLUDING REMARKS

- O&M are mostly under the sustainable condition;
- So far, no records were reported damaged, even for the case of huge earthquakes.
- O&M problems are related to sedimentation, water distribution during the season of scarcity, and percolation and water losses.

CONCLUDING REMARKS

- The O&M of irrigation networks are more and more difficult due to limited O&M budget and personnels.
- For instance, in Bali Island, the total area of 100,000 ha w/ tunnel length of about 100 km (1979); 300 ha (2009) currently under the scarcity of personnel & resources.
The book is freely downloadable from this URL:
http://issuu.com/hafiedgany/docs/tunneling

THAT’S ALL
THANK YOU