IRRIGATION TUNNELING IN ANCIENT INDONESIA
(HISTORICAL PERSPECTIVE)

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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 technology of land preparation by utilizing cattle power.
The relief of Borobudur temple showing the farming activities for pest control.

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; Ili-ili in Lampung; etc.

TRADITIONAL IRRIGATION

The Subak System in Bali, for instance, has been in practiced for hundreds of years, and still continuously practiced today.

TRADITIONAL IRRIGATION

The simpler the approach the easier the farmer to participate and adopt the techniques and more sustainable would be the irrigated agriculture.
These include: traditional technique on measurement devices (environmentally friendly) agriculture and "Traditional Tunneling Technique".

TRADITIONAL IRRIGATION

TUNNEL

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TRADITIONAL IRRIGATION

TUNNEL
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).

PHYSICAL MEASUREMENT

Non exact measurement standard as we used today

Traditionl tools that are used by tunnel builders during the ancient time, (tool for design, land surveying, tunnel excavation, & operation and maintenance).
### EQUIPMENTS, TOOLS & FACILITIES (for making survey equipment)

<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 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 staking out and discharge measurement)

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.

CRAWL AND SQUAT TYPE;

STANDING TYPE;

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

Aerations are crucial for the proper functioning of tunnels. They help to maintain the necessary oxygen levels and prevent the accumulation of harmful gases. The determination of aeration holes involves considering factors such as the type of soil, water discharge, and the sediment transport.

Slope determination is also crucial. The slope of a tunnel depends on the soil material, water discharge, and sediment transport. Based on experience, standard categories like supercritical, critical, and laminar flow have been developed.

Here is a table summarizing the conditions for different types of flows:

<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>Sikap 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 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.

Based on experience, they have standard categories like supercritical, critical, and laminar flow.
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.

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of Equipment and Facilities</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Peganjing Dasar (Slope level)</td>
<td>To measure the slope of tunnel bottom</td>
</tr>
<tr>
<td>2.</td>
<td>Panyong (pickax)</td>
<td>To excavate hard soil</td>
</tr>
<tr>
<td>3.</td>
<td>Udud (ordinary pickax)</td>
<td>To dig ordinary soil</td>
</tr>
<tr>
<td>4.</td>
<td>Prapen (fireplace)</td>
<td>Fire squirt (blower)</td>
</tr>
<tr>
<td>5.</td>
<td>Benang (string/yarn)</td>
<td>String (yarn)</td>
</tr>
<tr>
<td>6.</td>
<td>Patok (wooden peg)</td>
<td>Wooden Peg</td>
</tr>
<tr>
<td>7.</td>
<td>Seleran (ruler)</td>
<td>To extend straight line</td>
</tr>
<tr>
<td>8.</td>
<td>Sodo (bamboo shovel)</td>
<td>To shovel and accommodate soil excavation</td>
</tr>
<tr>
<td>9.</td>
<td>Soporangkat keranjang tigenan bamboo basket</td>
<td>To place and transport the soil excavation out.</td>
</tr>
<tr>
<td>10.</td>
<td>Gedeg dilabur putih (white painted woven bamboo)</td>
<td>To reflect the sun shine into the tunnel</td>
</tr>
<tr>
<td>11.</td>
<td>Sambhe (penyembean) (Survey equipment for direction)</td>
<td>Indicator for showing direction</td>
</tr>
<tr>
<td>12.</td>
<td>Sepat gantung (hanging coconut oil lamp)</td>
<td>Hanging lamp for straight lining the tunnel axis (minimum 3 units)</td>
</tr>
<tr>
<td>13.</td>
<td>Linggis, (crowbar) etc.</td>
<td>For digging the hard soil or gravel.</td>
</tr>
</tbody>
</table>
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

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.

SUSTAINABILITY

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

TUNNEL MAINTENANCE

TUNNEL MAINTENANCE

TUNNEL PRIOR TO TOUTINE MAINTENANCE

THANK YOU
THANK YOU
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.

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.

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

- 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

- 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.

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.

GOVERNMENT AWARD

The book is freely downloadable from this URL:
http://issuu.com/hafiedgany/docs/tunneling

THAT’S ALL
THANK YOU