A monitoring programme for embankment dams

Hydro developments in China

Roman dams in Portugal
Roman dams in southern Portugal

By A. C. Quintela, J. L. Cardoso and J. M. Mascarenhas, Professor of Hydraulic Engineering *, Geologist ** and Doctor of Biogeography and Planning ***

The results of the inventory and characterization of the Roman dams in southern Portugal are briefly presented. This study was based on bibliographical analysis inquiries, information provided by archaeologists and field surveys. Eight unknown Roman dams and ten others already mentioned in publications were recognized. A typological classification is presented here.

Roman engineers were the first major dam builders in the Mediterranean area and in the Middle East, not only for water supply but also for irrigation and other purposes such as ore treatment and hydropower.

In Spain the three largest known Roman dams (Proserpina, Cornabio and Alcántarilla, the first two still in operation), and a large number of smaller ones, are concentrated in the drainage basins of the rivers Guadiana (Merida nucleus), Tagus (Toledo nucleus) and Ebro. The presence of Roman dams in southern Portugal would have expected, although no systematic research has been carried out. The only inventory on Portugal was a list drawn up by V. S. Mantás. This list refers to the location of several Roman dams and has a bibliography. The information given by the bibliographical references is usually scarce and, in many cases, it is limited to the simple mention of the dams, without any indication of their precise location.

Results of the inventory
The present inventory of Roman dams south of the Tagus river began with an analysis of the available published information and enquiries to local authorities and associations. Information was also obtained from the IPPC (Instituto Português do Património Cultural — Portuguese Institute of the National Heritage), as well as from a large number of archaeologists and through contact with local people.

The inventory and characterization of the Roman dams south of the Tagus is summarized in Fig. 1: eight Roman dams unknown until now have been identified. The Roman dams south of the Tagus were intended mainly for water supply, irrigation or both.

The drainage basins of the dams are in regions of annual average precipitation less than 800 mm and in almost two thirds of cases, less than 600 mm (Fig. 1).

The water courses have an extremely irregular regime, being dry for most of the year. The run-off water could only be used if it was stored in reservoirs. Difficulties in managing floods would have also led to the construction of dams in river sections where drainage basins were small. Table I shows the distribution of dams according to the area of the drainage basin, A(km²):

<table>
<thead>
<tr>
<th>Table I — Drainage basin areas vs number of dams</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A \leq 1$</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>7 dams</td>
</tr>
</tbody>
</table>

Table II, Represa (Gavião) and Monte Novo (Évora), have not been included in this list because their Roman origin is unconfirmed. Many of the inventoried dams were associated with villas. The way of life in the villas was deeply influenced by Rome; they generally had baths which, in the region under consideration, were frequently supplied by the associated reservoirs.

Many of the Roman dams in Portugal are small in height (Table II). The number of dams varies according to the maximum height (Ht), (visible height or probable height in case of partial destruction, in m) in the following way:

<table>
<thead>
<tr>
<th>Table III — Height vs number of dams</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H \leq 2$</td>
</tr>
<tr>
<td>8 dams</td>
</tr>
</tbody>
</table>

As before, dams of unconfirmed Roman origin have not been included.

Table IV — Type of construction

<table>
<thead>
<tr>
<th>Description</th>
<th>No. of dams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall with a rectangular section</td>
<td>7 dams</td>
</tr>
<tr>
<td>Wall with a rectangular section and downstream buttresses</td>
<td>8 dams</td>
</tr>
<tr>
<td>Wall with a downstream earthenfill</td>
<td>1 dam</td>
</tr>
<tr>
<td>Double wall with an intermediate earthenfill and buttresses</td>
<td>1 dam</td>
</tr>
<tr>
<td>Earthenfill (maximum height of 0.8 m)</td>
<td>1 dam</td>
</tr>
<tr>
<td>Rectilinear plan</td>
<td>13 dams</td>
</tr>
<tr>
<td>Polygonal plan</td>
<td>2 dams</td>
</tr>
<tr>
<td>Curvilinear plan</td>
<td>3 dams</td>
</tr>
</tbody>
</table>

Of the 18 dams 15 are of the usual Roman type consisting of a wall made of a nucleus of opus caementicum (rockfill) or opus incertum (earthenfill), externally lined with blocks, with or (Continued on page 40)
**Table II — Roman dams south of the Tagus river**

<table>
<thead>
<tr>
<th>Designation</th>
<th>Typology (structure/plan)</th>
<th>Dimensions (m)</th>
<th>Drainage basin area</th>
<th>Nearest known Roman site</th>
<th>Probable purpose</th>
<th>Bibliography</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Tapada Grande (Castelo de Vide)</td>
<td>WE/R</td>
<td>H = 1.6</td>
<td>L = 76</td>
<td>0.3</td>
<td>Press device about 60 m away. Villa about 1300 m away</td>
<td>Irrigation</td>
</tr>
<tr>
<td>2 Almarjão (Craio)</td>
<td>WR/R</td>
<td>H = 5.2</td>
<td>L = 55</td>
<td>5</td>
<td>130 m</td>
<td>Water supply and irrigation</td>
</tr>
<tr>
<td>3 Muro (Campos Maior)</td>
<td>WB/P</td>
<td>H = 2.2</td>
<td>L = 174</td>
<td>1.7</td>
<td>380 m (possible connection with a villa 2700 m away)</td>
<td>Water supply and irrigation</td>
</tr>
<tr>
<td>4 Olivá (Campos Maior)</td>
<td>WB/R</td>
<td>H = 3</td>
<td>L = 45</td>
<td>1.1</td>
<td></td>
<td>Irrigation</td>
</tr>
<tr>
<td>5 Mourinha (Campos Maior)</td>
<td>WR/R</td>
<td>H = 0.4</td>
<td>L = 100</td>
<td>0.04</td>
<td>380 m</td>
<td>Irrigation</td>
</tr>
<tr>
<td>6 Moralves (Elvas)</td>
<td>WR/R</td>
<td>H = 3.2</td>
<td>L = 161</td>
<td>6.6</td>
<td>1500 m</td>
<td>Irrigation</td>
</tr>
<tr>
<td>7 Carraxo (Elvas)</td>
<td>WR/R</td>
<td>H = 1.7</td>
<td>L = 117</td>
<td>1.3</td>
<td>140 m</td>
<td>Water supply and irrigation</td>
</tr>
<tr>
<td>8 Comenda (Setúbal)</td>
<td>WB/R</td>
<td>H = 1.2</td>
<td>L = 13</td>
<td>2.6</td>
<td>1000 m</td>
<td>Water supply and irrigation</td>
</tr>
<tr>
<td>9 Nossa Senhora da Represa (Cuba)</td>
<td>WB/C</td>
<td>H = 1.8</td>
<td>L = 81</td>
<td>2.5</td>
<td>620 m</td>
<td>Irrigation</td>
</tr>
<tr>
<td>10 Maro da Prega (Beja)</td>
<td>WB/R</td>
<td>H = 3.9</td>
<td>L = 62</td>
<td>3</td>
<td>1750 m</td>
<td>Water supply and irrigation</td>
</tr>
<tr>
<td>11 Hortas de Baleiaço (Beja)</td>
<td>WR/R</td>
<td>H = 1.1</td>
<td>L = 120</td>
<td>1</td>
<td>?</td>
<td>Irrigation</td>
</tr>
<tr>
<td>12 Pições (Beja)</td>
<td>WR/R</td>
<td>H = 4.3</td>
<td>L = 58</td>
<td>18.6</td>
<td>200 m</td>
<td>Water supply and irrigation</td>
</tr>
<tr>
<td>13 Muro dos Mouros (Serpa)</td>
<td>WB/C</td>
<td>H = 3</td>
<td>L = 130</td>
<td>0.7</td>
<td>375 m</td>
<td>Irrigation</td>
</tr>
<tr>
<td>14 Monte Novo do Castelinho (Almolódavar)</td>
<td>E/R</td>
<td>H = 0.8</td>
<td>L = 56</td>
<td>0.3</td>
<td>300 m</td>
<td>Water supply and irrigation</td>
</tr>
<tr>
<td>15 Alamo (Alcoutim)</td>
<td>WB/R</td>
<td>H = 3</td>
<td>L = 50</td>
<td>0.3</td>
<td>90 m</td>
<td>Water supply and irrigation</td>
</tr>
<tr>
<td>16 Santa Rita (Vila Real de Santo António)</td>
<td>DWB/R</td>
<td>H = 2.2</td>
<td>L = 50</td>
<td>0.3</td>
<td>?</td>
<td>Irrigation</td>
</tr>
<tr>
<td>17 Fomte Cuberta (Lagos)</td>
<td>WR/R</td>
<td>H = 2.6</td>
<td>L = 75</td>
<td>1.9</td>
<td>1500 m</td>
<td>Water supply and irrigation</td>
</tr>
<tr>
<td>18 Vale Tesnado (Loulé)</td>
<td>WR/R</td>
<td>H = 1.2</td>
<td>L = 220</td>
<td>37.5</td>
<td>1600 m</td>
<td>Water supply and irrigation</td>
</tr>
<tr>
<td>19 Represa* (Oavalo)</td>
<td>DW/R</td>
<td>H = 2.3 (base)</td>
<td>L = 78</td>
<td>26.7</td>
<td>1800 m</td>
<td>Water supply and irrigation</td>
</tr>
<tr>
<td>20 Monte Novo* (Evora)</td>
<td>WB/C</td>
<td>H = 5.7</td>
<td>L = 52</td>
<td>2.9</td>
<td>?</td>
<td>Hydropower</td>
</tr>
</tbody>
</table>

**Structure:**
- Wall with a rectangular section:
- Wall with downstream buttresses:
- Wall with a downstream earthfill:
- Earthfill:
- Double wall with an intermediate earthfill and downstream buttresses:

**Plan:**
- Rectilinear: WR
- Curvilinear: WE
- Elliptical: E
- Polygonal: P

**Dimensions:**
- Width: W
- Length: L
- Thickness: T
- Spacing: S

* Dates of unconfirmed Roman origin

Water Power & Dam Construction May 1987
without buttresses (Figs. 2 and 3). Studies of this type of dam show that the nucleus (juxtaposed layers) and the wall surface (lining blocks) were constructed simultaneously.

The only reliable exceptions to this type of structure are the Monte Novo do Castelinho dam, which is of the earthfill type, the Tapada Grande dam, with a stabilizing downstream earthfill, and the Santa Rita dam, with a double wall, an intermediate earthfill and buttresses placed downstream. The only other known Roman dam of this type is that of Ereruisk (Soviet Armenia), dating from the fifth century AD.

In three cases (Muro, Muro dos Mouros and Santa Rita), the upstream wall surface shows traces of mortar lining. Fig. 2 shows the typical cross-sections of the known dams, with the exception of the earth dam of Monte Novo do Castelinho.

It should be noted that some of the dams with buttresses (Muro, Nossa Senhora da Represa, Muro da Prega and Alamo), did not require buttresses for structural stability because the wall section is oversized. In Nossa Senhora da Represa, the buttresses do not contribute at all to the stability of the intermediate sections of the wall, because they are spaced too far apart.

The plan of the dams is rectilinear, polygonal or curvilinear with a concave shape facing upstream (Fig. 3). None of the Roman dams which have been inventoried are in operation. This is because of openings which allow the water to pass through the dam or the deviation of the stream towards one end of the dam (Fig. 3).

The silting of the reservoirs is variable, depending on drainage basin erosion, as well as on the operational life of each reservoir and on further modifications in the thalwegs, already mentioned. The reservoirs 'of Oliva, Nossa Senhora da Represa and Muro da Prega are badly silted. The reservoirs had small or very small capacities. Topographic surveys of only six reservoir areas are available; their capacities, according to the present tops of the dams, are as follows:

- Muro dam: 178 000 m³
- Muro da Prega dam: 6200 m³
- Pisões dam: 80 000 m³
- Muro dos Mouros dam: 80 000 m³
- Alamo dam: 2100 m³
- Santa Rita dam: 13 200 m³

The Muro dam stands out among the others for its architectural characteristics and also for the technical solutions that were adopted. It has an outstanding height and size; it is the only case in which parallel and horizontal rows of large bricks are laid evenly, and arches between the buttresses which are subject to greater strains. The function of such arches was presumably to concentrate weight on the buttresses.

There is clear evidence of bottom or middle level outlets in the dams of Pisões and Muro dos Mouros. Pisões dam has at least one bottom outlet, made of a sluice in the wall, with a brick layer, showing the outline of perfect archways. In the wall of Muro dos Mouros dam, a certain distance up from the base, there is a pottery pipe, which was certainly used to discharge the stored water. The position of the bottom outlet of the Muro (Continued on page 70)
(Continued from page 40)
dam corresponds, no doubt, to the present thalweg. There were
certainly bottom outlets in other dams, but they are no longer
visible because of their poor state.

It should be noted that three earthfill dams have been found
north of the Tagus: Rochoso, Idanha-a-Velha and Lameira.
Only the second one has been recorded before⁴. The detailed
study of these dams is of great interest, since of the earthfill
dams so far discovered, only the masonry spillways survive⁵.

Acknowledgement
This paper summarizes the work on this subject carried out by CEHIDRO
(Instituto Superior Técnico — Technical University of Lisbon) for the
General Board of Water Resources Works. Thanks are due to both
organizations for the permission given to publish this paper.

References
1. ZOREDA, L. C. AND RAMOS, F. J. S., "Presas romanas y dados sobre
probablonamento romano y medieval en la provincia de Toledo", Noticiario
Arqueologico Hispanico 14, Ministerio de Cultura, Dirección General de
Bellas Artes, Archivos y Bibliotecas, Madrid; 1982.
2. QUINTELA, A. C., CARDOSO, J. L. AND MASCARENHAS, J. M.,
"Aproveita-Mentos Hidraulicos Romanos A Sul Do Tejo", Natural
Resources And Environment State Secretariat; Lisbon, Portugal; 1985.
3. SCHNITTER, N. J., "The evolution of buttress dams on Irrigation and
Drainage, 12th Congress, Special session on History of Irrigation,
Colorado State University, Fort Collins, USA; 1984.
XXXV; 1961.

Bibliography
PACO, A. AND FARRADOTA, J., "Subsídios para uma carta arqueológica do
concelho de Loulé", Arqueologia e História, Vol. XII (8a Série); 1966.
POTE, M. P. C. S. C., "Baragem romana no rio Degebe", Free
University of Lisbon (Policopiado); 1981.
QUINTELA, A. C., CARDOSO, J. L. AND MASCARENHAS, J. M., "Barragens
romanas do Sul de Portugal", Contribuição para o seu inventário e
RIBERO, F. N., "A villa romana de Pisões", Junta de Turismo de Bega;
1972.
SARRÃO, H. F., [CA. 1600] in GUEIRREIRO, M. V. AND MAGALHÃES, J. R.,
"Duas descricões do Algarve do Século XVI", Cadernos da Revista de
SCHNITTER, N. J., "The evolution of buttress dams", 12th Congress on
Irrigation and Drainage. Special session on History of Irrigation, Colorado
State University, Fort Collins, USA, 1984.
VERGA, E., "Antiguidades monumentais do Algarve", O Arqueólogo
VIANA, A., "Notas históricas, arqueológicas e etnográficas do Baixo
VIANA, A., "Notas históricas, arqueológicas e etnográficas do Baixo
VITA-PINZI, C., "Roman dams in Tripolitania", Antiquity, Vol. XXXV;
1961.
ZOREDA, L. C. AND RAMOS, F. J. S., "Presas romanas y dados sobre
poblamiento romano y medieval en la provincia de Toledo", Noticiario
Arqueologico Hispanico 14, Ministerio de Cultura, Dirección General de
Bellas Artes, Archivos y Bibliotecas, Madrid; 1982.

Water Power & Dam Construction  May 1967