THE DRAINAGE SYSTEM OF THE BAYON COMPLEX, ANGKOR THOM

アンコール・トム, バイヨン寺院の排水システム

Sokuntheary SO*1, Takeshi NAKAGAWA*2 and Shin-ichi NISHIMOTO*3

The paper is a study on the drainage system of the Bayon temple. The authors attempt to identify and distinguish each drain by its purpose, physical feature and function as well as to analyze how present malfunction of these drains are contributing to the deterioration of the temple building. As a result of document research and series of field surveys, drains in the Bayon could be categorized largely into two types by their purposes. One would be the drains that function as to evacuate rainwater from its center outwards; and the other drains are found to be added in the course of building renovation for the purpose of ameliorating previously existed drains. It is interesting that the drainage system is found to be unique and possibly be quite an imaginative traditional approach to drain excessive precipitation. However it is evident that the present malfunction of the system is contributing to further decay of the physical appearance of the building.

Keywords: Cambodia, Khmer Architecture, Angkor, Angkor Thom, Bayon, Drainage

1. Introduction

The Bayon temple is one of the most conspicuous buildings in the center of Angkor Thom of ancient Khmer empire. It was documented as the state temple of deities worshipped in the empire of the great King-god Jayavarman VII (1181-1220), who has been deemed to be a Mahayana Buddhist.1

The drainage investigation was carried out as a part of preparatory work to compile the master plan for the conservation and restoration of the whole Bayon Complex.2 Properly draining mountain temple structures has long been a communal challenge throughout monuments in the Angkor region. Therefore the objective of the study was to identify and distinguish each drain by its purpose, physical feature and function as well as to analyze how present malfunction of these drains are contributing to the deterioration of the temple building.

Prior to on-going investigation, H. Marchal discovered in 1919 the first three outlets of drain at the east wing of the northern part of the outer gallery. He also discovered the similar drain at the west wing of northern part, and at the east wing and west wing of southern part of outer gallery.3 In 1967, J. Dumarçay took on Marchal’s discovery and made further study on the drains. He drew a drain plan with a short explanation on water evacuation. The plan of drains (Fig. 1) exhibits those located in the inner, cruciform and outer galleries.4 The study was based upon this Dumarçay’s initial plan and his description of drainage system in the Bayon. The term “drainage system” in the paper is defined only for the descriptive purpose of giving a generic term to the numbers of drains, tunnels and

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grooves found in the Bayon complex as a whole.

2. Research Methodology
The most recent major research project regarding drains has been conducted and continued on to the present by the Japanese Government Team for Safeguarding Angkor (JSA) since 1995. In addition, during the period August 1997 to January 1998, the team led by the authors conducted series of drain tests one by one. The purpose of the field survey was to confirm the entire drainage network system as well as to verify their present function.

The research methodology began from clearance work and tests were conducted by pouring water into the drains to clarify its structure and function (Phs. 1 and 2). During clearance work, new drains were confirmed and the general network system was clarified. Plan (Fig. 2) presents locations of the drains. Many of these drains were found buried in sand and earth due to lengthy neglect. Some drains of particular attention were confirmed using microscopic camera inserted into the cavity, while the images were monitored by a portable computer in situ to verify their underground routes and internal structure non-destructively (Ph. 10). Only very few of them were confirmed to be functioning as originally intended. The research in relation to the drainage system included various field survey in the field of petrology, archaeology, measurement and geology. The paper attempts to confirm the drainage system based upon the cross-referenced data obtained from the above mentioned surveys.

3. Types of Drains
As a result of document research and series of field survey, drains in the Bayon could be categorized largely into two types by their purposes: Drains made with special purposes and the drains made to function as a regular drain. Drains with special purposes are made to discharge sacred water used for rituals and religious ceremonies (Somautra) (Phs. 1-5). The importance of these drains with special purposes should never be dismissed, and we would like to leave that subject for another study. The following drains described in (3) through (14) are the ones categorized as drains used to evacuate rainwater and are the main subject of this study.

3.1. Drains with special purposes:
(1) Drains (a-o) were made to evacuate water from the inside of the towered shrines to the outside (Phs. 1-5).
(2) Drain A must have been made to prevent the overflow of so-called “Lucky Well” (Phs. 6 and 12). However, the outlet of the drain was purposely blocked at the inner gallery: it was not

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Fig. 2. The drainage system of Bayon Complex (Original plan by J. Dumaçay, Revised and digitalized plan by O. Cunin, Plan of drainage system added by So Sokuntheary)
meant to function and further investigation is necessary to identify the purpose and characteristic of this drain. It is clear that Drain A should not be simply categorized as the drains that evacuate the water eastward.

These sets of drains are obviously distinguished from others for their purposes and function, therefore they are excluded from the following discussion.

3.2. Drains to evacuate rainwater

(3) Drains of B group (B-1−B-7) were built at the foot of the upper terrace platform to let the rainwater flow down from the upper terrace and to make it accumulate in the area between the upper terrace and the cruciform gallery (Ph. 6). This accumulated water will eventually run through the drains groups C and D.

(4) Drains of C group (C-1 and C-2) were built across the cruciform gallery to evacuate above mentioned rainwater that was accumulated at the foot of the upper terrace to the inner courtyard (four corner courtyards inside of inner galleries).

(5) Unlike groups B and C, drains of D group (D-1−D-7) which were built in the structure located at the four ends of the

![Fig. 3. Plan and section of drains D-4 and D-5](image3)

- Inlet of adjusted
- Drain on the pavement
- Outlet of G-2

![Ph. 4, Tower 15, inlet (d)](image4)

Ph. 4, Tower 15, inlet (d)

![Ph. 5, Tower 15, outlet (d)](image5)

Ph. 5, Tower 15, outlet (d)

![Ph. 6, Drain A, drain B, sump and around basement](image6)

Ph. 6, Drain A, drain B, sump and around basement

![Ph. 7, Drain G-5 and two culverts below](image7)

Ph. 7, Drain G-5 and two culverts below

![Ph. 8, Drain G-7, chisel traces (additional drain)](image8)

Ph. 8, Drain G-7, chisel traces (additional drain)

![Ph. 9, Drain D-1, inlet by LCD camera](image9)

Ph. 9, Drain D-1, inlet by LCD camera

![Ph. 10, Drain D-1, inside structure](image10)

Ph. 10, Drain D-1, inside structure

![Ph. 11, Drain D-1, outlet](image11)

Ph. 11, Drain D-1, outlet

![Ph. 12, Present state of Lucky Well](image12)

Ph. 12, Present state of Lucky Well

![Ph. 13, Drain under balustrade](image13)

Ph. 13, Drain under balustrade

![Ph. 14, Inlet of G-2, drain on the pavement](image14)

Ph. 14, Inlet of G-2, drain on the pavement

![Outlet of culverts C1, C2](image15)

Outlet of culverts C1, C2

![Ph. 15, Drain G-11, culverts](image16)

Ph. 15, Drain G-11, culverts
cruciform gallery (except for D-3, clearly later addition), drains are built to run through the foundation platform (Fig. 3). The drains are designed to let the water come out from the outlets found in the inner gallery foundation wall. These drains are made to evacuate rainwater that was accumulated at the foot of the upper terrace and to drain to the outside of the inner galleries (Phs. 9, 10 and 11).

(6) Grooves were carved onto the pavement stones of the cruciform gallery, inner courtyard and outer courtyard in order to let the water run through and into the inlets found at the cruciform gallery, inner gallery and outer gallery (Ph. 14).

(7) Drains of E group (E-1-E-5) were set up across the inner gallery, in order to evacuate rainwater that was accumulated in the inner courtyard to the outside of the inner gallery.

(8) Drains of F group (F-1-F-19) were set up under the porch steps connecting inner gallery to passage halls (not existing at present). These drains are to evacuate rainwater that was accumulated at the outer courtyard of the lower terrace between the inner galleries and outer galleries.

(9) Drains of G group (G-1-G-13) were built to cut across the outer gallery in order to evacuate rainwater that was accumulated in outer courtyard to the outside of the outer gallery (Phs. 7, 8, 14, 15, 16 and 17).

(10) Drains of H group (H-1-H-5) were built on the causeway (east) in order to evacuate rainwater from the causeway to the lower marsh ground located at north and south of the causeway.

4. Analyses of Drains

4.1. Value of finding chronological order of drains

Looking closely into the drains chronologically to identify their construction processes bring about a new discussion of architectural history of the Bayon. According to the archaeological excavation survey (Fig. 6) the tunnel and the inlet of culvert are found.10 This became an important piece of evidence that support J. Dumarçay’s theory of the building phases, which is

<table>
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<th>No.</th>
<th>Measurement Place</th>
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<th>Size of Drain Outlet</th>
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<td>F-9 hairpin drain</td>
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<td>C-3 hairpin drain</td>
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<td>B-1 hairpin drain</td>
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<td>A-3 hairpin drain</td>
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Table A. The estimation of rainwater volume which corresponding to the area, the drains which obtain and run off the amount of rainwater (mm/h) and the size of its outlet.
divided into four stages. Furthermore, the results collected by petrological survey that mapped distributions of magnetic susceptibility of the sandstone blocks also favorably support his theory of building phases too. The summary of Bayon’s succinct relative chronology made by the petrological survey was divided into three stages: the central tower to cruciform gallery and inner gallery as the first stage, the outer gallery as the second stage and the last stage was attributed to the construction of libraries and raised terrace of the causeway.

The characteristic of the “drain” itself is worthy of description. What found to be of particular attention here was how some drains were abandoned whereas some drains were added. Addition could have been made later to ameliorate problems, but never to be placed independently. Thus the detailed chronological analysis of drainage system of the Bayon becomes to be of value to reveal complex constructional phases of the Bayon. The Figs. 7-1 and 7-2 summarized the chronology of the drainage system.

4.2. Analyses by their physical features and functions

The basic drainage system of the Bayon was to evacuate rainwater from the uppermost terrace making use of the series of drains in various locations.

However well the drainage system in the Bayon could have been, the present condition of these drains is obviously far from working properly. The reasons for their malfunction could either be original poor design, lack of maintenance, displacement of the building itself or there may have been a drastic change in weather pattern occurred in the area.

As far as the total drainage system is concerned, what puzzles an observer are the sizes of drains and their placements. Though it is quite natural to consider placing larger size of drains located outwardly, existing drains do not show such tendency or on the contrary sizes tend to become even smaller. This tendency is more evident in the southwest section of the building (Table A). According to Tsukawaki’s research conducted in 1996, the climate condition in the area must not have been too different from what it is today, therefore it is unlikely to think that the people at that time were not used to heavy precipitation. The investigation on drained water volume conducted in 2002 by the geology unit of JSA together with analysis of such drainage design brought unprecedented yet credible hypothesis with regard to the traditional approach for draining rainwater: to make excessive water distribute throughout the building and have them intentionally seep into the internal foundation mass. This hypothesis was backed up by unfavorable phenomenon apparent in various places: sands are coming out with rainwater through the small joint openings of the foundation walls (Ph. 18).

What has been happening to the building over time due to its unique system seems to be affecting the building adversely. Since the system allows continuous flow out of the internal sand to lessen the absolute volume of the foundation mass, eventually it became the cause of uneven displacement of the building, shifting of vertical architectural members, and inclination of horizontal surfaces, all of which contribute to further malfunction of various drains and thus to create vicious cycle for the building deterioration. Lengthly stay of unwanted water also becomes a direct factor causing chemical and biological problems that degrade the building material which are sandstones (Ph. 19).

5. Conclusion

In conclusion, following arguments are to be recognized as an outcome of the study. As a result of comprehensive investigation conducted by the authors with cooperation of JSA, it is noteworthy that several drains as well as tunnels were newly confirmed. Due to the nature of drain functionality, the value
of chronological analysis of the drainage system should not be ignored as far as the research on construction phases of the Bayon is concerned. It is not unreasonable to say that the findings based upon existing research or future discovery in regard to the drainage system would directly affect various theories of construction phases of the Bayon.

Moreover, the fundamental concept drainage layout just to the north and south is more closely tied to the phases of construction. But according to the remodeling process where the new drains were added, it was difficult to keep the rule as the present layout of the drains (Fig. 2). In the first stage the drains D-1 to D-7 excepted D-3, were set up to the north and south of cruciform galleries. Drain A is also excepted, which was set up for special purpose as described in 3.1(2). In the second stage drains C-1, C-2 and D-3 were set up later as the construction traces is remarkable. In the third stage, drains E-1, G-1, G-2, G-3, G-6, G-7, G-8, G-10, G-12 and G-13 were set up later to support drains E-2, G-4, G-5, G-9 and G-11 when there was problem with function neglect or not enough drain to evacuate rainwater (Fig. 7-1 and Fig. 7-2).

How the existing drainage system does not function as expected greatly contribute to the degradation of the building at the present. In other words, to create alternative measures and/or provide new drainage system, assuming that the original system is insufficient to ameliorate existing problems, could possibly prevent further deterioration of the building.

Acknowledgements:
This research was supported by the Japanese Government Team for Safeguarding Angkor (JSA) under UNESCO/Japanese Trust Fund for the Preservation of the World Cultural Heritage. This paper could not have come through even to this far without Dr. Olivier Cunin’s benevolent offer for our research team to use his digitalized drawings in return for the future findings of this research. We believe our mutual collaboration will benefit to expand the scope and depth of studies of the Bayon. The special thanks to Mrs. Namiko Yamauchi, Mrs. Katsura Sato, Messrs. Hiroki Hattori, Ichita Shimoda and Masaki Kiowai for reading our manuscript and providing valuable suggestions.

Notes:

(2) Tsuyoshi Narita and So Sokuntheary, “Survey of the Drains at Bayon”, Annual Report on the Technical Survey of Angkor Monument (ARISA) 1998, Japanese Government Team for Safeguarding Angkor (JSA), pp. 48–60; and So Sokuntheary, Takeshi Nakagawa and Shin-ichi Nishimoto, “The drainage system of the Bayon Complex and its problem”, Summaries of Technical Papers of Annual Meeting, August 2002, AJI, No. 9322, pp. 643–644. We would like to make a correction on our description in the above articles which said ‘the drains set up to drain water from inside to the rooms to the outside which had been considered that it had not been planned at the time of construction’, but when we confirmed by using CCD camera (note No. 7) it was clear enough to say that those drains were planned to set up at the time of the construction.


Fund for the Preservation of the World Cultural Heritage.
(6) Tsuyoshi Narita and So Sokunheary, op.cit.; and So Sokunheary, Takeshi Nakagawa and Shin-ichi Nishimoto, op.cit. Those were concerned with the types of the drains and the main drain only, if counted the number of the drains it would be more than one hundred. For instance, the drains inside the tower shrines 14 drains, drains on the east entrance terrace 5 drains, drains located under the porch step between inner galleries porch’s towers and the passage halls 19 drains, drain under the east staircases to the upper terrace 2 drains, water and rubbish accumulated sumps 5 places, drains built to evacuate water from inside of towered shrines 13 drains, drains under the naga balustrade of east entrance terrace, under the naga balustrade of outer gallery and drains under the naga balustrade of upper terrace 43 drains, drains on the terrace surfaces 32 places. These numbers are not included the ditch carved on the roof, the ditch carved on the surface platform and the ditch on the central top.
(7) CCD camera: a Charge-Coupled Device (CCD). The survey is a part of ‘A Comprehensive Study on the Intensification of Architectural System’; and has been supported in 1990-2003 by a grant from the Japan Society for the Promotion of Science.
(10) Tsuyoshi Narita, Shin-ichi Nishimoto, Naho Shimizu and Yasushi Akazawa, op.cit.
(13) Olivier Cunin, Etsuo Uchida, op.cit., Fig.

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Fig. 7-2, The chronology of drainage system
(Digitalized plan by Olivier Cunin and Etsuo Uchida based on the drawing by EFEO; Drainage plan added by So Sokunheary)
和文要約
本稿は、アンコール・トムの中心に位置するバイヨン寺院の
排水システムに関する研究である。既往研究により、バイヨン
寺院内には主に26箇所の排水溝が認められているが、新たに
多数の排水溝が確認された。本稿は、バイヨン寺院の建造過
程と排水システムの敷設の関連について解明することを目的と
している。

バイヨン全体の排水計画は、増改築が行われた過程でその都度更
新され、水はけの悪い箇所が出現すると、新たな排水路を増設
していた様子が観われる。発掘調査では、内回廊の基壇を南北
に貫通する横穴と、外回廊基壇を南北に貫通する二本の暗渠が
確認された。横穴は内回廊の中庭と、内外回廊間が嵩上げされ
る以前に、中庭から外側へ雨水を排出するための排水溝であっ
たと推察される。また、暗渠は内外回廊間が嵩上げされる以前
に、外回廊の内側から外側へと雨水を排出するための排水溝で
あったと推察される。

建造過程と排水溝の敷設関係については、Dumarçayによるバ
イヨンの建造過程の考察と、砂岩の帯磁率特性を利用した岩石
学的な分析結果に、排水溝の敷設過程を突き合わせた結果、
Dumarçayの建造過程を支持するものである。排水は外側へ
至るに従って、雨水は次々と合流するため、外側の排水口ほど
大きな断面を有するはずであるが、実際は外側のものほど断面
が小さくなる傾向を示している。

雨水と排水量の計測から、現在雨水の大半は伽藍の基壇に染
み込んでいることが確認された。基壇内に浸透した雨水は基壇
を汚すため、基壇の沈下や破壊の原因となっている。全体の保存修復にあたっては、床面からの
雨水の浸透を防ぐために、基壇の排水溝を活用した適切な排水
計画が求められる。

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