Dismantling for Reconstitution of N1 Tower of Prasat Suor Prat, Angkor Thom, Cambodia

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Angkor

Established in 802
Continued till 1443

1860 French
1908 EFFEO
1939 WW II
1942 Japanese Army
1945/3 Independence
1945/9 De Gaul sent Army
1954/12 cast the right of war compensation
1993 Mr. Akashi as UNTAC
Topological Setting of Angkor
The first boring study in Angkor
March 1994
Geological Section by Boring to reach base rock in Angkor

- Silty Fine Sand
- Quaternary Sediment
- Tertiary Sediments
- Base Rock
Grain Size Distribution of Soils

Surface Soil

Sand fill at Bayon North Lib.

Clay  0.002  Silt  0.074  Sand  2.0mm  Gravel  60mm
Prasat Sour Prat
(Towers for Rope Dancer)
Inclination of Towers

Outer Wall Inclination to North(°)

Outer Wall Inclination to East(°)

N Group

S Group

N-pond

S-pond
N3 was found heavily damaged. In 1960' the upper structure was dismantled and reconstituted but the tower was deformed again within a few years.
Khmer did not use Wedge arch but corbel arch
Heavy load compressed the laterite block
Distortion
bottom beams are wider than top ones
Spreading Outwards of Foundation mound
Differential Settlement

40cm/10m
Possible mechanism of the Tower deformation

Horizontal Spreading and Inclination

Simple Compression

Base Wedge Failure

Two Sided Shear Slidings

One sided Shear Sliding
Dismantling N1 Tower
Excavated foundation

No Sliding Deformation was found.
Streak Lines found in a Section of Trench Face
Distribution of Patterns of Line Segments

\[ \theta = 45 \pm \phi/2 \]

\[ \phi = 30^\circ \]
No Major shear sliding was identified

No shear sliding in the ground beneath the foundation

Local failure

Block slid down

North pond

Vertical Compression/
Horizontal spreading
Geotechnical Condition

Silty Sand SPT N=15

Clayey Fine Sand N=10
FEM Simulation by PLAXIS

Vertical Load = 400kPa

Filled C=25kPa, $\phi=30^\circ$

Natural Soil C=20kPa, $\phi=30^\circ$
Development of Plastic Zones

When the load increases to 400kPa, plastic zones become to distribute in the soil mound beneath the foundation.
Process of Deformation

1. Compression of soil mound with horizontal spreading
2. Redistribution of Loads from upper structure
3. Bearing failure
4. Slip-down of sidestep stones
Jayavarman VII  Bayon
Conclusions(1)

• The Inclined foundation with spreading was considered as caused by the soil deformation underneath the soil mound of the Prasat Suor Prat.
• Dismantling the foundation revealed complete different mechanism.
  • ① vertical compression with yielding with horizontal spreading of the soil mound.
  • ② settlement caused load redistribution from center to edge resulted local bearing failure.
  • ③ Side step stones also slid down along the soil mound that has caused apparent inclination of the Tower.
Conclusions(2)

⑤ Dismantling by archaeological method was useful to understand the full mechanism of the deformed process.

Thank you for your attention.