TECHNISCHE UNIVERSITÄT DRESDEN

IMS International Masonry Society

8IMC_317

Seismic Assessment for Restoration of Prambanan World Heritage Temples Damaged by the Central Java Earthquake of 2006, Indonesia

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1. Introduction
Prambanan World Heritage Temple

1. Introduction Unique Story

- Originated in 9th Century
- Ruined during long history
- Candy Siva : Reconstructed by Other buildings : Reconstructed by Indonesian engineers in the end of 1980s
- Other buildings : Reconstructed by Indonesian engineers in the end of 1980's

1. Introduction Outlines of Project

Indonesian Government requested in emergency the cooperation of Japanese Government to assess the earthquake damage to Prambanan Temples.

- International collaborative project (Japan-Indonesia) have been successfully performed for over 3 years.
- Multi-disciplinary team was established.

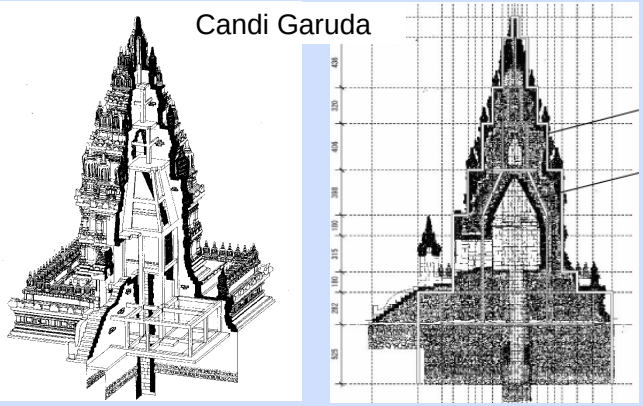
1. Introduction Objectives

(1)To identify the cause of the damage from a structural engineering point of view

(2)To conduct seismic diagnosis for safety of both the present and the post-restoration

1. Introduction Inner Structure

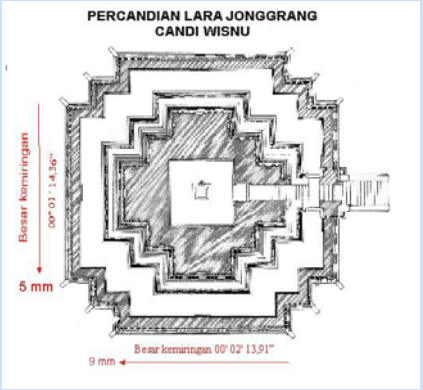
Candi Garuda



1. Introduction Earthquake Damage

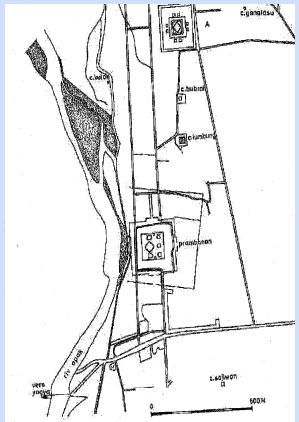
2. Geotechnical and Structural Survey Irregular settlement of foundation

- **Kemelesakan kaki 1 antara 0,2 – 0,8 cm**
- **Kaki 2 : 0,4 – 1,8 cm**

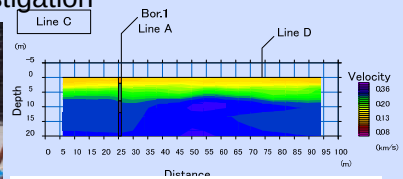


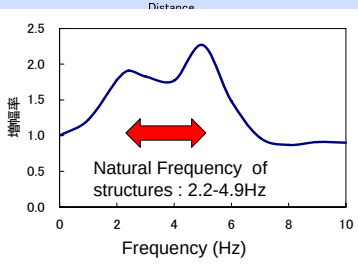
After Prambanan Restoration Office

2. Geotechnical and Structural Survey
Geographical Condition

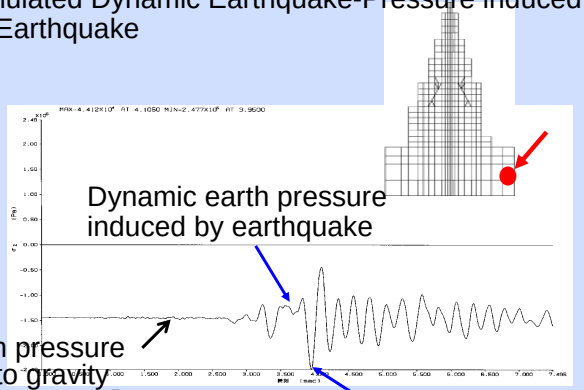


2. Geotechnical and Structural Survey
Geotechnical Investigation





2. Geotechnical and Structural Survey
Simulated Dynamic Earthquake-Pressure induced by Earthquake



2. Geotechnical and Structural Survey
Stability of soils and foundation

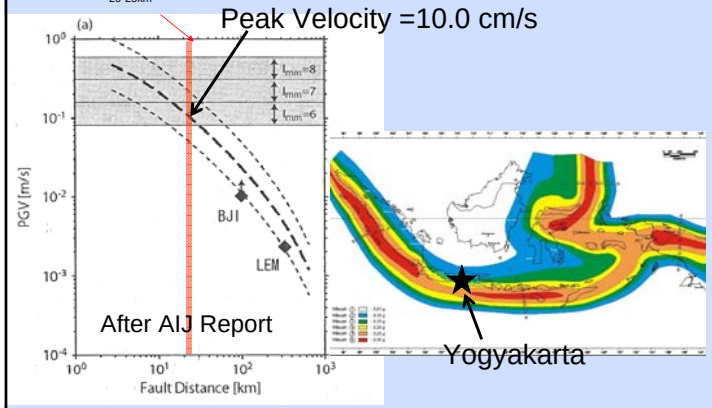
- Are the soils that support the Prambanan temples natural deposits or man-made embankment ?
- The geotechnical investigation indicates that the soils are natural ones and differential settlement of foundation was not caused by the seismic response to the Central Java Earthquake.

2. Geotechnical and Structural Survey
Microtremore Measurements

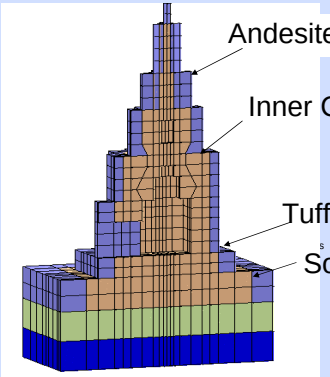
Candi		Natural Frequency (Hz)	Height (m)
Siva	NS	2.24	47
	EW	2.34	
Garuda	NS	3.66	22
	EW	3.69	
Brahma		3.05	37
Vishnu		3.10	37
Nandi		3.62-3.72	27.5
Hangsa		4.05	22
Apit		4.87	17

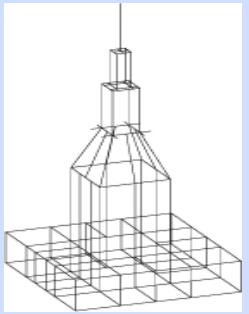
2. Geotechnical and Structural Survey
Sampling and Mechanical Tests

2. Geotechnical and Structural Survey
Earthquake Ground Motion for Assessment



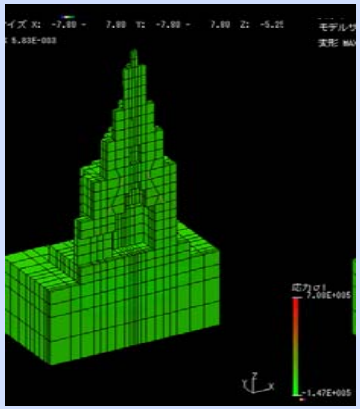
3. Seismic Response Analysis
Analysis Model





Beam Element

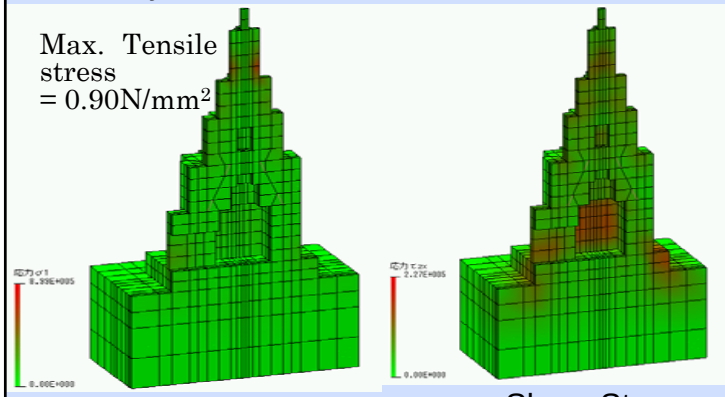
3. Seismic Response Analysis
Simulation – input motion : Athens EQ of 1999



Input level :
PGV=12.4cm/s
PGA=0.217G

3. Seismic Response Analysis
Analysis Results - Stress in Stone and Rubble

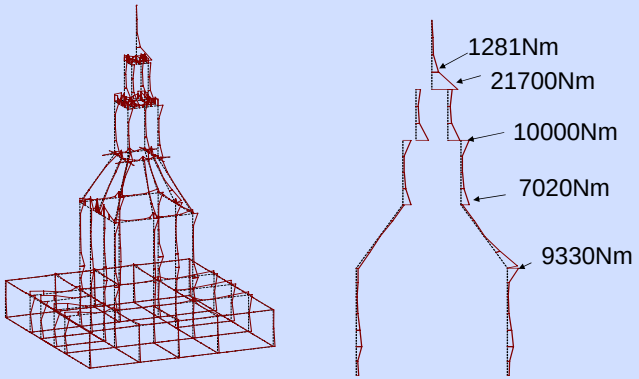
Max. Tensile stress = 0.90N/mm^2



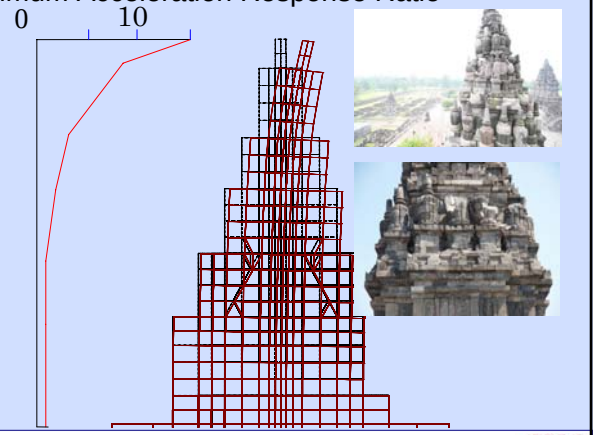
Principal Stress

Shear Stress

3. Seismic Response Analysis
Flexural Moment Induced in RC Frame

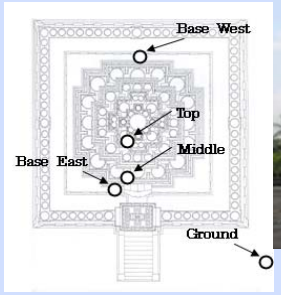


3. Seismic Response Analysis
Maximum Acceleration Response Ratio



3. Seismic Response Analysis

Earthquake Monitoring



Candi Angsa

3. Seismic Response Analysis

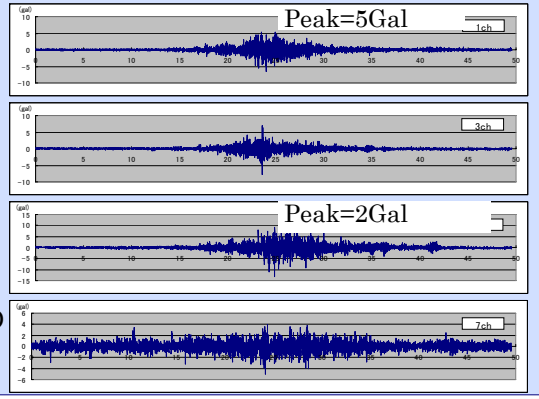
Acceleration Record (NS-Comp.) of March 25,2008

TOP

MIDDLE

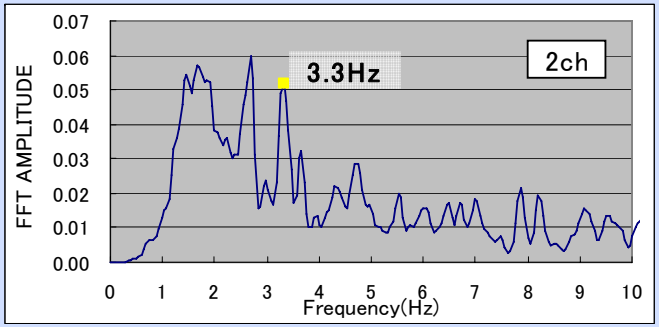
BASE

GROUND



3. Seismic Response Analysis

Fourier Spectrum of the acceleration at Top (NS-Comp.) of Earthquake of March 25,2008



4. Conclusions (1)

Structural assessment of the stone heritage structures affected by earthquakes has been studied for the structural restoration of the Prambanan Temples damaged by the Central Java Earthquake of 2006, Indonesia.

1. The structural analysis indicate that the inner concrete structures were not seriously damaged by the earthquake for the cases of Candi Garuda and Angsa

4. Conclusions (2)

2. The analysis also indicate that the apparent differential settlement of the foundation was not caused by the earthquake.
3. Whipping phenomena of the structural response caused the serious damage to the decorative stones of stupa and ratona. The dynamic seismic loads for designing strengthening of the decorative stones were provided by the simulation.

Conclusions (3)

4. The predominant period of the surface soil response corresponded to the natural frequency of the structures. Such resonant behaviors might cause the serious damage to the Prambanan Temples.
5. The seismic response analysis indicated that the response of the stone structure was significantly affected by strain-dependent soil stiffness of the surrounding soils during the earthquake.

Conclusions (4)

It was suggested that dynamic soil-structure interaction should be considered to study earthquake response of such massive and rigid structures on deposited soils.

International Cooperation in Conservation of Cultural Heritages has been successfully performed for 4 yours.