

## Muon radiography Monitoring for Structural Survey of the Prambanan World Heritage Temple

HANAZATO, Toshikazu<sup>1\*</sup> ; TANAKA, Hiroyuki<sup>2</sup> ; KUSAGAYA, Taro<sup>1</sup> ; OKAMOTO, Yumiko<sup>1</sup>

<sup>1</sup>Mie University, <sup>2</sup>University of Tokyo

Muon cosmic-ray can penetrate rocks and soils and give us projection of the path' density, therefore, muography technology has been successfully developed in the geological field for disaster prevention of volcano explosion 1). Furthermore, it was utilized to survey the inner condition of a blast furnace in a steel mill during its operation time. On the other hand, non-destructive tests are required, in general, to conduct structural survey of heritage structures with cultural and historical values. In particular, when World Heritage Monuments are surveyed, we have to follow this principle strictly. There are a number of World Cultural Heritages of masonry in seismic regions in the World. When their seismic safety is assessed, seismic structural survey is conducted by employing non-destructive tests. Considering that muography technology can be useful for structural survey of massive masonry structures as a non-destructive test, we installed the muon detecting system at the Prambanan Temples, World Cultural Heritage in Indonesia and monitored the muon cosmic-ray for 5 months. Here, the Prambanan Temples of stone masonry structures were severely damaged by Central Java Earthquake of 2006. We have been successfully involved in architectural and structural survey project conducted by an international and interdisciplinary team. The damaged masonry monuments have been restored after the earthquake, however, restoration work of Candi Siva, the oldest and highest monument of the Prambanan Temples, was not started yet, as its inner structural condition was unknown. If the inner structural conditions are revealed, 3-D finite element model is available for seismic structural diagnosis of such massive masonry structures. The scope of the present paper is to describe this challenge of non-destructive test utilizing muography technology for the Prambanan restoration project and to demonstrate applicability of this advanced technology to structural survey of World Cultural Heritages of masonry. The muon data obtained at the site indicated that the monument must have inner chambers that had been unknown. The data also indicated their sizes and locations. This information will be useful to provide analysis model for seismic evaluation.

### References

- 1)Tanaka,H.K.M.,Taira,H.,Uchida,T.,Tanaka,M.,Takeo,M.,Ohiminato,T.,Aoki,R.,Nishiyama,et al. :  
Three-dimensional computational axial tomography scan of a volcano with cosmic ray muon radiograph,  
J. Geophys. Res.,115, B12332, 2010

Keywords: muon, structural survey, masonry, World Heritage, seismic safety