# STUDY OF FLOW AROUND COMPLEX SHAPED TALL STRUCTURE

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## 1. INTRODUCTION

The Ryukyu Kingu Kan'non Bosatsuzou in Okinawa, which was made from iron-aluminium alloy and was 25 m high and 40 ton weight, was collapsed by Typhoon Trami on September 30th, 2018, regardless of reinforcing wires on four sides of the statue. The reason for falling might be either an increase in wind load acting on it during the typhoon or a complex wind flow around it. Therefore, to avoid this kind of accident, flow fields around the complex-shaped structure needs investigation in detail. In this study, flow fields around a statue are calculated using large eddy simulation (LES) and compared with those of a circular cylinder.

## 2. FLOW FIELD ANALYSIS CONDITIONS

Fig. 1 shows the statue model located in Myanmar, the exterior configuration of which was obtained by performing an on-site 3D laser scanning. The width and height of the statue are 47.629 m and 129 m, respectively. A circular cylinder with the same height as the statue was also studied, whose diameter was 30.22 m, corresponding to the average diameter of the statue along the vertical direction. Fig. 2 shows the computational domain around the statue. The unstructured mesh was employed with boundary layer meshes. The height of the first cell was 0.09m (=$D$/480, $D$: side length of the statue model). The pressure was set to zero for the outlet and the Neumann condition for the other boundaries. A logarithmic wind profile was provided for the inlet surface, where wind speed at 10-m height was 31.3 m/s (MNBC)[1)]. The logarithmic wall function was given to the ground surface with a roughness length of 0.01m. The turbulence model was the standard Smagorinsky model. The time step was 0.0005 s. Approaching wind angle for the statue model was set to 0° (S1 case), 5° (S3 case), 50° (S5 case), and 90° (S6 case), where 0° means that approaching wind is orthogonal to the front surface of the statue.

Fig. 1. Laykyun Sekkya Standing Statue

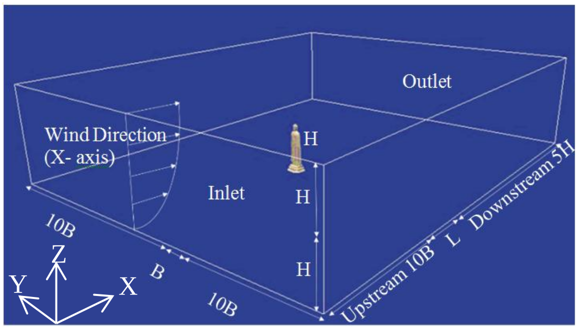


Fig. 2. Computational Domain

## 3. SIMULATION RESULTS AND DISCUSSIONS

To investigate the characteristics of flows around the models in detail, the models are divided into 26 parts along the vertical direction, and wind force coefficients and Strouhal number for each part are discussed. Fig. 3 (a) shows the mean along-wind coefficient of all cases. The influence of the wind profile is significant near the ground for both models. Similarly, the effect of vortex at the top of the models is also significant near the top. For cylinder model, the mean along-wind coefficient is almost constant between 0.19$H$ and 0.85$H$. However, the coefficient for the statue gradually

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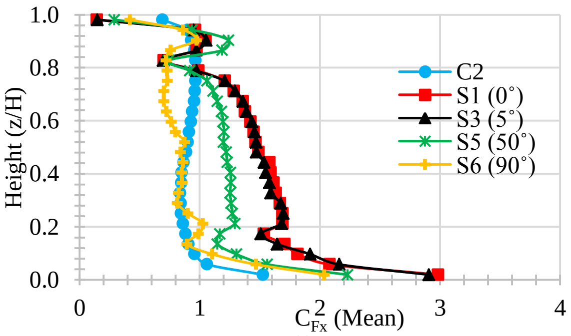
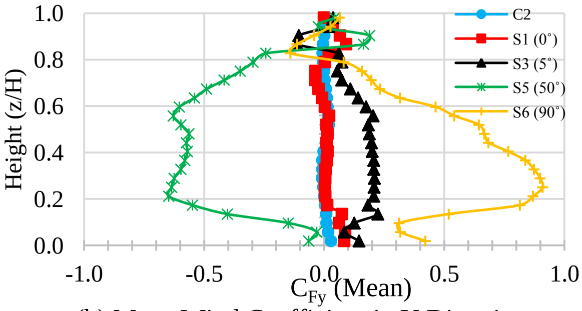
decreases in this region due to its complex shape. Moreover, sharp changes are also observed around 0.19*H* and 0.82*H*. Fig. 3(b) illustrates the mean cross-wind coefficient. S1 (0˚ case), has zero lift force like that of the circular cylinder between 0.19*H* and 0.77*H*. However, the coefficient differs slightly on the remaining parts of S1. Except that, other cases have a non-zero lift forces as the statue shape is similar to rectangular at the base, elliptic at middle and circular at the top on an individual basis.

One massive vortex on the upper side and the smaller one on the lower side are observed in the wake region behind the circular cylinder. In S1 (0˚), S3 (5˚) and S5 (50˚), the size of these two vortices are the same between each other. However, the wake regions are larger compared to that of circular cylinder. Alternatively, in S6 (90˚), one small vortex between 0.85*H* and *H*, one large vortex between 0.19*H* and 0.85*H*, and one medium vortex underneath 0.19*H* are observed. Generally, the vortices behind the statue are complicated as shown in Fig. 4 as the statue is unsymmetrical.




(a) Mean Wind Coefficient in X Direction




(b) Mean Wind Coefficient in Y Direction

Fig. 3. Mean Wind Coefficient

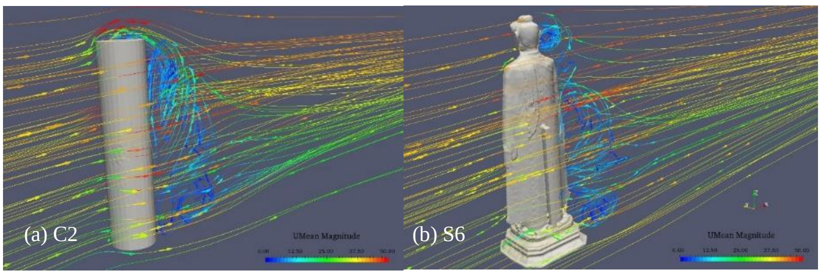



Fig. 4. Mean 3D Velocity Streamline

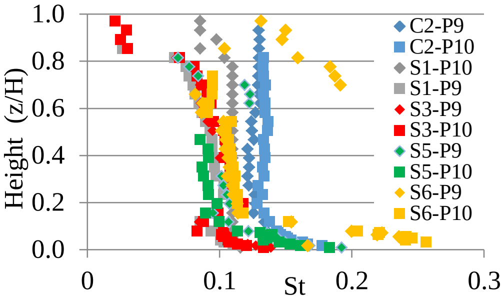



Fig. 5. Strouhal Number (St)

Fig. 5 illustrates the Strouhal number. It decreases steadily with an increase in height between the ground level and 0.16*H*, which may be due to the presence of wind profile. Except S5, St is around 0.11 between 0.16*H* to 0.78*H*. The St values of all statue cases, besides top and bottom parts of S6, are less than St of a circular cylinder. The Strouhal number of the circular cylinder is smaller than 0.2 as the elevation becomes higher while the vertical aspect ratio (*H*/*D*) at the highest point is 4.27. This agrees with the findings of Fox et al.[2)] and the static wind tunnel test results of Ma et al[3)].

## 4. CONCLUSIONS

As the statue's shape is in-between circular, elliptic and rectangular, mean along-wind coefficients are larger and mean cross-wind coefficients are significantly different from that of a circular cylinder. The vortices in the wake region of the statue are more complicated compare to that of the circular cylinder since the statue is unsymmetrical in all aspects. Moreover, the Strouhal number of the statue is smaller than the circular cylinder.

## REFERENCES

1) Myanmar Engineering Society: Myanmar National Building Code, 2006. 2) Fox et al.: Fluid Induced Loading of Cantilevered Circular Cylinders in a Low Turbulence Uniform Flow Part 1 Mean load, J. Fluids and Structures, 7, 1-14, 1993. 3) Ma et al.: Aerodynamic Characteristics and Excitation Mechanisms of the Galloping of an Elliptical Cylinder in the Critical Reynolds Number Range, J. Wind Engineering & Industrial Aerodynamics, 171, 342-352, 2017.