

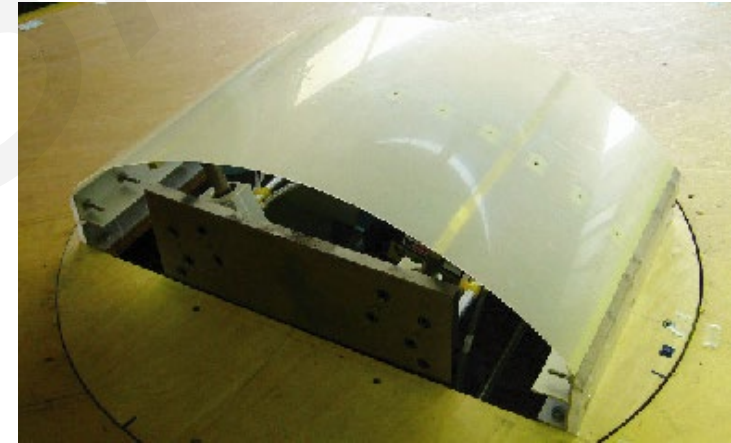
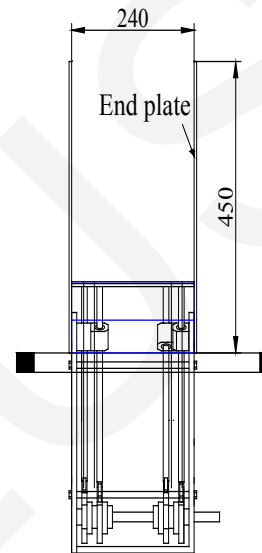
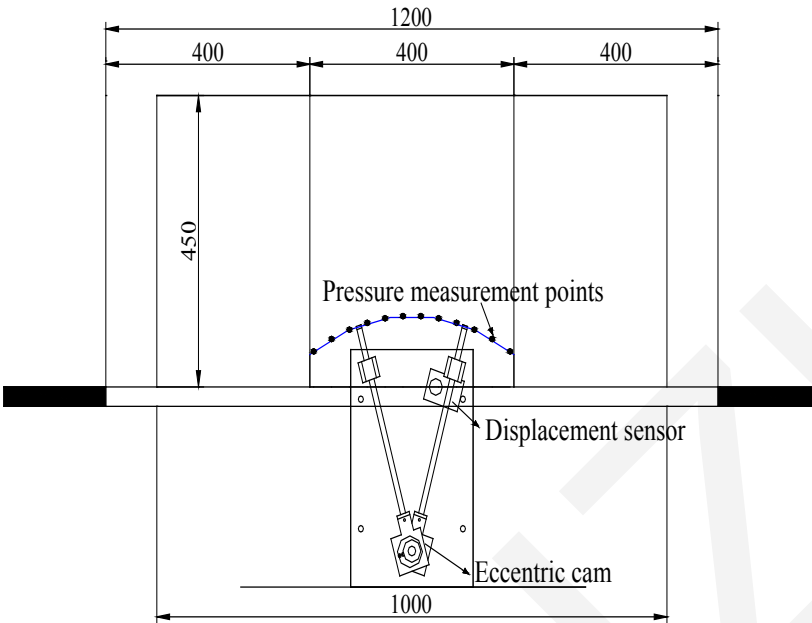
# Large eddy simulation of unsteady aerodynamic behavior of long-span vaulted roofs

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# Wind tunnel test

## Forced vibration test



**Limitation**

**Size of wind tunnel**

**Wind speed**

**Forced vibration frequency**

**etc ... ..**

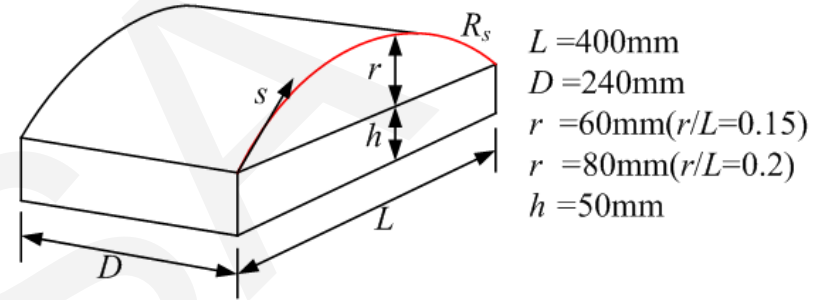
# Outline of the present work

## Large eddy simulation

- Discuss the influences of roof's vibration on the wind pressure and flow field
- Investigate the characteristics of unsteady aerodynamic forces in a wider range of the reduced frequency of vibration

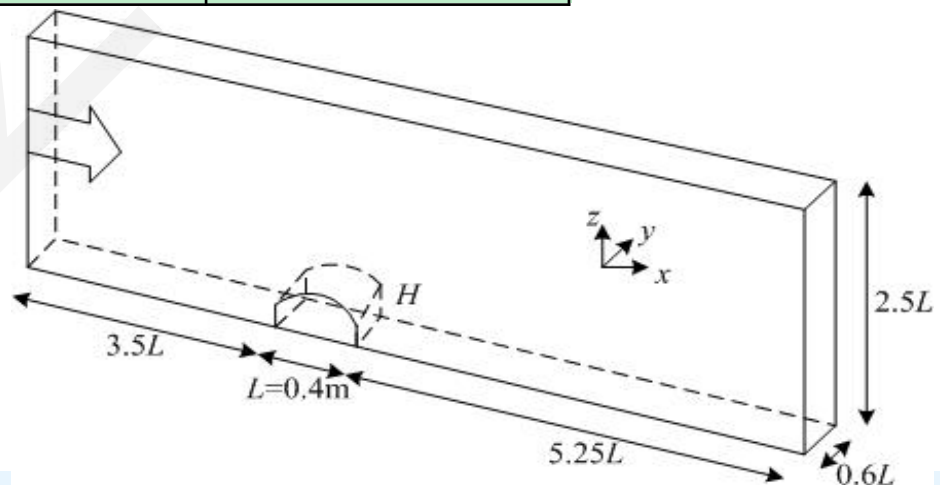
# Computational Profile

- **Method:** Forced vibration test  
(First anti-symmetric mode)
- **Model:** Curved roof
- **Flow :** Turbulent boundary layer
- **Parameter**



Rise/span ratio $r/L$	0.15, 0.20, 0.25
Forced vibration amplitude $x_0$ (mm)	4.0
Wind speed $U_H$ (m/s)	5.0
Forced vibration frequency $f_m$ (Hz)	0 ~ 160 (@10Hz)

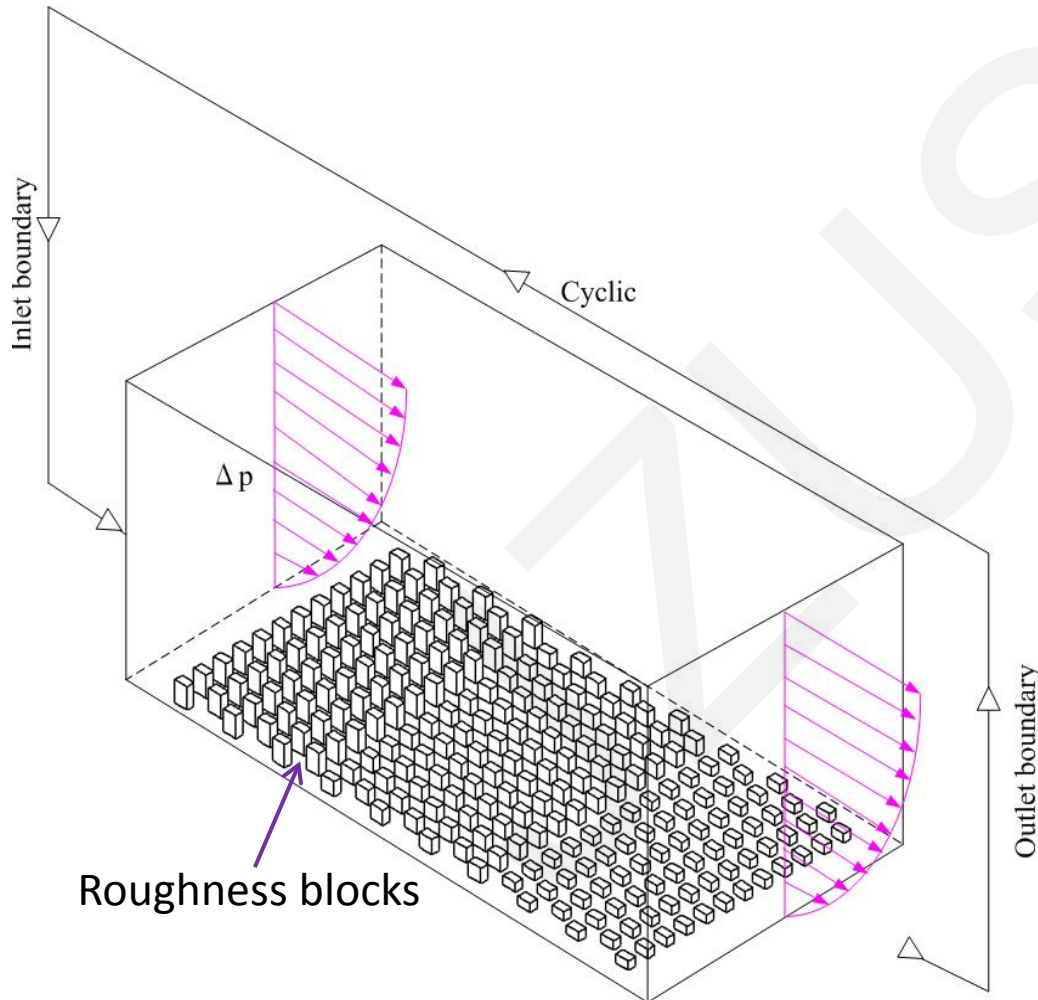
- **Computational domain**



# Computational Profile

- Inflow turbulence-

Store the time history of velocity fluctuations  $v(t)$



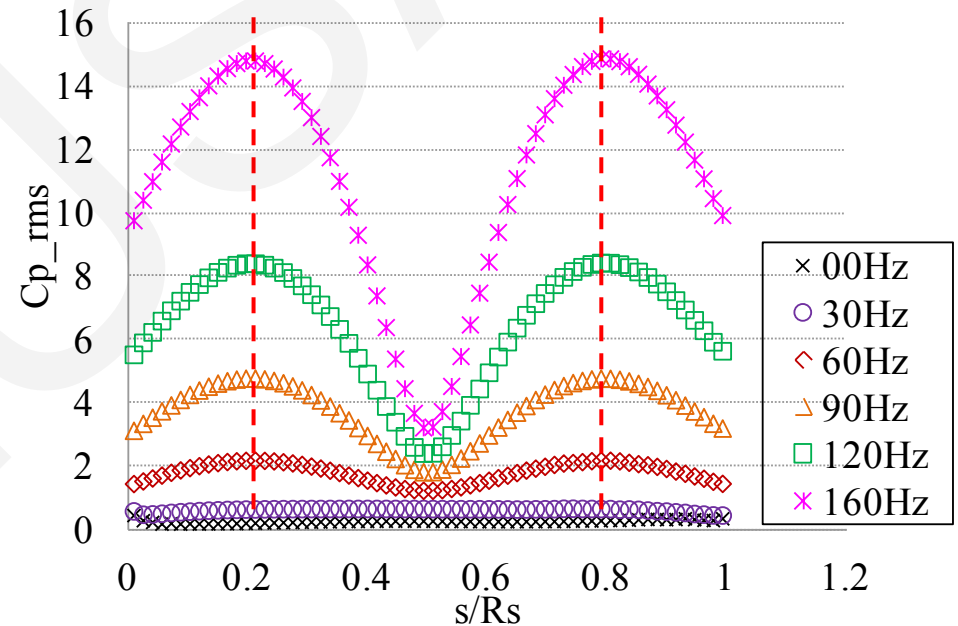
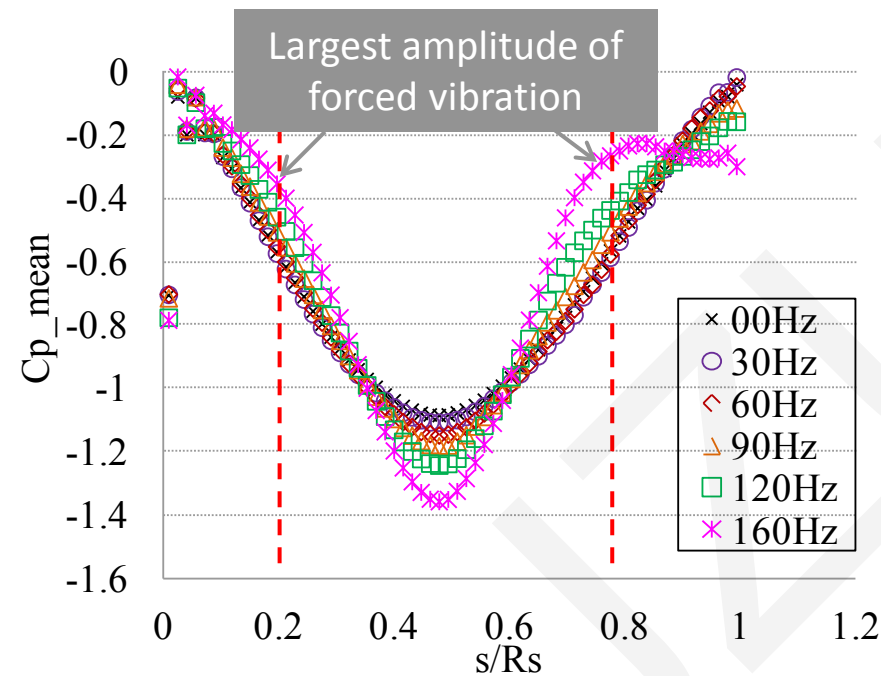
**Preliminary computation:**  
(LES turbulence model)

- ◆ **Roughness blocks** are arranged on the ground.
- ◆ The **periodic condition** is used.
- ◆ **Pressure gradient ( $\Delta p$ )** is added to the inlet.

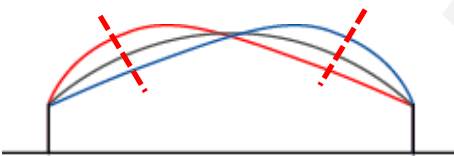
# Computational Results

## Discussion of wind pressure on the roof

Variation of mean and RMS wind pressure coefficients with **forced vibration frequency**



$r/L = 0.15$



■ Wind pressure field on the vibrating roof is influenced by the vibration of roof itself significantly.

# Computational Results -2

## Flow field around the roof

$f_m = 20$  Hz

Increase in  $r/L$



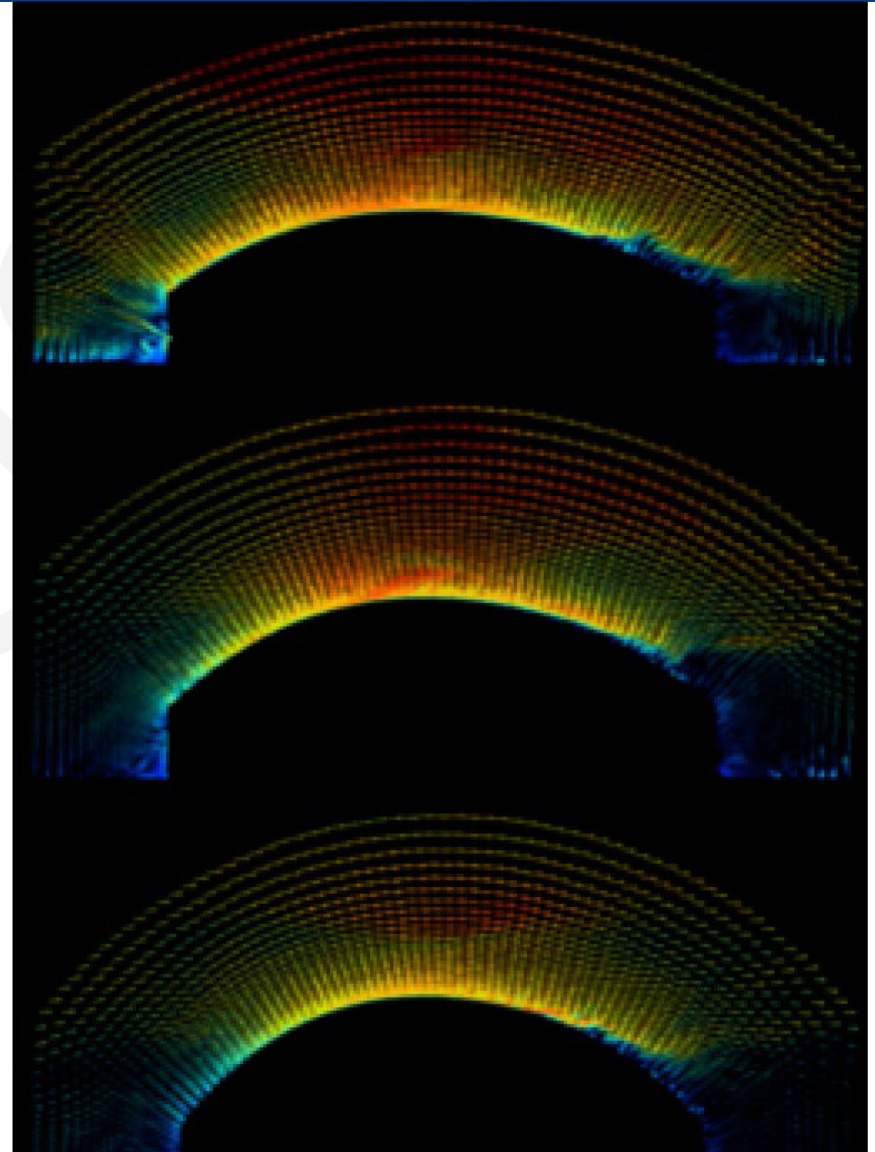
➤ Larger vortex near the rearward of roof

➤ Higher wind speed at the top of roof

$r/L = 0.15$

$r/L = 0.20$

$r/L = 0.25$



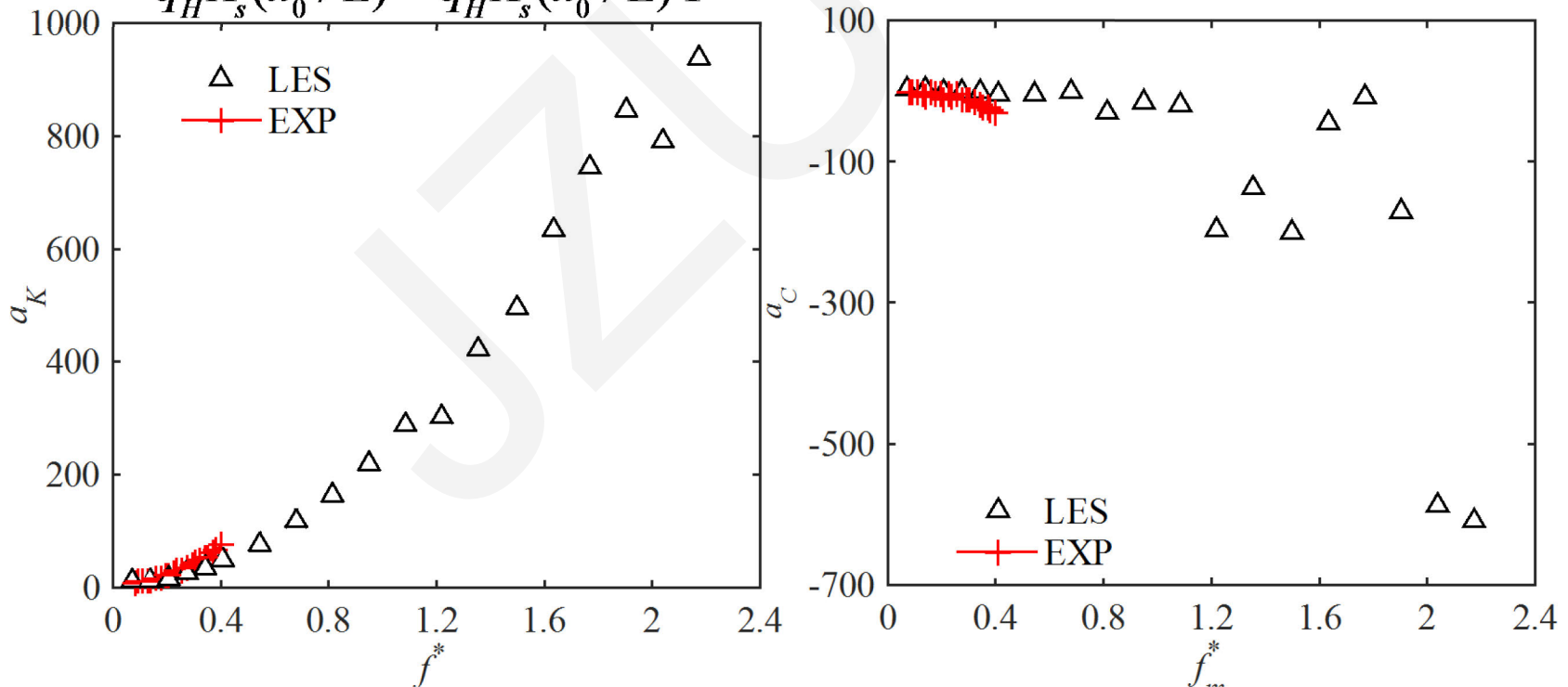
# Computational Results -3

## Evaluation of unsteady aerodynamic forces

◆ Aerodynamic stiffness and damping coefficient

$$a_{Kj} = \frac{F_R}{q_H A_s(x_0/L)} = \frac{1}{q_H A_s(x_0/L)} \frac{2}{T} \int_0^T F_j(t) \cos 2\pi f_m t dt$$

$$a_{Cj} = \frac{F_I}{q_H A_s(x_0/L)} = \frac{1}{q_H A_s(x_0/L)} \frac{2}{T} \int_0^T F_j(t) \sin 2\pi f_m t dt$$



# Conclusions

- **The influences of roof's vibration on the wind pressure and flow field have been investigated.**

(1) The wind pressure field around the vibrating roof is significantly influenced by the vibration.

- **The characteristics of unsteady aerodynamic force acting on a long-span curved roof have been evaluated.**

(1) The agreement between experiment and LES is generally good both for the variation of aerodynamic stiffness and damping coefficients with the reduced frequency of forced vibration. The LES is effective for the investigation of the characteristics of unsteady aerodynamic forces

(2) Within the limits of the present study, flow-structure interaction decreases the total stiffness of the system and increases the total damping of the system.