

Study on Aerodynamic Stability of a High-Rise Building with Base Isolation by means of New Hybrid Aerodynamic Vibration Technique

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1 INTRODUCTION

High-rise buildings with the base isolation are being constructed in Japan. The base isolation gets yielded in high-rise buildings by not only the earthquake loading but also the wind loading. In the case of the base isolation getting yielded by the earthquake loading, the input energy to the structures decreases because the natural frequency of the structure gets smaller and steps away from the frequency at the peak of power spectrum of earthquake excitation. However, in the case of the base isolation getting yielded by the wind loading, the input energy to the structures increases because the natural frequency of the structure gets smaller and gets closed to the frequency at the peak of power spectrum of the wind excitation. Furthermore, the risk to occur the resonance by wind loading gets higher than the building with the same configuration and without the base isolation. Consequently, it is necessary to examine aerodynamic stability of high-rise buildings with the base isolation. However, previous studies do not give us an effective technique to simulate the aerodynamic stability of buildings with base isolation. One of the authors has proposed a new approach for simulating aerodynamic oscillation in a wind tunnel. The approach was named Hybrid Aerodynamic Vibration Technique or HAT. As the modified approach, the author has also proposed New Hybrid Aerodynamic Vibration Technique, which is referred as NHAT. It is easy for this

technique to carry out parametric studies in a wind tunnel even under structural non-linear behavior. As considered the advantage of NHAT, the simulation is performed to investigate the characteristics of aerodynamic vibration of high-rise building with base isolation by means of NHAT.

2 SIMULATION OF AERODYNAMIC PHENOMENON

In this simulation, the NHAT system developed by the authors is used. The concept of NHAT is shown in Fig.1. Dimension of the given building and its lumped-mass model is shown in Fig.2. The dimension is 25m×25m×125m, and the building has 36 stories and 1 base isolation story at the bottom. Based on the similar low, the geometric scale is 1/250, the wind velocity scale is 1/20 and the time scale is 1/12.5. The lumped-mass model has 36 lumped-mass and 36 shear stiffness. The elastic model is adapted to the shear stiffness at the each story, and the bi-linear model as shown in Fig.3 is adapted to the base isolation. The yielding load Q_y of the base isolator is equal to 3.1×10^3 kN which is the maximum shear force in the elastic behavior when the wind velocity at the top of the buildings is 60m/s. The structural parameter in this simulation is the bi-linear coefficient that is the ratio of the plastic stiffness to the initial stiffness. The bi-linear parameter is set up to 0.01, 0.07, 0.10 and 0.15. The viscous damping system is expressed by the proportional matrix to the initial stiffness, the damping parameters in the each mode are 0.5%. The Modal Explicit Technique is adapted to the step-by-step algorithm. The integration time interval and the number of step are 0.002sec and 26000, respectively. The modes higher than 16th are neglected. The experimental flow is approximately the smooth flow as shown in Fig. 4.

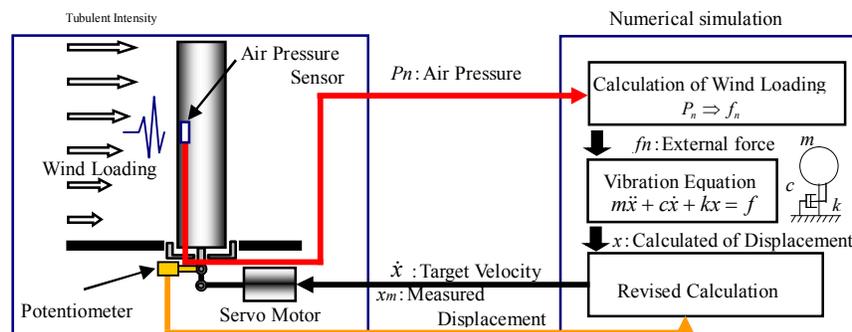


Fig.1 Concept of New Hybrid Aerodynamic Vibration Technique

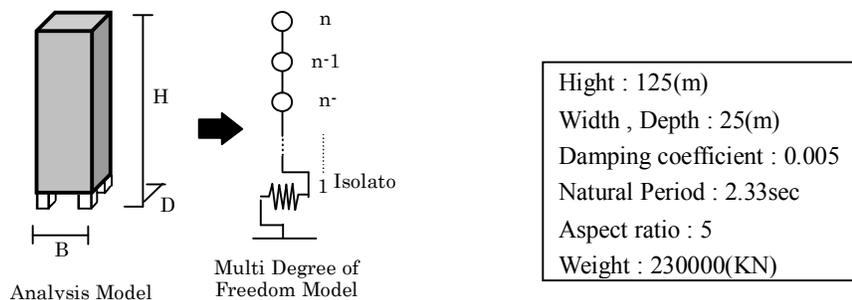


Fig.2 Given Structure and Analytical model

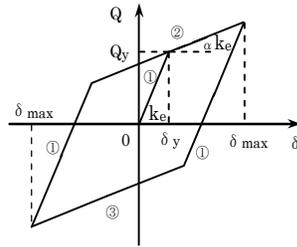


Fig.3 Hysteretic Model of Base-Isolator

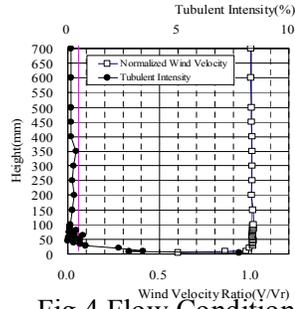


Fig.4 Flow Condition

3 SIMULATION RESULTS

The response curves of the building with the base isolation under wind loading are shown in Fig.5. The response curves of the building when the base isolation behaves under elasticity are expressed for comparing with the elasto-plastic behavior. The response curve goes up at the reduced wind velocity $V_r=9.3$ and take the peak value around $V_r=12.1$. From those values of V_r , it is inferred that the phenomenon is the vortex-induced oscillation. Fig.6 shows the resonance wind velocity which is estimated from the equivalent natural period in the plastic range. The parameter is the bi-linear coefficient α in this figure. The equivalent natural period is based on the equivalent stiffness which is evaluated from the maximum response displacement. The resonance wind velocity decreases from 128m/s in elastic range to 67m/s. It is confirmed that the resonance phenomenon doesn't occur even though the isolation gets yielded and the resonance wind velocity of the building gets decreased.

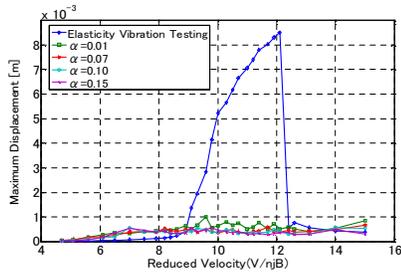


Fig.5 Response Curves

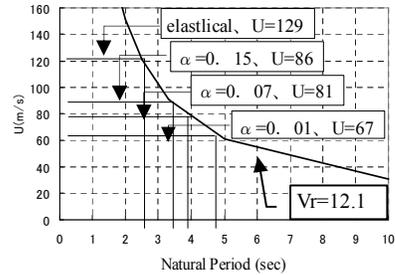
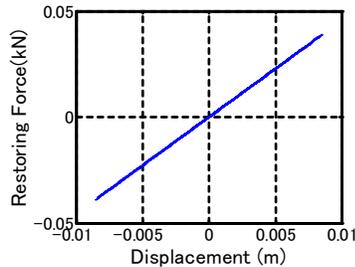
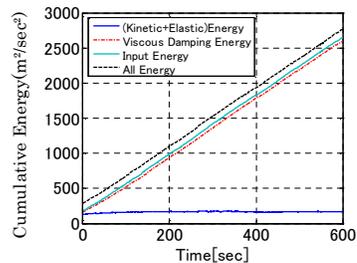


Fig.6 Resonance Wind Velocity

The result is analyzed for the dynamical energy in order to investigate why the vortex-induced oscillation doesn't occur. Fig.7 and Fig.8 show the response displacement in time history, the cumulative energy of kinetic, hysteretic, damping and external force in time history.

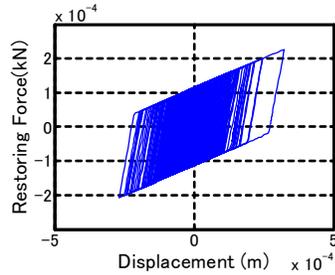


(a) Hysteretic curve

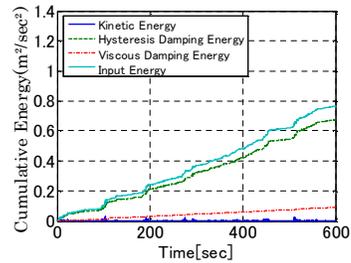


(b) Cumulative energy in time history

Fig.7 Response characteristics in elastic range



(a) Hysteretic curve



(b) Cumulative energy in time history

Fig.8 Response Characteristics in Elasto-Plastic

Fig.7(a) indicates the case of elastic behavior, Fig.8(a) indicates the case of the hysteretic curve of the elasto-plastic behavior which yielding load is equal to $3.1 \times 10^3 \text{ kN}$ and the bi-linear coefficient is equal to 0.07. In Fig.7(b), the viscous damping energy increases in proportion to the external force energy. The input energy is dissipated by the viscous damping energy. In Fig.8(b), the hysteretic energy increases in proportion to the external force energy. The input energy is dissipated by the hysteretic energy. The input energy in the elastic behavior is approximately 2800 J/kg at 600 sec passed at $V/r = 12.1$. On the other hand, the input energy in the elasto-plastic range is only 0.8 J/kg . There is a huge difference in input energy between the resonance and the nonresonance. From the result, it is clear that the resonance is suppressed by the dissipation of base isolation for the input energy by not only the earthquake excitation but also the wind excitation.

4 CONCLUSION

It is found out for the characteristics of wind response of the high-rise buildings with base isolation that the vortex-induced vibration is suppressed by the yielding of base isolation even though the vortex-induced vibration occurs in the elastic range and the most of input energy by wind excitation is dissipated by the hysteretic energy of the base isolator in the plastic range.

Henceforth, the dependent wind force is estimated from wind pressure distribution which is measured by means of NHAT.

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