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DISCUSSION OF SESSION 16 - BLUFF BODY AERODYNAMICS AND MATHEMATICAL MODELS OF WIND LOADING

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)ISCUSSION ON PAPER BY PROFESSORS N. SHIRAISHI AND M. MATSUMOTO

COMMENT BY MR. R.L. WARDLAW

For application in bridge structures, one can conclude from this paper that there are appropriate trailing edge and leading edge configurations to suppress motion of road deck sections, e.g., a rectangular trailing edge and a circular leading edge. What can be done in a practical way to accomodate the wind coming from either side of the bridge?

AUTHOR'S REPLY - Professor Shiraishi

The vortex-induced oscillations of a majority of bridge sections belong to Group 2 and 3 (Fig. 5). The leading and trailing edges have different roles in suppressing the vortex-induced oscillations. We claim that EA type cross-section is so far the most stable section. In other words, the leading edge should be equivalently rounded in the aerodynamic sense and the trailing edge should be rectangular in similar sense. Through modification of the geometrical shape of the sections and by applying varous aerodynamic stabilizing attachments, the generation of separated vortices from the leading edge can be suppressed and such devices can interrupt stable vortex formation from the trailing edge.

COMMENT BY DR. TOSHIOUEDA

The incident wind direction is a function of time, therefore, the directional stability of bridge sections must be taken into consideration. In this regard, one needs to devise modifications in the geometrical shape of the section as well as aerodynamic appendages for stabilizing the bridge section. I think the authors have had sucessful experiences in the application of such devices on prototype bridges. Could you please share some of your experiences with us?

AUTHOR'S REPLY - Professor Shiraishi

This has been answered in Mr. Wardlaw's question.

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COMMENT BY PROFESSOR H. TANAKA

For practical applications do the authors have any special consideration for the leading edge-trailing edge treatment of the proposed configuration. Also, would you comment on the discussion in session NO. 12 regarding the behavior of 1x2 prism?

AUTHOR'S REPLY - Professor Shiraishi

The answer to the first question has been covered in reply to Mr. Wardlaw's question. Regarding the second question, the 1x2 rectangular section is associated with very peculiar behavior and it is not yet clearly understood. We are very interested in the behavior of the 1x2 rectangular section. Obviously we need to pursue this investigation further. Probably, the characteristics of the 1x2 section are affected in a complicated fashion by the flow patterns characterized by group 1 as well as group 2.

COMMENT BY PROFESSOR M. NOVAK

I would like to commend Professor Shiraishi for his contribution to the explanation of the behavior of some basic shapes. His emphasis on vortex shedding from both the leading edge and the trailing edge may explain the behavior of the rectangular cross section 2 to 1 and the need for a triggering amplitude required for the start of the oscillations at higher level of damping.

DISCUSSION ON PAPER BY DRS. Y. TAMURA, AND A. AMANO

COMMENT BY PROFESSOR M. NOVAK

The model of the authors is very interesting but they make two assumptions which are not in general compatible; the model allows for spanwise variation of wind speed but assumes full correlation of the lift forces. The model would be improved if the authors could extend the model to include the spanwise correlation of the lift force and its variation with the amplitude of motion.

AUTHOR'S REPLY - Dr. Y. Tamura

Thank you for your advisory comment. I agree that the correlation effect is a very important problem, and I plan to include this in my model. Presently, the following simplified and approximate approach is used in the proposed model. The correlation effects of lift force can be viewed as the influence of correlation on a stationary and an oscillating cylinder. The correlation effect of a stationary cylinder is considered approximately by using the averaged value of lift force on the entire length of the cylinder to estimate C_{L_0} which is the amplitude of the lift coefficient of a stationary cylinder. Otherwise, if possible, averaged over the top 1/3 length or something similar to that value may be used. Similar approach should be considered for (Strouhal no) or C_D (drag coefficient). In fact, this model provides the basic procedure to predict the vortex-induced response of structure which needs further modifications before it can predict reliably the response of actual structures.

COMMENT BY DR. MAKUMOTO

The experimental results, shown in the last slide, were obtained in a uniform flow. Therefore, the agreement between the computed and experimental results does not indicate applicability of your model in shear flow.

AUTHOR'S REPLY - Dr. Tamura

The experimental results, shown in the last slide, were obtained in a wind tunnel for the response of a chimney in a uniform flow. Of course, I do not think that my model is applicable in a shear flow, since it has not been validated yet. Nevertheless, the validity of this three dimensional mathematical model of vortex-induced oscillation, which was developed from a two dimensional model, has been established. Therefore, I am hopeful that given the appropriate aerodynamic parameters this model may provide results for a shear flow.

ISCUSSION ON PAPER BY PROFESSOR M.T. TACHIKAWA

COMMENT BY MR. R.L. WARDLAW

In many possible situations, the missile will have an initial rotational velocity. Has Professor Tachikawa looked at the trajectory of the missile when there has been an initial rotational velocity or has he observed the trajectories to a distance when an equilibrium rotational speed has been reached?

AUTHOR'S REPLY - Professor M. Tachikawa

The model scale of our free flight tests in series 2 and 3 (see table 3) is about 1/20. We observed trajectories to a distance of 200 cm, which corresponded to about 40m in full-scale. In many cases, the models reached a steady-state auto-rotation in a relatively early stage of the motion. Missiles became air-borne from various initial conditions. We have not observed the initial motion in any detail. This is one of the remaining problems for us to pursue.

DISCUSSION ON PAPER BY PROFESSOR J. KANDA

COMMENT BY DR. H.W. TEUNISSEN

The turbulence characteristics presented in Table 1 show a value of turbulence intensity at gradient height of $\sigma_u/U = 0.078$ for all three types of terrains. This is higher than expected values at this height by a factor of two or even three. Why were such large values chosen, and would it have made any difference to the conclusions if a lower value had been used at this height?

AUTHORS REPLY - Professor J. Kanda

In order to make a model of turbulence characteristics, gradient height for various terrains was assumed, then the turbulence intensity data were examined to determine α_T in eq.(2) with reasonable agreement of model turbulence intensity values to measured data at typical elevations representing highrise buildings (50m to 200m) in various terrains. The results obtained are reported in Table 1 (e.g., $\alpha_T = 0.08$, $\sigma_u(z_g)/U(z_g) = 0.078$). I have not checked model turbulence intensity values directly with measured data near the gradient height which is needed by all means. The values used in this model are assumed.

If lower values are used for turbulence intensity, G_F should decrease as shown in Fig. 6. But if turbulence intensity is reduced, then one should increase α_T to keep reasonable agreement of turbulence intensity at around $z =$ 50- to 200m, then the results can be obtained from Fig. 7, which indicate drastic reduction of G_F for very tall buildings.

There was no formal discussion on Dr. G. Solari's paper.

RAPPORTEUR'S COMMENT:

This session was highlighted by papers related to basic aerodynamics of bluff bodies and procedures for estimating the dynamic behavior of structures.

Professor Shiraishi and Matsumoto presented a very enlightening classification of flow patterns around oscillating bluff bodies into three broad categories based on the separated vortices from the leading and trailing edges and secondary-vortices at the trailing edge. The authors identified an aerodynamically improved section (section EA) which suppresses the generation of separated vortices from the leading edge and interrupts stable vortex shedding of secondary and separated vortices from the trailing edge. However, the section EA being unsymmetric about the center line cannot be very effective for the wind approaching from either side of the bridge. The authors also proposed modifications in the cross-sectional shapes of bridge decks and suggested inclusion of aerodynamic appendages or attachments to stabilize various sections which they have successfully employed on a few prototype bridges.

The dynamic response of tall slender structures of circular cross-section exposed to atmospheric turbulent boundary layer involves a number of complex wind-structure interactions which have prohibited mathematical solution of the problem. Any analytical treatment would involve the solution of coupled aero-structural dynamics equations which is presently intractable. Semi-empirical mathematical models have been proposed in lieu of the solutions of above mentioned system of coupled equations. These models are based on the extension of forced vibration theory in which all motion dependent phenomena are represented by non-linear aerodynamic damping. Alternatively, non-linear wake-oscillator models have been formulated which provide phenomenological description of observed motion of elastic bodies of circular cross-section. Drs. Tamura and Amano's paper is based on the latter approach. Non-linear wake-oscillator models have provided good qualitative agreement between the model predictions and measurements for two-dimensional flow around circular cylinders. In a recent critique of non-linear oscillator models, E.H. Dowell has developed a rational, self consistent-non-linear oscillator model, (Non-Linear Oscillator Models in Bluff Body Aeroelasticity by E.H. Dowell, J of Sound and Vibration, 1981, 75(2) pp. 251-264). He reported very encouraging comparisons with the experimental results of Jones at high Reynolds numbers. Appropriate manipulation of high Reynolds number data, from full-scale measurements, with luck may help to predict the behavior of tall chimneys using the authors' approach. Bifurcation techniques can provide better insight to the behavior of wake-oscillator models and provide analytical tools for their modifications. Similarly, innovative techniques for solving coupled equations in such models would help to achieve more rational models for this class of dynamical systems, e.g. use of the Fokker-Planck equation.

Dr. Kanda computed cov of G_F by linearizing the expression for G_F at the mean value of the variables involved (Taylor's series) using FOSM approach. This approximation may introduce error in case of nonlinear functions i.e., G_F. A Monte Carlo simulation approach may be used to validate the results.