August 27-31, 2023
FLORENCE - ITALY
16th International Conference on Wind Engineering
ICWE 16

Interference effects on tall concrete chimneys: Disparity between codes and wind tunnel

Vivek Kanti[1], Tom George[1], Rahul P. S[2], Suresh Kumar[3]

[1]*Scientist/Engineer, RWDI, Trivandrum, India*
[2]*Technical Director, RWDI, Trivandrum, India, P.S.Rahul@rwdi.com*
[3]*Principal/Vice President - Global Consultant, RWDI, Milton Keynes, UK*

SUMMARY:
Tall concrete chimneys in power plants are slender structures that are susceptible to vibrations caused by either self-induced vortex shedding and/or interference from adjacent chimneys and other power plant structures. Most of the past studies discussed interference effect only on across-wind response excluding along-wind. Further, the codes discuss only the interference effect between inline chimneys and not when they are at skewed angles. This study investigated the interference effect between two identical chimneys at different distances for inline and skewed wind directions. Wind tunnel tests were performed on an aeroelastic model to investigate the interference effect between chimneys in a supercritical flow regime. Contrary to international codes, the results from the study showed a substantial increase in along-wind response other than the obvious increase in across-wind response. The results from this study show how critical skewed angles are while addressing the interference effect between chimneys. Thus, it is quintessential to consider both along-wind and across-wind loadings with skewed wind directions while addressing the interference effect between chimneys.

Keywords: Codes, interference effect, tall chimney, wind tunnel

1. INTRODUCTION

Chimneys are power plant structures that are used to discharge flue gas into the atmosphere. They are tall and slender in shape which makes them susceptible to across-wind response and wake interference from nearby chimneys and other power plant structures. The interference effect between two chimneys has been investigated in the past (Galsworthy and Vickery, 1999; Moriya et al., 2001; Rao,1985; Sun et al., 2020; Zhou and Alam, 2016). Researchers have mostly focused on the amplification of across-wind load due to wake created from upstream chimneys. However, Rao and Reddy (1993) confirmed the amplification of along-wind loads as well. These studies in past had shown that the interference effect varies with the distance between chimneys and the angle of wind incidence. The wake interference between two cylinders had seen a surge in research interest in the past few decades which had been reviewed in detail by Zhou and Alam (2016). This review showed that the studies are very limited in the supercritical flow regime and most of the studies were done in subcritical Reynolds number, hence, their applicability to chimneys is questionable (ACI 307-08). Furthermore, international chimney codes such as ACI 307-08 attribute the amplification of wake-induced loads to across-wind loading and address it through magnification factors. The wake-induced amplification in the along-wind loads or from the skewed angle of wind incidence is not addressed in the chimney codes.

The present study investigated the interference effect between two identical chimneys subjected to inline and skewed angles of wind incidence. The wind tunnel test setup showing two identical chimneys at different *l/d* ratios for different skewed angles is shown in Fig. 1. The variation of wind tunnel test results compared to the loads calculated by code analytical methods throws more insight into the shortcomings of code-based interference effects.

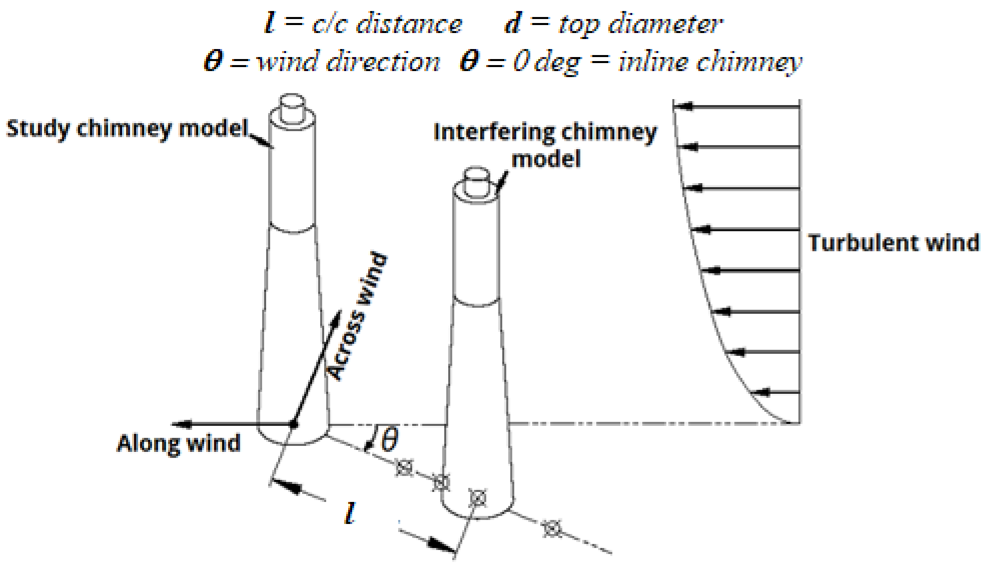

Figure 1. Schematic diagram of the test setup

2. WIND TUNNEL TEST METHODOLOGY

The study chimney is concrete with a variable cross-section (top dia-15m, base dia-24.5m) and an overall height of 150 m. The first natural frequency of the study chimney is 0.805 Hz. A 1:250 scale aeroelastic model was designed and tested using a base balance at RWDI's wind tunnel facility at Trivandrum, India. The wind tunnel flow conditions tried to match the full-scale Engineering Science Data Unit (ESDU) targets for the open terrain category. The details of the aeroelastic modeling, testing, and analysis will be elaborated on in the final paper.

At the design speed of a typical RCC chimney, Reynold's number falls in the upper range of the supercritical regime where the mean drag coefficient is expected to be between 0.5 and 0.7 as shown in the first plot in Fig. 2. The wind tunnel used for this study cannot generate supercritical

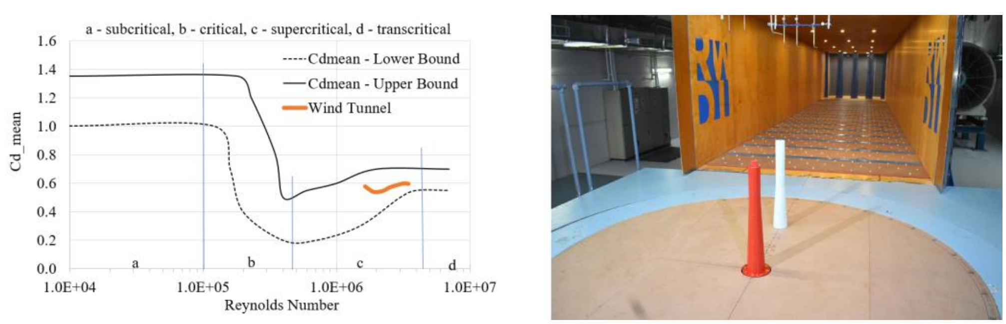

Figure 2. Reynolds number effects and wind tunnel simulation

flow. Hence such flow condition is generated artificially by adding roughness in the form of 0.5mm diameter smooth wire placed vertically and uniformly around the aeroelastic model as shown in the right plot of Fig. 2. The mean drag coefficient (Cd) obtained during the wind tunnel test is shown in the first plot in Fig. 2. It shows that the simulated Cd is in the supercritical regime and lies between the upper and lower bounds of measurements from various researchers.

3. RESULTS AND DISCUSSION

The peak along wind moment as a function of the *l/d* ratio and angle of wind incidence is shown in Fig. 3 for wind directions 0^o to 20^o along with ACI stand-alone value. It shows the along wind load increased with *l/d* ratio and reached a peak at an *l/d* ratio of 5 when the wind direction is skewed at 15°. The along wind load starts decreasing after *l/d*=5 and after *l/d*=15 effect is minimal. Fig. 3 also shows the amplification of along wind loads in the form of interference factor compared to ACI along wind loads. It can be seen that at *l/d*=5, the interference factor is almost twice that of code loads. This effect is only mentioned by a few researchers in the past, and the details of this mechanism will be elaborated on in the final paper.

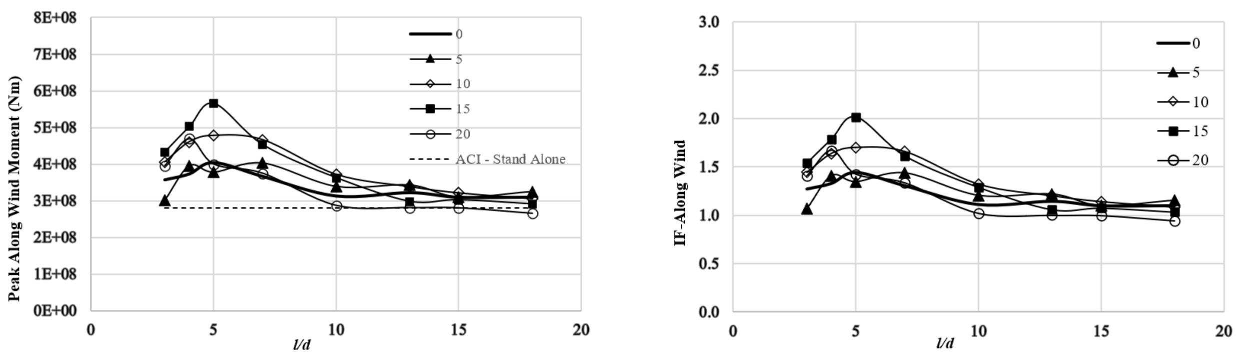

Figure 3. Peak along wind response and interference factor

Peak across wind moment as a function of the *l/d* ratio and angle of wind incidence is shown in Fig. 4 along with ACI predicted loads. The variation of across wind response with *l/d* ratio is almost the same as along wind response. It is clear from these results that across wind load is

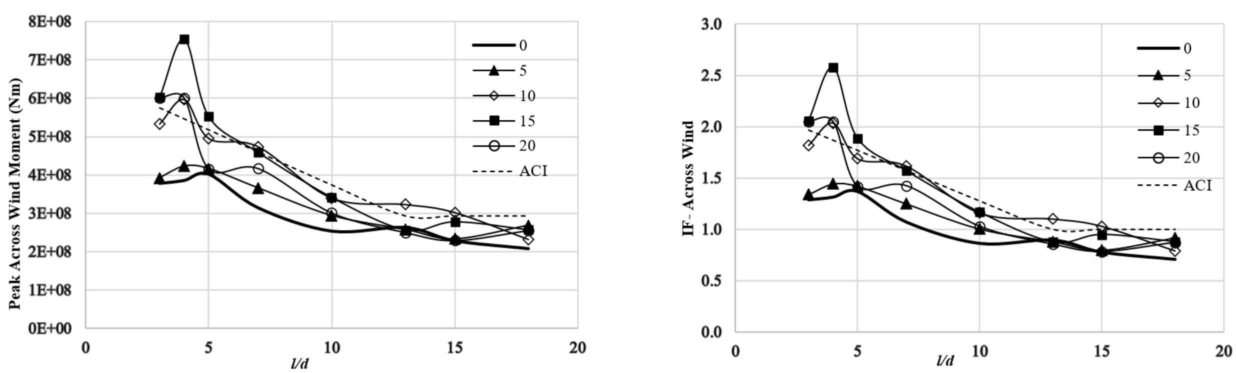

Figure 4. Peak across wind response and interference factor

maximized at *l/d*=4 when the wind is from a skewed angle of 15°, where the ACI prediction is lower. Fig. 4 also shows that the interference factor reached a maximum value of 2.5 compared to the ACI value just below 2. The details of the mechanism will be presented in the final paper.

Interference factors from the present study are compared against various other studies including ACI in Table 1. It is clear that along wind interference is also notified by other researchers (Sun et al 2020; Rao and Reddy, 1993). Further, the effect of the skewed angles on both along wind and across wind loads is clear from the present study, where the interference factors are above ACI values. This observation is also supported by the findings of Galsworthy and Vickery (1999), and Rao (1988) though there are differences in values due to the different sizes.

Table 1. Comparison of interference factors

		Reynolds Number	Interference Factor (maximum obtained)					
			l/d=2	*l/d*=3	*l/d*=4	*l/d*=5	*l/d*=6	*l/d*=7
Galsworthy and Vickery		Supercritical	-	7.7	5.6	4.75	-	-
Rao		Subcritical	-	3.4	5.8	7.1	6.8	5.6
Sun et al.	Along wind	Subcritical	1.35	1.2	-	-	-	-
	Across wind		1.7	1.9	1.7	1.6	1.4	-
Present study	Along wind	Supercritical	-	1.54	1.79	2.02	-	1.66
	Across wind		-	2.06	2.58	1.89	-	1.62
ACI	Along wind	-	1	1	1	1	1	1
	Across wind		2.06	1.97	1.87	1.77	1.67	1.57

4. CONCLUSIONS

The along-wind and across-wind responses in skewed directions are far more magnified compared to the inline direction. The results also show that the interference effect is not only magnified across-wind load but also along-wind considerably. These observations emphasize that the interference effect on along-wind and across-wind responses for skewed wind angles cannot be ignored and it should be considered in codes and future studies while addressing the interference effect between chimneys.

REFERENCES

ACI 307-08, 2008. Code Requirements for Reinforced Concrete Chimneys and commentary. American Concrete Institute.

Galsworthy, J. K. and Vickery, B. J, 1999. Full scale and model studies of wind loads on a pair of circular cylinders. Wind Engineering into the 21st Century, Proceedings of the Tenth International Conference on Wind Engineering, 21-24 June 1999, Copenhagen, Denmark, 1641-1647.

Moriya M., Alam M. M., Takai K. and Sakamoto H., 2001. Fluctuating fluid forces acting on two circular cylinders in a tandem arrangement at a subcritical Reynolds number. Journal of Wind Engineering 89, 697-700.

Rao, G. N. V, 1988. A survey of wind engineering studies in India. Sadhana 12 (1&2), 1988, 201-218.

Rao, G. N. V. and Reddy, K. R., 1993. Buffeting along-wind loads on ventilation stack of nuclear power stations due to nearby natural draft cooling towers. SMiRT-12, Elsevier Publishers B.V., 257-260.

Sun, Y., Li, Z., Sun, X., Su, N. and Peng, S., 2020. Interference effects between two tall chimneys on wind loads and dynamic responses. Journal of Wind Engineering and Industrial Aerodynamics 206 (2020) 104227.

Zhou, Y. and Alam, M. M., 2016. Wake of two interacting circular cylinders: A review, International Journal of Heat and Fluid Flow 62 (B), 510-537.