Praise Worthy Prize

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Innovative Assessment of Tall Building Dynamics Under Wind Loads Using an Advanced Fluid-Structure Interaction Approach

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Abstract

The computational simulation of Fluid-Structure Interaction (FSI) has become a crucial tool in civil engineering, particularly for analysing aeroelastic effects on tall buildings. Incorporating FSI simulations into the design process allows engineers to effectively assess the dynamic behaviour of tall structures under wind loads. This study investigates the dynamic behaviour of such buildings using a novel uncoupled unidirectional FSI method. Computational Fluid Dynamics (CFD) techniques were employed to capture the dynamic properties of both the fluid and the structure, considering the turbulent characteristics of the flow through computational discretization. The Commonwealth Advisory Aeronautical Research Council (CAARC) standard building served as the

evaluation model to assess the effectiveness of the proposed FSI method. The results demonstrate the method's efficiency in accurately calculating wind pressure and the dynamic response of the structure, achieving low computational times compared to other methods. This validation underscores the potential of the proposed FSI method to enhance the design and analysis process of tall buildings subjected to wind loads.

Keywords

Computational Fluid Dynamics (CFD); Structural Dynamis; Wind Engineering; Fluid-Structure Interaction

Full Text:

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References

S. Frolking, R. Mahtta, T. Milliman, T. Esch, and K. C. Seto, Global urban structural growth shows a profound shift from spreading out to building up, Nat. Cities, vol. 1, no. 9, pp. 555-566, 2024.
https://doi.org/10.1038/s44284-024-00100-1

L. Zheng, W. Lu, L. Wu, and Q. Zhou, A review of integration between BIM and CFD for building outdoor environment simulation, Build. Environ., vol. 228, no. September 2022, p. 109862, 2023.
https://doi.org/10.1016/j.buildenv.2022.109862

C. Feng and M. Gu, CFD simulation of wind loads of kilometer-scale super tall buildings with typical configurations in veering wind field, Struct. Des. Tall Spec. Build., vol. 33, no. 1, pp. 1-26, 2023.
https://doi.org/10.1002/tal.2066

Z. Xu and J. Yin, The Influence of Aeroelastic Effects on Wind Load and Wind-Induced Response of a Super-Tall Building: An Experimental Study, Buildings, vol. 13, no. 7, 2023.
https://doi.org/10.3390/buildings13071871

Y. Abu-Zidan, P. Mendis, T. Gunawardena, D. Mohotti, and S. Fernando, Wind Design of Tall Buildings: The State of the Art, Electron. J. Struct. Eng., vol. 22, no. 1, pp. 53-71, 2022.
https://doi.org/10.56748/ejse.2233101

K. C. S. Kwok, Wind-Induced Vibratoins of Structures: With special Reference to Tall Building Aerodynamics, in Advanced Structural Wind Engineering, Springer, Ed., 2013, pp. 121-155.
https://doi.org/10.1007/978-4-431-54337-4_5

F. Hou and P. Sarkar, Time-domain model for prediction of generalized 3DOF buffeting response of tall buildings using 2D aerodynamic sectional properties, Eng. Struct., vol. 232, p. 111847, Apr. 2021.
https://doi.org/10.1016/j.engstruct.2020.111847

C. Klein, D. Yorita, and U. Henne, Comparison of Lifetime-Based Pressure-Sensitive Paint Measurements in a Wind Tunnel Using Model Pitch-Traverse and Pitch-Pause Modes, Photonics, vol. 11, no. 6, 2024.
https://doi.org/10.3390/photonics11060546

G. Frison, A. M. Marra, G. Bartoli, and R. Scotta, Full-Aeroelastic Model of CAARC Building: Iterative Design Procedure and Wind Tunnel Tests, Lect. Notes Civ. Eng., vol.

27, pp. 310-323, 2019.
https://doi.org/10.1007/978-3-030-12815-9_25

K. Wijesooriya, D. Mohotti, A. Amin, and K. Chauhan, Wind loads on a super-tall slender structure: A validation of an uncoupled fluid-structure interaction (FSI) analysis, J. Build. Eng., vol. 35, p. 102028, Mar. 2021.
https://doi.org/10.1016/j.jobe.2020.102028

M. R. Mohd Radzi et al., Structure Integrity Analysis Using Fluid-Structure Interaction at Hydropower Bottom Outlet Discharge, Water (Switzerland), vol. 15, no. 6, 2023.
https://doi.org/10.3390/w15061039

Y. Zhang, W. G. Habashi, and R. A. Khurram, Predicting wind-induced vibrations of high-rise buildings using unsteady CFD and modal analysis, J. Wind Eng. Ind. Aerodyn., vol. 136, pp. 165-179, Jan. 2015.
https://doi.org/10.1016/j.jweia.2014.11.008

T. Hasama et al., Evaluation of aerodynamic instability for building using fluid-structure interaction analysis combined with multi-degree-of-freedom structure model and large-eddy simulation, J. Wind Eng. Ind. Aerodyn., vol. 197, p. 104052, Feb. 2020.
https://doi.org/10.1016/j.jweia.2019.104052

V. A. U. De Alwis, P. H. T. D. Weerarathne, and K. K. Wijesundara, Rigid and Aeroelastic Analysis of Wind Induced Flow Behavior Around Unscaled Tall Buildings using Numerical Techniques, arXiv, Feb. 2022.
https://doi.org/10.48550/arXiv.2202.02795

A. M. Hussin, Numerical Simulation of Fluid-Structure Interactions on Super-Tall Slender Structures Using Two-Way Coupling Techniques, Appl. Math. Inf. Sci., vol. 18, no. 5, pp. 1125-1140, 2024.
https://doi.org/10.18576/amis/180518

R. Weinhandl, P. Benner, and T. Richter, Low-rank linear fluid-structure interaction discretizations, ZAMM - J. Appl. Math. Mech. / Zeitschrift für Angew. Math. und Mech., vol. 100, no. 11, p. e201900205, Nov. 2020.
https://doi.org/10.1002/zamm.201900205

N. Gangasudan and H. M. Y. C. Mallikarachchi, Predicting wind response of tall buildings using fluid-structure interaction, MERCon 2018 - 4th Int. Multidiscip. Moratuwa Eng. Res. Conf., pp. 345-349, Jul. 2018.
https://doi.org/10.1109/MERCon.2018.8421969

R. K. Jaiman and V. Joshi, Fluid-Structure Equations with Body-Fitted Interface, in Computational Mechanics of Fluid-Structure Interaction, Springer, Singapore, 2022, pp. 43-61.
https://doi.org/10.1007/978-981-16-5355-1_3

K. Wijesooriya, D. Mohotti, A. Amin, and K. Chauhan, An uncoupled fluid structure interaction method in the assessment of structural responses of tall buildings, Structures, vol. 25, pp. 448-462, Jun. 2020.
https://doi.org/10.1016/j.istruc.2020.03.031

M. N. Reis, T. F. A. de Lavôr, J. da C. Pantoja, and J. L. V. de Brito, Numerical-experimental study of neighboring wind effects on tall buildings related to serviceability via reliability, Rev. IBRACON Estruturas e Mater., vol. 15, no. 5, pp. 1-16, 2022.
https://doi.org/10.1590/s1983-41952022000500007

D. Zhu, Y. Dong, and D. M. Frangopol, Experimental and numerical investigation on wave impacts on box-girder bridges, Struct. Infrastruct. Eng., vol. 18, no. 10-11, pp. 1379-1397, 2022.
https://doi.org/10.1080/15732479.2022.2044356

K. Wijesooriya, D. Mohotti, K. Chauhan, and D. Dias-da-Costa, Numerical investigation of scale resolved turbulence models

(LES, ELES and DDES) in the assessment of wind effects on supertall structures, J. Build. Eng., vol. 25, Sep. 2019. https://doi.org/10.1016/j.jobe.2019.100842

F. Xing, D. Mohotti, and K. Chauhan, Experimental and numerical study on mean pressure distributions around an isolated gable roof building with and without openings, Build. Environ., vol. 132, pp. 30-44, Mar. 2018. https://doi.org/10.1016/j.buildenv.2018.01.027

A. Moradi, E. Salajegheh, M. M. Tavakol, A. Heidari, and G. Ahmadi, Numerical simulation of turbulent airflow around a tall telecommunication tower model, Adv. Aerodyn., vol. 6, no. 1, pp. 1-42, 2024. https://doi.org/10.1186/s42774-024-00185-1

J. M. B. de Oliveira, L. K. Araki, M. A. V. Pinto, and S. de F. T. Gonçalves, An alternative full multigrid SIMPLEC approach for the incompressible Navier-Stokes equations, Numer. Heat Transf. Part B Fundam., vol. 83, no. 6, pp. 410-432, 2023. https://doi.org/10.1080/10407790.2023.2167752

Z. Liu, Y. Hui, Q. Yang, and Y. He, Along-wind and across-wind coupling analysis of high-rise buildings: Modeling and parameter identifications, J. Build. Eng., vol. 69, no. March, p. 106313, 2023. https://doi.org/10.1016/j.jobe.2023.106313

C. Liu, Z. Xie, L. Zhang, and X. Yu, Investigation on modal coupling-aeroelastic effect of a super tall building by MDOF aeroelastic model test, J. Wind Eng. Ind. Aerodyn., vol. 231, no. September, p. 105248, 2022. https://doi.org/10.1016/j.jweia.2022.105248

L. Zou, F. Li, J. Song, T. Shi, S. Liang, and O. Mercan, Investigation on aeroelastic effects of high-rise buildings based on three-dimensional forced vibration wind tunnel tests, J. Wind Eng. Ind. Aerodyn., vol. 327, 2025. https://doi.org/10.1016/j.engstruct.2024.119556

K. Wijesooriya, D. Mohotti, A. Amin, and K. Chauhan, Comparison between an uncoupled one-way and two-way fluid structure interaction simulation on a super-tall slender structure, Eng. Struct., vol. 229, p. 111636, Feb. 2021. https://doi.org/10.1016/j.engstruct.2020.111636

R. Van Hout, A. Hershkovitz, G. E. Elsinga, and J. Westerweel, Combined three-dimensional flow field measurements and motion tracking of freely moving spheres in a turbulent boundary layer, J. Fluid Mech., vol. 944, p. A12, Aug. 2022. https://doi.org/10.1017/jfm.2022.477

P. W. Bearman and E. D. Obasaju, An experimental study of pressure fluctuations on fixed and oscillating square-section cylinders, J. Fluid Mech., vol. 119, pp. 297-321, 1982. https://doi.org/10.1017/S0022112082001360

A. L. Braun and A. M. Awruch, Aerodynamic and aeroelastic analyses on the CAARC standard tall building model using numerical simulation, Comput. Struct., vol. 87, no. 9-10, pp. 564-581, May 2009. https://doi.org/10.1016/j.compstruc.2009.02.002

B. Pallás, Study of fluid-structure interaction in blunt aerodynamic bodies, Univeritat politécnica de Valéncia, 2020.

S. Thepmongkorn, K. C. S. Kwok, and N. Lakshmanan, A two-degree-of-freedom base hinged aeroelastic (BHA) model for response predictions, J. Wind Eng. Ind. Aerodyn., vol. 83, no. 1-3, pp. 171-181, 1999. https://doi.org/10.1016/S0167-6105(99)00070-7

Irinislimane, K., Hamane, D., Numerical Simulation of the Flow Around a Cylinder, (2023) International Review of Mechanical Engineering (IREME), 17 (11), pp. 526-532. https://doi.org/10.15866/ireme.v17i11.23253

Kunjappan, J., Prakash, A., Computational Fluid Dynamics Study of Aircraft Wing with Winglet Performance at High Subsonic Speeds, (2022) International Review of Aerospace Engineering (IREASE), 15 (5), pp. 254-261. https://doi.org/10.15866/irease.v15i5.22870

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