Wind Tunnel Experimental Examination of Vehicular Emission Dispersion for Single-Storied Inline and Staggered Building Configurations Under Wake Interference Flow Regime

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Abstract: Issues of plume dispersion for urban built-up area is explored by physical model utilizing varieties of buildings in 1:100 scales, in layer consisting of boundaries airflow for single storied structures in two different building configurations. Experimental setup of wind tunnel made for boundary conditions considering height of 3.5m for single storied building. Vertical gas tracer fixations were taken at downwind separation of 375H, 298H, 179H and 119H from inline source having parallel width of 8H, 16H and 24H. Experiment directed for inline ground storey array and staggered one storied array configurations under wake interference flow regime. Focus variety with downwind separation for one storied structure inline arrangement under wake obstruction concentrated by plotting C/Co versus Z/H and it is observed that decrease in concentration was at higher rise when compared with the floor level. In staggered array building configuration study there was increase in concentration at lower elevation at higher level than that of inline building array arrangement under wake interference. Dispersion observed was less in staggered compared to inline building arrangement. The results of experiment showed that there were major deviations between concentrations estimated in downwind separation under both inline and staggered clusters in wake interference flow system.

Keywords: Dispersion, Inline, Staggered, Vehicular Emission, Wake interference, Wind-Tunnel.

I. INTRODUCTION

The examination of the effects of traffic toxins on air quality has been done by a wide margin, and the most well-known activity is treating dispersion pollutants in urban areas. The inescapable nature of traffic pollutants isn't uncovering for present purposes, where deliberately structured tracer and flow field observations are substantially more helpful. This is, actually, an exceptionally demanding requirement and not many scientific studies have created adequately huge datasets to meet it. Mavroidis and Griffiths (1996) broke down the stream and scattering of various obstacles and concluded that wind tunnel work doesn't experience the ill effects of long span pollution tracing. As trial conditions can be kept up for whatever length of time that is required, and are repeatable. Output can likewise be as detailed as required and also can be supported by flow representation, it become an incredible tool for creating an understanding of the physics of the procedures involved. This is an actuality a well-established and has been used in most extreme investigations. In an investigation by Gowda, R.M.M et al. (2005) explained important role of wind tunnel, to explore physics and to obtain high order datasets.

Dispersion in urban condition is complicated and includes the attributes of the collaboration of the flow field and plume with a few obstacles. This sort issue isn't commonly feasible by computational methods and subsequently physical demonstrating is the most ideal approach to acquire reasonable outcomes. When utilizing line-model in urban locality for predicting pollutants, it is basic that the model should represent building impacts. There is a more prominent degree to see efficiently the impacts of significant changing parameters on dispersion instruments through varieties of obstacles. For investigating local pollution parametric impacts, a tunnel consisting of a boundary layer is an advantageous instrument to explore the impacts about potential specifications.

Scattering depends on number of basic parameters and surfaced layer and a little scope is given to meteorological issues, for instance, wind speed and its harshness and so forth. The effect of close-by structures with different buildings of changing landscape classes bring on additional unpredictability in the dispersion activity. Hunt (1975) and Meroney (1995) have examined the complexity of dispersion activities in building clusters or arrays. As of now writing on this subject has been very inadequate.

The principle point of the this paper is to explore tentatively, vehicular-emission (line source) phenomenon of dispersion in reenacted ways of conditions and also to comprehend the pattern of dispersion through a one storey model setup of building in the close field of roadway utilizing wind tunnel.
II. WIND TUNNEL EXPERIMENT SETUP

In the present assessment, model plans have been picked with model geometry of size 1:100, which addresses unique structures tallness of 3.5 m (one storied structures). For such thing, staggered structure model arrangement were picked. Physical displaying scattering tests were done with urban category ABL-III which to centers around the enormous city around nearby roadway field in EWT. Estimations were considered to get gas fixation from vertical tracer profiles about one storied structure at initially-picked downwind separation of 357H, 298H, 179H and 119H from the point of convergence of line-source indicated by arrangement showed up in Fig.1. And these estimations were seen about a picked vertical stature for one storied structures model Theurer, W. et al. (1996).for chosen parallel width of floor of tunnel. For 90°, tracer tests were done. Lateral concentration estimations (along the width of the investigated area) initially-picked parallel width of 8H, 16H, and 24H for the one storied structural model for the all downwind separations about centerline of each side.

III. EXPERIMENTAL CONFIGURATION IN THE WIND TUNNEL

For the study, wood cubical building model is laid on the floor of entry line-source for all downwind region of section. The model was laid about an extent so that line of structures was a t 35mm(1H) to the structures, Macdonald, R.W.(1997). This strategy showed that line-source arranged in the middle of structure model.

\[ \lambda = \frac{1}{(1+R)^2} \]

Where, \( S \) = Distance between two consecutive array element

Taking into account plan zone thickness, various stream frameworks have been portrayed for shown cubical course of action squares. The qualities of these central stream frameworks are displayed in Table.1. The present assessments have been coordinated a confined harshness stream framework for one storied structures for the plan district according to Table 2.

| Sl. No. | Average building height (m) | Scale | Flow regime | Prototype cubic model H (mm) |
|--------|-----------------------------|-------|-------------|-----------------------------|
| 1      | 35                          | 1:100 | 1-1:55/4<2.0·25 | W=2H                        |
|        |                              |       | 8-11<1.0<16·25  | 35                          |

In a solitary structure, a cube model having a stature(H) of 35 mm and separation(S) between beside components is 85 mm and the plan thickness is viewed as 8.5 % (or S/H = 2.4). As indicated by the stream framework considered by Macdonald (1997), the models of cube were used for the assessment are comprised of wood at a model of geometry of size of 1:100, that addresses certified structure rise of 3.5 m. Estimations of the models are (L)X(W)X(H) i.e., 35 mm x 35 mm x 35 mm. The dimension of the staggered setup cluster was 8 x 10. The arrangement detailing for one storied is shown in Fig 2.

IV. RESULTS AND DISCUSSIONS

4.1 Variation of concentration with downwind separation for one storied structure inline exhibit design with wake interference

Institutionalized concentration variation is drawn at picked downwind separation of 375H, 298H, 179H and 119H from line source having parallel width of 8H, 16H and 24H for one-storied structure model with inline display arrangement showed up in Fig. 1. Fig. 4 depict the institutionalized focus variety profile C/Co versus picked downwind separations Z/H for one-storied structure model of design in an inline way. From plots, it can be seen that tracer fixation is most outrageous near the line source (at X=119H) and focus reduces as downwind augmentation in separation (X = 357 H). Furthermore, it was obvious from the plots (look design line) that downwind fixation reduces with downwind separation. The comparable tracer fixation design has been referenced by Griffiths and Macdonald [1997].

Table 1: Characteristic of the flow regime (Macdonald et al. [1997])

| Flow regime          | Array spacing | Plan Area density (%) |
|----------------------|---------------|-----------------------|
| Isolated Roughness   | S/H=2.0·2.5   | \( \lambda \)·8·11    |
| Wake Interference    | I:0·1·55/H<2.0·2.5 | 8·11<1.0<16·25   |
| Skimming Flow        | S/H=1.0·1.5   | 16·25<\( \lambda \)   |
Table 3-5 presents the institutionalized downwind focus distinction for picked downwind separation of inline one storied cluster structure at Y=8 H, 16 H and 24 H. In Table 3, at a horizontal width of Y=8 H, a reduction in concentration percentage of 64.8% and 89.7% were seen at some place in the range of 119 H and 357 H.

a) Y=8H

b) Y=16H

c) Y=24H

Fig. 4.Concentration variation at selected downwind distance for single storied inline array configuration at different lateral width with wake interference

Table 6: (C-O) variation at selected downwind separation for single storied staggered array configuration with wake interference at Y=8H

| Z/H | Downwind distances | Percentage reduction between 16H and 32H |
|-----|--------------------|-----------------------------------------|
| Y=8H | Y=16H | Y=32H | Y=64H | Y=128H |
| 0 | 1.1 | 0.75 | 0.5 | 0.5 | 0.5 |
| 0.1 | 0.95 | 0.65 | 0.35 | 0.5 | 0.5 |
| 1.1 | 0.94 | 0.65 | 0.36 | 0.46 | 0.51 |
| 1.71 | 0.89 | 0.6 | 0.38 | 0.43 | 0.51 |
| 2.25 | 0.6 | 0.37 | 0.39 | 0.43 | 0.51 |
| 2.11 | 0.7 | 0.43 | 0.43 | 0.51 | 0.51 |
| 3.42 | 0.51 | 0.35 | 0.51 | 0.51 | 0.51 |
| 4 | 0.41 | 0.35 | 0.36 | 0.38 | 0.38 |
| 4.57 | 0.6 | 0.46 | 0.34 | 0.24 | 0.24 |
| 5.16 | 0.61 | 0.44 | 0.31 | 0.22 | 0.22 |
| 5.71 | 0.8 | 0.42 | 0.31 | 0.21 | 0.21 |
| 6.32 | 0.44 | 0.31 | 0.2 | 0.2 | 0.2 |
| 6.93 | 0.35 | 0.26 | 0.16 | 0.16 | 0.16 |
| 7.43 | 0.32 | 0.18 | 0.18 | 0.18 | 0.18 |
| 8 | 0.4 | 0.37 | 0.27 | 0.17 | 0.17 |

Table 7: (C-O) variation at selected downwind separation for single storied staggered array configuration with wake interference at Y=10H

| Z/H | Downwind distances | Percentage reduction between 16H and 32H |
|-----|--------------------|-----------------------------------------|
| Y=10H | Y=20H | Y=32H | Y=64H | Y=128H |
| 0 | 1.4 | 1.1 | 0.6 | 0.6 | 0.6 |
| 0.57 | 1.3 | 1.01 | 0.71 | 0.56 | 0.56 |
| 1.14 | 1.24 | 0.99 | 0.64 | 0.52 | 0.52 |
| 1.71 | 1.18 | 0.82 | 0.56 | 0.48 | 0.48 |
| 2.28 | 1.01 | 0.74 | 0.52 | 0.39 | 0.39 |
| 2.85 | 0.91 | 0.65 | 0.45 | 0.35 | 0.35 |
| 3.41 | 0.84 | 0.59 | 0.42 | 0.32 | 0.32 |
| 4 | 0.75 | 0.54 | 0.4 | 0.3 | 0.3 |
| 4.57 | 0.67 | 0.48 | 0.38 | 0.28 | 0.28 |
| 5.14 | 0.61 | 0.45 | 0.36 | 0.26 | 0.26 |
| 5.71 | 0.54 | 0.4 | 0.32 | 0.22 | 0.22 |
| 6.32 | 0.47 | 0.42 | 0.32 | 0.21 | 0.21 |
| 6.93 | 0.45 | 0.35 | 0.2 | 0.2 | 0.2 |
| 7.42 | 0.43 | 0.3 | 0.18 | 0.18 | 0.18 |
| 8 | 0.42 | 0.37 | 0.26 | 0.16 | 0.16 |

Table 8: (C-O) variation at selected downwind separation for single storied staggered array configuration with wake interference at Y=24H

| Z/H | Downwind distances | Percentage reduction between 16H and 32H |
|-----|--------------------|-----------------------------------------|
| Y=24H | Y=48H | Y=96H | Y=192H | Y=384H |
| 0 | 1 | 0.7 | 0.5 | 0.5 | 0.5 | 0.5 |
| 0.57 | 0.96 | 0.66 | 0.55 | 0.45 | 0.45 | 0.45 |
| 1.14 | 0.88 | 0.64 | 0.52 | 0.42 | 0.42 | 0.42 |
| 1.71 | 0.82 | 0.59 | 0.48 | 0.39 | 0.39 | 0.39 |
| 2.28 | 0.75 | 0.52 | 0.41 | 0.32 | 0.32 | 0.32 |
| 2.85 | 0.68 | 0.47 | 0.39 | 0.31 | 0.31 | 0.31 |
| 3.42 | 0.61 | 0.43 | 0.36 | 0.28 | 0.28 | 0.28 |
| 4 | 0.52 | 0.36 | 0.29 | 0.21 | 0.21 | 0.21 |
| 4.57 | 0.5 | 0.43 | 0.35 | 0.27 | 0.27 | 0.27 |
| 5.14 | 0.46 | 0.4 | 0.32 | 0.24 | 0.24 | 0.24 |
| 5.71 | 0.44 | 0.38 | 0.3 | 0.22 | 0.22 | 0.22 |
| 6.32 | 0.41 | 0.35 | 0.26 | 0.18 | 0.18 | 0.18 |
| 6.93 | 0.39 | 0.33 | 0.25 | 0.17 | 0.17 | 0.17 |
| 7.42 | 0.37 | 0.31 | 0.23 | 0.15 | 0.15 | 0.15 |
| 8 | 0.35 | 0.29 | 0.21 | 0.13 | 0.13 | 0.13 |

V. CONCLUSIONS

The dispersion appears that with increment in height the concentration is diminishing. The tracer fixation comparatively is more at the recreated line-source than the downwind separation, moreover the tracer focus is most extreme at the passage floor than at more significant level. Dispersion concentration observed in inline array configuration is little less compared to that of staggered array arrangement building model. From the simulation result it can be seen that, dispersion pollutant particles moves faster with inline array than the staggered and also at lower level ,concentration of particles is higher than that of inline array arrangement. Pollutants stuck in between staggered arrangement buildings resulting in higher concentration of particles at lower level. Consequently, still it requires a further examination to study the eddies behavior in selected flow system conditions dentally. It is concluded that the concentration of tracer is most extreme at the source than the downwind distances and at the ground level than at greater elevations under wake interference flow system for single storied buildings.
REFERENCES

1. Gowda, R.M.M., Khare, M., Chaudhry, K.K., Effect of the homogeneous traffic on vertical dispersion parameter in the near field of road ways—a wind tunnel study, Environmental Modelling and Assessment, 10, 55–62 (2005).
2. Mavroidis, L., Griffiths, R.F., Dispersion of airborne pollutants in vicinity of isolated obstacles, In: Proceedings of the International Conference, Protection and Restoration of the Environment III, Chania, Greece (1996).
3. Hunt, J.C.R., Fernholz, H., Wind Tunnel Simulation of the Atmospheric Boundary Layer, A Report on EUROMECH 50, Journal Fluid Mechanics, 70(3), 543–559 (1975).
4. Meroney, R.N., Pavageau, M., Rafailidis, S., Schatzmann, M., Study of line source characteristics for 2-D physical modelling of pollutant dispersion in street canyons, Journal of Wind Engineering and Industrial Aerodynamics, Personal Communication (1995).
5. Theurer, W., Plate, E.J., Hoeschele, K., Semi-empirical models as a combination of wind tunnel and numerical dispersion modeling, Atmospheric Environment, 30(21), 3583–3597 (1996).
6. Macdonald, R.W., Griffiths, R.F., Hall DJ., A comparison of results from scaled field and wind tunnel modeling of dispersion in arrays of obstacles, Atmospheric Environment, 32(22) 3845–3862 (1998).
7. Hosker, R.P., Flow and diffusion near obstacles, Atmospheric Science and Power Production, 7, 241–326 (1984).
8. Davidson, M.J., Mylne, K.R., Jones, C.D., et al., Plume dispersion through large groups of obstacles, Atmospheric Environment, 29, 3245–3256 (1995).
9. Macdonald, R.W., Griffiths, R.F., Field experimental of dispersion through regular arrays of cubic structures, Atmospheric Environment, 31(6), 783–795 (1997).
10. Davidson, M.J., Snyder Jr., W.H., Lawson, R.E., Hunt, J.C.R., Wind tunnel simulations of plume dispersion through groups of obstacles, Atmospheric Environment, 30(22), 3715–3731 (1996).
11. Mavroidis, L., Griffiths, R.F., Velocity and concentration measurements within arrays of obstacles, Global Nest, 2(1), 109–117 (2000).
12. Hosker, R.P., Methods of Estimating Wake Flow and Effluent Dispersion Near Simple Block Like Buildings, NOAA Technical Memorandum ERL ARL-108, NOAA, Environmental Research Laboratories, Department of Commerce, USA (1981).
13. Gowda, R.M.M., Khare, M., Chaudhry, K.K., Physical simulation of stack dispersion phenomenon in the neutrally stabilised boundary layers. In: Agarwal, S.K., Lakshmy, P. (Eds.), Proceedings of the 2nd National Seminar on Wind Engineering, 3–4 April 1997, Allied Publishers Limited, New Delhi (1997).
14. CPCB, Auto Emissions Parivesh Newsletter, New Delhi, 6(1) (1999).
15. Gowda, R.M.M., Wind Tunnel Simulation Study of the Line Source Dispersion in the Near-Field of Roadways under Heterogeneous Traffic Conditions, Ph.D. Thesis, IIT, Delhi (1999).

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