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Study of Dispersion Concentration with Downwind Distance for Single Storied and Double Storied Building configuration in Wind Tunnel

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ABSTRACT: In urban area plume dispersion behavior is simulated by wind tunnel considering built up as obstacles in 1:100 scalewithin simulated atmospheric boundary layers (ABL) for single storied and double storied buildings of inline and staggered configurations. The height of the single storied building considered represents 3.5m height and 7m for double storied building. The concentration of tracer gas was measured in vertical directions at downwind distance of 119H, 179H, 298H and 375H from the center of line source at a lateral width of 8H, 16H and 24H for single storied and 4H, 8H and 12H for double storied. In addition, wake interference was considered in both cases along with building array configurations in both inline and staggered arrangement. Based on the results obtained from single and double storied building configurations, from comparison of results obtained from simulation study it is seen that the variation in concentrations in downwind distances and lateral widths is slightly gradual in case of inline array building configurations, when compared to staggered building configurations in single and double storied building configurations. Increase in height of the building, shows higher concentration which in turn act like obstacles to the downwind dispersion of concentration. In both the cases of inline and staggered array configurations of single and double storied structures, the downwind concentration were fitted best in power-law profile. Finally, it is concluded that while comparing single and double storied building configurations (inline and staggered array) of both the heights, variations in concentration trend is almost following the observation made in Macdonald and Griffiths experimental work.

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

INTRODUCTION

The gradual increase in vehicular numbers in urban areas resulted into a steady increment in concentration of various pollutants emission. It is important to comprehend the dispersion phenomenon of pollutants in the environment to develop mitigation strategies for vehicular pollution control. The dispersion of pollutants near the roadways is dominated by the turbulence induced by the vehicles which are moving on the roadway. This can be observed as a result of the interaction between the vehicle wake in the atmosphere and dispersive state of pollutants emitted by vehicles (Gowda R.M.M, 1999). Further the dispersion criteria of pollutants in the environment depends on different parameters and meteorological parameters like wind speed, wind direction, roughness condition etc. at the surface layer. This phenomenon was explained by Hosker(1984), Hunt &Fermholz(1975) and Meroney et. al. (1995).

The behavior of pollutants dispersion in urban regions is complex and involves the interaction of the plume and flow field with number of obstacles. This kind of problem is not generally addressed by computational methods, thus physical modelling is the best way to obtain the accurate and sensible results by considering most of the parameters relevant to dispersion phenomenon. Wind tunnel study has shown higher potential to understand the dispersion of pollutants. The major advantage of wind tunnel study is that the controlling of variables and the economy in terms of time and money (Maroney et. al., 1995). Many works here have been conducted earlier using wind tunnel simulation study. Most of these works have not considered wake interference buildings as obstacles under wake interference flow regime. Therefore the present work is to compare the dispersion phenomenon of pollutants in single and double storied building under inline and staggered building configurations in near field roadways of urban areas by considering wake interference.

2. Wind Tunnel Experiment Setup

To carrying out study on flow and diffusion of systematic dispersion of pollutants in the urban environment, Environmental wind tunnel (EWT) facility was developed atMandya P.E.S.C.E, Located in Karnataka, India. Fig.1 shows the setup of EWT. Total length of EWT is 19.7m ,excluding section diffuser and in which 12m length is the test section. Size of wind tunnel section is 1.2X1.2m and from 1.45m from bottom surface of test section above ground level. In this study, building model made of wood cubical fit has been laid on

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the floor of the entry from line source to entire downwind zone of section. The height of single storied building model was 35mm represent 3.5m and 70mm for double storied building model shows 7m height in actual at 1:100 scale Macdonald R.W (1997).

Table 1: Harshness flow system (Macdonald et al.)

Flow regime	Array spacing	Plan Area density (%)
Isolated Roughness flow	S/H>2.0-2.5	λ<8-11
Wake Interference Flow	1.0-1.5<S/H<2.0-2.5	8-11< λ <16-25
Skimming Flow	S/H<1.0-1.5	16-25< λ

Table – 2:Flow regime characteristics for the single storied buildings model

Sl. No.	Average building height (m)	Scale	*S/H* (>2.0–2.5)	λ_{ar} (%) (<8–11)	Width	Prototype cubical model *H* (mm)
1	3.5	1:100	2.40	8.5	*W*=2*H*	35

Table – 3:Flow regime characteristic for the double storied buildings model

Sl. No.	Average building height (m)	Scale	*S/H* (>2.0–2.5)	λ_{ar} (%) (<8–11)	Width	Prototype cubical model *H* (mm)
1	7	1:100	2.00	11.0	*W*=*H*	70

Table 1 represents a flow system of isolated harshness for single and double storied structures for the arrangement and Table 2 and Table 3 represent flow system configurations for single and double storied building plan.

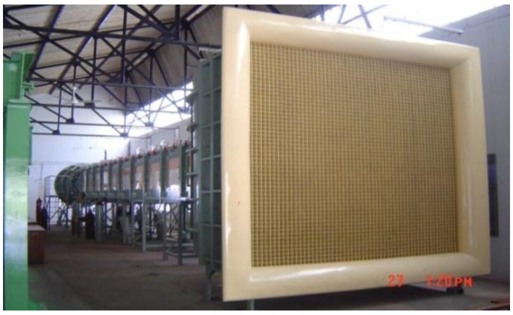

Plate – 1: EWT at P.E.S.C.E., Mandya

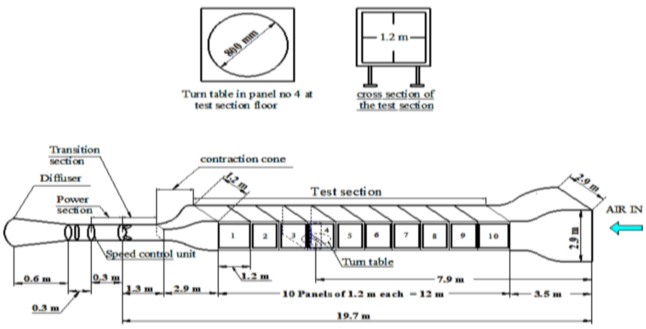

Fig. 1: EWT Layoutat P.E.S.C.E., Mandya

2.1 Simulation of ABL flow

Atmospheric boundary layers (ABL's) is produced in the EWT in the combination of Counihan's spheres a passive devices, Tripping barriers and roughness blocks on the floor of wind tunnel, 3 Counihan's spheres of 94 cm height systematically placed at the initial place of EWT test section. Furthermore the overall floor of EWT covered with 23 roughness elements with a spacing of 70mm at 23 x 23 x 23 mm. Further a stripping barrier of 300 mm height was placed after the Counihan spheres at 1.25m. The cubical blocks designs is carried out as per Counihan J (1975) and Gowda(1997).

2.2 Mean Velocity Profile

The mean velocities is recorded at selected heights over the floor of tunnel by traversing single wire probe of hot-wire anemometer (HWA). The recordings of velocityis taken at 7.9 m from the initial point oftest section. Personal computer (Pentium-IV) is availableat our lab facilitated to record digital readings of measured data. The computer is equipped withsoftware 8 channelfor data acquisition. Mean velocity profile in simulated ABL III is represented by the power-law shown below:

$$\frac{u}{U_\infty} = \left(\frac{z}{\delta}\right)^{\alpha},$$

Where U_∞ is the mean velocity, δ, and α is the power-law index. It is observed that the longitudinal mean velocities found to be in fitting best with the best fit curves. The power law index (α) was 0.6for ABL- 3 simulated condition. These values found in the values quoted by Snyder(1981), Davenport (1965) and Counihan(1975)for urban categories.

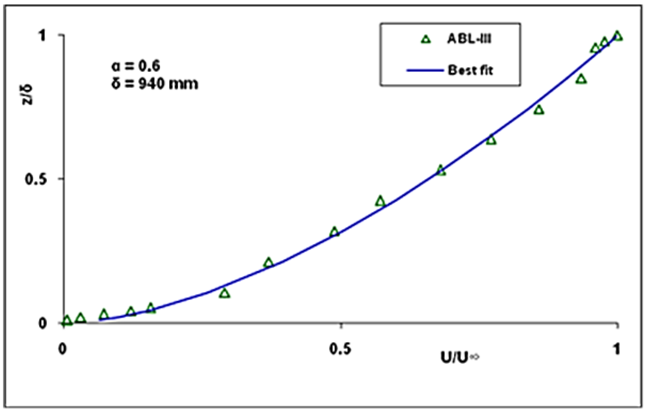

Fig.2: Mean Velocity Profile for simulated ABL

Table 4 : Estimated Roughness Parameters for the Simulated ABLs

ABLs	u_* (m/s)	d_0 (mm)	z_0 (mm)	u_*/U_∞	α
ABL-III	0.268	1.840	0.993	0.0607	0.60

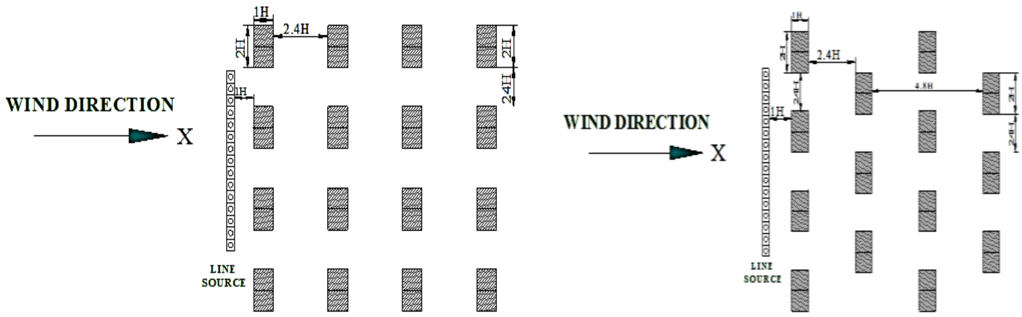

Fig. 3: Inline& staggered array building arrangement plan for single storied [H=35]

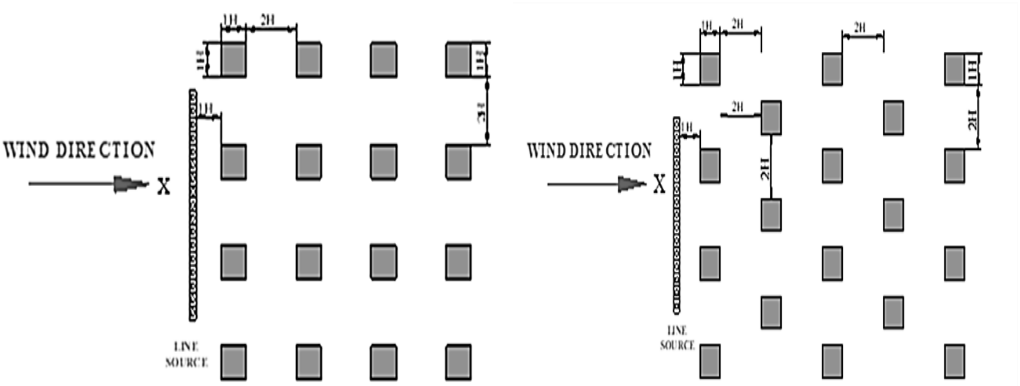

Fig. 4: Inline& staggered array building arrangement plan for double storied [H=70].

2.3 Tracer Gas Sampling and Analysis

For measuring flow in low mean velocity and level of turbulence in flow field of EWT, a sensor named Hot Wire Anemometer (HWA) calibrated in least ranged velocities. Analog-to-digital (A/D) board converter (ADS774 of Adlink Technologies Inc., make A/D board, Taiwan) with relevant software was procured and it was installed in PC in laboratory. For measuring concentration of tracer gas, a Flame Ionization Detector (FID) type of Gas Chromatograph (GC), is available in the laboratory. It was operated for the detection of hydrocarbon tracer gas in experimental samples with processed computer output. 5% acetylene in Grade-I nitrogen is used as tracer gas because of its buoyant neutral property. The tracer obtained by blending pre-calculated rate of flow in laboratory grade 95.5% acetylene and Nitrogen of Grade-I(99.9%) in mixing unit. Different input lines from acetylene and nitrogenGrade-Ibottles was taken into a pre-calibrated flow meters (i.e., flow rate measuring devices) and attached to blending unit (welding gun). Controlled rate of flow was maintained through input lines by maintaining equal output pressures at the output of the acetylene and nitrogen of Grade-I gas bottles by adjusting suitable control valves.

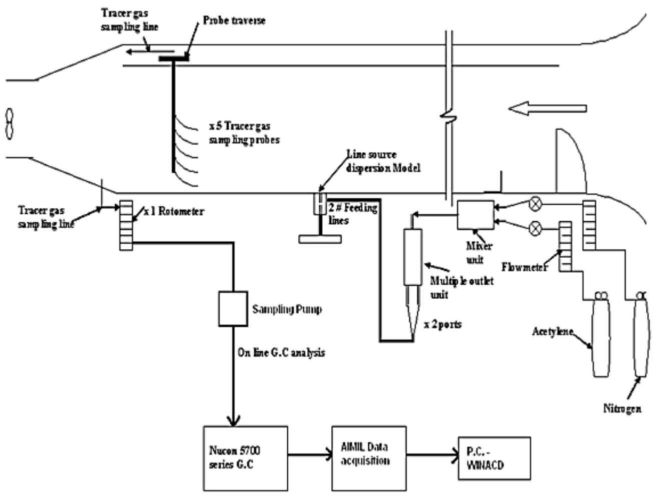

Fig. 5: View of schematic line source dispersion experiment in the EWT

3. Results and Discussions

The experiments under stimulated ABL's-3 were conducted in simulated wind tunnel representing the centre of near field of large city of road ways in EWT for inline and staggered double and singlestoried building model arrangements. The studies were conducted for scale of 1:100 in a geometric model, representing a building height 3.5m& 7m for singleand double storied building configuration. The variation in vertical concentration for selected downwind distances of X = 119 H, 179 H, 298 H and 357 H from the line sourcecentrefor selected width of Y= 8 H, 16 H and 24 H for single storied building models and for double storied Y=4H, 8H and 12H for inline and staggered array configurations were compared and discussed.

3.1 Comparison of concentration variation with downwind distance for single storied v/s double storied buildingconfiguration with wake interference at different heights

Fig. 6 depicts comparison C/C_0 normalized concentration with Z/H vertical heightabove the floor of tunnel for inline and staggered array configuration for single and double storied building at X=119H, 179H, 298H, and 357H and for width of Y=8H.The profile of power-law best fitted for the vertical concentration profile. The R^2 value observed 0.91–0.99.It shows thatC/C_0 represented decreased concentration trend of with higher heights and concentration observed was higher in double storied staggered configuration compared to single storied building configurations.

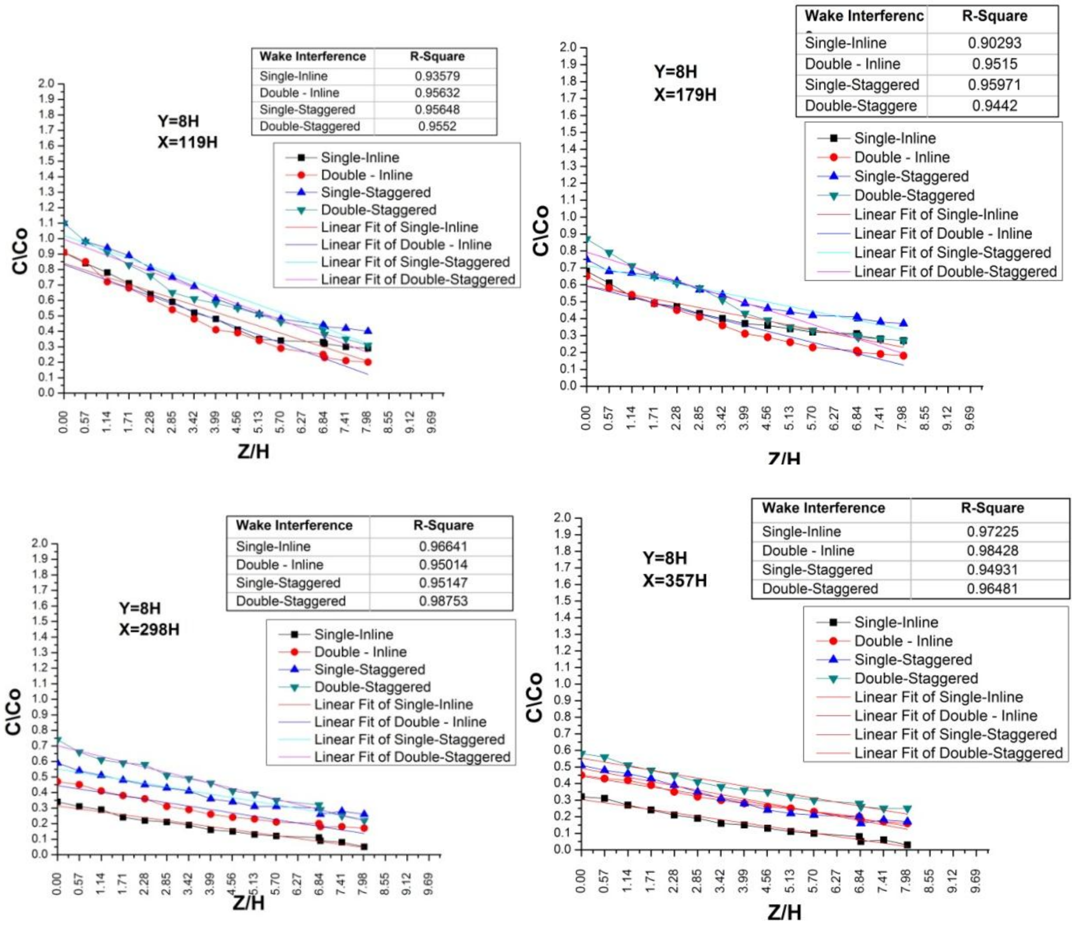

Fig. 6: Differencebetweenconcentration variations at selected downwind distance for Y= 8H with wake interference

Fig. 7 shows difference between C/C_0 normalized concentration with Z/H vertical heightabove the floor of tunnel for inline and staggered array configuration for single and double storied building at X=119H, 179H, 298H, and 357H and for width of Y=16H. The profile of power-law best fitted for the verticall concentration profile. The R^2 value observed 0.86–0.99. It shows thatC/C_0 represented decreased concentration trend of with elevated heights and concentration observed was higher at initial downwind distance, concentration was higher at staggered configurations of double and single storied compared to inline building configuration.

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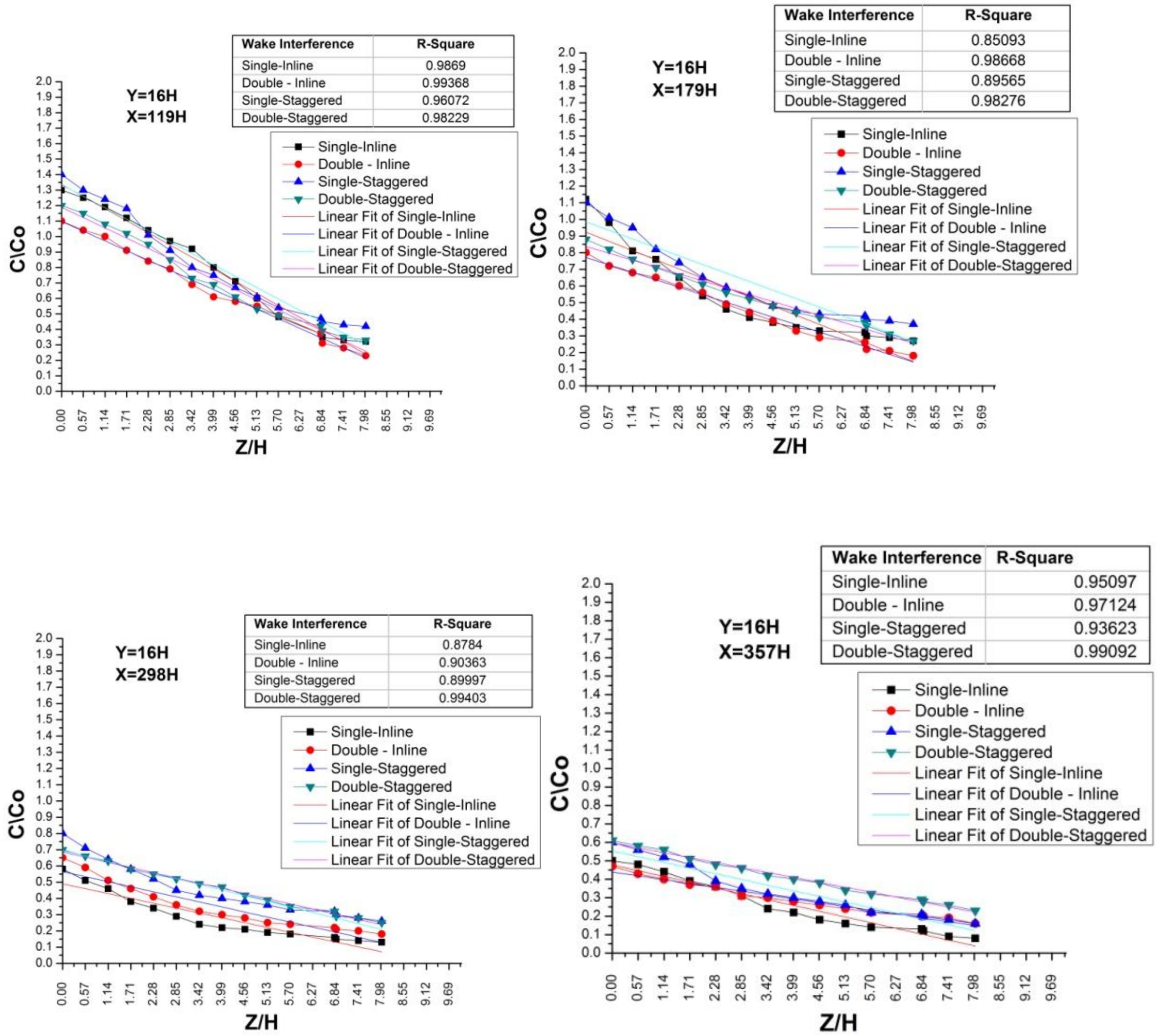

Fig. 7: Differencebetweenconcentration variations at selected downwind distance for Y= 16H with wake interference

Fig. 8 depicts difference between C/C_0 normalized concentration with Z/H vertical at X=119H, 179H, 298H, &357H and for width of Y=24H. The profile of power-law best fitted for the vertical concentration profile. The R^2 value observed 0.92–0.99.It shows thatC/C_0 represented decreased concentration trendwith elevated height and concentration seen was higher at initial downwind distance, concentration was higher at staggered configurations of double and single storied compared to inline building configurations.

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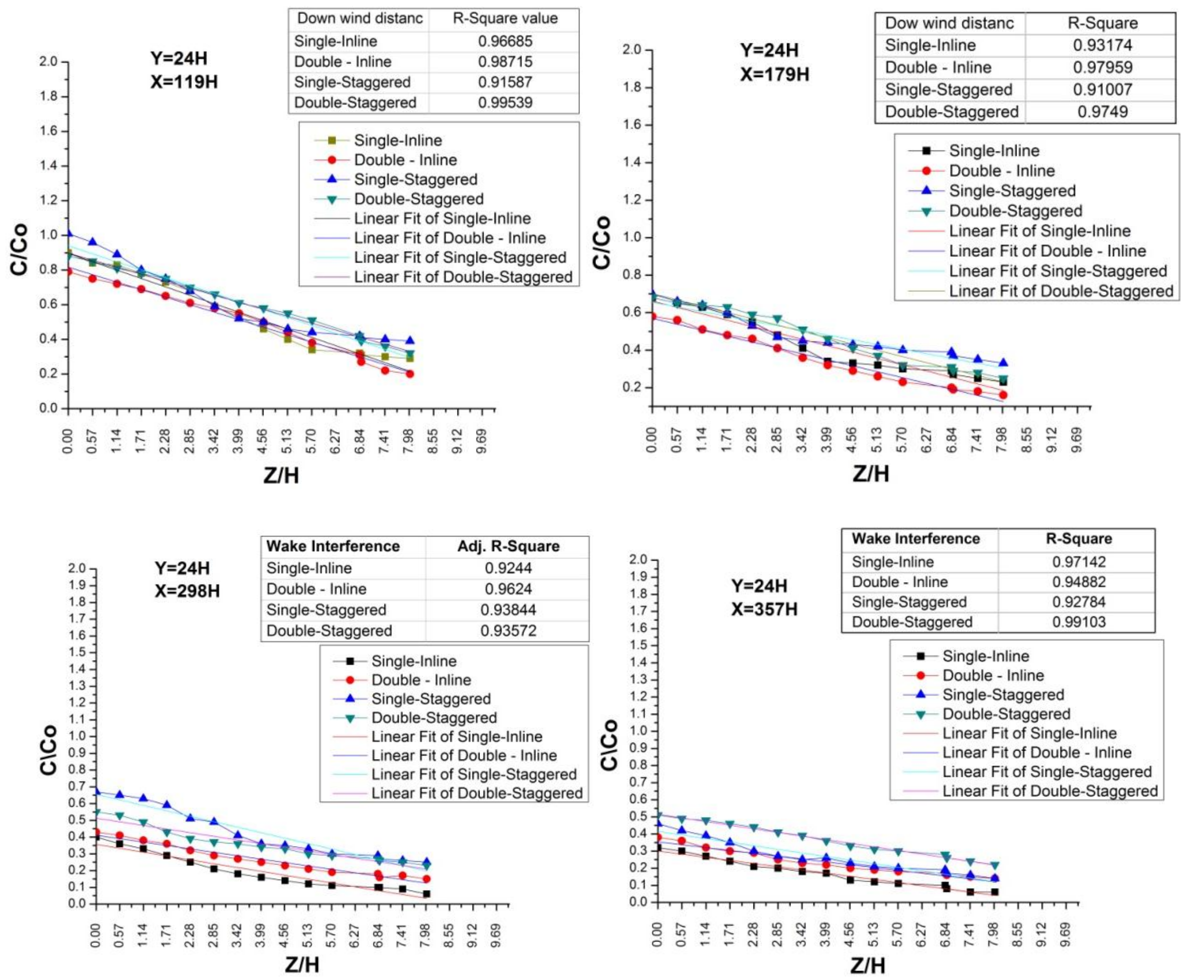

Fig. 8: Differencebetweenconcentration variations at selected downwind distance for Y= 24H with wake interference

4. Conclusions

From the comparison study it showed a decreasing trend of C/C_0 with elevated heightsin both configurations of inline and staggered array in single and double storied modelled buildings. This says that, the concentration of tracer is higher at the floor of the tunnel in staggered double storied configuration than that of higher extended elevations. This comparative study also concludes that there was a notable difference between concentrations of non-dimensional measured in the obstaclesdownwind in staggered&inline array. Despite of difference in quantitative, staggered&inline array depicted the same general result trend. In all the cases, 85% of the downwind concentration profiles were observed at boundary layer depth and the power law profileare best fitted for vertical concentration profiles. The R^2 values of the cases are in the extent of 0.86 -0.99 forthe profile of power-law and fitting best to the vertical concentration profiles. Finally, it is concluded that both the building configurations(inline and staggered array) in single and double storied building model, the variation in concentration trend is almost following the observation made in Macdonald and Griffiths (1998)] experimental work and there was a little deviation in the concentration mainly due difference in height and by considering wake interface.

References

1. Gowda, R.M.M., Khare, M., Chaudry, 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, I., 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(Part 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 D.J., 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, I., 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).
16. Snyder, W.H., Guideline for Fluid Modelling of Atmospheric Diffusion, Report No. 600/8-81-009, USEPA, Research Triangle Park, NC 27711 (1981).