EXPERIMENTAL STUDY FOR THE ASSESSMENT OF THE ROLE OF THE GREEN BELT IN REDUCING WIND VELOCITY AROUND MINERAL PILES

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Abstract. *An experimental study for the assessment of the role of the green belt (GB) in reducing the effects of wind field over mineral piles was performed to in a wind tunnel. In this idealized study, model scale trees were chosen to represent a GB around mineral area. In order to investigate the flow field in a wind tunnel test, it was simulated a boundary layer similar to the atmospheric boundary layer typical of the suburban site. The effectiveness of the GB was evaluated by analyzing tree height, the width of GB, geometry and distance from the mineral piles. The results showed that green belts effectively provides a shelter effec upwind of the piles.*

Keywords*: green belt, mineral piles, atmospheric boundary layer, turbulent flow*

1. INTRODUCTION

The steel and mining industries are necessary to economic and social development of Vitória, a city of Espírito Santo State, Brazil. These industrial plants are installed in the Tubarão Harbor, local where predominant wind direction of NE is responsible for transportation of particulate matter to the urban region. The impacts of dust emission from open storage mineral piles is a serious environmental problem, due to this process have been leads the human health deteriorated and causes degradation of air quality (Cong *et al*., 2011).

The impacts of particulate matter (PM) on the human health vary significantly depending on its size distribution, composition and exposure to inhalable PM.

A green belt (GB) is defined as mass plantation of pollutant tolerant trees for abatement the air pollution by filtering, intercepting and absorbing air pollutants in sustainable manner (Gareth *et al*., 1992; Sharma and Roy, 1997). In addition, green belt has the ability of reduce industrial noise pollution, reuse the treated wastewater and the enhancement of the aesthetics of the area (Fang and Ling, 2003; Rao *et al*., 2004; Pathak, *et al*., 2011). The green belt can be applied as a pollution abatement tool in urban, industrial or historical site/sensitive area protection plan (Rao *et al*., 2004).

In the context of environmental pollution mitigation a green belt offer the ability to remove PM and consequently improve the air quality. Trees remove PM from the air stream in three ways by absorption into the trees, deposition on leave and fallout of particles on the leeward side of the vegetation due to the slowing of the air movement (Prajapati and Tripathi, 2008; Jamil *et al*., 2009). According Prajapati and Tripathi (2008) the leaf petioles are more efficient particulate impactors than either stems or leaf lamina.

Several works have designed models for GB development which include factors such as distance of the pollution source, density, width and height of the green belt (Chaulya *et al*., 2000).

Rao *et al*. (2004) evaluated the performance of the green belt of 500 m width near a refinery in the West coast of India. The objective was to evaluate a model for the estimation of pollution attenuation factor of GB around pollutants sources. This model has been developed using a combination of an exponential law for dry deposition during the pollution transport on natural surface and through a plant canopy of GB. The results show that the air pollution was effectively reduced with an efficiency of about 655 and noise levels were also to about 33%.

Jamil *et al*. (2009) investigated different plants (with certain traits) that have to be taken into account while planning a green belt for fly ash exposed area near the coal based thermal power plants (TPP) located in Sonbhadra district of Uttar Pradesh, North India. Ten plant species that grown in the vicinity of fly ash handling area were selected. Results indicate that leaf surface morphology greatly determines dust trapping capacity of a particular species. The authors suggested certain factors that have to be considered during a design of the green belt around fly ash-handling areas near thermal power plants, such as, fly ash trapping capacity, metal accumulation capacity, leaf surface morphology and metal tolerance were the keys factor and the inclusion of shrubs and subshurbs a long with tree species.

This paper evaluates experimentally the potential of different green belts structures on the reduction of speed of oncoming wind around the material piles. The goal of the present work was to examine the optimal performance of the GB based on qualitatively and quantitatively study of velocity and turbulent flow around mineral piles.

2. MATERIALS AND METHODS

The experiments were performed in an open-return atmospheric boundary layer wind tunnel with a test section of 2.0 m long, 0.5 m wide and 0.5 m hig of Energy Laboratory of Ifes, Vitória, Brazil. According with Irwin (1981) wood spires (0.35 m high) and roughness elements (cubical wooden blocks of 0.035 m) were placed upstream of a model forest eucalyptus to create an atmospheric boundary layer similar to that over a forest under neutral conditions, Fig. 1.

The mean streamwise velocity has the following power la profile:

$$\frac{U(z)}{U_\delta} = \left(\frac{z}{\delta}\right)^p \tag{1}$$

where δ = 0.30 m is the atmospheric boundary layer thichkness. The velocity profile was fitted with p = 0.25, which corresponds superficial roughness to the wind over suburban terrain.

The scale model material pile has a triangular prism configuration with height of 0.08 m (1/100 scale of the prototype coal pile of Vale Mining Company) (Malcum, 2006). Measurements of the vertical velocity profile of wind were obtained with a Pitot-static tube with probe of 3 mm diameter couplet to micromanometer (TSI, model EBT720). The velocity vertical profile wind represented the wind profile over suburban terrain. For each experiment, seven configurations of green belts with trees upstream and downstream of material piles were tested. Each green belt was refereed to as WTGB (Wind Tunnel Green Belt). The experimental set-up and coordinate system used in this work are shows in Fig. 1. Table 1 shows the physical proprieties of GB configurations used in this work.

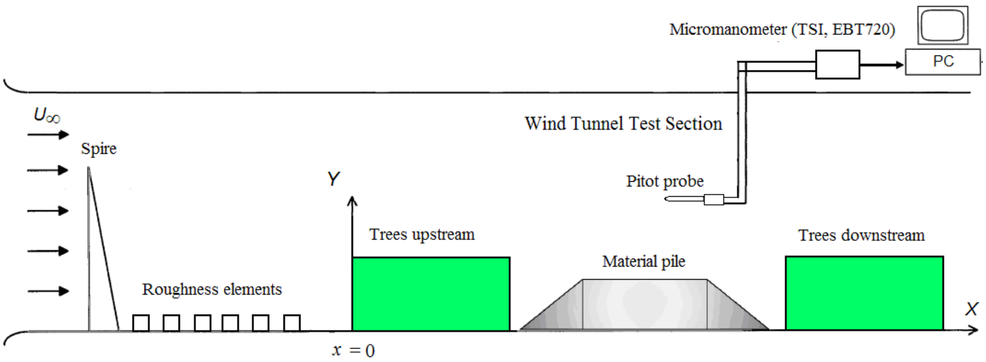

Figure 1. Sketch of the wind tunnel test section, measurement system and green belt localization.

Table 1. Green belts physical properties.

Green Belt		Length (m)	Tree number	Tree density / m^2	Tree hight (m)	Category
WTGB1	Upstream	0.40	115	0.055	0.10	Dense
	Downstream	0.40	128	0.061	0.10	Dense
WTGB2	Upstream	0.40	53	0.029	0.10	Sparse
	Downstream	0.40	56	0.030	0.10	Sparse
WTGB3	Upstream	0.20	84	0.090	0.10	Dense
	Downstream	0.20	80	0.085	0.10	Dense
WTGB4	Upstream	0.20	44	0.048	0.10	Sparse
	Downstream	0.20	44	0.048	0.10	Sparse
WTGB5	Upstream	0.10	43	0.092	0.10	Dense
	Downstream	0.10	45	0.095	0.10	Dense
WTGB6	Upstream	0.10	89	0.193	0.16	Dense
	Downstream	0.10	77	0.162	0.16	Dense
WTGB7(a)	Upstream	0.10	89	0.193	0.16	Dense
	Downstream	0.10	77	0.162	0.16	Dense

(a) WTGB was formed by tree and shrub.

3. RESULTS

3.1 – Flow visualization

Figure 2, 3 and 4 show the visualized flow fields around the green belt and mineral piles for various green belts structures. The oncoming flow separates at the top edge of the piles and forms a re-circulating bubble behind the piles models. Large eddies were shed downstream from the pile model and form a wake. It was difficult to observe the wind reduction of the flow that passes by mineral piles in theses figures. Flow images were captured using a Fujifilm HS10 camera which can capture images at a sampling rate of 240 fps (frame per second).

Figure 2. Flow visualization around the WTGB1 and mineral piles.

Figure 3. Flow visualization around the WTGB2 and mineral piles.

Figure 4. Flow visualization around the WTGB3 and mineral piles.

3.2 – Effect of green belt in wind field

Tables 2 and 3 show the performance of green belts for reducing the wind velocity around mineral piles. In the windward region $x = 0.5\ h_p$ of the mineral piles (downstream of first group of the trees) occurred greatest reduction of the wind velocity due to green belts. These results suggested that the shelter effect of trees was effective for all green belt used. The green belts WTGB1 (length of 0.40 m and dense); WTGB3 (length of 0.20 and dense) and WTGB7 (length of 0.10 with trees and shrubs) were found to be effective for decreasing the wind velocity in the range of $0 < y/h_p \leq 1.0$, respectively, 75.57%; 67.56% and 66.15%. Among the seven green belts used in this study, WTGB1 and WTGB6 showed the largest reduction of wind velocity downstream of the first group of the trees ($0 < y/h_p < 2.0$). Compared the wind velocity upstream the second group of the tree, WTGB7, WTGB6, WTGB2 and WTGB1 showed the largest reduction.

Table 2. Performance (%) of first tree group of GB for reducing the wind velocity around mineral piles.

	WTGB1	**WTGB2**	**WTGB3**	**WTGB4**	**WTGB5**	**WTGB6**	**WTGB7**
			***x* = - 0.5 h_p upstream of the first group of trees**				
$0 < y/h_p \leq 0.5$	22.51	39.32	35.08	40.63	42.94	31.50	39.12
$0.5 < y/h_p \leq 1.0$	26.81	39.64	40.25	43.32	43.16	38.35	43.98
$1.0 < y/h_p \leq 2.0$	12.65		25.70	28.45	25.96	29.73	34.56
$2.0 < y/h_p$		3.01	9.54	9.78	7.69	12.05	13.19
			***x* = 0.5 h_p downstream of the first group of trees**				
$0 < y/h_p \leq 0.5$	49.53	15.16	63.46	36.78	16.35	30.61	57.60
$0.5 < y/h_p \leq 1.0$	91.73	65.36	70.63	68.82	56.76	91.31	63.24
$1.0 < y/h_p \leq 2.0$	60.67	56.14	39.95	41.68	27.90	83.83	62.74
$2.0 < y/h_p$				3.09	1.59	1.90	0.19

Table 3. Performance (%) of second tree group of GB for reducing the wind velocity around mineral piles.

			x = 0.5 h_p upstream of the second group of trees				
$0 < y/h_p \leq 0.5$	58.72	91.55	65.63	59.66	64.68	82.17	93.01
$0.5 < y/h_p \leq 1.0$	81.19	79.64	62.46	53.11	51.45	77.57	80.10
$1.0 < y/h_p \leq 2.0$	65.13	47.44	59.96	40.20	32.01	53.24	67.61
$2.0 < y/h_p$				0.98	4.97	6.80	1.43
			x = 0.5 h_p downstream of the second group of trees				
$0 < y/h_p \leq 0.5$	66.67	54.71	77.89	45.86	71.03	48.41	84.27
$0.5 < y/h_p \leq 1.0$	84.57	77.34	85.98	79.31	81.66	88.77	86.15
$1.0 < y/h_p \leq 2.0$	64.48	54.24	51.46	44.05	38.36	66.74	63.57
$2.0 < y/h_p$			3.79				1.84

Figure 5 shows the vertical profile of the mean wind velocity of the wind upstream of the first group of trees. All seven GB showed mean velocity reduction upstream of the first group of trees compared with the no GB case. Therefore, upstream flow retards as the flow approaches to the GB. The mean velocity reduction was smallest for the WTGB7, the green belt dense with presence of shrubs and length of 0.10 m.

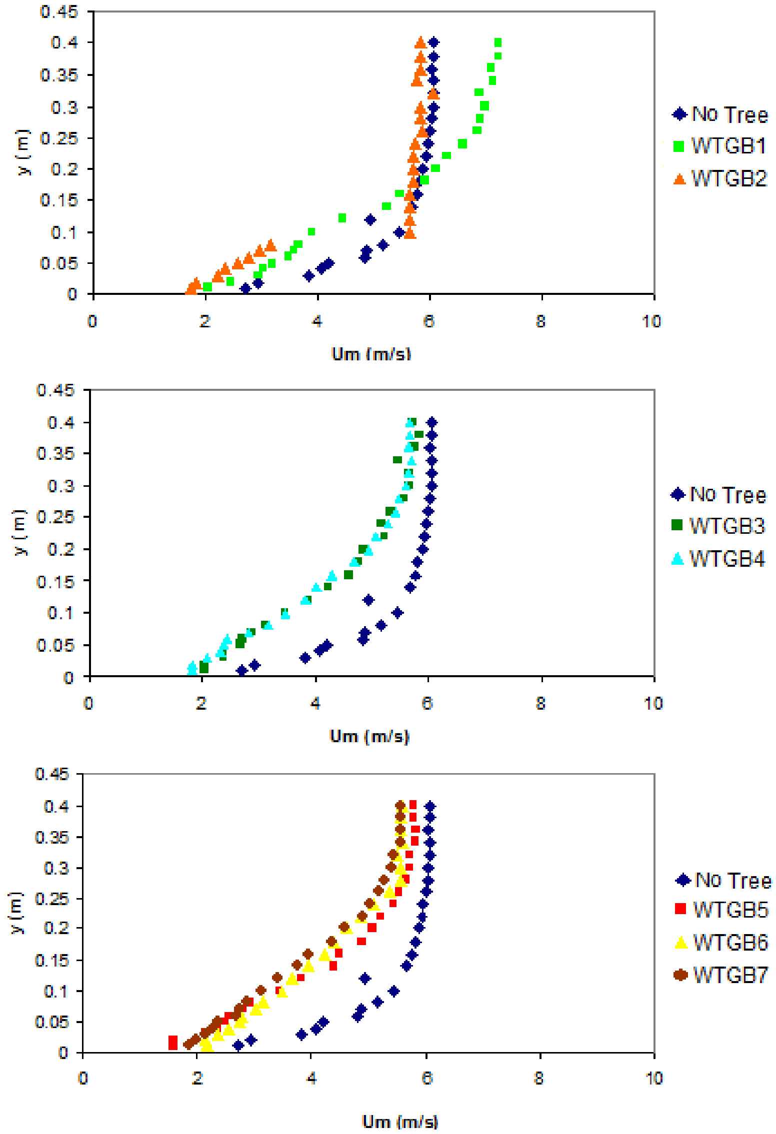

Figure 5. Vertical profile of the mean wind velocity upstream of the first group of trees.

Figure 6 shows the vertical profile of the mean wind velocity of the wind downstream of the first group of trees (upstream of the mineral piles). All seven GB showed large mean velocity upstream of the mineral piles for $y < 0.10$ m (approximately 1.25 h_p) compared with the no GB case. The vertical velocity profiles have small values at the green belt top with an inflection point due to the strong wind shear. These results suggested that velocity differences as a function of the green belts length was not significant compared to the dense and sparse trees.

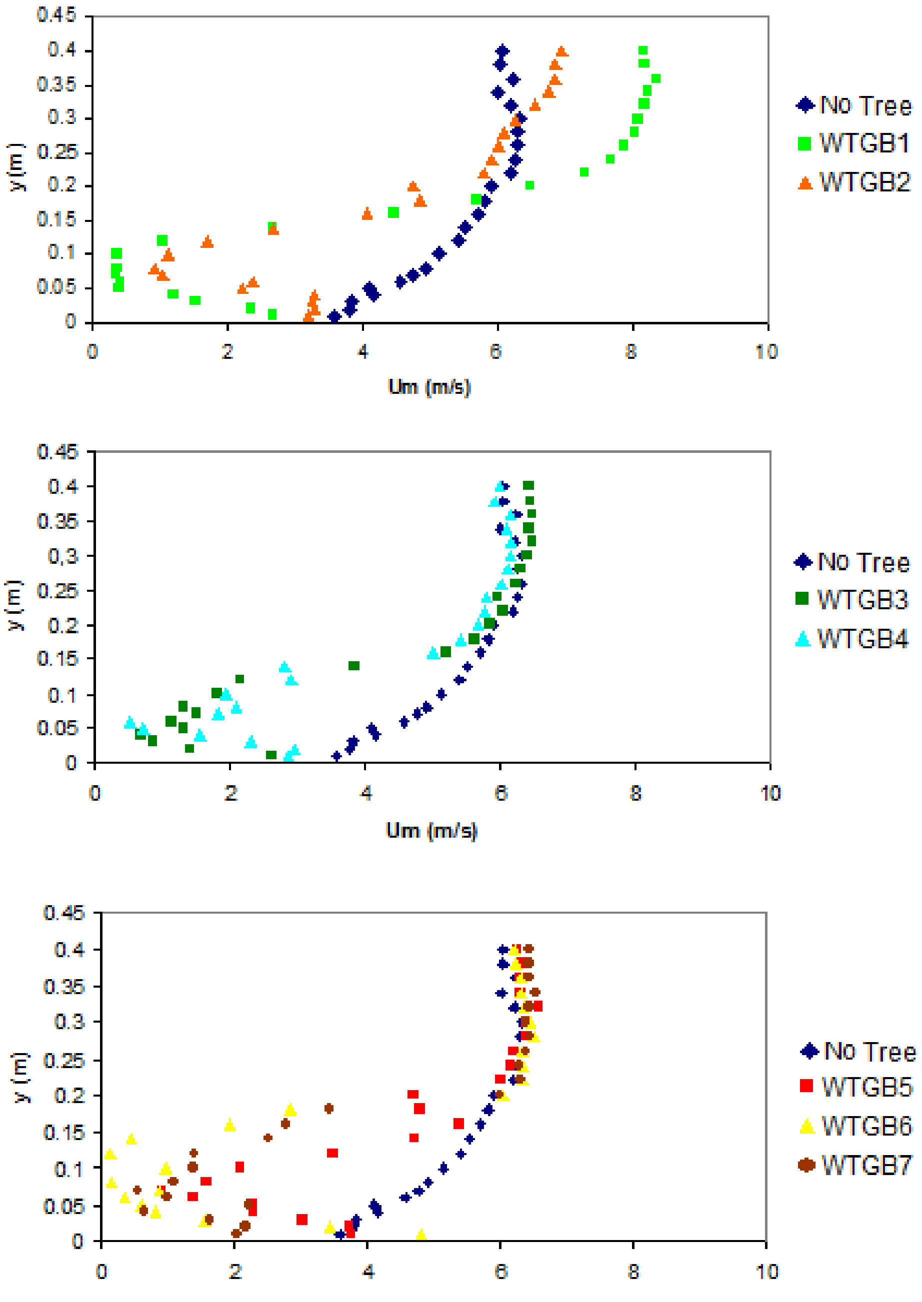

Figure 6. Vertical profile of the mean wind velocity downstream of the first group of trees (upstream of the mineral piles).

Figure 7 shows the vertical profile of the mean wind velocity of the wind upstream of the second group of trees (downstream of the mineral piles). In this case the seven GB showed large mean velocity upstream of the mineral piles for y < 0.20 m (approximately 2.5 h_p) compared with the no GB case.

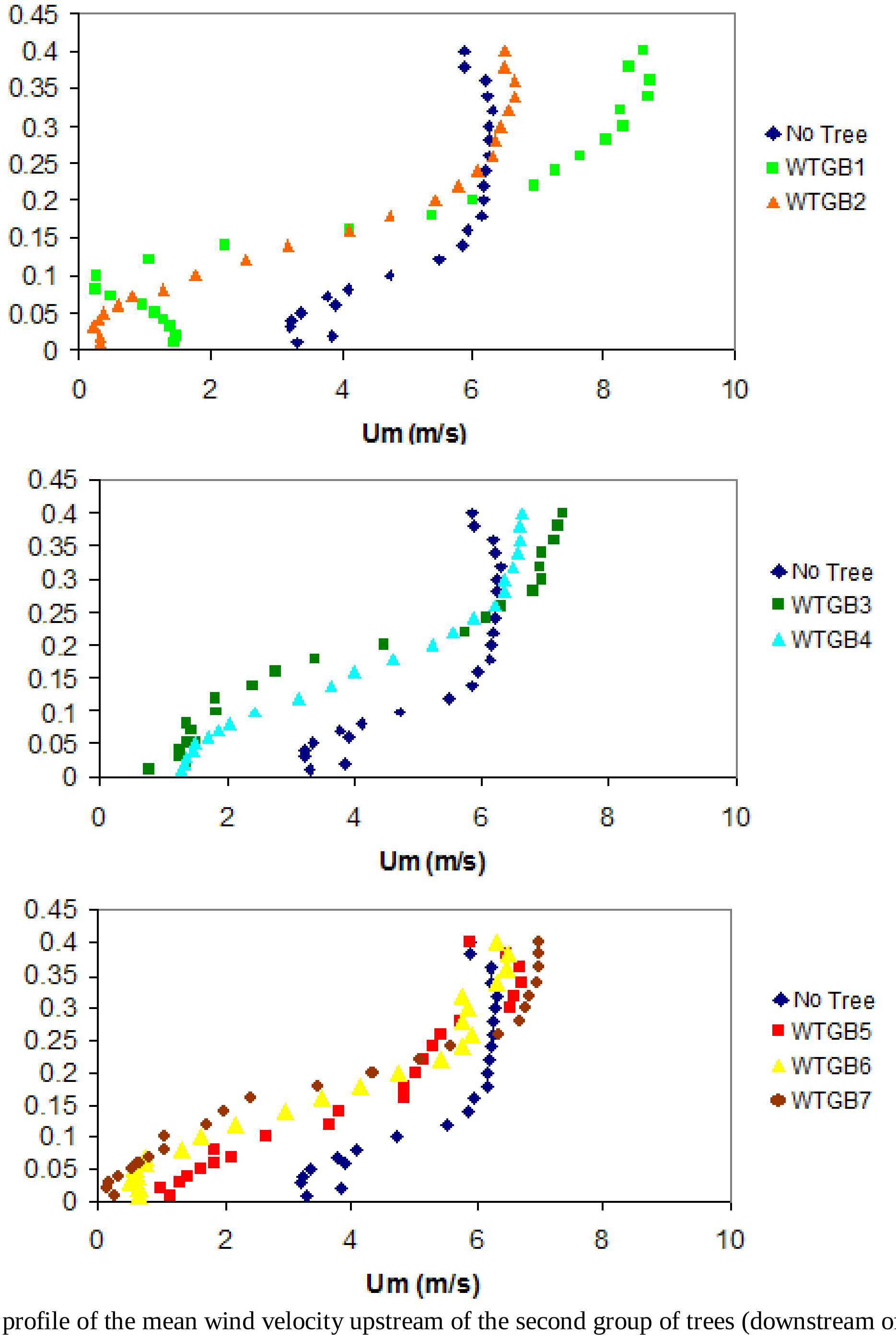

Figure 7. Vertical profile of the mean wind velocity upstream of the second group of trees (downstream of the mineral piles).

Figure 8 shows the vertical profile of the mean wind velocity of the wind downstream of the second group of trees. All seven GB showed large mean velocity upstream of the mineral piles for y < 0.20 m (approximately 2.5 h_p) compared with the no GB case. The vertical velocity profiles too have small values at the green belt top with an inflection point . In this case too was observed that velocity differences as a function of the green belts length was not significant compared to the dense and sparse trees.

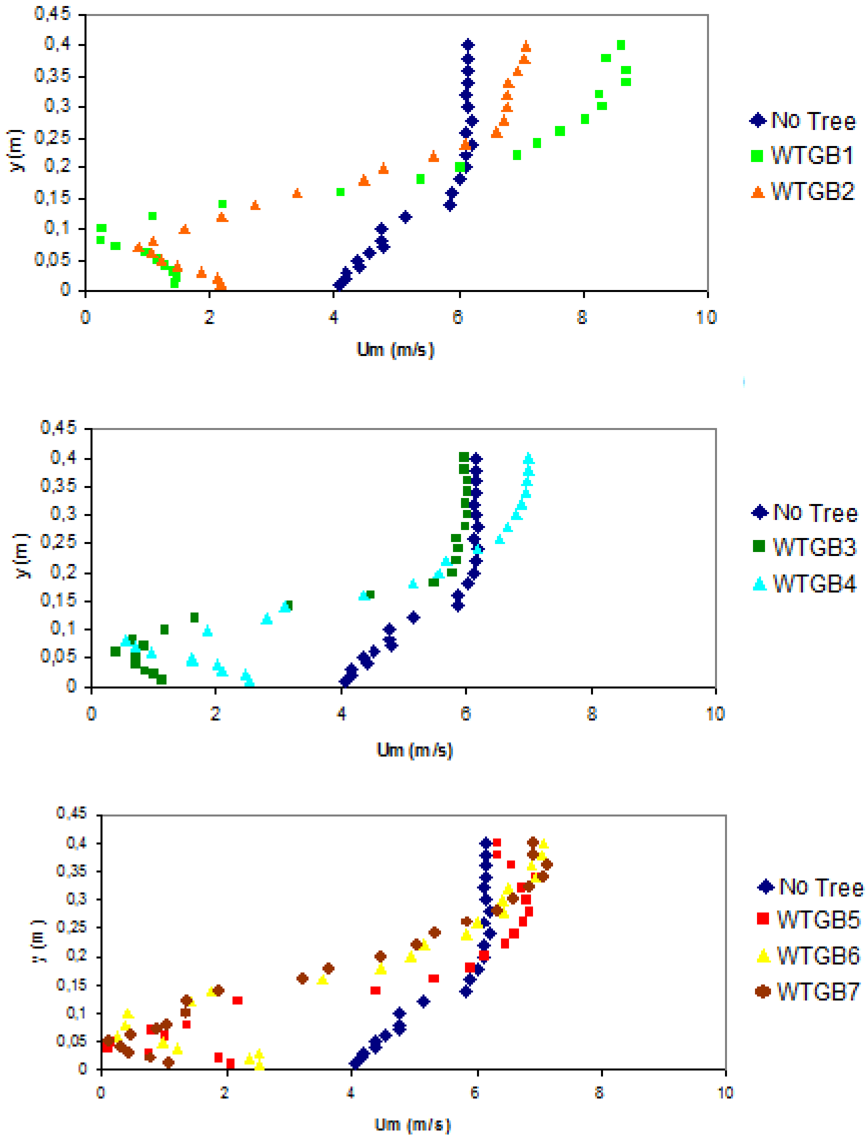

Figure 8. Vertical profile of the mean wind velocity downstream of the second group of trees.

4. CONCLUSION

In this work seven green belts with different structure (length, tree density and tree height) have been investigated experimentally. Among the seven scale models green belts tested, all showed an efficient wind reduction around scale material piles. This can be explained by the wind flow retardation due to blockage effect of the trees. In addition, at the tree top was observed an inflection point in mean wind vertical profiles due to a strong wind shear.

Its overall efficiency of green belt with dense tree was about 60%. However the GB with a combination of tree and shrubs was most efficiency, which was about 73%. These results suggested that green belt might be very useful in the reduction of wind and erosion of the particulate matter around the open storage material piles.

5. ACKNOWLEDGEMENTS

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