

Materials for Noise Control: Paper ICA2016-128**Investigation of the noise reduction provided by
vegetation belt in different design styles****Qinying Zhang^(a), Linxuan Zhao^(a), Hainan Cui^(a)**^(a) University of Tianjin University, School of Architecture, Tianjin, China, qinying_zhang@163.com**Abstract**

Contemporary principles on Landscape plants design mainly guided by Visual effects, it's rarely reported that how the community structure influenced on noise attenuation. In this article, what effect did the community structure with Visual oriented design on noise attenuation was studied by researching the relationship between the arrangement of the green belt and noise reduction(LAeq and 1/3 OCT analyses) in Tianjin, China. 12 green belts were selected for the measurement of noise attenuation in Tianjin Avenue. Based on actual traffic noise as a source of noise, both LAeq and 1/3OCT were measured on both sides of the green belt, in winter and summer respectively. The results showed that the greatest effect of green belt structure on LAeq attenuation was the width of green space, especially the width of the woody pants layer. A parabola pattern was showed between the relationship of noise attenuation and frequency by 1/3 OCT analyses in all green belts measured. The frequency band of maximum attenuation was 500-1600Hz, with the frequency of peak attenuation at 630Hz.

Keywords: Planting design; Sound attenuation; Green space function

Investigation of the noise reduction provided by vegetation belt in different design styles

1 Introduction

Noise is one of the main pollutants in urban environment, in which traffic noise is the major source of noise pollution. Plants have been proposed as effective tissues on reducing noise disturbance from earliest research by Eying (Eyring, 1946). In order to improve the application of the noise reduction function of plants, scholars across the world had done the researches on the effective of plant morphological characteristics and plant arrangement on the ability of noise attenuation, while it was difficult to obtain a consistent conclusions due to different methodology, plant species and experiment environment as well (Aylor D., 1972a, 1972b, Fang C. and Ling D., 2003, Peng et al. 2014).

On the other hand, contemporary principles on Landscape plants design mainly guided by Visual effects, which paid lots of attention on colour, spatial, seasonal variety, it's rarely reported that how the community structure influenced on noise attenuation. In this article, aiming to promote the application of research results in acoustics attenuation of plant to landscape plant designing, what effect did the community structure with Visual oriented design on noise performance was studied by researching the relationship between various factors of green belt and noise reduction (LAeq and 1/3 OCT analyses) in Tianjin, China.

2 Methodology

Twelve vegetable belt communities were chosen in this experiment from the Tianjin Avenue roadside green belt, where the other side of the green belts was open fields to simulate the free sound field environment in order to avoid the interference of the environment barrier. All of the plants are native or naturalized plant in Tianjin. They are listed in Table 1. Plants were classified as ground level, up to knee height, knee to eye height and above eye level according to their morphology refer to the most useful size categories for the designer as ground level, up to knee height, knee to waist height and below or above eye level, identified by Danish landscape architect Preben Jakobsen (Robinson, 2004). Plants in different height were arranged in stepwise style, that means the side of vegetable belts facing the road traffic, named 'front', was lowest plant species (ground level), and the opposite side, named 'rear', was highest species (above eye level). Vertical density was tested as the shield ratio that people standing in front of vegetable belt look toward rear side.

Two type AWA6228 sound level meters with the facility of statistic and 1/3-octave band analysis were used for noise monitoring. The equipment were mounted on tripod stands at a height of 1.2m above the ground level and placed on each side of the vegetable belt (Fig. 1). At each site noise monitoring were made for 1 min at the sampling rate of one observation/one-tenth of a second, repeated 3 times. The experiments were done on a calm and clear sunny day with wind speed no more than 5.5M/S in the winter and summer season respectively.

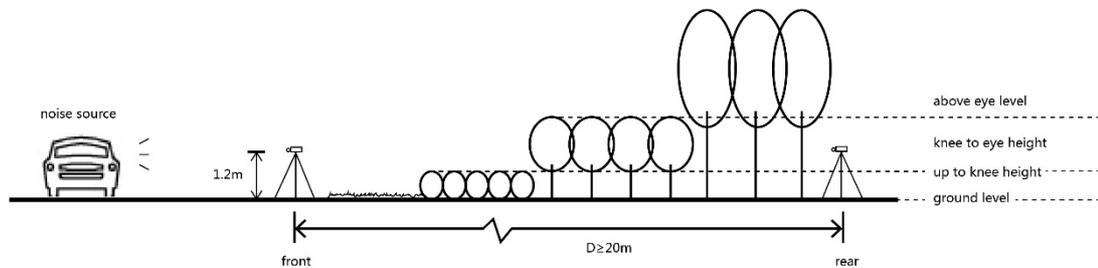


Fig.1: The profile of experimental design

Table 1: Characteristics of twelve vegetable belts tested in the experiment.

Site no.	Species in different layers				Width (m)	Woody plant width (m)	Vertical density	
	Above eye level	Knee-eye height	Up to knee height	Ground level			Summer	Winter
1	<i>Fraxinus chinensis</i>	<i>Pinus tabuliformis</i>		Lawn grass	23	17	0.85	0.80
2	<i>Populus tomentosa</i> <i>Firmiana platanifolia</i>	<i>Lonicera maackii</i>	<i>Ligustrum × vicaryi</i>	Lawn grass	23	21	0.90	0.35
3	<i>Populus tomentosa</i> <i>Firmiana platanifolia</i>	<i>Lonicera maackii</i>	<i>Ligustrum × vicaryi</i>	Lawn grass	23	15	0.91	0.29
4	<i>Populus tomentosa</i> <i>Sophora japonica</i>	<i>Prunus persica f. pyramidalis</i>		Lawn grass	23	19	0.77	0.17
5	<i>Fraxinus velutina</i> <i>Acer negundo</i>	<i>Malus micromalus</i>		Lawn grass	32	23	0.75	0.17
6	<i>Fraxinus velutina</i>	<i>Prunus armeniaca</i>		Lawn grass	20	13	0.79	0.16
7	<i>Robinia pseudoacacia</i>	<i>Pinus tabuliformis</i>	<i>Sabina chinensis</i> 'Kaizuca'	Lawn grass	24	17	0.93	0.86

8	<i>Robinia pseudoacacia</i>	<i>Pinus tabuliformis</i> <i>Punica granatum</i>		Lawn grass	25	19	0.97	0.44
9	<i>Populus tomentosa</i> <i>Sophora japonica</i>		<i>Ligustrum × vicaryi</i>	Lawn grass	20	17	0.73	0.10
10	<i>Populus tomentosa</i> <i>Ulmus pumila</i> <i>Crataegus pinnatifida</i>		<i>Buxus megistophylla</i>	Lawn grass	20	13	0.74	0.18
11	<i>Populus tomentosa</i> <i>Sophora japonica</i> <i>Crataegus pinnatifida</i>	<i>Picea asperata</i>		Lawn grass	20	15	0.87	0.33
12	<i>Sophora japonica</i>	<i>Morus alba</i> <i>Syringa oblata</i>	<i>Berberis thunbergii</i> var. <i>atropurpurea</i>	Lawn grass	22	18	0.93	0.43

3 Results and discussion

3.1 Correlation between vegetable belt arrangement and LAeq

Fig.2 showed the relationship of width of vegetable belts and LAeq attenuation in winter and summer. The width of vegetable belts showed the same tendencies with the noise attenuation especially in summer, which could be considered that demonstrated a direct link between the distance and noise attenuation in spite of different plant species and layer arrangement.

In summer, the change trend of LAeq attenuation and vertical density was consistent, with the exception of site 5 with 32m-width of vegetable belt, at which site the influence of distance prevailed over the influence of vertical density. This was consistent with the report that visibility, which indicated the density of vegetable belts, was the prominent noise reduction parameter, having a logarithmic negative relationship with relative attenuation (Fang, 2003). The trend in winter was poor consistency that showed more complex path for sound propagation through the barrier of plant branches (Fig. 3).

Furthermore, on closer examination of the site2 and site3, there were same species and belt width, but different in woody plant width. Noise attenuations at site 2 both in winter and summer were higher than at site 3 owing to the bigger woody plant width at site2 than site3. And the same result concluded from the compare between site 9 and site 10. So it was showed the

greatest effect of green belt structure on LAeq Excess Attenuation was the width of vegetable belts, especially the width of the woody plant layer.

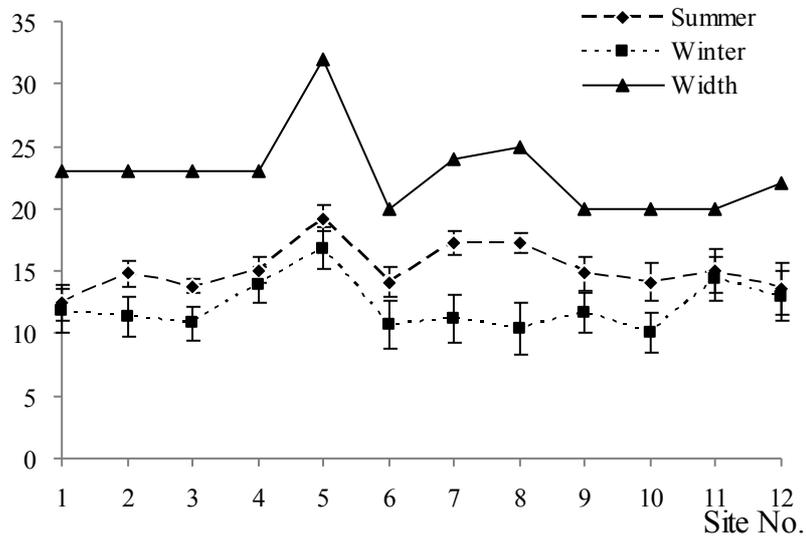


Fig.2: The relationship of the width of green belt and sound attenuation in summer and winter

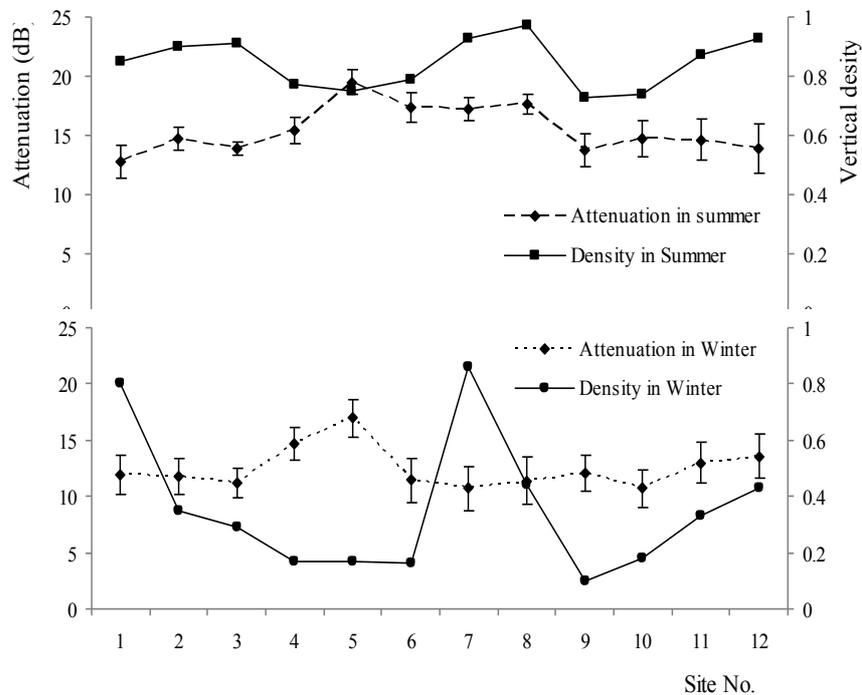


Fig.3: The relationship of vertical density and sound attenuation of vegetable belts in summer and winter.

3.2 Correlation between vegetable belt arrangement and noise-reducing spectrum

Fig. 4 showed the average attenuation of twelve sites at various 1/3 Octave frequencies and LAeq in winter and summer. There were similar trend of noise reducing in different frequency in winter and in summer, perform a parabola patten with peak attenuation in 630Hz. Blow 630Hz, noise attenuation increased with increase in frequency, and upper 630Hz, it decreased with increase in frequency, but the down slope of that relationship was more gradual.

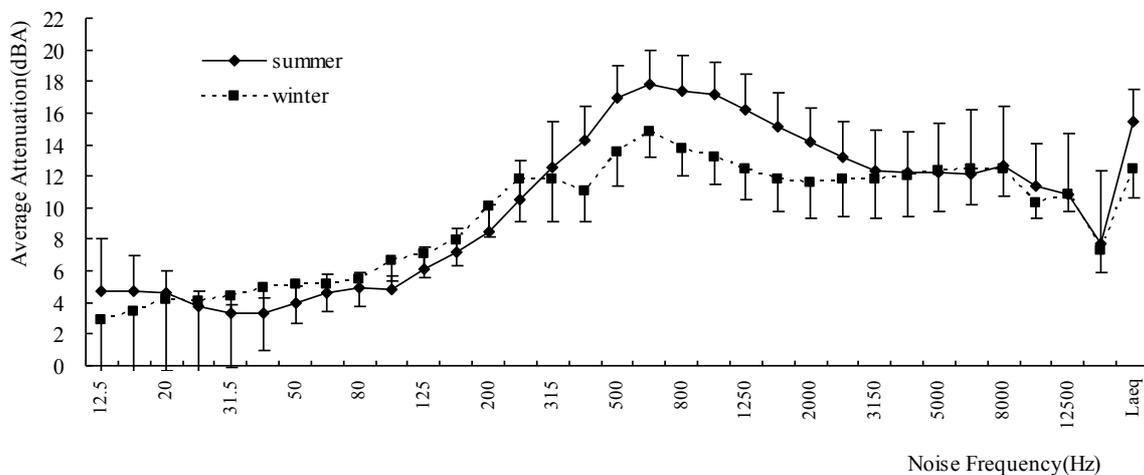


Fig.4: The average noise-reducing spectrum in summer and winter.

The magnitude of attenuation in summer is higher than in winter at frequency 315Hz to 3K15Hz, that is higher in winter than in summer in the frequency interval 25-315Hz, while there is similar beyond 3K15Hz. Attenuation of between 10 and 15 dB are observed in the frequency interval between 250Hz and 12KHz in summer, and between 200Hz and 12KHz in winter. A comparatively great attenuation (>15dB) is observed in the frequency range between 500 and 1.6 KHz in summer.

There was reported that the sound attenuation values obtained in outdoor experiments for some periodic tree configurations, especially at low frequencies (<500Hz), were far higher than those obtained from a typical green belt or forest(Martinez-Salaa,2006). In experiment sites , most of the plants are deciduous tree, so forks and branches play a major role for noise reducing in winter, which showed more complex way for noise propagation by absorb, scatter, also the action of sonic crystal.

There is an obviously valley attenuation at 400Hz in winter, which is inconsistent with result obtained by Tyagi(2006), who made measurements over three vegetable belts and got peak attenuation near 400Hz in all sites. It was reported that low frequencies (250 to 500 Hz) were

attenuated by the absorbing qualities of the ground - qualities which may be enhanced by the plant root system and leaf litter (Huddart, 1990). In this research sites, the ground effect of interaction between the sound waves and bare earth in winter might be the reason of the valley attenuation at low frequency.

A point source was used in most of the research (Tyagi V. et al 2006, Yang, et al, 2010,). Beranke and Vèr (1992) have pointed out that the noise attenuation of a point source is better than that of a line source. In this research, the in situ traffic noise was the noise sound, which could be more accurate results to evaluate the ability of vegetable belts.

In this paper, attenuation maxima are observed at middle frequencies between 500 and 1.6KHz. Because the human ear is most sensitive in the middle of the frequency range, the results presented here indicate that the plant species arranged in stepwise style could be an effective way for traffic noise control.

Acknowledgments

The research leading to these results has received funding from National Natural Science Foundation of China under reference No. 51308380.

References

- [1] Aylor, D. Noise reduction by vegetation and ground. *Journal of the Acoustical Society of America*, Vol 51, 1972a, 197–205,
- [2] Aylor, D. Sound transmission through vegetation in relation to leaf area density, leaf width, and breadth of canopy. *Journal of the Acoustical Society of America*, Vol 51, 1972b, 411–414,.
- [3] Beranke, L.L.; Vèr, I.L. Noise and Vibration Control Engineering. *Wiley/Interscience*, New York, 1992.
- [4] Eyring, C.F. Jungle acoustics. *Journal of the Acoustical Society of America*, Vol 18,1946, 257-270,.
- [5] Fang, C; Ling D. Investigation of the noise reduction provided by tree belts. *Landscape and Urban Planning*, Vol 63, 2003, 187–195,.
- [6] Martinez-Salaa R.; Rubio, C.; García-Raffi, L.M.; Sánchez-Pérez, J.V ; Sánchez-Pérez, E.A; Llinares, J.. Control of noise by trees arranged like sonic crystals. *Journal of Sound and Vibration*, Vol 291(1-2), 2006, 100-106,.
- [7] Peng, J.; Bulien, R; Kean S. The effects of vegetation on road traffic noise. *Inter-noise*, 2014, 1-10
- [8] Robinson, N. Ed., *The Planting Design Handbook*, Ashgate Publishing Limited. Revised Edition, 2004.
- [9] Tyagi, V; Kumar K; Jain V. A study of the spectral characteristics of traffic noise attenuation by vegetation belts in Delhi. *Applied Acoustics*, Vol 67, 2006, 926–935,.
- [10] Yang, F ; Bao, Z.Y ; Zhu, Z.J ; Liu J.N.. The Investigation of Noise Attenuation by Plants and the Corresponding Noise-Reducing Spectrum. *Journal of Environmental Health*, Vol 72(8), 2010, 8-15..