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Analysis on the Structure Mechanism of Natural Top Ventilating and Soundproof Bay Windows

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Abstract. To reduce noise transmitted by natural soundproof windows, two measures are usually adopted: changing window materials and structures. One of the researches is how to achieve ventilating and acoustic proof effects through changing the window structures of high buildings when ordinary materials are used. In this research, it is studied how to achieve both effects through installing top intakes and small acoustic barriers on bay windows, so to put forward new directions to the research of natural ventilating soundproof windows. In the meantime, it is aimed at providing new solutions to improve sound environment of high buildings through the practices in real construction cases.

Introduction

The influences of traffic noise is getting more and more serious with the increasing number of vehicles. When designing high buildings adjacent to streets, designers always find it hard to resort to ground virescence and road acoustic barriers to reduce traffic noises because of the height of the buildings. Presently, the most effective soundproof way is to improve the quality of the outside walls and windows. In acoustic window barrier researches, the efficiency has been improved greatly A--weight sound level of double glazing glass and plastic-steel windows being 32dB and single glazing glass being 24dB[1]. When double glazing and single glasses are installed together, the efficiency can be even higher. However, ventilation still remains a problem when acoustic problem is solved.

There are always ventilation difficulties in soundproof windows. For a normal window, soundproof efficiency reduces when it is opened, hence, electric fans are installed for mechanical ventilating; but these fans cause extra expenses, consume energy, and make extra noises. As to a natural ventilating soundproof window, it is usually installed with small air intakes, together with sound absorbing structures in the intakes. In this situation, ventilation becomes less effective because of the small intake and complicated soundproof devices in it.

Compared to normal windows, bay windows with top ventilating intakes can not only achieve natural air-intake, but also reduce traffic noise influences. In order to apply this structure in practical constructions, it is necessary to make analysis and calculations to sum up its working principles and mechanism.

Structure principles and research target analysis:

Principles of a top ventilating soundproof bay window: rebuild the upper retaining structure of the bay window -- change the upper concrete plate into sashes and open an intake to avoid direct acoustic influences; small acoustic barriers are installed around the intake to minimize diffraction sound. Double glazing glass and plastic-steel frames can be applied to the obverse casements; when necessary, an extra layer can be added to improve soundproof efficiency through the airspace in between; meanwhile, resonance can also be avoided because of the different structures of the two layers of glasses.

Analysis on the design habits of high-rise resident buildings in China: there are two main types of high-rise buildings: slab-type and tower type, which are always influenced by direct traffic noise when they are constructed adjacent to the streets. It is suggested in the residential design codes that the floor height of an apartment be 2.8M [2] (some also be 3.0M), the wall below the window being 0.9M, and height of the window being 1.5-1.8M. Therefore, there is still 1.5-1.8M above the bay window for ventilation. Small acoustic barriers (0.3-0.9M) can be installed in the 1.5-1.8M space for soundproofing, leaving 0.9-1.5M for ventilation intakes. As to the materials for windows, normal plastic-steel frames and double glazing glass can be adopted, which are popular in Chinese markets.

Key research contents:

Three assuming bay window models are constructed for ventilation and acoustic research, together with main structures analyzed.

Structure analysis of model I: (refer to: Fig. 1)

Assuming structure conditions of model I: the bay window reaches out of the wall for 0.6-0.9m, with the obverse being double glazing sliding casements, the sides being fixed ones, the bottom being reinforced concrete plates. Revolving sashes are installed on the top, together with small acoustic barriers (0.3-0.9M). When all the casements are closed, it can meet the soundproof requirements by the outer window.

Structure analysis of model I: this model is applicable for buildings with low noise grades. When the obverse sliding casements of the outer window are closed, the revolving sashes on the top can be opened for airing. There are two modes: unventilated and ventilated quiet.

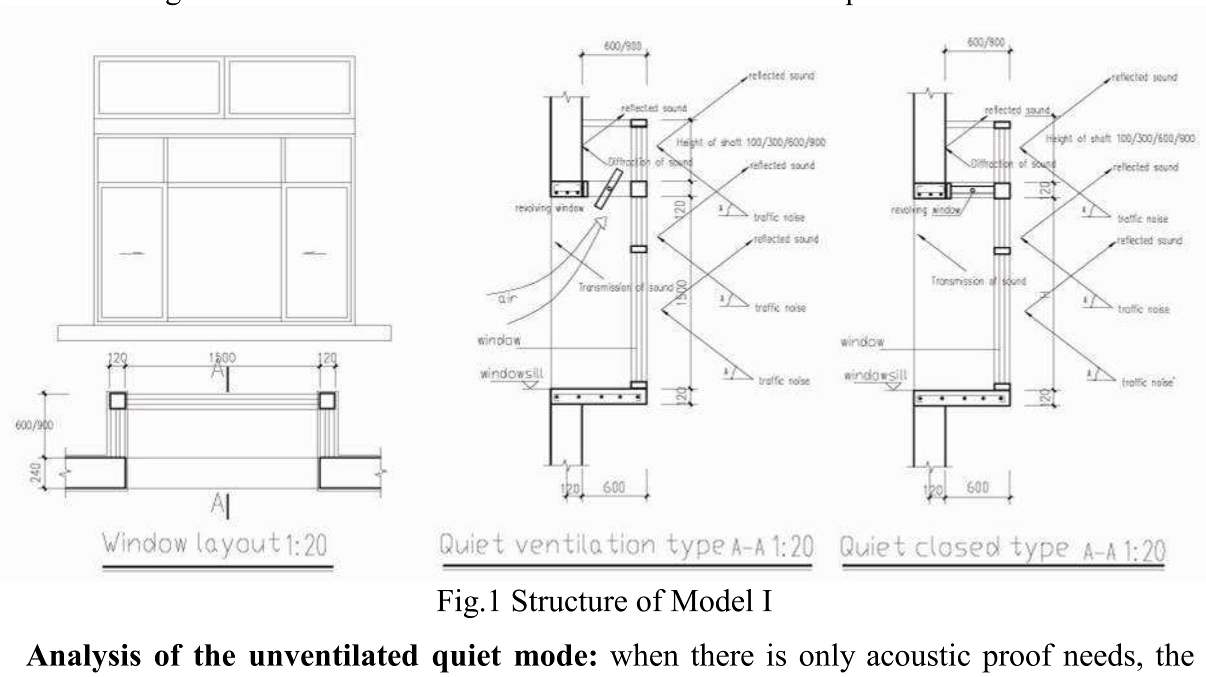

Fig.1 Structure of Model I

Analysis of the unventilated quiet mode: when there is only acoustic proof needs, the top revolving and the obverse sliding casements can be closed, so that part of the traffic noise can be reflected away from the building, leaving the rest transmitted into the room through the double glazing glass. The small barriers on the top can both reflect and absorb some noise, while the transmitted sound can be absorbed and reflected by walls, so is the most of the diffraction sound. Since the top casement is double glazing glass, it can also help to improve soundproof efficiency. Therefore, if the double glazing glass and plastic-steel frames can reach the design requirements, this mode can reach the required soundproof value.

Analysis of ventilated quiet mode: when both acoustic proof and ventilating are to be achieved, the revolving casements on the top can be opened, leaving the slidings closed. Sound can be proofed when the obverse casements are closed. In this condition, noises to the top are mainly diffraction sounds, whose attenuation is closely related to the frequency of the noise source, material and size of the small barriers. Therefore, materials, angles, and sizes of the small acoustic barriers can be adjusted to meet soundproof needs; as to ventilation, when the top revolving sashes are opened, convections among different windows and doors can be formed because of indoor and outdoor temperature differences, so that the air in the room can be refreshed. If more fresh air is needed, the obverse casements can be opened temporarily for ventilation, as provides an alternative to some specific conditions.

Structure analysis of model II: (refer to: Fig. 2)

Assuming structure conditions of model II: the bay window of the old building were designed to reach out of the wall for 0.6-0.9M, with the obverse being double glazing sliding casements, the sides being fixed ones, the bottom and the top being thin reinforced concrete plates. Remove the concrete plate on the top and install revolving casements, with small acoustic barriers (0.3-0.9M) installed on three sides. In the middle of the wall, single plastic glass sliding window is adopted, with 0.6M-high sashes on the top.

Structure analysis of model II: this mode is applicable to buildings influenced by higher-grade traffic noises, especially to the existing ones which have already been disturbed seriously. It is not complicated to alter the flat window into a bay with top ventilation intakes, neither is it difficult to add a flat window to a bay; further, the cost is relatively low since only average materials are needed. When the obverse sliding casements are closed, the revolving and the inner sliding casements can be opened for airing. This model can also be classified as unventilated and ventilating quiet modes.

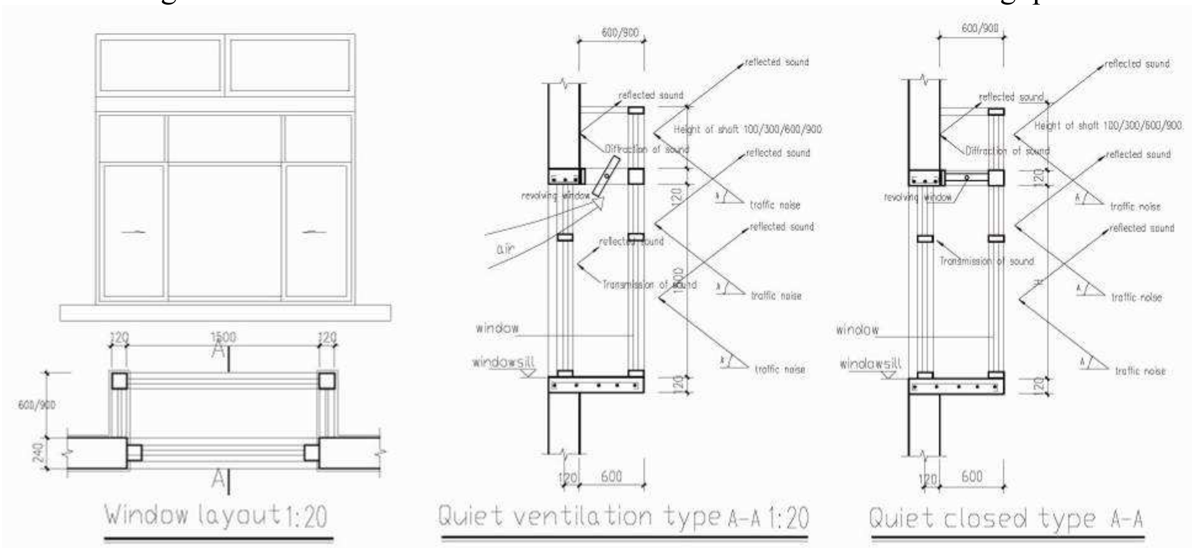

Fig.2 Structure of Model II

Analysis of the unventilated quiet mode: when the top revolving, the obverse and the inner sliding casements are all closed, part of the traffic noise can be reflected away from the building, while the rest is transmitted into the space of the double glazing glass and absorbed by repeated reflections, which is in accordance with the quality-spring-quality principle; thus acoustic effect can be improved when this mode is applied to buildings influenced by louder traffic noises. In the meantime, diffraction sound can be attenuated by collective functions of the small barriers and the revolving casements on the top.

Analysis of the ventilated quiet mode: if acoustic proof and ventilating are both to be achieved, the revolving and inner sliding casements on the top can be opened, leaving the obverse slidings closed to achieve the originally designed soundproof results. The closed sliding can meet the needs for sound proof; transmitted noise is attenuated when reflected repeatedly in between of the two layers of window; while the noise to the intake can be reduced with the adoption of perforated material on the inner casements. Diffraction noise to the top can be reduced by adjusting materials, angles, and sizes of the small barriers. Through reconstructing, sound proof efficiency of the window can be improved greatly. Further, the revolving and top inner sliding casements can be opened for ventilation; if more fresh air is needed, the obverse slidings can be opened temporarily for airing.

Structure analysis of model III: (refer to: Fig. 3)

Assuming structure conditions of model III: the bay window of the old buildings were designed to reach out of the wall for 0.6-0.9M, with the obverse being double glazing sliding casements, the sides being fixed ones, the bottom and the top being thin reinforced concrete plates. Remove the concrete plate on the top and install revolving casements and small acoustic barriers (0.3-0.9M) on three sides. 0.15M inside the original bay window, an extra single glass plastic-steel sliding window is installed. As to a new building, bay windows can also be designed double-layered, keeping the space between the two layers for 0.15M; while the top can be revolving sliding casements, with small acoustic barriers on three sides.

Structure analysis of model III: this mode is applicable to buildings influenced by loud traffic noises, to both the reconstruction of windows of the old ones and the design of new buildings. In this model, ventilation is achieved through the revolving casement on the top and sound is proved through a quality-spring-quality principle of the double-layer window, which can make the best use of the space between the two layers. This model can also be classified as unventilated and ventilated quiet modes.

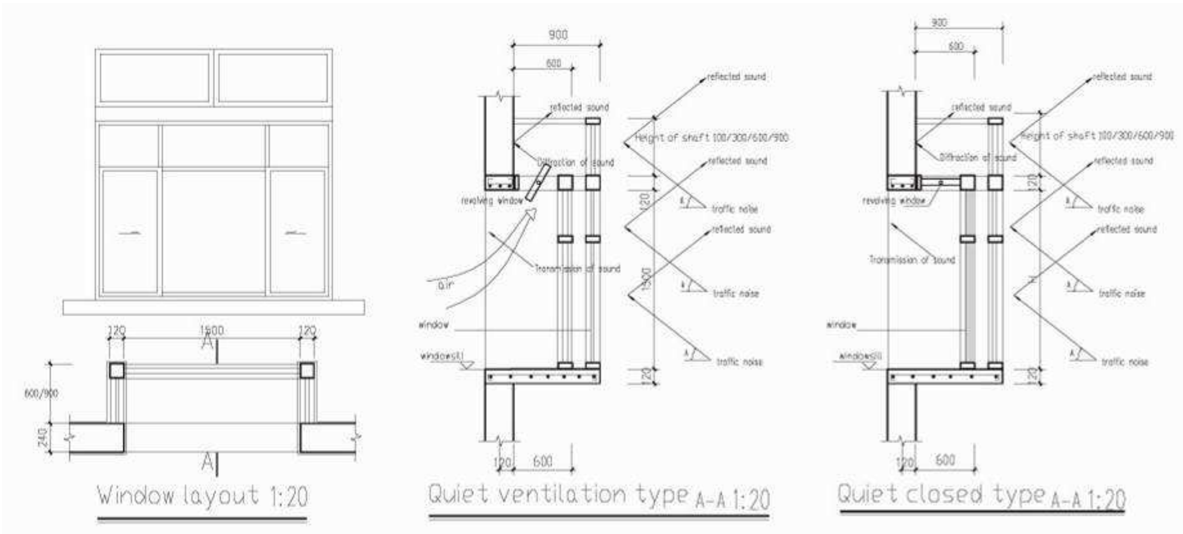

Fig. 3 Structure of Model III

Analysis of the unventilated quiet mode: when the top revolving, the obverse sliding, and the inner sliding casements are all closed, part of the traffic noise can be reflected away from the building, while the rest is transmitted into the space of the double glazing glass and absorbed by repeated reflections. Compared to model II, this mode is more applicable to high buildings influenced by higher grade noises, since it does not have inner top sashes and soundproof efficiency of the original window can be achieved greatly. In the meantime, diffraction sound can be attenuated by the small barriers and the revolving casements on the top.

Analysis of the ventilated quiet mode: if acoustic proof and ventilating are both needed to be achieved, the obverse sliding casements can be closed for sound proof, leaving the revolving on the top for ventilation. The closed obverse sliding casements are able to meet high-degree soundproof effects; also, the transmitted noise is reflected and absorbed by the space between the two layers, thus is reduced greatly; as will increase soundproof effect of the original window. In the meantime, diffraction sound is attenuated by maximizing the height of the sound barriers, so to achieve acoustic proof effect. For ventilation, when the revolving sashes on the top are opened, airing can be realized because of the indoor and outdoor temperature differences.

Conclusions

The following conclusions are reached through analysis on the conditions of the three bay window models and summaries on the structure mechanism of the top ventilating soundproof windows with small sound barriers:

The obverse and side casements of the bay window must meet soundproof needs. To improve efficiency, one extra layer can be added, leaving 0.15M space in between.

0.3-0.9M small acoustic barriers must be installed to attenuate diffraction sound.

The top of the bay window should adopt revolving casements, so as to reflect diffraction sound through different angles.

Acknowledgements

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