DESIGN APPROACHES TO NOISE ABATEMENT FOR THE HIGH-RISE RESIDENTIAL ALONG THE SHENZHEN MAIN ROADS

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Shenzhen is a fast urbanization city that has been decorated by density high-rise buildings along fast-speed roads. To the peoples inhabited along the Shenzhen main roads, noise problem is rather big which is ranked the first environment problem by local peoples. In this paper, traffic noise problems from three Shenzhen main roads have been investigated. The result shows that three main roads from east to west have serious noise problem with above 75dB noise level. In terms of typical noise impact on the high-rise residential along the roads, various design approaches are proposed to reduce noise impact via studying noise maps around roads’ area and surrounding buildings. It is found that three design approaches from site-plan, room layout and balcony design can be used to achieve noise abatement.

1. Study background

With the development of urbanization, the influence of traffic noise on urban life has been becoming more and more serious. Especially in large cities such as Shenzhen, with constant urbanization, it is very common to build high-rise residential along the city main road and causes a number of noise problems to its habitants. Such situation is considerably serious in Shenzhen because of its geographic feature. Shenzhen has a long east-west side but and narrow south-north side. Three roads from east to west construct the main Shenzhen’s transportation, which are named the Bei Huan, Shen Nan, and Bing Hai. Because of a tight land-use, plenty of high-rise residential buildings are unavoidably built along these three roads. According to the Shenzhen recent years’ environment report, noise complain is ranked the first environment problem. It is undoubtedly important to study approaches to noise abatement especially to the noise from the heavy traffic roads in Shenzhen in order to provide a peaceful and comfortable living environment for this city.

Many studies have been done in looking for efficient and feasible ways to deal with traffic noise within an urban context\textsuperscript{1-3}. Noise from a vehicle motor is the main donator to traffic noise. It is caused by the sounds from engine, tires’ fraction and turbulence. Noise impact to the high-rise along a road is decided by three factors that are vehicle sound source, distance between traffic sound and a receiver, and a receiver. Study of noise abatement is usually focused on reducing vehicle noise and protecting a receiver. Lots of efforts have been done to reduce vehicle noise by vehicle manufacturers and institute researchers\textsuperscript{4,5}. What left for urban designers and architects can do is to use feasible approaches to protect receivers and cut off noise transmission. It is necessary to know the exact noise impact on a building, and then develop correspondent approaches to cope with. Macroscale acoustic modelling such as noise map technique is considered useful in studying noise.
impact on its surrounding buildings. In this paper, using Cadna software, noise levels of the Shenzhen three main east-west roads have been analysed, and then noise impact to the high-rise residential buildings has been studied. Finally, design approaches for noise abatement to the high-rise residential along the Shenzhen main roads have been explored.

2. The Shenzhen main road noise level

The location order of these three roads from north to south is the Bei Huan, Shen Nan, and Bing Hai. Amongst them, the Bei Huan and Bing Hai are fast-speeding roads mainly along with high-rise residential buildings whereas the Shen Nan is a main city road mostly governed by office skyscrapers.

As the main city’s traffic roads, the Bei Huan, Shen Nan, and Bin Hai has its different transportation functions. The Bei Huan contains most heavy lorries and trucks those are forbidden to travel in the Shen Nan and Bin Hai. In the study, noise level distributions along the three main roads are obtained by computer simulation using Cadna/A and verified by on-site measurements.

The Bei Huan Road is the most north road among the three main roads. It is an inner city speed-road without traffic light. It has four lanes for one way and totally eight lanes for the main road with a vœux-road for each way. The speed limitation of the Bei Huan is 80km/h with cars and heavy vehicles. Based on amount of traffic flowing data, a noise map for the Bei Huan has been produced and shows the noise level is around 75dB to 80 dB in the area within 30 meters’ away from the middle of the Road. It also shows when the distance is doubled the noise level is reduced 1dB. The results from noise map have been compared with the on-site measurement presenting 1.4dB average bias of computer simulation and measurement, which proves that the noise map analysis is reliable in the study.

The Shen Nan lies between the Bei Huan and the Bin Hai Road. It is the first main road in Shenzhen, which has been playing an important role in the Shenzhen’s economic development and also as the City’s Avenue to a certain extent. The speed limitation of this road is 60 km/h lower than the Bei Huan. The whole road can be divided into three parts from east to west, namely the Shen Nan Eastern Road, the Shen Nan Middle Road, and the Shen Nan Avenue. The width for each part is rather different varied from 140m to 350m (decorated with vœux-road too). A noise map for the Shen Nan shows the noise level is around 70dB to 75dB within 30m’s area from the middle road to the side, which is average 5dB less than the Bei Huan. The Bin Hai is in the most south part among the three roads. It is also an inner speed-road without traffic light but vœux-road. Same as the Bei Huan, the speed limitation for it is also 80 km/h but only cars are permitted to travel. According to a noise map analysis, the noise level of the road within 30 meters road scope is around 75dB, which is rather less than the Bei Huan for a possible reason of no heavy vehicle passing.

3. Noise impact on the high-rise along the roads

An impact model corresponding to a real situation is feasible to study noise impact on the high-rise residential buildings along the roads. Using a typical high-rise residential model drawn from 21-field study cases, the plan layout, orientation, and elevation etc. influence on the noise level is analyzed and discussed in this section.

3.1 Noise impact simulation

According to noise maps for the three roads horizontal and vertical directions as shown Figure 1, it can be seen that with the height increasing the noise level is reducing and this tendency is significant within 50m’s high, however, after 50m’s height, the reduction tendency is not that clear. Comparing to vertical variation, the horizontal distance change does not influence the noise level change that much. The result also shows that the height influence on noise level is becoming less
with distance increasing. A typical case study shows that when a distance of a building to the middle of the Bei Huan is increasing from 25m to 35m, the noise level reduces to 3dB, but a reduction tendency is becoming slow after 35m. It is interesting to note when the distance increasing from 50m to 60m, the noise level only reduces to 1dB.

![Figure 1. Noise level distribution in the Bei Huan(a), Shen Nan(b), and Bin Hai (c)](image)

In addition, differences of planning forms on noise impact has been studied. To flat block planning form, two typical enclosing types relating to the road has to be considered, one is inward and the other is outward. However, to non-enclosing flat block, the situation is similar as a tower block but short indeed. According to simulation results as shown in Figure 2, it can be seen that enclosing flat block present a better noise abatement performance than the tower block. With its long and enclosed wings, the building behind area could get a large quiet shadow no matter horizontally and vertically.

![Figure 2. Noise level simulation using noise mapping technique](image)

Addition to planning forms, direction of a unit of a high-rise residential building towards a road is considerably important too. Using a typical residential unit model for the high-rise, noise mapping analyses have also been made as shown in Figure 3. The unit direction towards the roads has been studied in three angles, Based on simulations of three different directions of a unit to a road, it is found that with the angle increasing the noise impact is reducing until to 45 degree, after that, noise impact on the other side is increasing.
3.2 Results and discussions

In order to study noise impact on the high-rise residential buildings, some typical simulation model has been drawn and its relations with the roads have been studied. According to the noise mapping results of a building distance to the roads, it is found that with a distance increasing the noise level is reducing and this change is clearer to a vertical direction than a horizontal direction. To distance increasing in horizontal direction, it is interesting to note that a noise level reduction of distance increasing is not in direct proportion. When a distance changing within 35m, a 10m increasing can reduce 3dB, but after 35m, a noise level reduction is not that much, it shows when a distance increasing from 50m to 60m, the noise level only reduces 1dB. According to the simulation results of a building planning form, it is found that enclosing flat block form is better than tower block and the outward enclosing (relative to the road) is the best. According to the noise mapping analyses of a unit direction towards the roads, the result presents that the best noise abatement is obtained when a unit has a 45-degree angle towards the roads.

4. Noise abatement approaches

According to the above analyses, it can be seen that with a change of a building distance of a road, a change of building planning form, and also a change of facade parts, the noise impact on a high-rise along the road can be changed. It therefore concludes three noise abatement approaches in this study, which are the layout design approach, the planning design approach, and the elevation design approach.

4.1 Layout design approaches

Corresponding to a distance change impact on noise level, layout design approaches are provided to search suitable layout of a high-rise residential towards the Shenzhen main roads. Using a typical model, variations of distance and building direction on noise abatement are explored. It is found that a horizontal distance change between 50m can reduce noise level to some extent and the most efficient change is within 35m. A change of building unit direction presents that a 45-degree of the residential unit to the road is the best direction for noise abatement. Generally speaking, layout design approach suggests that when a high-rise is close to a road, increasing distance is a useful way to reduce noise level, however, when a distance is more than 50m’s far, the other layout design approaches such as changing the building’s direction should be taken into more account.

4.2 Planning design approaches

Due to different rooms having a different requirement, a planning design approach suggests putting non-acoustic sensitive rooms toward the road, such as stairwell, corridor, kitchen, and bathroom etc. A problem of such an approach is when a high-rise residential building standing on the north side towards the road, this planning design approach cannot be implemented because of sunshine issues as non acoustic sensitive rooms are usually less important rooms in a residential unit that requires less sunshine. If this is the case, another planning design approach of changing the plan’s outline might be useful. The approach is to use a complex room connection to form a convex
and concave building’s outline that helps to reduce noise level. In addition to benefit noise abatement, such a design approach is also good to natural ventilations.

4.3 Planning design approaches

For the elevation design approach, a change of façade parts could be useful in noise abatement. In the study, functions of a balcony on noise abatement are focused. It is found that a balcony’s depth, broad, and upper ceiling has played some roles in noise abatement. The result suggests that a deeper a balcony is, the better efficient it makes on noise abatement. The result also shows that a balcony broad height and its angle also influencing noise abatement to the building. The higher the broad is the more noise protection it make. When a balcony depth and its broad height cannot add more, using a planting frame can improve its effect. For using a balcony’s upper ceiling to noise abatement, the ceiling tilt angle as well as using sound-absorbing material plays some roles in noise abatement. When using a balcony to protect noise, two kinds of sound penetrating have to be considered, which are direct penetrating sound and first reflection sound. For a high-rise residential building, direct penetrating sound is determinant to the lower parts, direct penetrating as well as first reflection sound plays an important role to the middle parts, whereas first reflection sound is the main noise donator to the upper parts. Therefore, it suggests that for a high-rise residential building’s lower parts, adding balcony’s depth and changing its broad are efficient approaches to noise abatement, and for the upper parts, changing a ceiling tilt and using sound-absorbing material are useful, and for the middle parts, combined approaches to lower and upper parts should to be considered.

5. Conclusion

In this study, the noise impact of three main east-west roads of Shenzhen on the road along high-rise residential has been explored. It is found that noise level of these roads is considerably high that is above 75dB within 35m from the middle of the road to the side. The result shows that such a high noise level can be obviously reduced if a high-rise building stays an enough distance from the road, typically 35ms away. Based on noise map analyses, the study investigates factors influencing noise impact on high-rise residential along the roads. It is found that the building layout, planning arrangement, and the façade component have significant impact on noise abatement. Coping with these factors’ influence, three design approaches including layout design, planning design, and elevation design are proposed in the study to improve noise abatement. First of all, layout design approaches that are distance changes between the building and road and angle changes of the building along to the road should be considered at a design planning stage. Secondly, planning arrangements of each room to the road and irregular floor plan should be taken into account at a floor planning stage. Thirdly, elevation components such as a balcony structure have to be considered when the other two approaches cannot be implemented. In general, this study provides some feasible approaches to aid architects and designers in noise abatement of high-rise residential buildings along the Shenzhen main east-west road.

REFERENCES


