

Preliminary Study on Technical Standard for Sound Insulation Renovation of Existing Housing Which is Affected by Urban Traffic Noise

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Abstract. This paper analyzes and puts forward the key technical points for compiling the standard of sound insulation renovation in existing residences, considering that there is no targeted standard yet in china. On the aspect of sound insulation control index, it should be designed based on Code for design of sound insulation of civil buildings GB50118-2010. On the aspect of safety and usability of project implementation, key points of the content and process of sound insulation renovation, requirements of survey and inspection, construction, acceptance and post occupancy evaluation(POE) were analyzed emphatically and the corresponding suggestions for standards compilation were proposed. Several existing residences which were influenced by traffic noise of aircraft, elevated road and railway were taken for application. The results of follow-up investigation and onsite monitoring indicate that the proposed research results can well regulate and guide the implementation of sound insulation renovation projects. The research can provide a reference for the standard compilation of sound insulation renovation of existing housing.

1. Introduction

Traffic noise is becoming one of the most prominent environmental problems with the rapid growth of city traffic construction. The monitoring results of functional areas acoustic environment in 309 prefecture-level or above cities show that approximately 7.8% day monitoring point-times and 26% night monitoring point-times noise level are exceeded in 2016[1]. Moreover, noise levels in the vicinity of traffic trunk lines such as airport, elevated road and railway are more excessive. Consequently, the control of urban traffic noises have become a critical issue, and the problems of noise control of existing residences around traffic trunk lines are urgent to solve especially. In addition, sound insulation renovation is an effective way to solve the problem of traffic noise pollution.

Many studies have investigated the traffic noise control technology such as railway environmental noise control[2], aircraft noise control strategies[3], sound insulation technologies[4-5] and soundproof products[6-9]. Besides technical standards for noise control have been formulated

comprehensively in china, which mainly focused on acoustic environment quality evaluation[10-11], noise monitoring methods[12-13], sound insulation design of residential building[14], and soundproof components[15-16]. However, there is no specific technical standard for sound insulation renovation of existing residences in china[17].

Sound insulation renovation project of existing residences is a multi-disciplinary project involving the fields of environmental science, acoustics, architecture, civil engineering, sociology and so on, which has the characteristics of obvious contradiction, high social attention and high social sensitivity. Current standards mainly focus on acoustic noise level requirements, while ignoring the safety, durability, comfort. Furtherly, energy-saving reconstruction and old fitness retrofit haven't been considered basically.

In order to regulate and popularize the sound insulation renovation of existing residences, it is necessary to carry out the research on technical standards of sound insulation renovation of existing residences and to analysis its key technical difficulties. The standard not only specifies the requirements of acoustic environment quality after renovation, but also puts forward the requirements of construction safety and relevant provisions of whole process management. Therefore, the objective of this study is to analyze the key technical issues of sound insulation renovation for existing residences, and to provide a technical reference to standard compilation.

2. Research on the key technical issues for compiling the standard of sound insulation renovation

On the basis of sound insulation design, the standard should also provide relevant requirements of implementation and management from the perspective of safety and usability.

2.1. Implementation content and process

According to engineering practice experience and investigation, sound insulation renovation management should include five processes, including acoustic environment noise monitor, survey and inspection, program design, implementation, acceptance and *POE*. Diagram of implementation process of sound insulation renovation for existing residence is showed in figure 1.

- Acoustic environment noise monitor: acoustic environment noise and indoor noise level of noise-sensitive buildings should be monitored strictly accordance with the relevant technical standards according to different characteristics of traffic noises.
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- Survey and inspection: basic knowledge of the existing residence should be acquainted, and damaged condition should be diagnosed.
- Program design of sound insulation renovation: the implementation contents need to be determined, and parameters of soundproof components should be determined appropriately according to the monitoring values of outdoor-indoor noise levels
- Implementation of sound insulation renovation: construction should be carried out based on designed program, including production and installation of soundproof windows and doors, reinforcement or renovation of roofing, balcony and wall, and others such as repairation of facade, remediation of residential environment.
- Acceptance and *POE*: completion acceptance and *POE* should select typical houses to monitor their indoor and outdoor noise levels, besides of launching resident interviews, resident questionnaires and seminars.

2.2. Sound insulation index control standard

Acoustic environment quality requirements, sound insulation evaluation criteria and test method have

been clearly defined in current technical standards. Table 1 shows the allowed noise level limits of bedroom and living room. So in the standard of sound insulation renovation of existing residences, it only need to put forward the principle of noise control target design , that is to say, noise control objective should be designed reasonably according to noise source characteristic, outdoor acoustic environment quality and housing features.

- For indoor allowed noise level, it should be designed based on GB50118-2010.
- For the evaluation criteria of components for sound insulation renovation, it suggest to be designed by following the principle of equal sound insulation index[18].

Main soundproof components' evaluation criterias including facade windows, doors, balcony railing and walls are showed in Table 2. Among it, R_w is refers to weighter sound reduction index, C is refers to pink noise spectrum adaptaion term, C_{tr} is refers to traffic nosie spectrum adaptation term.

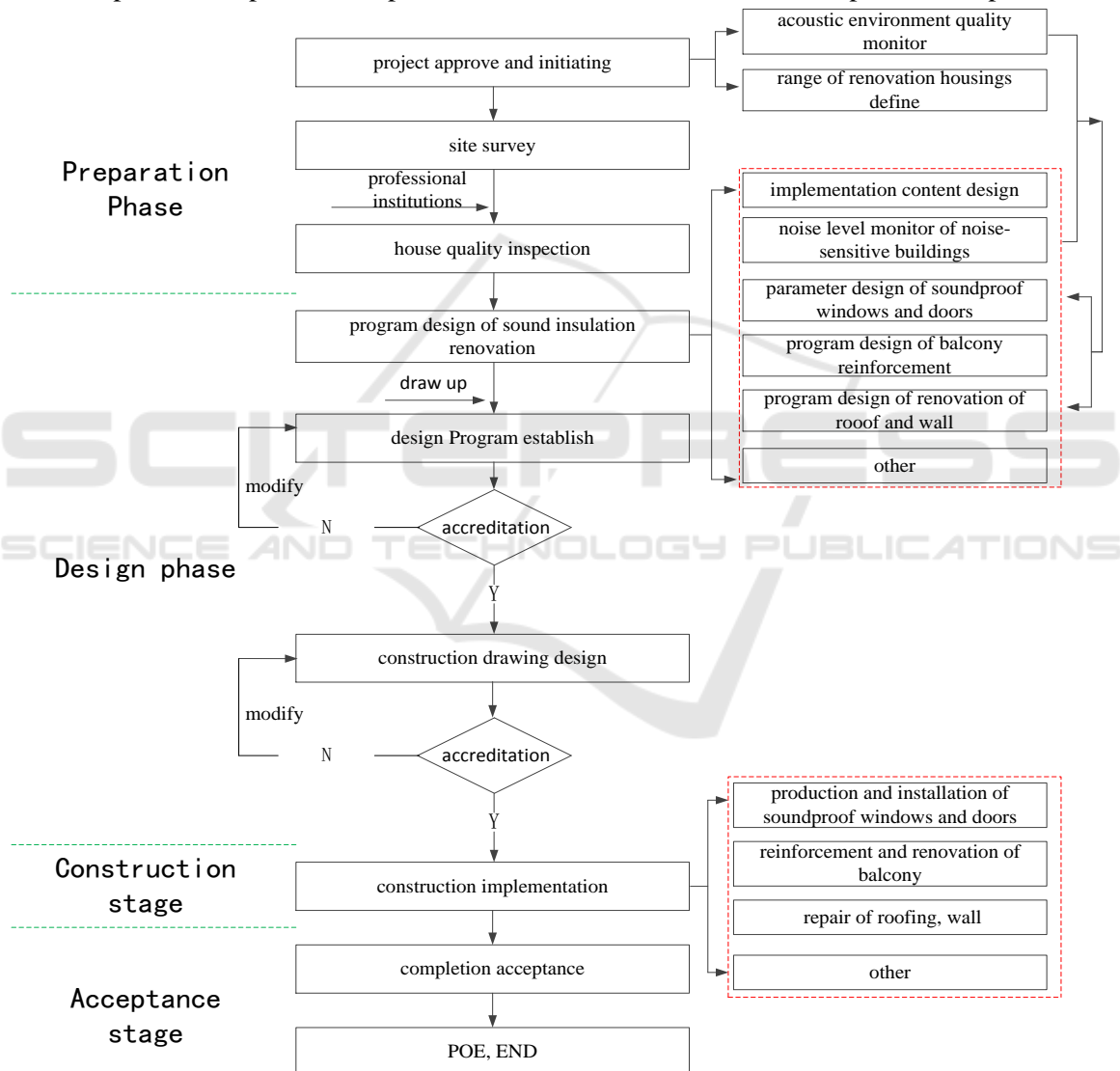


Figure 1. Diagram of implementation process of sound insulation renovation.

Table 1. Allowed noise level of bedroom and living room(unit:dB(A)).

room type	common residence		high standard residence	
	day-time	night-time	day-time	night-time
bedroom	≤45	≤37	≤40	≤30
living room(hall)	≤45		≤40	

Table 2. Evaluation criteria of components for sound insulation renovation(unit:dB(A)).

room type	sound insulation evaluation criteria of components	
bedroom window	R_w+C_{tr}	≥30
living room(hall) window		
kitchen window	R_w+C_{tr}	≥25
bathroom window		
facades, balcony railing	R_w+C_{tr}	≥45
doors or windows facing the corridor or aisle	R_w+C	≥25

2.3. Survey and inspection

Onsite survey is an indispensable part for sound insulation renovation of existing residences. On the one hand, basic knowledge of the existing residences could be acquainted through site survey, such as the numbers, structural forms and using condition of windows and doors, damage state of balconys enclosure. On the other hand, illegal affairs including illegal construction and changing of the use purpose of house could be checked and recorded. In addition, a template of onsite survey report or record sheet should be provided in the standard.

According to investigation, house quality inspection is often ignored in the project of sound insulation renovation of existing residences. In particular, increasing loads caused by sound insulation renovation of windows may cause insufficient capacity of the balcony, which may trigger a safety accident in future. Hence it is necessary to stipulate the sampling laws of house inspecting or balcony special-inspecting. Also the contents, implementation requirements, structural calculation requirements and precautions of house safety inspection should specified in standard.

In particular, it is obligatory to dispose the security risks timely and promptly when serious security risks are found during survey and inspection.

2.4. Implementation of sound insulation

Sound insulation renovation of existing residences is generally applied by the characteristic of "house with people living in it", in accordance with the principle of "construction based on program, safe and reliable, orderly organization, minimum intervention". Also implementation process is required to minimize the interference of residents' normal life. Meanwhile, implementation process should be pay attention to the manufacture and installation quality of soundproof components such as doors and windows with normative, safety and assurance. The standard should provide key points by following:

1) Materials, fittings and equipments used should comply with the relevant standards, and soundproof doors and windows shall be subject to sampling inspection as required.

2) Soundproof windows and doors should be factory-made, instead of being produced on site. Also transportation, storage should avoid high temperature and humidity environment.

3) During the installation of soundproof doors and windows, the expansion joints between the doors or windows should be filled with sound-insulating materials such as sealant or cement mortar.

In addition, when it is required to carry out the reinforcement of balcony, the reinforcement method should be chosen reasonably based on the structural type of balcony, damage degree and construction conditions. Superimposed plate method, simply supported method, diagonal pull rod method, chisel (groove) reinforcement method are ordinary methods of balcony reinforcement. For slab balcony and beam balcony, reinforcement method chosen should be different[19-20], and the materials used and planting operations should meet the technical requirements of relevant standards. Structure safety monitoring of balcony should be carried out if necessary.

2.5. Acceptance and *POE* for sound insulation

It's found that there is no specific technical standard for the completion acceptance of sound insulation renovation project of existing residences. Generally, it is in accordance with relevant current codes such as DBJ15-30, DBJ13-35, GB50550 and other construction standards.

Sound insulation renovation is different from the general renovation or improvement projects. Apart from the above acceptance standards, it should be carried out sampling monitoring of indoor and outdoor noise levels, of which sampling houses should be chosen in random and sampling number should be determined according to the actual situation.

The application of *POE* in sound insulation renovation project of existing residences can help to find the existing problems and further practical experience summarization, and provide accumulating data or feedback information for subsequent project. However, application of *POE* in sound insulation renovation project is still on a preliminary exploration stage currently. Reference[21] takes the existing residence sound insulation renovation project in the vicinity of an airport in Shanghai as an example to analyze the basic requirements and implementation flow of *POE* application. Therefore, the standard should be involved the provisions of content, implementation process and data requirement of *POE* assessment.

3. Study cases: application to sound insulation renovation projects

According to different types of traffic noise, some existing housings nearby and influenced by Shanghai hongqiao airport, Shanghai central elevated road and Shanghai south railway station are selected respectively. Based on the above research, renovation is implemented in order as shown in Figure 1, and indoor and outdoor noise levels are monitored.

It's found that the application houses are all six-story brick masonry houses, which are built between 1980~1995, and with the features of 240mm thick brick walls, 60~80mm thick concrete slabs of balcony with painting outside. Moreover, the facade windows are multifarious and great different of damage state, including steel window, wooden window, plastic window and aluminum window. House quality inspection finds that some balconies are lack of capacity when taking into account structural safety and sound insulation requirements, so reinforcement of slab balconies is put before installation of soundproof windows [19]. Design of sound insulation control indexes and soundproof components are based on the test results of indoor and outdoor noise level. For example, soundproof windows using in bedroom or balcony are all 40dB or above of R_w with double-glazed windows. Besides, the facade and community environment are repaired in the same time. Figure 2 shows the comparison between before and after by sound insulation renovation. Among it, picture(a),(b),(c) is the initial situation, and picture(d),(e),(f) is the status after renovation correspondingly.



Figure 2.Comparison between before and after retrofit of sound insulation renovation.

AWA6228+ multi-function sound level meter is used in monitoring of indoor and outdoor noise level both before and after the renovation. Figure 3 shows the scene of noise monitor onsite. Factors as hour equivalent continuous A-level L_{eq} , day-time equivalent sound level L_d , night-time equivalent sound level L_n are measured. The monitor results of the existing residences' sound insulation indexes before and after in three types of traffic noise are showed in table 3.



Figure 3. Implementation of noise monitor onsite.

From the monitor datas, it can be found that the noise levels of outdoor acoustic environment are similar for both before and after, which both exceed the limits of the functional area's noise level. The indoor noise levels of the tested rooms after renovation are lower than the national regulatory requirements. The sound insulation indexes of the houses after renovation are all significantly improved compared with that before. The values of sound insulation indexes of the monitor points are almost increased by 4.6dB~19.6dB. But there is a difference between different conditions, which is mainly due to the different types and damage conditions of the exterior envelope components. For example, test results show that the improvement of sound insulation index of the two test points influenced by aircraft noise is about 12dB differ because of their different type of windows using in initial, that is to say, the sound insulation index of room 603 which is of steel windows is about 16dB before renovation, while room 601 which is of aluminum windows is about 24dB before renovation.

Table 3. Test results of indoor and outdoor noise levels before and after renovation.

types of traffic		aircraft noise				viaduct noise				railway noise	
test location		room 601		room 603		room 201		room 601		room 404	
estimating parameters		L_d	L_n	L_d	L_n	L_d	L_n	L_d	L_n	L_d	L_n
before	outdoor	67.1	55.5	72.7	69.1	72.9	67.1	76.3	69.7	68.1	62.9
	indoor	42.8	31.8	56.9	53.1	51.7	42.7	51.2	44.8	50.2	46.4
	difference	24.3	23.7	15.8	16	21.2	24.4	25.1	24.9	17.9	16.5
after	outdoor	66.2	59.0	72.8	68.8	69.4	64.4	69.7	63.6	64.8	62.5
	indoor	36.3	26.6	38.2	33.2	39.1	26.6	32.9	25.0	42.3	35.8
	difference	29.9	32.4	34.6	35.6	30.3	37.8	36.8	38.6	22.5	26.7

4. Conclusions

Traffic noise is becoming one of the most prominent environmental problems with the rapid growth of city traffic construction. Sound insulation renovation is one important way to solve the problem of traffic noise pollution effectively, while there is no specific standard yet in china. This paper analyzes the key technical issues for compiling the standard of sound insulation renovation of existing residences, and puts forward some suggests including design principles of sound insulation control indexes, safety and usability requirements of project implementation. Ulteriorly, several existing residences which are influenced by traffic noises of aircraft, elevated road and railway are taken as application objects. It's verified that the research is effective by follow-up investigation and onsite monitoring. This paper can provide a reference for the standard compilation of sound insulation renovation of existing housing.

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