Dependency of noise level indicators on the heating power of rooftop boiler room

A Plotnikov¹, T Zhilina¹

¹Institute of Civil Engineering, Tyumen Industrial University, Volodarskogo Street, 38, Tyumen, 625000, Russia

E-mail: plotnikovas@tyuiu.ru

Abstract. The paper presents results of practical measurements and results of data processing of the noise level from rooftop boiler rooms used in monolithic framed buildings. Three types of rooftop boiler rooms with power of N=0.8 MW; N=1.0 MW; and N=1.2 MW were used for data recording and analysis with further obtaining of dependencies regarding various levels of their heating efficiency. A distinctive feature of monolithic framed house building is a stiffening core formed of staircase and elevator section. The basic load-bearing capacity of the frame is provided by the joint work of metal reinforcement (metal) and elements made from concrete. During observation of operating boiler rooms noise measurements were carried out in order to collect and analyze information characterizing operation mode of rooftop gas boiler house under various climatic conditions per heating period. Based on the obtained dependencies it is possible to predict future noise levels from boiler rooms while designing further territory development. Authors supplement the existing method to evaluate noise pollution of the city districts. Result of experiment and application of the obtained dependencies is predicting of harmful physical factors occurrence at different levels of heating efficiency with further reduction of negative impacts on building structures; predicting noise levels while noise mapping of the territories under development; increasing comfort of living. The given conclusions can be applicable for further modeling of noise transmission into the environment.

Keywords: noise, noise maps, noise prediction, independent heat supply sources, boiler room facilities, analytical dependencies

1. Introduction

Urban development in Russia determines high level of urban growth, increasing housing density and rising average noise level.

Acoustic comfort inside the buildings and on the surrounding territories relies upon the indicators combining both noises from external and internal sources. In order to evaluate the indicators of noise radiated from rooftop boiler rooms under various environmental conditions and transmission of acoustic energy into the environment during heating period one needs predictive methods for selection of optimal solutions in choosing building structures and noise mapping of the territories under development. The issue of capital investment into construction and installation works has always been relevant. Climatic aspects of regions for construction in our country [1,2] determine
application of rational methods in construction industry. The advantages of using rooftop boiler rooms include decreased heat losses during heat carrier transportation, the minimum losses in “quality” of temperature chart and lowering of expenditures for heating. The necessity of noise mapping of the city districts (both existing and the ones planned for development) can be referred to its drawbacks [18]. Evaluation of each of the separate noise source takes long time, thus requiring significant time expenditures during estimation of residential areas of various scopes. Detection of noise level dependency on the productive power of boiler room is an opportunity to predict the noise level. Authors consider that performance analysis of operating independent heat supply sources is the key to predict development of areas being favorable for construction.

The paper aims to evaluate the noise indicators from engineering equipment on the territory of the city as a condition of steady noise in different periods.

2. Materials and Methods
Theoretical foundation for the study includes acoustic laws, and laws of the nature of sound and vibration, the known research works on acoustics and noise distribution in residential and industrial buildings, noise evaluation methods from street and road network in urban development, statistical data processing techniques and methods to record the noise level by measuring equipment [6, 9, 10, 11].

Evaluation of ambient noise level in urban development is a multivariable process including accumulation of various kinds of information. The intensity of traffic in street and road network, presence of detached linear and local noise sources are being evaluated upon multiple variables, which complicates participatory rapid noise assessment of existing and designed territories. Noise evaluation of boiler room facilities requires performing noise measurements, conducting calculations on noise generation from equipment and sound spectral overlap. The noise sources from equipment are rotating mechanisms, flow pulsations in the elements of air channels and liquids in the pipes. During urban development planning of future territories the level of reliable estimate of future noise pollution from rooftop boiler rooms should be based on the dependencies obtained while observation and recording of indicators in operating boiler rooms.

3. Experiment
Indicators of equivalent continuous sound level were recorded on three independent heat sources – rooftop boiler rooms with power of \( N = 0.8-1.2 \text{ MW} \). Sound level meter ASSISTANT TOTAL was used for data recording. The basic noise sources in boiler rooms are [3]: circulating-water and booster pumps, burner units, moving of heat carrier along the pipelines, operating peculiarities of boiler plants. These boiler rooms are equipped with burner units CIB UNIGAS [7]. These burner units are marked by correspondence of the noise level during operation with the requirements of national standards [4, 5, 6]. The noise level was recorded in four various climatic seasons, as independent sources work to cover the needs in heat carrier heating for hot water and heat supply. During observation of boiler rooms [8] the level of heating efficiency was recorded in percentage ratio regarding the maximum possible efficiency taken as 100%.

For replication of the obtained data on actual measurements the methods of physical similarity theory were applied. Regression equation is presented by a second degree polynomial and is given as (1)

\[
y = 0.1548x + 70.333
\]  

(1)

Determination coefficients of regression equations of the obtained dependencies are \( R^2 = 0.98 \). Reproducibility of experimental data was proved by Cochran’s Test. Regression equation obtained during experiment to define the design noise level while determining dependencies of operation of various kinds of rooftop boiler rooms with power of \( N = 0.8–1.2 \text{ MW} \). The obtained data can be found in Tables 1-3.
Table 1. Boiler room No.1, power $N = 0.8$ MW

| Recorded acoustic load, $L$ [dBA] | Acoustic load obtained from regression equation, $L$ [dBA] | Discrepancy between the actual and predicted acoustic loads, % | Heating efficiency of boiler room, % |
|-----------------------------------|----------------------------------------------------------|---------------------------------------------------------------|-----------------------------------|
| 72                                | 71.88                                                    | -0.17                                                         | 10                                |
| 74                                | 73.43                                                    | -0.78                                                         | 20                                |
| 75                                | 74.98                                                    | -0.03                                                         | 30                                |
| 77                                | 76.53                                                    | -0.62                                                         | 40                                |
| 77                                | 78.07                                                    | 1.37                                                          | 50                                |
| 79                                | 79.62                                                    | 0.78                                                          | 60                                |
| 81.5                              | 81.17                                                    | -0.41                                                         | 70                                |
| 82                                | 82.72                                                    | 0.87                                                          | 80                                |
| 84                                | 84.27                                                    | 0.31                                                          | 90                                |
| 87                                | 85.81                                                    | -1.38                                                         | 100                               |

Table 2. Boiler room No.2, power $N = 1.0$ MW

| Recorded acoustic load, $L$ [dBA] | Acoustic load obtained from regression equation, $L$ [dBA] | Discrepancy between the actual and predicted acoustic loads, % | Heating efficiency of boiler room, % |
|-----------------------------------|----------------------------------------------------------|---------------------------------------------------------------|-----------------------------------|
| 71                                | 71.88                                                    | 1.23                                                          | 10                                |
| 74                                | 73.43                                                    | -0.78                                                         | 20                                |
| 75                                | 74.98                                                    | -0.03                                                         | 30                                |
| 77                                | 76.53                                                    | -0.62                                                         | 40                                |
| 77                                | 78.07                                                    | 1.37                                                          | 50                                |
| 80                                | 79.62                                                    | -0.48                                                         | 60                                |
| 82                                | 81.17                                                    | -1.02                                                         | 70                                |
| 82                                | 82.72                                                    | 0.87                                                          | 80                                |
| 84                                | 84.27                                                    | 0.31                                                          | 90                                |
| 88                                | 85.81                                                    | -2.55                                                         | 100                               |

Table 3. Boiler room No.3, power $N = 1.2$ MW

| Recorded acoustic load, $L$ [dBA] | Acoustic load obtained from regression equation, $L$ [dBA] | Discrepancy between the actual and predicted acoustic loads, % | Heating efficiency of boiler room, % |
|-----------------------------------|----------------------------------------------------------|---------------------------------------------------------------|-----------------------------------|
| 69                                | 71.88                                                    | 4.01                                                          | 10                                |
| 72                                | 73.43                                                    | 1.95                                                          | 20                                |
| 73                                | 74.98                                                    | 2.64                                                          | 30                                |
| 75                                | 76.53                                                    | 1.99                                                          | 40                                |
| 75                                | 78.07                                                    | 3.94                                                          | 50                                |
| 78                                | 79.62                                                    | 2.04                                                          | 60                                |
| 80                                | 81.17                                                    | 1.44                                                          | 70                                |
| 81                                | 82.72                                                    | 2.08                                                          | 80                                |
| 83                                | 84.27                                                    | 1.50                                                          | 90                                |
| 86                                | 85.81                                                    | -0.22                                                         | 100                               |
Resulting from the obtained regression equation a diagram was built (Figure 1), describing the relation of actual measurements of the noise level [12, 13, 14] and the results received empirically. These values lie within the 5% discrepancy interval. Reproducibility of results has the accuracy of 0.98.

![Analytical dependencies of noise indicators on heating efficiency](image)

Figure 1. Analytical dependencies of noise indicators on heating efficiency

4. Conclusions
The findings of this study can be understood as:

- analysis of noise parameters of existing independent heat supply sources enables obtaining valuable analytical dependencies with accuracy of 0.98 and maximum deviation of no more than 5;
- the obtained regression equation is applicable for predicting noise level from rooftop boiler rooms during noise mapping of the territories under development;
- accuracy of obtained results is applicable to technically similar rooftop boiler rooms.

The given conclusions can be applicable for further modeling of noise transmission into the environment [15,16,17].

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