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SOUND REDUCTION EFFECTS OF PLASTERED ROCK WOOL SLAB FAÇADE THERMAL INSULATION SYSTEMS (I)

BY

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Abstract. Insulating the exterior walls subsequently is one of the most important tasks at energy efficient modernization of old buildings. Depending on their material and structural design, the new layers can increase or decrease the sound reduction ability of the original supporting wall. If due attention is given for the protection against noise during the design, the plastered rock wool (RW) slab façade thermal insulation systems can result better sound insulation performance for the exterior walls in some cases, so they can increase the acoustic comfort in the rooms of buildings exposed to exterior ambient noise (coming usually from road transport). On the basis of the relevant features of the components of the complete outer wall, with the available detailed calculation method, the paper defines how the weighted sound reduction index of the original supporting wall can change, considered also the spectrum adaptation term suitable for road traffic noise. With help of praxis oriented characteristic structural parameters, it examines the options of the acoustic optimization, and the values of $\Delta(R_w + C_{tr,50...5,000})$ which are available during energy and noise conscious construct.

The first section describes the acoustic model, the calculation method, and the modifying effect under standard conditions. The second part will analyse the acoustic role of each ingredient, and the changes of the sound reduction at characteristic structural solutions.

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All formulas presented in this paper were developed by L. Weber in a semiempirical model based on a large number of measurements in building acoustic laboratories (Weber, 2013). The eqs. adopted in the paper lean on this source, however, modify the original relations somewhat.

Key words: building structure; exterior wall; façade heat insulation; rock wool slab; protection against noise; sound insulation; sound reduction.

1. Introduction

If a plastered rock wool (RW) slab thermal insulation system is built on the outside of an originally single leaf massive wall, a double leaf dual-mass structure is produced in acoustic sense: the new façade plaster gives the one (smaller) mass, the old supporting wall the other (the much larger). Between the two mass there is the new RW slab insulation, which acts as a spring in the oscillating system,

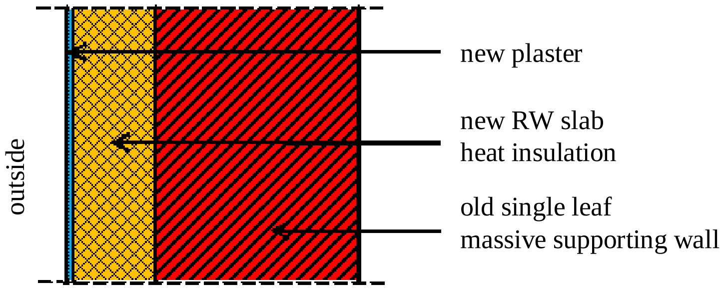


Fig. 1 – Simplified build-up of an originally single leaf massive external wall provided with plastered RW slab thermal insulation system.

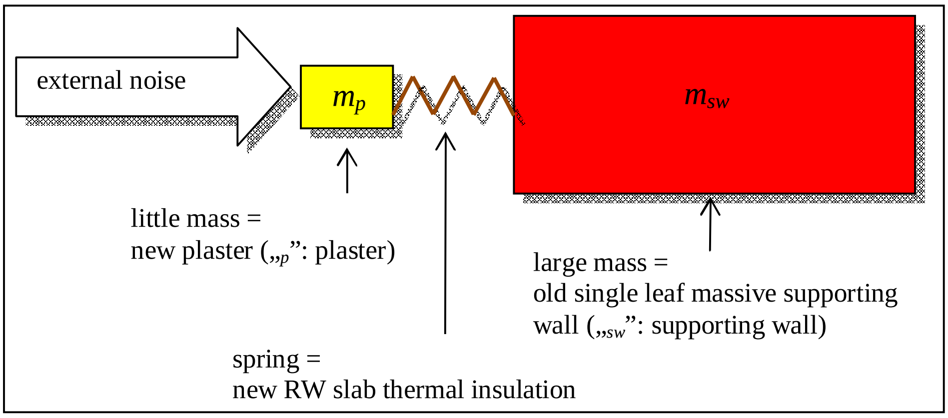


Fig. 2 – Mass-spring-mass model of an originally single leaf massive external wall provided with plastered RW slab thermal insulation system.

so an external wall operating on principle of mass-spring-mass is created in terms of sound reduction (Figs. 1 and 2) (Cziesielski & Vogdt, 2007; Metzen, 2003).

2. Calculation Method of Sound Reduction Consequences of Plastered RW Slab Thermal Insulation Systems

The following components affect the sound reduction of the renewed entire structure at massive façade walls provided with plastered RW slab thermal insulation systems: the RW slab; the plaster for the RW slab; the plug anchors for the RW slab; the adhesive mortal for the RW slab; the supporting wall (Figs. 3 and 4).

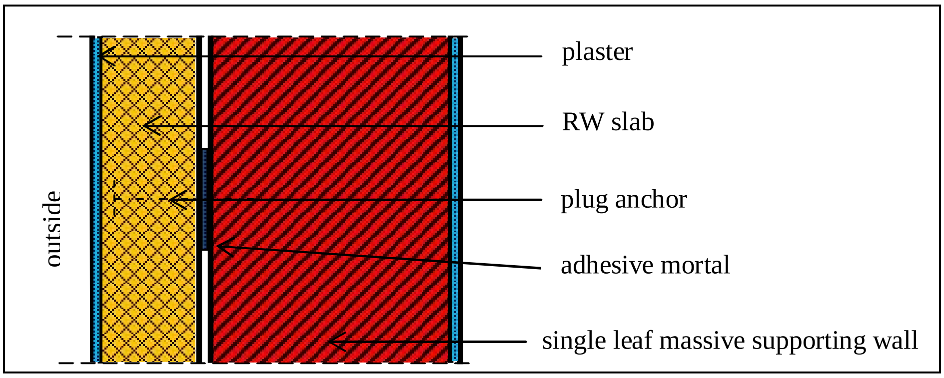


Fig. 3 – Detailed build-up of an originally single leaf massive external wall provided with plastered RW slab thermal insulation system I. (Kocsis, 2010)

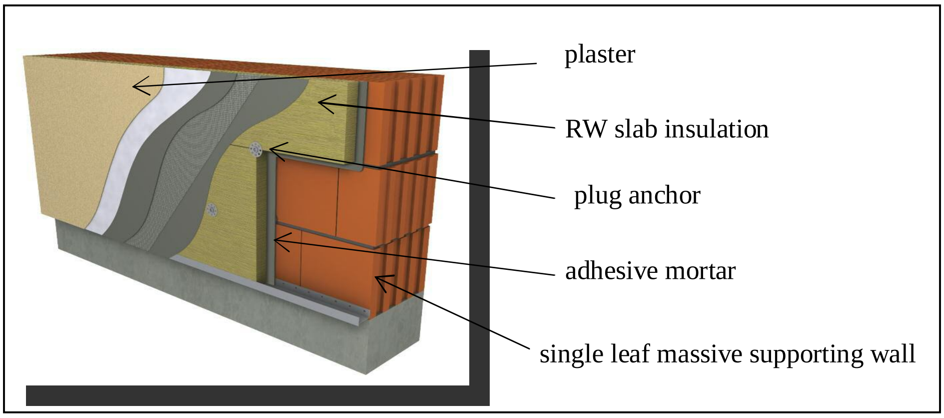


Fig. 4 – Detailed build-up of an originally single leaf massive external wall provided with plastered RW slab thermal insulation system II. (MÉSZ, 2012).

By reason of the acoustic properties and impacts of the components of the complete outer wall, with the available detailed calculation method, it can be estimated how the follow-up plastered RW slab thermal insulation system changes the weighted sound reduction index of the original supporting wall, R_w, considered also the spectrum adaptation term, C_{tr} (which is suitable for road traffic noise). Measurements revealed that the $R_w + C_{tr,50\text{-}5000}$ value (concerning the frequency-domain of 50...5,000 Hz) is most suitable to qualify the sound reduction at exterior walls of such construction, because it is the nearest to the characteristics of human hearing. If the spectrum adaptation term would not be determined, the R_w itself could overvalue the acoustic performance of the modernized wall significantly. According to measurements, the overestimate could achieve approx. 10...23 dB in the lower (approx. 50...125 Hz) resonance frequency domain, which usually characterizes the plastered RW slab thermal insulation systems.

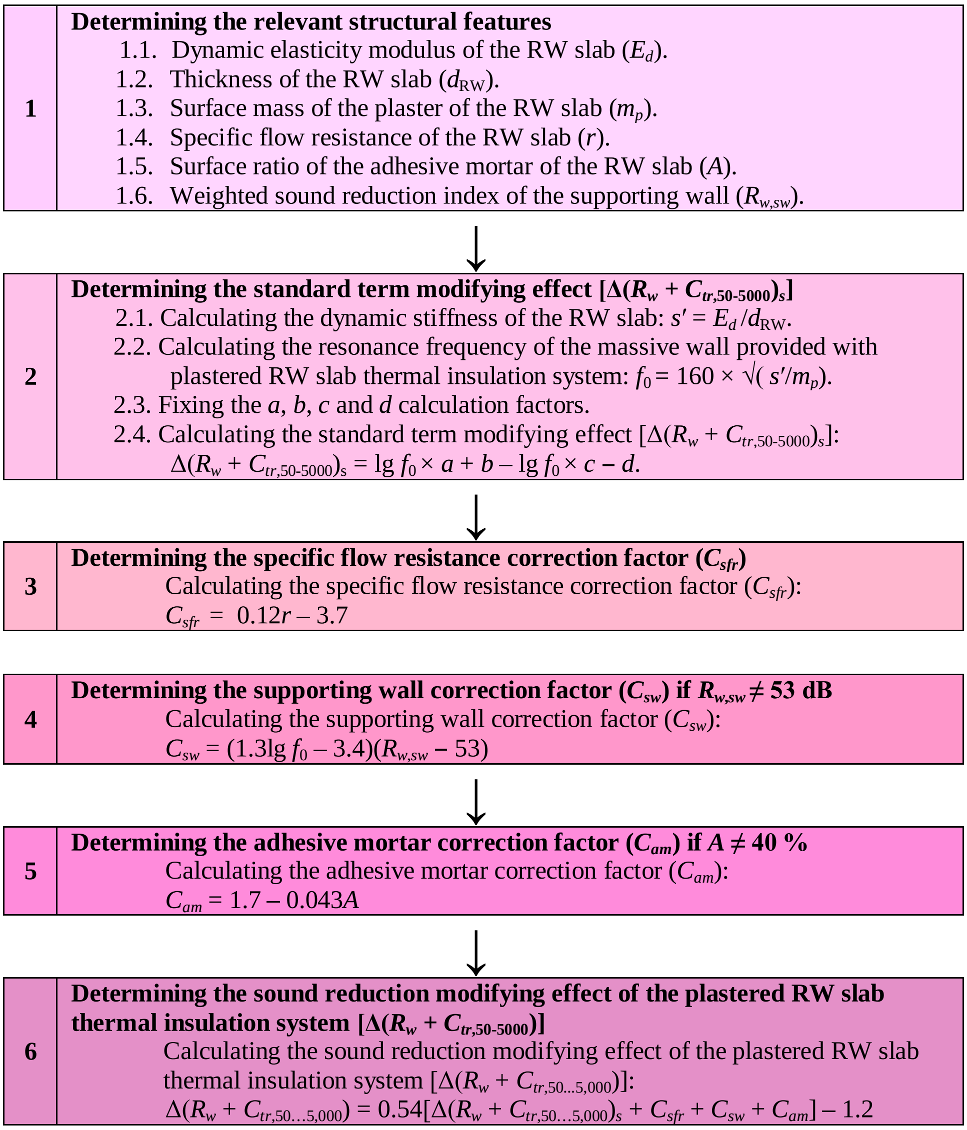
It must be also considered during the application of the process that its accuracy is ±2.2 dB (namely the standard deviation of the differences between the measured and the counted data has such a value; the mean of the differences is equal to zero). The method was developed by L. Weber in a semiempirical model based on a large number of measurements in building acoustic laboratories. The eqs. adopted in the paper lean on this source, however, modify the original relations somewhat (Weber, 2005, 2013; Weber & Brandstetter, 2004).

Due to universal nature of the calculation procedure, its essence is that the sound reduction modifying effect of the insulation system is determined first with standard conditions (with the lack of the effect of the specific flow resistance of the RW slab, with 53 dB weighted sound reduction index of the supporting wall, with 40% bonding surface ratio, without plug anchors). According to the real state, this must then be modified with correction factors and arithmetic method to consider also the acoustic roles which spring from specific flow resistance of the RW slab, from possibly from the standard different supporting wall and adhesive mortar, as well as from required plug anchors:

$$\Delta(R_w + C_{tr,50\ldots5,000}) = 0.54 \times [\Delta(R_w + C_{tr,50\ldots5,000})_s + C_{sfr} + C_{sw} + C_{am}] - 1.2, \quad (1)$$

where: $\Delta(R_w + C_{tr,50\ldots5,000})$ is the modifying effect of the plastered RW slab thermal insulation system for the weighted sound reduction index of the single leaf massive supporting wall, with considering the $C_{tr,50\ldots5,000}$ spectrum adaptation term, in dB; $\Delta(R_w + C_{tr,50\ldots5,000})_s$ – the modifying effect of the plastered RW slab thermal insulation system for the weighted sound reduction index of the single leaf massive supporting wall, with considering the $C_{tr,50\ldots5,000}$ spectrum adaptation term, with standard (“$_s$”) conditions (with the lack of the effect of the specific flow resistance of the RW slab, with 53 dB weighted sound reduction index of the supporting wall, with 40% bonding surface ratio, without plug anchors), in dB; C_{sfr} – the specific flow resistance correction factor, in dB (C – correction factor, “$_{sfr}$”: specific flow resistance); C_{sw} – the supporting wall correction factor, in dB (“$_{sw}$”: supporting wall); C_{am} – the adhesive mortar correction factor, in dB (“$_{am}$”: adhesive mortar).

Fig. 5 shows what tasks must be performed in the calculation process to determine the $\Delta(R_w + C_{tr,50...5,000})$ sound reduction effect of a plastered RW slab façade thermal insulation system.



1 **Determining the relevant structural features**

1.1. Dynamic elasticity modulus of the RW slab (E_d).
1.2. Thickness of the RW slab (d_{RW}).
1.3. Surface mass of the plaster of the RW slab (m_p).
1.4. Specific flow resistance of the RW slab (r).
1.5. Surface ratio of the adhesive mortar of the RW slab (A).
1.6. Weighted sound reduction index of the supporting wall ($R_{w,sw}$).

2 **Determining the standard term modifying effect [$\Delta(R_w + C_{tr,50\text{-}5000})_s$]**

2.1. Calculating the dynamic stiffness of the RW slab: $s' = E_d / d_{\mathrm{RW}}$.
2.2. Calculating the resonance frequency of the massive wall provided with plastered RW slab thermal insulation system: $f_0 = 160 \times \sqrt{(s'/m_p)}$.
2.3. Fixing the a, b, c and d calculation factors.
2.4. Calculating the standard term modifying effect [$\Delta(R_w + C_{tr,50\text{-}5000})_s$]:
$\Delta(R_w + C_{tr,50\text{-}5000})_s = \lg f_0 \times a + b - \lg f_0 \times c - d$.

3 **Determining the specific flow resistance correction factor (C_{sfr})**

Calculating the specific flow resistance correction factor (C_{sfr}):
$C_{sfr} = 0.12r - 3.7$

4 **Determining the supporting wall correction factor (C_{sw}) if $R_{w,sw} \neq 53$ dB**

Calculating the supporting wall correction factor (C_{sw}):
$C_{sw} = (1.3\lg f_0 - 3.4)(R_{w,sw} - 53)$

5 **Determining the adhesive mortar correction factor (C_{am}) if $A \neq 40$ %**

Calculating the adhesive mortar correction factor (C_{am}):
$C_{am} = 1.7 - 0.043A$

6 **Determining the sound reduction modifying effect of the plastered RW slab thermal insulation system [$\Delta(R_w + C_{tr,50\text{-}5000})$]**

Calculating the sound reduction modifying effect of the plastered RW slab thermal insulation system [$\Delta(R_w + C_{tr,50...5,000})$]:
$\Delta(R_w + C_{tr,50...5,000}) = 0.54[\Delta(R_w + C_{tr,50...5,000})_s + C_{sfr} + C_{sw} + C_{am}] - 1.2$

Fig. 5 – Detailed counting algorithm of the sound reduction effect of a plastered RW slab thermal insulation system.

3. Sound Reduction Modifying Effects of Plastered RW Slab Thermal Insulation Systems with Standard Terms

The basic element of the estimation procedure is determining the sound reduction modifying effect of the plastered RW slab thermal insulation system with standard terms. Due to universal design of the method (it is suitable for manifold thermal insulation systems), the initial state is that

a) the influencing role of the specific flow resistance of the RW slab is not taken into account (a specific flow resistance correction factor will ensure its counting in a later stage of the process);

b) the single leaf massive supporting wall has a weighted sound reduction index of 53 dB (otherwise a supporting wall correction factor have to be applied);

c) bonding of the insulation expands to 40% of its surface related to the wall (if greater chemical fixation is prepared, it can then be calculated with help of the adhesive mortar correction factor, according to the real structural solution);

d) the effect of the plug anchors fixing the RW slab is not included (the assessment system will take this into account on arithmetic method).

The following relationship can be applied to determine the $\Delta(R_w + C_{tr,50...5,000})_s$ value:

$$\Delta(R_w + C_{tr,50...5,000})_s = \lg f_0 \times a + b - \lg f_0 \times c - d, \qquad (2)$$

where: $\Delta(R_w + C_{tr,50...5,000})_s$ is the modifying effect of the plastered RW slab thermal insulation system for the weighted sound reduction index of the single leaf massive supporting wall, with considering the $C_{tr,50\text{-}5000}$ spectrum adaptation term, with standard (“$_s$”) conditions (with the lack of the effect of the specific flow resistance of the RW slab, with 53 dB weighted sound reduction index of the supporting wall, with 40% bonding surface ratio, without plug anchors), in dB; lg – the base -10 logarithm; f_0 – the resonant frequency of the external wall provided with plastered RW slab thermal insulation system, in Hz; *a*, *b*, *c*, *d* – calculation factor.

According to data of measurements, the dynamic elasticity moduli of the plasterable façade RW slabs fluctuate between E_d = 0.4 – 0.8 MN/m^2, and it can be calculated with 0.5 MN/m^2 as a characteristic average value (Weber, 2013) (the article does not examine the rock wool lamellas, which have vertically oriented fibers, *i.e.* ones perpendicular to the wall surface). From E_d and its thickness, it can be computed that its dynamic stiffness is s' = 3.13 – – 2.50 MN/m^3 if its latter dimension is 16...20 cm for the sake of an increased insulation (Table 1).

Table 1
Dynamic Stiffnesses (s′) of Plasterable RW Slab Façade Thermal Insulations if their Thicknesses are 16…20 cm

Type of the rock wool	Thickness of the rock wool (d_{RW})	
	16 cm	20 cm
	Dynamic stiffness of the rock wool (s')	
Plasterable RW slab	3.13 MN/m^3	2.50 MN/m^3

With knowledge of the dynamic stiffness of the RW slab and of the surface mass of its plaster (m_p), it can be determined that the resonance frequency moves between $f_0 = 54…90$ Hz if the rock wool is $d_{\mathrm{RW}} = 16…20$ cm thick with energy efficient design (so $s' = 3.13...2.50$ MN/m^3), and $m_p = 10...22$ kg/m^2 (this latter value of weight is a little typical of the present practice). From the data of the Table 2, in case of the material properties examined previously, it can be seen that the least value of $f_0 = 54$ Hz can be achieved with 20 cm RW slab and 22 kg/m^2 plaster, while the largest one with 10 kg/m^2 surface mass plaster and with 16 cm insulation thickness.

Table 2
Representative Values of Resonance Frequencies (f_0) of Massive Walls Provided with Plastered RW Slab Thermal Insulation Systems

No.	Dynamic stiffness of the RW slab (s')	Surface mass of the plaster of the RW slab (m_p)	
		10 kg/m^2	22 kg/m^2
		Resonance frequency of the wall (f_0)	
1	3.13 MN/m^3 (16 cm thick)	90 Hz	60 Hz
2	2.50 MN/m^3 (20 cm thick)	80 Hz	54 Hz

The a, b, c and d calculation factors are formed with constant character depending on band ranges of the resonance frequency, f_0 (Weber, 2013). In case of the structural parameters analyzed above (16...20 cm thick RW slab and 10...22 kg/m^2 plaster), the four calculation elements will assume the following values: $a = -45.5$ ($f_0 < 125$ Hz); $b = 98.1$ ($f_0 < 125$ Hz); $c = -57.1$ ($f_0 < 100$ Hz); $d = 120.0$ ($f_0 < 100$ Hz).

Based on the resonance frequency (f_0) and the a, b, c, d factors, it can be determined the modifying effect of the plastered RW slab thermal insulation system for the weighted sound reduction index of the single leaf massive supporting wall, with considering the $C_{tr,50...5,000}$ spectrum adaptation term, with standard conditions (Table 3).

From the data of the Table 3, it can be decided that the $\Delta(R_w + C_{tr,50...5,000})_s$ moves from –1.8 dB to 0.8 dB in narrow range if the f_0 value is formed between 54 Hz and 90 Hz. This means that the plastered insulation systems included in the calculation modify only less the weighted sound reduction index of the old supporting wall according to the standard conditions (with the lack of the effect of the specific flow resistance of the RW slab, with 53 dB weighted sound reduction index of the supporting wall, with 40% bonding surface ratio, without plug anchors).

Table 3

Representative Values of the $\Delta(R_w + C_{tr,50\ldots5,000})_s$ *in Case of* $f_0 = 54\ldots90$ Hz

No.	Resonance frequency (f_0), [Hz]	Thickness of the RW slab (d_{RW}), [cm]	Surface mass of the plaster (m_p), kg/m^2	$\Delta(R_w + C_{tr,50\ldots5,000})_s$, dB
1	54	20	22	–1.8
2	60	16	22	–1.3
3	80	20	10	0.2
4	90	16	10	0.8

Fig. 6 demonstrates how the $\Delta(R_w + C_{tr,50\ldots5,000})_s$ value is formed if the resonance frequency moves between 50...120 Hz (by 10 Hz): it grows with continuous increase from –2.2 dB to 1.4 dB (it reaches this by 100 Hz), and it declines with steep drop thence to –0.3 dB.

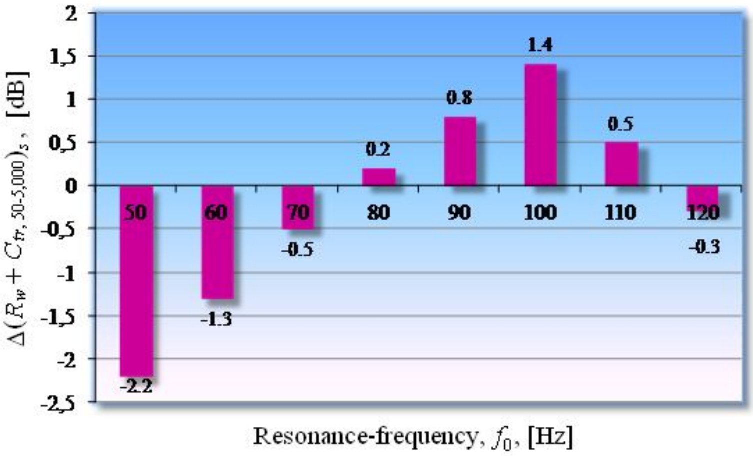


Fig. 6 – „$\Delta(R_w + C_{tr,50\text{-}5000})_s$” values if the resonance frequency moves between 50...120 Hz.

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EFECTELE DE REDUCERE A ZGOMOTULUI ALE SISTEMELOR DE IZOLARE TERMICĂ A FAŢADELOR ALCĂTUITE DIN PLĂCI DE VATĂ MINERALĂ (I)

(Rezumat)

Izolarea termică a pereților exteriori reprezintă o fază importantă în procesul de modernizare energetică eficientă a unei clădiri existente. În funcție de materialele utilizate şi de proiectarea structurii de rezistență, noile straturi puse în operă pot mări sau micşora capacitatea de izolare acustică a pereților existenți. Considerarea în faza de proiectare a utilizării plăcilor din vată minerală pentru izolarea termică a pereților exteriori poate avea ca rezultat o mărire a protecției la zgomot, mărindu-se astfel nivelul de confort acustic în cazul clădirilor expuse la zgomot ambiental exterior (provenit în mod normal din traficul rutier). Pe baza caracteristicilor straturilor componente ale peretelui exterior, utilizând o metodă disponibilă de calcul detaliat, lucrarea de față defineşte cum indicele de reducție sonoră al peretelui existent poate suferi schimbări, luând de asemenea în considerare factorul de corecție a spectrului caracteristic zgomotului rezultat din traficul rutier. Cu ajutorul parametrilor structurali caracteristici, sunt analizate opțiunile de optimizare acustică şi valorile pentru $\Delta(R_w + C_{\mathrm{tr},50...5,000})$.

Prima parte a lucrării descrie modelul acustic, metoda de calcul, precum şi efectul de modificare în cazul condițiilor standard. Cea de-a doua parte va analiza rolul acustic al fiecărui element şi schimbările reducerii zgomotului pentru soluțiile structurale caracteristice.

Toate formulele folosite în această lucrare au fost dezvoltate de L. Weber într-un model semiempiric bazat pe un număr mare de măsuratori efectuate în laboratoare acustice (Weber, 2013). Ecuațiile adoptate se bazează pe această sursă, modificând într-o anumită măsură relațiile originale.