ANNALS OF THE FACULTY OF ENGINEERING HUNEDOARA
2004, Tome II, Fascicole 3

THE APPLICATION OF LOW ENERGY BUILDING TECHNOLOGIES, PASSIVE VENTILATION AND DAY-LIGHTING IN ACOUSTICAL DESIGN

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1. INTRODUCTION

Environmental noise is a nuisance that cannot be overlooked, a follow up to the technological and technical development of the modern industrial age. It is an occurrence that is repeatedly perceived by the exposed population merely as a diminishing factor of the overall quality of urban environments. In order for noise factors to be properly regulated they have to be singled out and treated as distinct matters. But before that, they have to be perceived as such. Even the observable health effects, annoyance and sleep disturbance problems are not strong enough motives to raise the issue on the priority ladder. This especially applies to the developing countries, such as Serbia and Montenegro and neighboring Eastern European countries. The tendency to approach Western European standards dictates strict obedience of the international noise control standards and therefore deserves closer attention in time to come.

The 20th century witnessed a rapid development in various disciplines of applied acoustics with the intention of keeping up with the developing life standard, as well as bringing the musical experience on a level better conceived, understood and controlled. The question is whether a musical piece, once exposed to the audience, either through live performance or playback, can be perceived as a life standard parameter up to an extent. If the aesthetic qualities are put aside and critical listening favored before analytical listening, the significance that the quality of audio information imposes on the populace cannot be overlooked. This applies not only to audio professionals, musicians and audiophiles, but to the majority of population. Music is a form of artistic expression most widely consumed of all the art forms, principally because it doesn’t necessitate the level of competence in order to take pleasure in it. As an early music theoretician Herder denotes, music is an activity rather than an act of artistic expression, and we can engross ourselves in it without the need to understand its elements.

Before the musical information reaches the ears of the audience it undergoes certain modulations, primarily do to the coupling with the environment and other sound sources present in it. When subjected to live performance, the listener is exposed to the direct sound emerging from the performers, radiated sound as a consequence of room properties and background noise present in every environment. When joined together, these factors result in a certain quality that influences the psychological perception of the music. In other words, carefully designed listening environment will enhance the experience, while faulty design may prevent the audience to fully immerse itself in the listening process.

Not everybody attends music events, but most people are exposed to pre-recorded music through playback on a personal hi-fi system and FM receivers. Every recording, even the most sophisticated ones, contains a certain level of background noise that, during playback, adds up to the noise already present in the listening environment. Therefore, the aim of the recording studio design is to lower the noise levels without affecting the dynamics, sonic quality and spaciousness of sound.

2. OBJECTIVES

Under the circumstances, it is not likely that noise standards will be met in the Eastern European region in foreseeable future, so the advantages that the earth building materials propose to acoustic design cannot be sufficiently exercised and monitored. Finding a building contractor that is willing to tolerate additional expenses and apply experimental techniques, without being legally obliged to, can be a hideous task unlikely to provide results. For such reasons, it has been decided to focus on a design of an edifice that has high requirements for acoustical quality and low noise levels, and is likely to include additional assets to accomplish satisfactory results. This article discusses the problems that the presence of environmental, mechanical and structural noise poses to an everyday activity taking part at a work place, in this situation a highly specialized facility such as a recording studio.

The paper is intended to serve as a concept for a more detailed project that will evaluate the application of low energy building materials in different phases of studio design. For the time being, it seems appropriate to point out the stages which will be affected by this innovative, yet traditional construction technique, without quantifying the qualities. The reason lies in the multilayered approach that will involve numerous disciplines such as architectural design, noise abatement, energy flow analysis, material properties, ventilation issues, etc. Future articles will deal with each one of the stages in detail and hopefully come up with results that will compete with common acoustic treatment concepts and bring down the immense expenses normally encountered in such design.

Other sustainable building design methodologies, such as day-lighting and natural ventilation systems, encompass some of the similar technical solutions which should be summarized, evaluated and compromised to provide a more functional and cost effective building design approach. For example, ceiling design in both acoustic and natural ventilation systems incorporates false ceilings with free air space above them. In acoustic treatment, this space is regularly utilized to accomplish entrapment of unwanted frequency regions by means of bass traps, allowing at the same time more flexibility in shaping the ceiling in the desired style. In natural ventilation design, this cavity is used for channeling the air flow through the building from the air inlets to the outlets. Making a careful outline in the early planning stages can bring together the objectives of the two problems and help visualize a single solution that can be beneficial to both.

3. LOW ENERGY BUILDING MATERIALS AND CONSTRUCTION TECHNOLOGIES

The performance of a studio will depend on the decisions made at the initial design stages. The most beneficial situation occurs when building a studio from scratch and not executing acoustic improvements on an already existing structure. This will greatly influence the choice of the building material and the implementation method.

In the previous article (Krnjetin/Stojiljkovic/Grba: Energy and Earth Architecture. International conference on environmental problems of cities) the authors reviewed the most common earth construction technologies, which include un-stabilized, semi-stabilized and stabilized adobe blocks, rammed earth, cast earth and pise techniques. From an acoustical viewpoint, rammed earth construction, in combination with adobe blocks, has been evaluated as the most appropriate, principally for its insulation qualities as a consequence of the rammed earth's thermal mass. Rammed earth construction involves the use of massive thermal walls which regulate the interior's microclimatic conditions. Constant temperature and humidity throughout the whole year offer steady working environment for both the occupants and the electronic equipment recognized for its sensitivity to environmental factors. This especially holds true for the performance of microphones, which varies significantly with the temperature and humidity alterations. In the situations of extended work periods focused on a single project involving same microphone set-ups, it is desirable to recreate at later stages the conditions attained beforehand. A secure way to achieve this is by accepting the qualities projected by the natural building materials.

Constant year round temperature averaging around 20^{o} C makes it possible to exclude mechanical heating and cooling systems commonly identified as primary indoor generated noise sources. Massive rammed earth walls are exceptionally good thermal insulators, storing heat or cool air which strikes the building façade or is emitted by the equipment and the occupants and releasing it in accordance with the temperature variations, thus keeping the barometer at a constant value. The lack of HVAC systems makes it possible to keep the wall structures unpunctured, therefore diminishing the number of resonating bodies that could influence the room's frequency response. The installment of HVAC systems usually requires some kind of costly acoustic treatment (lowering the air flow rate, avoiding sharp turns in duct design, isolating the mechanical equipment, investing additional assets in special wents, applying adsorptive overlays on the duct surfaces etc), so having no system to install, treat or maintain considerably lowers the initial expenses imposed on the client.

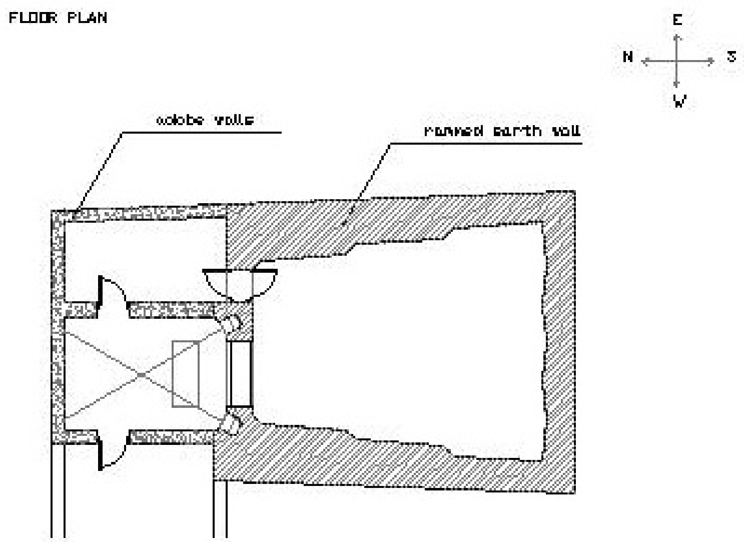
Along with the improved thermal properties, rammed earth walls proved as good isolators from the environmental noise. The proposed noise criteria curve value of NC 25 for recording and broadcasting studios should be easily met, as rammed earth introduces close to 50 dB of loss in sound intensity during transmission. The most common noise sources in urban environments average their sound pressure levels around 70 dB, thus falling within the controllable range. The exception is traffic noise which averages over 80 dB. A helpful fact is that the dangerous frequencies coming from vehicles in motion travel in a horizontal plane, so they can be controlled by surrounding the edifice with absorptive earth beams.

4. ROOM DESIGN

The procedure for constructing rammed earth walls includes the following steps: aluminum or wooden frame is built to a desired shape and filled with an earth mixture consisting of clay, water, sand, caliche and other earth forms. Technically, rammed earth is a mixture of slightly damp, sifted earth (often from the site itself) and a small amount of cement (roughly 3% by weight, depending on soil composition). The mixture is compacted to ¾ of its original volume for better structural strength that will, similar to concrete, increase in the following year.

The result is a single homogenous wall structure without sections and joints that could cause structural noise and vibration problems. The acoustic design goes by the rule that the smaller the number of adjoining elements, the smaller the number of troublesome resonant frequencies. Incorporating this method means that only one element is present in the entire wall form. This may be the reason for extraordinary performance of rammed earth houses when subjected to extremely low frequencies that occur as a result of seismic activities.

In addition to this, porous qualities of unbaked ceramic materials are known to influence sound diffusion in positive manner, resulting in a more uniform frequency response throughout the room. The question is how the mixture constituents can be varied to achieve specific densities of the material to meet the exact needs of different types of studios. The purpose of the studio (broadcasting, acoustic music recording, pop music recording) will dictate precise values of parameters such as reverbation time, early reflections, decay rate and the steady-state response of a room as a function of frequency. These parameters are primarily influenced by the room shape and the materials used. Rammed earth offers certain advantages when it comes to forming the desired wall patterns. The use of metal or wooden forms allows the execution of practically any shape imaginable, curved or straight. In addition, the thickness of the wall, which will depend on its height (rammed earth walls are thicker at the bottom than at the top), along with shaping flexibility allows effortless creation of cavities often used for bass trap installment or speaker mounting.



icture 1: Floor plan of rammed-earth and adobe wall stuctures. The recording room is constructed with massive rammed-earth walls while the monitoring room and accompanying objects are built from adobe blocks. Rammed earth introduces exceptional wall shaping possibilities and easy execution of cavities for bass traps installment and speaker mounting.

It might be possible to combine the rammed earth walls with adobe blocks to make up for the insufficiencies of each one, while retaining the desired qualities. A following table indicates the attributes of both methods:

Table 1: Comparison of adobe wall and rammed earth attributes

Attribute of:	**Adobe**	**Frame**
Compressive Strength:	Good	Better
Torsional Strength:	Poor	Good
Cost:	High	Almost as high
Design flexibility:	Good	Good
Insulation:	Poor	Good
Acoustic separation:	Good	Better
Heat retention:	Good	Better
Water resistance:	Poor	Good
Authenticity:	Traditional	Nontraditional

Comparison of adobe and frame construction methods.

A possible arrangement could employ rammed earth walls in recording room design for improved insulation, torsional and compressive strength, shaping flexibility and better sound diffusion. The accompanying rooms that are adjacent to the studio can be oriented towards the street and built with adobe blocks for better acoustic separation. Adobe blocks could also be used for constructing acoustic barriers around the entire facility.

5. PASSIVE VENTILATION

Benefits arising from the use of passive ventilation systems include decrease of initial costs, low maintenance and operating expenses, durability, environmental gains in reducing energy use, low noise, and excellent microclimatic conditions. Several passive ventilation methods exist, ranging from the traditional methods still encountered in arid climates to the innovative modern concepts. Most commonly used techniques are:

- single sided ventilation
- cross ventilation
- displacement ventilation
- passive stack ventilation
- background ventilation
- solar control

It is yet to be determined which passive system complies best with acoustic requirements.

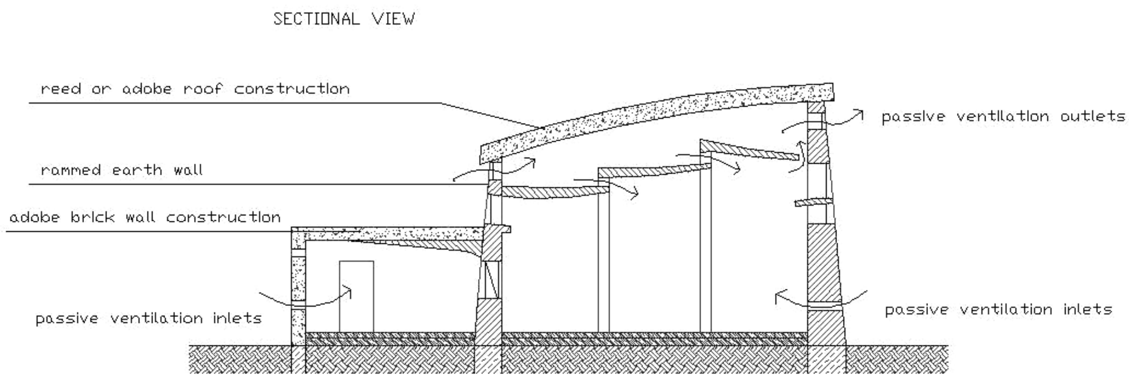
Passive ventilation design requires a detailed analysis of geo-morphological and climatic factors, among which the most prominent one is the wind rose used for determining the direction of the prevailing winds. This will dictate the amount of air that is imported from the environment and distributed within the structure. If possible, outlets, such as windows, doors and ventilation canals, should open away from prevailing winds, while the inlets should open in prevailing southwest and west-southwest winds.

In cases where the wind direction varies drastically and is not so easily predictable, wind catchers positioned on the roof can serve as the systems main terminals, including both inlets and outlets. Central body area of the wind catcher distributes the warm air from within the structure out into the open, while the sides transport cool air indoors. Having in mind the instability of air movement, the outer shell of the wind catcher is designed to control the air intake by opening or closing the shafts. Furthermore, the air flow speed and density will depend on the positioning of the inlets and the outlets, and shape and volume of ventilation canals if present. The openings for air intake are executed as acoustically treated wall or window inlets and outlets with high sound reduction index (over 40dB, depending on the dimensions of the opening).

If the air movement doesn't comply with the desired velocity values its extraction to the roof terminal is achieved by the use of a single, low energy vent located in the roof structure. If ducts are present and introduce new noise sources they can be acoustically treated with adhesion solutions such as envirospray for example.

The designer's goal is to maximize the air exchange using the natural flow and its existing energy, to optimize the air flow velocity and to avoid the additional expenses that would otherwise be utilized for artificial enhancement of the air stream velocity.

It is of utmost importance to keep the air velocity at optimal levels and to make sure that the equipment sensitive to air pressure changes, predominantly microphones, gives its best performance. It should be noted that the heating and cooling issues in the proposed studio design do not depend as much on the air flow velocity but on the thermal mass characteristics, building orientation and climatic conditions. The importance of optimal air flow lies primarily in the natural ventilation and temperature distribution issues.



Picture 2: Sectional view representing the natural air flow through the building. The height differential between the air inlets and outlets secures propper diffusion of cool and warm air. The acoustical ceiling provides the cavity for air flow, as well as the necessary openings for importing the air into the room.

6. OPENINGS

The thickness of rammed earth walls presents the engineer with limitations in the window design. Openings in form of windows should follow certain specifications. Namely, they should be of rectangular shape, horizontal, equally spaced with a maximum span of 2 m and should occupy a drastically smaller wall area than in common buildings.

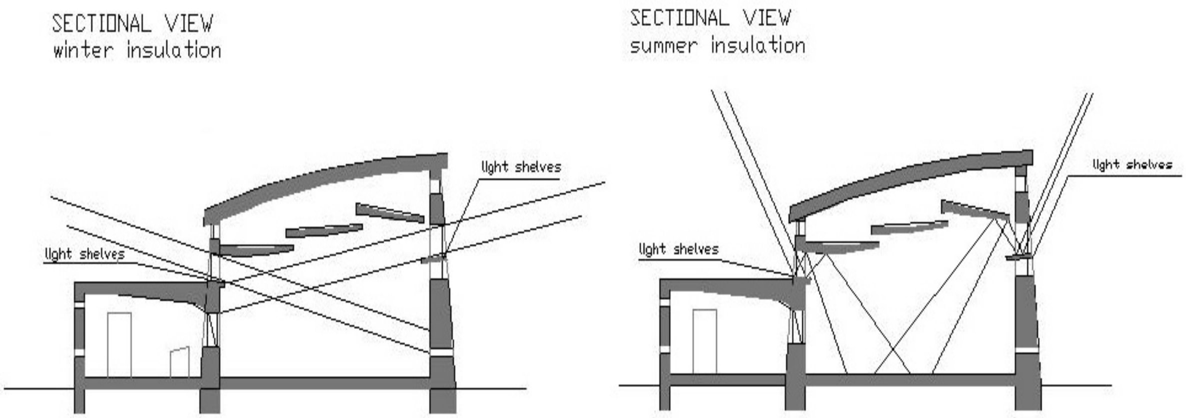
Numerous techniques exist for natural light enhancement, one of which, chosen for its low cost, applicability and efficiency, is the light shelf design. The basic principle of this technique assumes that the reflective surface of the light shelf radiates light to the ceiling which, if angled properly, should provide the deep end of the room with enough daylight. In accordance with this, it is recommended to place windows as high and close to the ceiling as possible

Another motive for increasing the window height is to diminish their interference with the sound distribution within the recording room. The importance of lateral reflections for perceiving space and time has been lately pronounced as probably the most desirable acoustic quality to be considered in room design, reducing the importance once given to ceiling reflections. This especially holds true for rooms of medium and high volume outfitted with high ceilings. Paying special attention to the height of the room can result in a number of benefits:

- enough space to install suspended ceilings

- big height differential between the inlets and outlets used for natural ventilation, resulting in air flow increase and improved diffusion of cool and warm air
- locating openings in less dangerous areas to diminish the influence of glass on lateral reflections
- favorable conditions for daylight control and interior illumination

The control room and other smaller special purpose rooms, such as vocal booths, should not contain any openings other than those reserved for visual communication between the engineer and musicians.



Picture 3: Sectional view presenting the interior daylight distribution in winter and summer periods. Diffusion of light is enhanced by the use of slightly sloped light shelves in conjunction with the acoustic ceilings. Windows are mounted in the rammed earth wall and positioned slightly below the ceiling.

7. CONCLUSION

As noted at the beginning of the article, the proposed innovations should serve only as guidelines for possible improvements, as no experimental data is available at the moment to assure that the proposed improvements will work in conjunction with each other.

Before any of the moderations are applied it is necessary to carry out the following studies in order to adequately incorporate acoustic, passive ventilation, and low energy building design:

- material availability
- geo-morphological studies – the influence on airflow and sound transmission pathways
- climatic factors studies – prevailing winds, precipitation data, average monthly temperature values, average amount of sunlight reaching the earth's surface
- field measurements
- assessing noise from external sources such as traffic noise, industrial noise, environmental noise etc.
- calculating expected noise levels
- mapping noise levels

- determine the purpose and the size of the studio (mastering, audio visual production or recording - acoustic music, pop music, multipurpose use, etc).
- defining the budget

Once these figures have been obtained, it is possible to include them in the early project stages and envision the design of a studio with a greater number of critical factors. Linking the limitations and improvements of each sustainable building approach and producing a complex interconected system should moderate the cost of the final construction.

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