USE OF SOIL MATERIAL WITH SOUND ABSORBING FEATURE

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ABSTRACT

For centuries, music and music venues have been closely related to architecture. Spaces are oriented and shaped according to the function, so spaces for listening need acoustic arrangements. Various methods have been developed for acoustic analysis from past to present. Methods and sound absorbing and reflective materials used have partially changed during the process. The first data that we know as written texts are included in Vitruvius' works. It has been observed that the theaters built with the information in the work exhibit high acoustic performance of similar quality to today's concert halls.

Since soil material is obtained from nature and can be used without requiring expertise, it has been used since ancient times. Examples of use for both structural and comfort purposes are available. In the Ancient Greek, Roman, Byzantine and Ottoman periods, there are examples of the use of soil material in the planning of the orientation and clarity of sound. In this paper, the use of soil material for acoustic planning purposes is examined and explained through examples.

Keywords: Soil Material, Sound Absorption

1 ENTRANCE

Soil materials are easily accessible materials that have been found in nature since the beginning of humanity. According to historical information, it is among the first structural materials used. It has been used more especially in regions where trees are scarce(Fındık 2017). It has become a material that can be used until today thanks to its features such as low production cost, no need for special space for production and good thermal insulation. Used in raw form or in combination with other materials. It is a material that can be used for both structural and decorative purposes and allows flexible design and has a wide range of uses.

The spaces where acoustic planning has been made in historical buildings are buildings for music, speech or religious purposes. Examples include amphitheater, church, cathedral and mosques. These structures were built to be symbolically important, to be open to the use of the majority of the people, to show the power of the current administration to the people and to leave a permanent work for the future. They are also carefully designed for visual, air quality, heat and lighting purposes. Structures with religious use should be considered as structures with both music and speech functions and appropriate acoustic analyzes should be made. Speech sound: d It occurs when sad or irregular sounds continue to follow each other over time. It consists of louder and quieter letters, and the intelligibility of speech depends mostly on the silent letters at high frequencies. The sound power of the voices is greater than that of the mute(Küçük 2000). Music sound: It is regular and harmonic, has a wide frequency range. It is shaped by many different parameters from the type of music to the type of instrument(Özkartal 2011).

The majority of vowels are in the low frequency range and the majority of consonants are in the high frequency range. Therefore, the quieter the letters, the harder it can be to hear as they move away from the source.

1.1 Soil Material

Soil material is produced by consuming less energy and its use can be continued for a long time. It is economical, easy to access, recyclable and reusable, harmless to nature and human health(Özgünler 2017).

Soil material can be examined in two groups as concise and unsubstantiated with the raw materials it contains. When it is shaped with water and dried, the proportion of raw materials with extracts that do not disrupt its shape is high, even in the form of fine grain, the type of raw materials that is difficult to shape and whose shape is disrupted due to external factors is high. Non-extractable raw materials are not suitable for use on their own, but in mixtures and structures. Extractive raw materials are suitable for structural use on their own and can be sorted according to the intrinsic ratio they contain. It is an important factor that it can be shaped with water according to the ratio of raw materials used when sorting(Fındık 2017).

When soil materials are used in the form of mortar, the proportion of non-extractable raw materials is higher. In this way, surface retention is increased. It shows similar properties with the physical properties of the raw material it contains. For example, thanks to the coarse-grained sand used, the mortar applied to the wall creates a rough surface, and as the coarseness of the sand increases, the surface roughness increases.

1.2 Sound Absorption of the Material

Sound absorbing materials are divided into three: porous material, vibrating sheet and resonators.

Porous equipment works with the principle that the majority of sound energy is converted into heat energy by increasing the surface area. The increase in the number of pores, the change in the filled empty ratio of the material surface, the increase in the pore depth and size, and the homogeneity of the pore distribution increase the absorption of the material. It is more efficient in the face of low frequency sounds. The majority of natural materials are porous, the sound absorbing ones are porous. Therefore, it is possible to find examples in historical buildings.

Vibrating plates work with the principle that sound vibrates the material by hitting the material surface, that is, sound energy is converted into motion energy. Thus, acoustic sound prevents pressure fluctuations. The absorption value varies depending on the weight of the material, the surface area, and the distance between the material and the surface behind it. It shows better swallowing in high-frequency sounds. It is not often encountered in historical buildings due to reasons such as being mounted in front of the surface, not adjacent to the surface, and its service life may be shorter.

Resonators are both porous devices and vibrating plates. It can be produced with different types of materials. The sound absorption of the resonator varies according to

the design, type, dimensions of the material, the dimensions of the space, and the distance of the source. In order for a material to be used as a resonator, its sound transmittance must be low. The earliest sound absorbing materials known are resonators. Examples of use have existed since ancient Rome. It has been used with different materials in different geographies.

When the use of soil material with sound absorption is examined, it is observed that it is mixed with additives (as a plaster) and used as a porous material or used as a resonator by shaping and cooking. There are examples of both in historical buildings. Heat and sound energies exhibit physically similar properties. The sound permeability of a material with low heat permeability is similarly low. The heat and sound permeability of the terracotta material is low. Suitable for use for acoustic regulation or insulation. The distribution of sound in concert, auditorium and speech spaces is examined in volume acoustics. For the clear and homogeneous distribution of the sound in the volume acoustics, the space should be in uniform geometric forms and proportional sizes, there should be no mutually reflective surfaces, and reflective surfaces should be used in the volume as fragments, not as a whole. Amphitheaters, opera halls, theater halls can be given as examples of these functional spaces.

2 BUİLT SPACES FOR LİSTENİNG İN ANCİENT TİMES

The first examples of places where acoustic arrangements were made and documented in history are Ancient Greek theaters. These theaters have characteristic features. They are in the form of semicircles with a seating area of just over 180 degrees. The scene is symmetrical in the middle, visible from every angle. In order to provide visual and acoustic comfort, seating areas increase by 1 to 2(Glass Sabah 2013). Ancient Greek theaters were built for both different musical genres and theatre purposes and are still an example for today's halls(Long 2006). The slope of the slope where the theater sits was determined by acoustic principles(Öz 2017). Roman and Late Hellenistic Period theaters were also built on the plan scheme of Greek theaters. The most important difference is that the stage has been raised and shadow elements have been added for the various backstage areas called backstage and the audience. While the backstage wall added in this period hid the backstage part, it increased the power of the sound on the stage and enabled it to reach the audience better(Glass Sabah 2013).

There are examples of stone resonators in theaters from the ancient Greek and Roman periods. Vitruvius mentions the bronze cubes used in Roman theaters to reach the back rows of sounds. The cubes are placed in niches that open between the seating areas. The cubes do not touch any edges of the niches and only the part of the niche facing the stage has an opening. In this way, while the niche itself acts as a resonator, the outer surfaces of the cubes form a reflective surface. Layout plans and niches were calculated mathematically. It is known that each niche and cube is placed for different notes and planning is made according to the principle that even the back row can detect all notes. However, these cubes were not found in the excavations, only niches carved from stone were found. Vitruvius stated that these bronze cubes were used in the Hellenic city states rather than Rome and that various climatic data were used when designing theaters(Vitruvius 2015). For example, the positioning of the theater to be protected from the wind is for ventilation, health and acoustic purposes. The wooden shadow element added to the theaters in the Roman period reflected the sound and strengthened the theatre acoustics. It is known that the shadow element adversely affects the acoustics when placed without calculation(Öz 2017).

In the Ancient Greek and Roman periods, resonators made of earth material for acoustic regulation, especially in indoor spaces, were encountered. These are single-layer and

2.1 Use of Soil Material for Sound Absorbing Purposes in Ancient Greek and Roman Periods

Ancient Greek and Roman resonator samples are empty boxes obtained by carving the stone. These are examples of the hollow resonator type, highly developed acoustic systems although they have a simple structure. The mouth of the boxes is narrow and the middle part is wider square and rectangular. Due to the fact that it is a stone material, some examples have survived to the present day. Large volumes of low frequencies increase the likelihood of resonance and ringing time. Porous materials and vibrating plates may not be sufficient alone in these areas. Cavity resonators provide the optimum acoustic solution for such spaces.

Other examples known to be used in the Roman period are narrow-mouthed, thin-necked jugs produced from soil with a wider bottom, called "Amphora" (Image 1). The main purpose in the production of these jugs is to transport water or store wine, which is also known to be used to regulate acoustics.

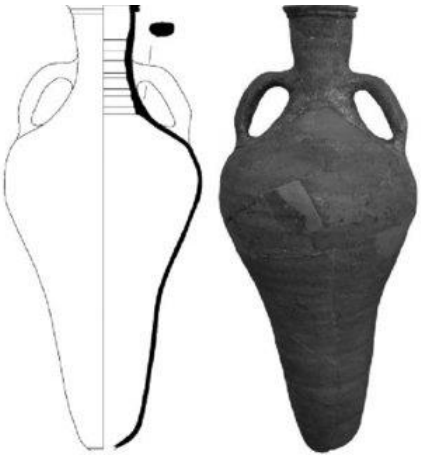

Image 1: Roman Amphora

The sound of narrow mouth and neck parts is to prevent the sound coming in and coming out. After the thin neck part, the surface area where the sound reaching the large diameter and long body part can reflect is larger. Thus, sound energy is trapped in a small confined space and converted into heat energy.

3 USE OF SOİL MATERİAL İN TURKEYS FOR SOUND ABSORPTİON PURPOSES

Turks experienced the period of principalities after the culture of nomadism in Central Asia and their settled lives were finalized during the Anatolian Seljuk period. Planning examples made by the Turks in Anatolia have been encountered since the Seljuk period. It is thought that Turks with no settled life experience were inspired by the artifacts they found in the lands they settled in in their structural arrangements. Because although there are traces of Roman works in the buildings from the Seljuk State, there is no perfect geometry and detailed planning in Rome. Examples of hollow resonators have been seen in Turks since the Seljuks. Water cubes made of soil were used. It is located in caravanserai, mosque and complex structures. However, as in the case of the Great Mosque of Manisa, the jugs (water cubes) in the brick wall in some buildings from the

Anatolian Seljuk period were used only for the purpose of lightening the structure, not resonator. Basically, the jugs placed for acoustic purposes were placed in the structure with a certain order and geometry, while the jugs placed for lightening the structure were placed according to the stability of the brick wall(Gök 2021). There are examples of the method of alleviating both the top cover and the walls of the building with empty jugs in the Roman, Byzantine, Seljuk and Ottoman periods.

In the Ottoman Empire, In the 19th century, Mimar Sinan made acoustic analyzes using water cubes similar to Roman Amphora. He applied these acoustic analyzes especially in mosque structures. Mosques and religious structures are mixed-functional structures. It is an example of listening and speaking spaces in terms of preaching, sermon and mawl recitation functions and religious structures in terms of worship function. For this reason, the only purpose of the space is not to swallow the sound, but to ensure the homogeneous distribution of the sound within the space without reverberating. From the moment the sound comes out of the source, it is subjected to friction and its energy is reduced thanks to material surfaces and listeners, especially air. In addition, the energies of high-frequency sound waves are low, and as the distance between the source receiver increases, it becomes difficult to reach the receiver. Therefore, the individual who is close to the source hears the fine sounds more clearly than the one sitting far away. In terms of speech, vowels remain intelligible even over long distances, while consonants become inaudible as they move away from the source. It is necessary to use acoustic planning and various reflective, absorbent surfaces to solve this problem.

Rectangular and square plans in mosque structures cause resonance of sounds at similar frequencies, especially at corner points. Mimar Sinan used pendant or muqarnas in the corners to solve this problem in Selimiye(Kayili 1988). In this way, sounds with similar frequencies were reflected away from the surface at different angles. After solving the problem in the places where the sound reflects the most, it is easier for it to spread homogeneously and make acoustic planning. In addition, he made internal planning by taking care to prevent the formation of acoustic shade between the pulpit, altar and the pulpit and the congregation.

The most obvious examples are found in Sinan's work Süleymaniye Mosque. The cubes used by Sinan in Süleymaniye Mosque are short (50 cm height), narrow-mouthed, thin-necked, oval section. Ağızları içe bakacak şekilde kubbeye 60 adet ve kubbe ayaklarına 4 adet toplamda 64 adet küp yerleştirilmiştir. There are a total of 45 cubes in the Sokollu Mehmed Pasha Mosque, 36 in the dome and 9 in the quarters outside. The mouth parts of the cubes are 1.5 cm in diameter. There are 35 cubes placed on the walls outside the dome in Şehzade Mosque. There are 40 cubes in total in 3 intertwined rings in Sultan Ahmet Mosque. The mouth parts of these cubes are 3 cm in diameter on the one hand and 6 cm on the other hand and can prevent resonance at different frequencies. The cubes were placed inside the stones, leaving only the mouth parts as openings, so that they did not have any visual effects on the interior. Since the inner surface of the dome is smoothly concave, the direct sound coming out of the source and reaching the dome tends to meet at a single point. The dome is an acoustically undesirable form due to this feature. Meanwhile, the time that may occur between the sounds reflected at different distances may also cause different echoes(Kayili 1988). The fact that Mimar Sinan was placed in accordance with the dome geometry of the cubes ensured homogeneous distribution of the sound and reduced the ringing time. 16 of this detail. The fact that it was thought and implemented in the 21st century shows that a technology and engineering were used beyond its time.

Mimar Sinan has reduced the ringing time with the materials he uses in mosques that have acoustic problems in terms of geometric form. These are Khorasan Mortar and its derivatives. Horansan mortar, soil

Uskudar Mihrimah Sultan Mosque, Istanbul Rüstem Pasha Mosque, Kadırga Sokollu Mehmed Pasha Mosque, Canabi Ahmed Pasha Mosque have used Sinan Khorasan Mortar to absorb the sound reflected from the dome on the surfaces. Khorasan mortar is a binder consisting of lime, aggregate, gravel, sand and broken soil pieces. It is of mineral origin, porous and soft structure. It shows better swallowing at low and medium frequencies. When Khorasan mortar is used as plaster, it is mixed so that 50% by weight is lime and it is preferred to use smaller granular aggregates. Flax and wool pieces are added to the classical Khorasan mortar and scarce Khorasan mortar is added. It is known that Sinan used this mortar in some of his mosques(Kayili 1988).

Sound absorption values of lime-added plasters vary over time. The material varies to different degrees for the swallowing it shows at all frequency values(Nursal, Tavukçuoğlu, and Çalışkan 2016). Therefore, the comfort of the buildings where these plasters are used is different from the current acoustic comfort.

Apart from using direct resonators or materials for acoustic analysis, Sinan also arranged the orientation of the carriers, walls or the niches, enclosures and large surfaces where the sound was dispersed.

4 RESULT

Mankind has built places for listening since the Ancient Greek Period. Over time, space comfort has been increased by making additions and changes in these spaces. Ancient theaters can offer acoustic, climatic and visual comfort conditions and give almost similar results to today's structures.

In ancient times, natural resonators were used for acoustic arrangements in theaters. These resonators are double-layered and planned to reflect or swallow according to the note of the music. It allows the sound to reach the rear most. These resonators, which are obtained by carving stones and placing bronze cubes in them, show how advanced the technology and acoustic knowledge of the Roman period is. Other resonator types used in the Roman period are amphoras. Roman amphoras are long water jugs made of terracotta. Although its main purpose is to store wine, it has also been used for acoustic purposes. The mouth parts are placed facing the sound source in accordance with the geometry of the space.

The beginning of Turks leaving permanent artifacts in Anatolia is based on the Anatolian Turkish Seljuk State. The Seljuks are in the beginning phase of the transition of the migrating Turks to the settled life. Therefore, the buildings in this period were originated from ancient Anatolian civilizations. Structures were built by taking only physical elements as an example, without knowing their main purpose. An example of this is the use of the jugs in the structure, except for the purpose of the resonator. In the Roman period, jugs were also used to alleviate the structure, and in the Seljuk period, jugs were used to alleviate the structure. However, contrary to the Roman period, there are differences between both the dimensions and the ratios of the jugs used. In addition, the amphoras used for resonator in the Roman period were also used as water cubes in the Seljuk period. Similar practices continued to be developed in the Ottoman Period. The most obvious examples are seen in the rise phase of the Ottoman Empire during the

period of Mimar Sinan. Sinan guided the sound with the technology of that day, absorbed it where necessary, and enabled it to make an echo and create an acoustic shadow. As the volume grew, it caused the sound to break down more to prevent it from resonating, and used reflective surfaces in the right places to reach the rear. While making these acoustic plans, natural resonators made of water cube, plasters and mortars made of soil material were used. Süleymaniye Mosque, Üsküdar Mihrimah Sultan Mosque, Sokollu Mehmed Pasha Mosque are examples of structures where water cubes are used as resonators, soil additive mortars are used and passive acoustic guidance is made.

Throughout history, various types of structures have been built that require acoustic planning. Although the materials and construction techniques vary over time, the acoustic planning and the working principle of the materials remain the same. Soil material was also used for acoustic regulation for a period of time and some samples have survived to the present day. It has been determined that the soil material is mixed with additives for acoustic purposes and used in plaster form and as a test by cooking and shaping. In this way, different properties of the soil material were utilized and the same material exhibited different sound absorption. The material, which has the feature of porous material in the form of a plaster, has the feature of a resonator while being tested.

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