

**ASPECTS OF BUILDING PHYSICS IN THE  
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**Annotation.** The construction of spectacular structures began in antiquity in Hellas. At that time, such structures were located on natural relief, which provided good acoustics. Theaters were used only during daylight hours. But at the beginning of the Renaissance, it became necessary to cover large spectacular interior spaces, which over time should accommodate an increasing number of spectators. Therefore, the issue of acoustics and daylighting of the innermost spaces and theatrical performances must be resolved at an appropriate quality level. These technical characteristics necessitated the use of unsupported ceilings in halls with large spans.

Such structures were erected using traditional building materials: stone, brick, metal, wood, glass. The step into the possibility of arranging large halls came in the 50s of the XX century. This is due to the emergence of polymer building materials. Such materials were lighter in weight compared to reinforced concrete with the ability to provide quality acoustics and lighting at any time of the day. Literary sources do not always explain the aforementioned peculiar technical devices of the theater halls. Therefore, the authors made an attempt in this study to combine the applications of these characteristics.

The relevance of the study lies in the fact that from antiquity to our time, the overlap of gigantic interior spaces with a large seating capacity for spectators with good acoustics and lighting coefficients occupy one of the main places in architecture in general.

The scientific novelty of the research lies in the fact that in spectacular structures, the issue of overlapping large internal spaces, taking into account the acoustic and light characteristics, must be carefully analyzed and combined, as revealed in modern public buildings.

Modern entertainment facilities include: theaters, cinema and concert halls, stadiums with a large seating capacity, where high-quality visibility from all points of the viewing space should be provided, as well as high-quality lighting of the auditorium and stage. Such modern structures can be both in the open (external) space and have overlapping of the internal space.

The types of spectacular structures have evolved over the centuries. By the end of antiquity, several types of theaters, amphitheaters, and sports facilities were proposed. Which were built of stone and did not have stationary ceilings. In the Middle Ages, this type of structure was not designed.

**Keywords:** entertainment facilities, theaters, amphitheaters, sports facilities, building materials, structures, acoustics, lighting.

**Analysis of the latest achievements and publications.** One of the first theaters to be closed was the Olimpico in Vicenza, 1580-1585 (Fig.1). Architect Andrea Palladio, studied at Scamozzi. The theater is built of stone and wood [1, p. 290, 307-308].

Theaters of this type were built in the second half of the 20th century. In the 20s of the twentieth century reinforced concrete floors began to appear. From the middle of the XIX century materials such as metal and glass were used. One of the first craftsmen who began to use reinforced concrete in the construction of bridges was engineer Robert Maillard [2, p. 342-345], and in 1939 he demonstrated the unique properties of reinforced concrete in an arch at the National Exhibition in Zurich [3, p.388]. This arch demonstrated only the possibilities of reinforced concrete, the top of which appeared (as one of such options) - the roof of the Sydney Opera House (Australia). The competition for the designs of this building was won by the Danish architect Eron Watson [3, p. 295, 228-229]. The expressive external image of the theater did not in any way correspond to the requirements of this particular type of internal space (at that time the problem of acoustics was not solved). Only later, during operation, it was necessary to fix it with a big waste of time and financial resources.

**The purpose of the study.** Building materials, constructions, acoustics and lighting in the development of enterprise constructions (history and modernity).

**Research objectives:**

1. Analyze the process of designing and building spectacular structures using new building materials.
2. Structures and solving the issue of acoustics and lighting in the context of history and modernity.

**Main text.** The 50s of the twentieth century gave builders new materials - polymers. And since then, it has become possible to erect spectacular structures with the necessary technical requirements, because: polymers are lighter than reinforced concrete, this material is flexible (takes various given shapes and volumes), lightweight in the construction process. Structures have become indispensable for the formation of spectacular structures.

The authors made an attempt to follow the development of types of spectacular structures in antiquity to the present time, identifying the main technical characteristics depending on building materials and structures.

The theater as a type of entertainment originated in the Eastern Mediterranean in the countryside of Hellas during the Archaic times and was associated with the festival of the grape harvest. The scenario of the holiday was set like this: the peasants stood in a circle, danced and sang, that is, each of them saw and heard everything that was happening around.

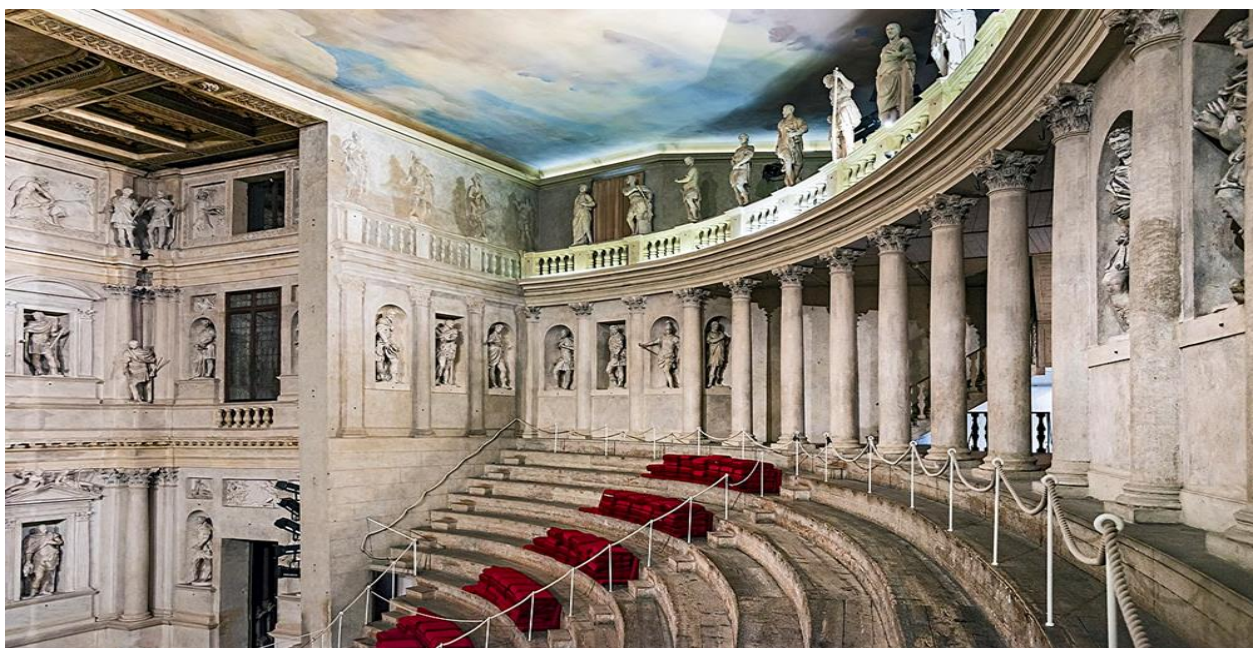


Fig. 1. Olimpico in Vicenza, 1580-1585 Architect Andrea Palladio

The tradition of the holiday, even in the archaic, passed from villages to cities, where a choir with songs, with an accompanying actor, moved around the circle specially on a round platform. The spectators were accommodated in a semicircle (the second half of it was occupied by a household tent for actors). There were not enough seats on the semicircle for all spectators. For these viewers-listeners, they began to make tiered wooden prefabricated structures - and those who wish saw everything and heard everything [4, p. 368; 5, p. 302-309, 8]. Due to the economy of wood and the saving of time in the manufacture of structures, they began to be used several times, which led to destruction. Therefore, at the end of the archaic, theatrical structures began to be erected on natural reliefs. But in this case, they found places where there was high-quality acoustics. And again, the audience was pleased. The practice of building theaters has become progressive (Fig.2).

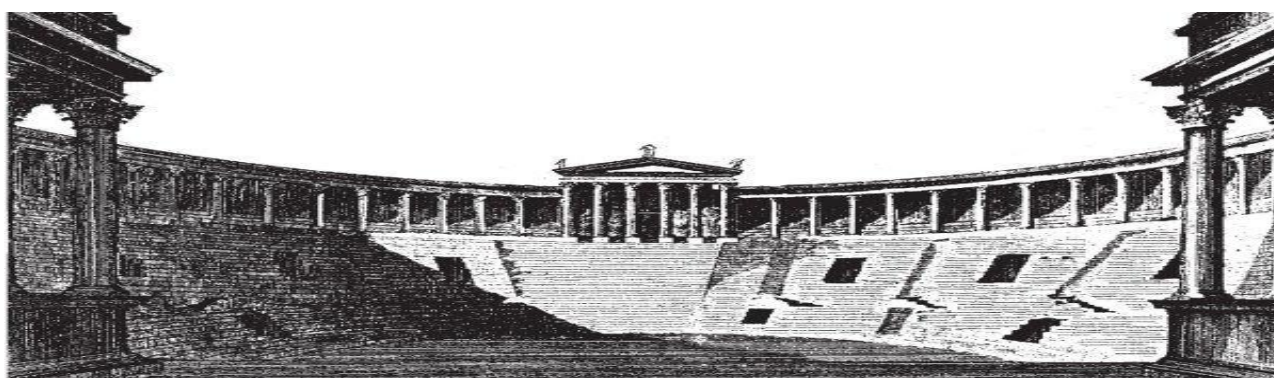


Fig. 2. The first stable theater in the Eternal City appeared under Pompey during the reign of Augustus

In the V century. BC. viewers began to watch such a genre as tragedy (this is the period of great classics). Drama and comedy were favored by the audience. IV-II c. BC. these are the periods of late classics and Hellenism - and all spectators were satisfied with the performances: the acoustics met the necessary requirements; theatrical performances were accompanied by artificial colored lighting. [2, p.268;5, p.305-321,9].

The Roman Republic copied the entire culture in Hellas. The advantage was the performances with bloody battles. Therefore, the arrangement of seats did not suit the spectators. By the III century. BC. they formed a kind of spectacular structures [6, p.34]. This type developed in general terms in the form of an amphitheater, which provided a comprehensive overview of the action. And again, the audience was happy [4, p.74,455,10].

At first, the Romans began to use artificial places for spectators when erecting amphitheaters, primarily at ground level (these are the first stone amphitheaters, which were partially preserved - in Sutra, in Pompeii). In the Sutra, spectator seats are completely carved into the rock. Its arena size was close to a circle and was 50.0 x 40.0 meters. Among the seats for spectators, there were no sectors and there were no stairs: instead of stairs, low seats were used. At the theater in Pompeii (70s BC), seats for spectators were dug into the ground (Fig.3).

The stage is also dug in the ground. The theater is designed for 20 thousand spectators. Special passages were made among the seats for spectators. The last theater of the republican period was in the town of Pola, 30s. BC. designed for 20 thousand spectators [4, p.455-457,11].

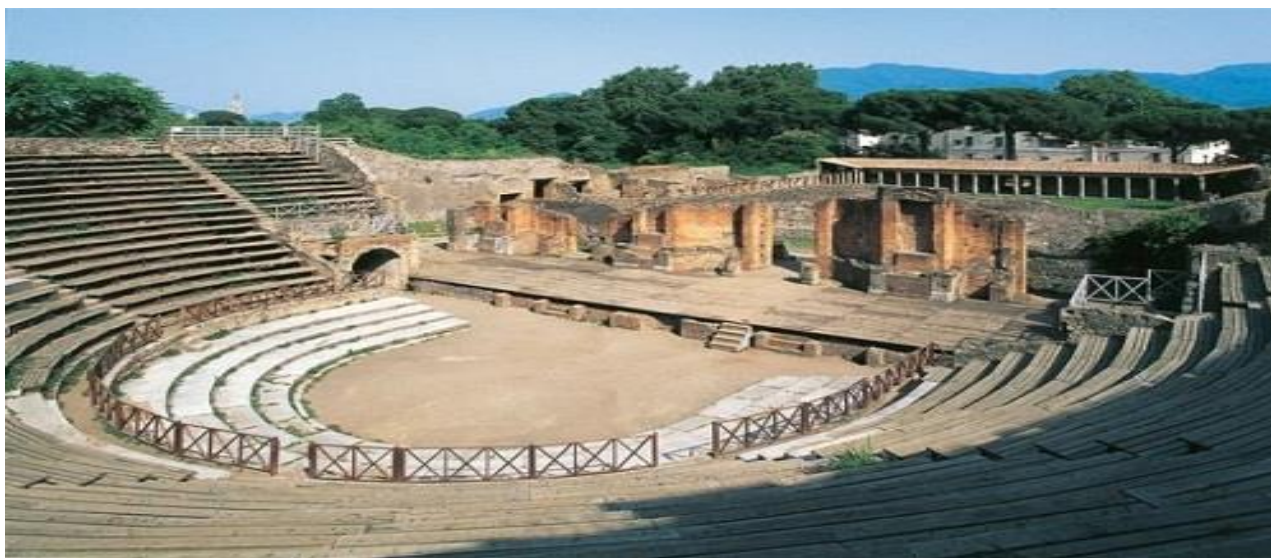


Fig. 3. One of the first amphitheaters of the Roman Empire was erected in Pompeii in 70 BC and accommodated 20 thousand spectators

Only by the middle of the 1st century. AD. the type of amphitheater was established in its main features. Most of the amphitheaters were brought together during the first two centuries of the Roman Empire in all its territories, even in the territories of military camps. One of the first is the amphitheater in Verona for 28 thousand spectators, with an arena 76.0 x 44.0 m, with external dimensions - 15.0 x 123.0 m. The amphitheater still has excellent acoustics, and theatrical performances are accompanied by multicolored lighting effects. The amphitheater in Puteoli had a special water supply system. Which was intended for performances with sea battles. One of the best amphitheaters in the Empire is in Capua. Outside Italy, one of its best amphitheaters is in Nimauzi, Galia (Fig. 4).



Fig. 4. Amphitheater of the Roman Empire - in Capua

The main amphitheater of the Roman Empire is the Colosseum in Rome (or the Flavian theater) arena-ellipse (85 x 53 m), external dimensions 188 x 156 m, erected in 79-80. AD

The amphitheater is four-tiered, arcaded: the first tier is Tuscan, the second is Ionic, the third is Corinthian, and the fourth is Corinthian pilasters. The amphitheater had a temporary

cover: in case of heat of the sun, or rain, it was covered with a canvas canopy. It was pulled by sailors from masts inserted along the top of the wall of the fourth tier.

In total, there are about 200 amphitheatres on the territory of the Empire, of which the Colosseum is the most perfect in terms of functions, structures and architecture. It embodied the dawn of architecture of this type of structures of the previous time, as well as all the previous experience in the development of architecture within the Roman Empire.

As for building materials and structures, the amphitheatres were erected on stone foundations, according to the principle of a support-beam system. They were thorough from the acoustic side and the ability to accompany theatrical performances with light effects [4, p.575-593, 12].

The Colosseum has become the basis for the development in our time of such structures as sports stadiums and complexes and as circus arenas (although they themselves had a round plan for the acting stages). In addition to theaters and amphitheatres, sports stadiums were also built in the Empire [4, p.593-595]. They were similar to examples from Hellas, where they played an outstanding role in life in general. At that time, the Olympic Games were held every four years (Fig. 5).



Fig. 5. Colosseum - UNESCO World Heritage Site

They lasted 5 days, then all military operations in Hellas ceased. Athletes performed at the stadiums of Hellas and horse chariots competed. In Rome, equestrian competitions were mainly held [7]. The current stadiums are based on the Colosseum. The stadiums of the Roman Empire were functionally more multifaceted. It was for their floors that modern structures and modern building materials were developed at that time [13].

Some of the Roman amphitheatres play a significant role in today's global cultural space. A new life has been returned to them in modern times: unique vivid performances are staged on their arenas (like in the Verona arena the first opera by G. Verdi was performed, dedicated to the opening of the Suez Canal to the 100th anniversary of its construction), as well as concerts of various genres. With the help of new modern materials, the Verona arena has been transformed

into a three-dimensional stage (which can never be achieved in a theater), and the seats for the audience have become comfortable.

Reinforced concrete, metal, polymers, glass, new means of wood processing - all this made it possible to erect unique spectacular structures of the 20th and early 21st centuries

**Conclusions.** Thanks to the search and the emergence of new building materials and structures, it became possible to erect structures with many spans, primarily entertainment structures (theater halls, stadiums, public buildings). When designing, they are provided with the necessary high-quality acoustics and artificial daylight.

In the twentieth century, it is necessary to note the existing theaters: - Berlin, a large drama theater, 1919, arch. G. Pelzig; - Brazil (capital), theater 1962, Arch. Niemeyer; Cologne, Opera House, 1958, architect. V. Raphan; - Sydney, Opera House, start of construction - 1959, architect. Jorn Watson. Outstanding sports facilities: - Florence, stadium, 1929-1932, Ing. Pietro Luigi Nervi; - Japan, Takamatsu, Sports Palace, 1958, architect. Kenzo Tange; - Rio de Janeiro, Maracanã stadium, 1950, architect. P. Baltus, R. Galvao. Kenzo Tange refers to various designs of large span slabs.

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## АСПЕКТИ БУДІВЕЛЬНОЇ ФІЗИКИ В АРХІТЕКТУРІ ГРОМАДСЬКИХ БУДІВЕЛЬ

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**Анотація.** Будівництво вражаючих споруд почалося в античності в Елладі. У той час такі споруди розташовувалися на природному рельєфі, що забезпечувало хорошу акустику. Театри використовували лише в світлий час доби. Але на початку епохи Відродження виникла необхідність охопити великі ефектні внутрішні простори, які з часом мали вмістити все більшу кількість глядачів. Тому питання акустики та денного освітлення внутрішніх приміщень та театральних вистав має бути вирішене на належному якісному рівні. Ці технічні характеристики зумовили необхідність використання неопорних стель у залах з великими прольотами.

Такі споруди зводилися з використанням традиційних будівельних матеріалів: каменю, цегли, металу, дерева, скла. Крок у можливість облаштування великих залів настав у 50-х роках ХХ століття. Це пов'язано з появою полімерних будівельних матеріалів. Такі матеріали були легше за вагою порівняно із залізобетоном з можливістю забезпечити якісну акустику та освітлення в будь-який час доби. Літературні джерела не завжди пояснюють вищезгадані своєрідні технічні пристрої театральних залів. Тому автори зробили спробу в цьому дослідженні поєднати застосування цих характеристик.

Актуальність дослідження полягає в тому, що від античності до нашого часу перекриття гігантських внутрішніх просторів з великою місткістю для глядачів з хорошою акустикою та коефіцієнтами освітлення займає одне з головних місць в архітектурі загалом. Наукова новизна дослідження полягає в тому, що в ефектних конструкціях питання перекриття великих внутрішніх просторів з урахуванням акустичних і світлових характеристик необхідно ретельно проаналізувати та поєднати, як це виявлено в сучасних громадських будівлях.

Типи ефектних споруд розвивалися протягом століть. До кінця античності було запропоновано кілька типів театрів, амфітеатрів, спортивних споруд. Які були збудовані з каменю і не мали стаціонарних стель. У середні віки такий тип споруд не проектували.

**Ключові слова:** розважальні заклади, театри, амфітеатри, спортивні споруди, будівельні матеріали, конструкції, акустика, освітлення.