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Console Structures in Building Design and Construction

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Abstract. The console structure is one of the structural systems widely applied in building design and construction, especially to meet the need for column-free space and architectural form expression. The application of the console structure allows building elements to protrude from the main support without direct support underneath, thus providing design flexibility as well as challenges from the structural and construction side. This article aims to examine the console structure in the context of building design and construction, covering the working principles of the structure, its role in the formation of architectural design, and commonly used construction systems. The research method used is a qualitative descriptive method through literature studies of textbooks, structural planning standards, and relevant scientific articles. The results of the study indicate that the console structure has an important role in the integration between the structural system and architectural design, but requires careful planning and construction implementation to ensure the safety and performance of the building, as well as sustainability. This study is expected to be an initial reference for designers and practitioners in applying the console structure appropriately in buildings.

Keywords: console structure; building design; construction system; building structure; building safety

1. Introduction

The development of building design in the modern era shows a tendency towards dynamic, efficient forms that can accommodate flexible space needs. One widely used approach to achieve this goal is the implementation of a console structural system. A console structure allows building elements, such as floors, balconies, or roofs, to protrude beyond the support plane without the need for supporting columns beneath them [1]. This provides both functional and aesthetic architectural advantages (Figure 1).

Figure 1. Space Expansion Using a Console Without Supporting Columns

Console elements are often used to create a light and dynamic impression, while expanding space without increasing the building's footprint. However, behind these advantages, console structures have their own challenges from a structural perspective,

especially related to the distribution of forces, bending moments, and the potential for greater deflection compared to conventional structural systems. The application of console structures provides flexibility in architectural design, but also requires more careful structural planning. Adaptable structures allow buildings to change according to the dynamic needs of users [2]. Flexibility is needed to face ever-evolving changes [3]. The proper application of consoles allows the creation of iconic designs without neglecting the safety aspects of the structure. Iconic design buildings serve as signs or symbols of an area and as markers of the times [4]. The use of these console structures must be in the right placement in the building (Figure 2).

Figure 2. Use of Console Structure in Building Design

In large-span buildings or modern facilities, the use of consoles allows for the exploration of forms that go beyond the boundaries of conventional architecture [5]. While pursuing futuristic forms, proper technical implementation ensures that structural loads remain safely distributed [6]. Massive consoles are often the main elements that define a building's visual identity. Visual elements, including the building's physical form or graphics, are a representation of the character and core values it wishes to communicate [7] [8]. Striking structures such as consoles create a brand image through their iconic physical form [6].

From a construction perspective, implementing a console structure requires careful planning, including material selection, connection details, and field implementation methods. Mistakes in planning or construction can result in reduced structural performance and even endanger building safety. Therefore, a comprehensive understanding of the principles of console structures, their relationship to architectural design, and appropriate construction systems is crucial.

Based on this background, this article is written to conceptually examine console structures in building design and construction. The discussion focuses on the basic principles of console structural systems, their role in building design, and their implementation for sustainability. This study is expected to provide a clear picture of the application of console structures as part of the integration between architectural design and building structural systems.

2. Methods

This research uses a qualitative descriptive method. This approach was chosen because the research objective focuses on examining the concepts, principles, and application of console structures in building design and construction. This approach begins with data collection.

Research data was obtained through the collection of relevant library sources, including building structure textbooks, structural planning standards, and journal articles discussing console and cantilever structural systems. National standards used as references include building structure planning standards published by, particularly those related to reinforced concrete structures and building structural systems [9], [10]. This method was used to obtain a conceptual understanding of console structures in building design and construction. Data was also obtained from field surveys. The survey related to the existence of consoles in buildings in the community.

The research stages are carried out through several steps, namely: (1) Identification of the concept of console structures, including the definition, characteristics, and working principles of console structures in buildings; (2) Analysis of the role of console structures in building design, especially their relationship to the formation of space and architectural expression, (3) Study of the console structure construction system, which includes the selection of materials, construction details, and implementation methods in the field; and (4) Synthesis of the study results, to obtain a comprehensive understanding of the application of console structures in building design and construction.

The collected data were then analyzed qualitatively by linking various concepts and findings from the literature. The results of the analysis are presented in the form of a systematic narrative description to illustrate the relationship between the console structural system in buildings, the integration of console structures in architectural design, and aspects of safety, comfort, and sustainability. This method is expected to provide a clear conceptual picture and serve as a basis for understanding for designers and practitioners in applying console structures to buildings.

3. Results and Discussion

3.1 Console Structural System in Buildings

Based on the results of the literature review, the console structure operates on the principle of structural elements that support the load through one side of the fixed support, while the other side is free without direct support. The load acting on the console structure produces significant shear forces and bending moments in the support area. Therefore, the support area becomes a critical zone that requires stronger structural design compared to conventional beam structures (Figure 3).

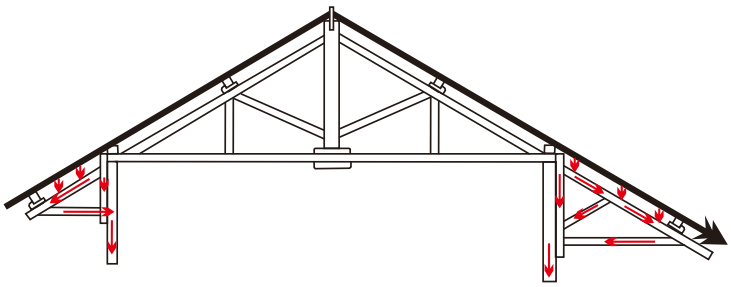

Figure 3. Flow of Building Load Forces Through the Console

Console structures are commonly used in building elements such as balconies, canopies, overhanging roofs, and floors that require column-free space. Structurally, consoles exhibit greater deflection characteristics, making deformation control a critical aspect of their design. Studies have shown that failure of console structures is more often influenced by inadequate dimensions of structural elements and reinforcement details in support areas.

From a construction perspective, console structures can be constructed using a variety of materials, with reinforced concrete and steel being the most commonly used. Reinforced concrete console structures are widely used due to their ease of construction and the concrete's ability to withstand bending moments through the reinforcement system. However, the construction of reinforced concrete consoles requires temporary scaffolding and strict quality control, particularly during the casting and dismantling stages of the formwork.

Meanwhile, steel console structures offer advantages in terms of construction speed and slimmer structural dimensions. This system allows for longer console spans with a relatively lighter structure weight. However, steel structures require precise connection details and protection against corrosion and fire. The study results indicate that the selection of a console construction system must consider the building's function, environmental conditions, material availability, and the technical capabilities of the contractor on site.

3.2 Integration of Console Structure in Architectural Design

From a building design perspective, console structures function not only as structural elements but also as space formers and architectural expressions. The application of console structures allows for the creation of column-free open spaces, the expansion of functional areas, and the creation of dynamic facades (Figure 4). However, the larger the planned console span, the higher the structural performance demands that must be met.

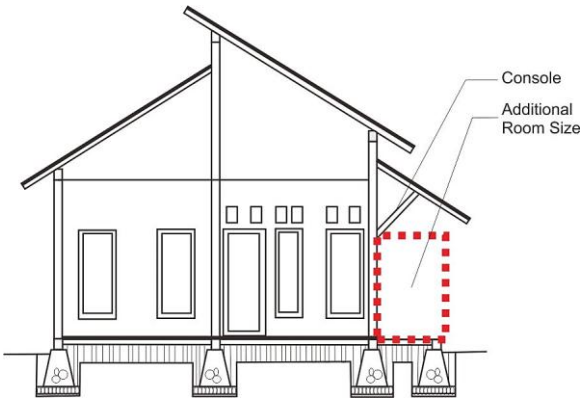

Figure 4. The application of the console creates an open space without columns

The integration of console structures into architectural design requires collaboration from the conceptual stage between the architectural designer and the structural planner. If design decisions are made without considering structural constraints, they can potentially result in console elements that are visually appealing but structurally inefficient. Therefore, the study's findings emphasize that console structures should be treated as an integral part of a building's structural system, rather than as add-on elements at the final design stage.

In architectural design, console structures play a strategic role in shaping a building's visual expression. Console elements create a light, dynamic, and modern feel, while also providing flexibility in spatial arrangement. The use of console structures is often associated with open space concepts and site efficiency, particularly in buildings in urban areas with limited land availability.

The study results show that the successful implementation of console structures in building design is highly dependent on the integration between architectural designers and structural planners. If console structures are treated solely as additional design elements without adequate structural considerations, they can potentially cause technical problems during the construction phase and during the building's operation. Therefore, console

structures need to be planned from the early design stages as part of the overall building structural system (Figure 5).

Figure 5. Building design expression using consoles

3.3 Safety, Comfort, and Sustainability Aspects of Console Structure

Console structures have direct implications for building safety because failures tend to be sudden and localized. Controlling deflection, cracking, and vibration is a critical component of console structural performance, particularly in buildings used by the public. In addition to strength, visual perception of deflection also needs to be considered, as it can impact occupants' sense of safety.

From a sustainability perspective, efficiently designed console structures can reduce the need for additional columns and foundations, potentially reducing material usage. However, excessive console structures can actually increase material consumption and construction complexity. Therefore, the implementation of console structures requires a balance between design requirements, structural performance, and resource efficiency.

Interpretation of the analysis results, the console structure works as a flexible element with one end fixed and the other end free, thus producing a maximum bending moment in the support area [11]. This condition causes the need for larger cross-sectional dimensions and reinforcement details compared to non-console structural elements. In addition, deflection is an important performance parameter because it can affect the comfort and safety perception of building users [12].

In architectural design, console structures are often used to create column-free spaces and dynamic expressions of building form. This structure is used as an aesthetic element to create a unique and attractive building form, which directly influences visual perception both inside and outside the building [13]. However, the longer the planned console span, the greater the demands placed on the structure's performance and the construction system used. For very long spans, large cross-sections are often required, which are beams with large cross-sectional sizes to withstand lateral and gravity loads [14]. Therefore, integration between structural planning and architectural design is key to the successful implementation of console structures. Design integration must take into account the displacement or shifting of the structure [15].

From a construction perspective, reinforced concrete and steel console structures require careful implementation methods, particularly during the temporary construction phase and connection details, because the tensile reinforcement on the console is located at the top [16]. Applicable loading and structural design standards must be used as a reference to ensure the safety and reliability of the console structure.

4. Conclusions

The conclusion that can be drawn is that the console structure is an effective structural element to meet the needs of column-free space and the formation of dynamic building forms, but it has more critical structural working characteristics than conventional structural systems. The force mechanism in the console structure is dominated by bending moments and shear forces in the support area, so that the planning of the dimensions of the structural elements and the connection details in the support zone are aspects that greatly determine the performance and safety of the structure.

Integration between structural planning and architectural design is a key factor in the successful implementation of console structures. Console structures planned from the early design stages tend to be more efficient, safer, and easier to implement than consoles added at the final design stage. From a construction perspective, console structures require careful implementation methods, particularly related to temporary construction stages, deflection control, and the quality of structural detail execution. Mistakes during the construction phase can have a direct impact on the long-term performance of the console structure. The selection of materials and construction systems for console structures must be adjusted to the building's function, site conditions, and the implementer's technical capabilities, to achieve a balance between strength, stiffness, safety, material efficiency, and sustainability.

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