Tectonics of Sukuh Temple as construction structure environmental response (earthquake friendly)

Darsini*, Y Winarto and K Sunoko

Sebelas Maret University, Surakarta, Indonesia

* Corresponding author: darsiniars@gmail.com

Abstract. The large number of temples and various forms in Indonesia is a cultural and architectural heritage that is one of the identities of the archipelago. From an architectural point of view, the temple has special tectonic complexities, one of which is the Sukuh Temple. Sukuh Temple is a building with the ability of a perfect structural and construction system and has architectural metaphysical values. The building of Sukuh Temple has existed since the 15th century. This building was built to fulfill the function of worship rituals, therefore this building is sacred. This building is located in an earthquake prone area, namely on the island of Java. The resilience of Sukuh Temple over the years proves that Sukuh Temple can adapt to the environment, from this evidence the tectonics of Sukuh Temple are interesting to study. The research objective was to determine how the ancestors used tectonic science and technology to adapt to nature and the existing environment. This research uses descriptive method with a qualitative approach. data and information collection is done through field observations, in-depth interviews, and related documents. This study found that local wisdom is the main factor that makes Sukuh Temple responsive to the environment.

Keywords: Sukuh Temple, tectonic, environmentally responsive

1. Introduction

Architecture and construction are an inseparable unity, seen from Vitruvius's statement that architecture consists of three elements, namely firmity, utility and venustas. Firmity can be interpreted as the material of the building and the implementation of building a building, thus discussing architecture or building an architecture cannot be separated from how to choose materials and how to arrange, construct buildings so that they can be used as a place to live in safely and comfortably. The architecture of Sukuh Temple is known for its distinctive shape through the lower, middle and upper structures which have aesthetic beauty of the structure and construction.

Structural systems mechanics form an architectural aesthetic system. The research on architectural tectonics of Sukuh Temple cannot be separated from research on structural and construction systems which focuses on aspects of stone construction which have a strong and elastic structural system. The ability of the ancestors to foster an architectural environment innovatively over a long period of time has made Sukuh Temple as one of the expressive architectural heritages and even embodies the philosophical symbolic elements of buildings. Its existence is very specific in its tectonic elements.

The concept of abstract thought patterns, beliefs, culture, customs, climate, environment, architectural form and structure cannot be known with certainty. The architecture of Sukuh Temple is one of the
many buildings in the archipelago with unique architectural forms, structures and constructions. Research review is examined through tectonics, because tectonics are part of architecture, according to Vitruvius dividing them based on function, strength (structure), and aesthetics (esthetic). Strength can be understood as a system of structure and construction (teckonics) is an integral part of architecture.

Tectonics is closely related to the art of material processing, structure and construction, which emphasizes the aesthetic value aspects produced by a structural system or is an expression of a structure which is more emphasized by the aspects of its ability to use structural technology. Kenneth Frampton's view in Studies in Tectonic Culture, 1995, that tectonics comes from the word tekton and is often written as the word tektonamai (Greek) which literally means carpentry or builder. In Sanskrit it can be likened to the word taksan which also means the art of carpentry using an ax.

Semper divides tectonics into two, namely technical (ontological) and symbolic (representational) (Frampton, 1995). With a focus on producing architectural elements, Semper also divides buildings into tectonic crafts and stereotomics. Tectonics is a linearly lightweight component frame construction, and stereotomics is a mass and volume component. Stereotomics, stacking and stacking heavy load elements like bricks, because the word comes from Greek with 'stereo' meaning 'solid' and 'Tomi' meaning 'to cut' (Frampton, 1995). Based on the understanding of formation, presenting tectonics in arranging and assembling buildings proposed by Semper emphasized the classification of buildings (architecture) with 2 (two) procedures that underlie the assembly process, namely (first) tectonics which are lightweight frames consisting of linear components forming a spatial matrix or can be said to be the development of constructions and structures used to form space; and (second) the stereotomic stage in the form of a basic part where the mass and volume of space are formed from heavy elements in the form of processing connection systems in construction and structures so as to increase expression in buildings by presenting artistic values.

Tectonics plays a role in providing articulation to the load transfer mechanism of structural elements. Innovative processing of forms to produce the potential for expression of architectural forms as a whole as well as artistic expressions of the connection details of the construction used. The forms that are produced are artistic forms that have artistic meanings, not just abstract or figurative forms, they are even able to express the philosophical symbolism of buildings. The use of construction materials and the joining / joining of construction elements in a beautiful (aesthetic-artistic) manner to produce a solid structural system (technical-technological) are the focus of tectonic studies. Expertise and tectonic skills in the form of "stringing and connecting" starting from the simplest technology to the most sophisticated, by means of: stacking, polishing / plastering, binding, weaving, stamping, pinching, and coating.

From the description above, the purpose of this research is to find out how the tectonic science and technology used by the ancestors to adapt to nature and the existing environment.

2. Research Methods
This research uses descriptive method with a qualitative approach. Descriptive method by means of observation in the field by describing the existing condition. A qualitative approach using tectonic theory and compared with the object of research in Candi Sukuh. Data was collected by field observation and literature study. Field observations to obtain physical data from Sukuh Temple which includes the current condition of the building (material, structural conditions, connection conditions, loads, and symbolic). Literature study was carried out to collect data on Sukuh Temple which included functions, meanings, and images of Sukuh Temple. Data are classified into two major groups, namely technical objects and symbolic objects. Engineering objects are directly related to techniques and construction elements that are formed to emphasize the role of statics or cultural status, while symbolic objects relate to something that is absent or hidden (symbolic) in the ancestral traditions of Sukuh Temple and the aesthetic value resulting from the structure and construction system.
3. Results and discussion

3.1 Construction Tectonics
Sukuh Temple was built using hard rock material in the form of Andesite which is a local material obtained from the closest source to the location where the temple was built. The construction technique for Sukuh Temple is by arranging or joining the material by means of pegs. The unification of the structure of each of these parts forms a compact structural system, the whole elements are interconnected and show the tectonic structure of the whole.

The arrangement of structural systems from the bottom to the top can be summed up as the presence of a tiered hierarchy where a simple structural system supports a complex system, as well as a complex system that supports a sophisticated system.

In terms of the use of materials in the tectonic construction system, it provides an advantage for Sukuh Temple because it is included in the light construction type because the inertia force experienced by Sukuh Temple when an earthquake occurs is reduced. The life and death burdens of Sukuh Temple are getting bigger and bigger. This affects the magnitude of the inertia force, because the inertia force is influenced by the mass of the building.

A structure must be able to withstand all the loads placed on it efficiently and safely. Structural loads are the result of natural forces. The most basic structural loads in Sukuh Temple are gravity loads that work in the vertical direction of the structure. This load includes both dead and live loads caused by the gravitational pull of the earth. The lateral loads of winds and earthquakes are live loads that act horizontally on the structure. When wind blows against a structure, it sways sideways. When an earthquake occurs, the ground on which a massive structure is erected quickly sways sideways. A large earthquake force acts on the structure when the mass of the structure withstand the sudden lateral force. The free-standing post-purus structural elements will remain stable even though the load of the Sukuh Temple building is very heavy. The shear stress on the ground will work flexibly. Equilibrium occurs when actions are opposed by reactions of the same magnitude.

When the load acts on the structural members, it is necessary to determine the active forces so that they are in equilibrium. The structural and construction system in a temple is a multiple structure, the reaction force of a member becomes an action load on the part of the structure that holds it. Ultimately a structural system must safely transfer all structural member loads to the ground. The main structural system of the temple building is the support and connection system. The load on the body wall of the building is transferred through the feet to the ground.
Tectonic research focuses on the aspects of combining construction materials and structures, joining / joining elements of construction beauty (aesthetic-artistic) to produce a solid structural system (technical-technological). Tectonics in Sukuh Temple have the ability to adapt structural systems and building construction into basic aesthetic forms which are specific. Assessment using tectonic expertise and skills in the form of 'stringing and connecting' starting from the simplest way used the theoretical approach proposed by Semper which emphasizes the classification of buildings (architecture) with 2 (two) procedures that underlie the assembly process, namely (first) tectonics which is a lightweight frame consisting of linear components to form a spatial matrix or can be said to be the development of constructions and structures used to form space; and (second) the stereotomic stage in the form of a basic part where the mass and volume of space are formed from heavy elements in the form of processing connection systems in construction and structures so as to increase expression in buildings by presenting artistic values.

3.2 The process of creating the Sukuh Temple
The division of elements of Sukuh Temple is divided based on Hindu cosmological elements, namely Bhurloka (underworld), Bhuvarloka (middle world), and Swahloka (upper world). The shape of this building has a stacked pyramidal shape proportion. When viewed from its shape, the Sukuh Temple building has the shape of its legs that are sunken or go inward. This concave formation will generally end with a flat side at the center of the foot molding. The shape of the sunken legs functions as a stabilizer for the building during an earthquake. Based on the relationship between architecture and culture, Java is a form of human adaptation strategy in creating building structures that can withstand nature (earthquakes). This form of adaptation is applied through structural and construction engineering through pedestal and connection systems, as well as the selection of local materials in the form of wood, bamboo and stone.
The Sukuh Temple building was built without any pseudo or structural columns on the walls proving the awareness of the complete form of the stone building or considered something unnecessary. If we look at the tectonic technique of joining the stones using the peg-purus technique, this is possible because the Javanese are already familiar with the technique of composing stones from the previous megalithic period such as punden terraces and various other stone buildings. This technique continues to be developed and has become a tradition in the archipelago, making it possible to create high inner spaces, such as for example in Prambanan Temple.

The structure and construction system of the pin-pin is a system that can stand alone, thus this system is separate from the systems in other parts. Compiling and uniting each part of the temple is a stereotomic stage where the mass and volume of space are formed from heavy and massive elements. Structural tectonics and pin-pin construction are simple systems that expect structural strength and construction from the joint relationships of each joint. Pasak-purus is a wealth of construction connection system at Sukuh Temple which is only owned by the ancestors.

3.3 Sukuh Temple Architectural Culture
The shape of the building refers to the mandala concept which presents an impressive spatial effect as the centerpiece. Mandala comes from the Sanskrit language which literally means circle. Mandala is a diagram of the universe which has a center in the middle. In Hindu and Buddhist beliefs, mandala is interpreted as the highest achievement of the spiritual life of humans. Mandala is the center, where the ultimate goal of life will be addressed.

Mandala depictions in Hindu and Buddhist architecture can be found in the architectural form of Sukuh Temple, where the Sukuh Temple building is centered in the center. It is in this center that the value of holiness is placed. Because the center is in the middle, the plan of the Sukuh Temple building is symmetrical.

4. Conclusion
From the results of the research that has been done, it can be concluded that the tectonics of Sukuh Temple and the ability to adapt to the environment can be drawn. Found in construction tectonics in the use of materials, tectonics of vertical and horizontal structural elements, building shapes, and structural arrangements.

There are findings of local wisdom which are the main factor in making Sukuh Temple able to adapt to the environment. Local wisdom on detailed tectonic sections of vertical structural elements, in processing joints between each part. The detailed processing of the joints for each part successfully ties between each part. This Sukuh temple uses andesite as its main material for structural and non-structural elements. Andesite is a lightweight material so it can reduce the magnitude of the lateral force caused by earthquakes.

5. References
[1]  Attoe, Wayne R.J. (1985). Architectural criticism. Chichester; New York: Wiley.
[2]  Frick, Heinz. (1997). Structural Patterns and Building Techniques in Indonesia (An Indonesia Architectural Approach through Constructive Pattern Language with the example of Central Javanese Architecture), Kanisius Publisher, Yogyakarta.
[3]  Frick, Heinz and Purwanto, LMF. (1998). Building Structural Form System (Basick of Construction in Architecture), Kanisius Publisher, Yogyakarta.
[4]  Glasser, D.E. (1976). Structural Considerations, in Snyder, James C and Antony J Catnese (Eds), Introduction to Architecture (pp. 268-272), Mac Graw-Hill, New York.
[5]  Noor, Djauhari. (2014). Tektoni Lempeng. https://www. Academi.edu/6464227/ Tektonik – Lempeng
[6]  Siddiq Suwandojo. (2001). Several Reviews of Material Aspects, Construction and Building Structures Traditional Indonesia (lecture notes), Master of Architecture, ITB.
[7] Subekti, Bambang. (1998). Efforts to Reduce the Risk of Damage Due to Lateral Force on Dutch Colonial Buildings in Bandung. Thesis of ITB Architecture Masters Program, Bandung.

[8] Acharya, Prasanna Kumar (1934) Manasara Series Vol 1: Dictionary of Hindu Architecture, Oxford University Press.

[9] Bharne, Vinayak. (2012). Rediscovering The Hindu Temple. Newcastle, UK: Cambridge Scholar Publishing.

[10] Edi, Sedwati; Hariani, Santiko; Hasan (2013) Candi Indonesia, Java series. Directorate of Cultural Heritage Preservation and Museum, Directorate of Cultural Heritage Preservation and Museum. ISBN 9786021766934

[11] Frampton, K, Studies in Tectonic Culture (England: Massachusetts Institute of Technology, 1995)

[12] Hardy, Adam (1995) Indian Temple Architecture: Form and Transformation, Abhinav Publication ISBN 9788170173120

[13] Herwindo, Rahardian P (2018) The existence of a temple as a masterpiece of Indonesia architecture in South East Asia., Pfluher Pt Kanisius. ISBN 9789792155167

[14] Kramrisch, Stella (1980) The Hindu Temple, Motilal Banarsidass. ISBN 9788120802223

[15] Perdana, Aditya Bayu (2018) Study of Architectural Relations of Hindu Temple in the Era of Ancient Mataram Within Relation to Vastusastra. Bandung: Final Thesis Parahyangan Catholic University

[16] Tjahjono, Gunawan. (2002). Indonesian Heritage: Architecture. Jakarta: Kailola. Volwahsen, Andreas (1969) Living Architecture India. Grosset & Dunlap New York

[17] Bakhtiar, 2014. Types of Theory in Archipelago Architecture According to Josef Prijotomo. MATRASAIN Media Journal. 11 (2). (Jenis. Ref.Jurnal)

[18] Lake, Reginaldo Ch. 2015. Tectonic Culture of Wologai Ende, East Nusa Tenggara, Journal of ATRIUM, 1(2). (Type Ref. Journal)

[19] Siwalatri, & Ni Ketut Ayu, 2016. Tectonics of Balinese Architecture, Journal of the National Seminar on Traditions in Change: Local Architecture and Built Environment Design-Bali. (Type Ref. Journal)

[20] Surya, Rudy, & Naniek Widayat Priyomarsono, 2015. Aspects of Tektonics Responding to Today’s Architecture. (Type Ref. Journal)