

Ethnomathematics: Mathematical ideas and educational values on the architecture of Sasak traditional residence

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ABSTRACT

Sasak traditional architecture, including the shape of the structure, layout, and other supporting buildings, has references and rules in its designing and planning. Traditional residence is one of the cultural artifacts. A residence is not only built based on aesthetic values, but is also reviewed from strengths and values contained philosophically. Thus, this study aimed to describe mathematical ideas that are contained in the architecture of Sasak traditional residence as well as educational values in the culture that can be made as the initial step in designing learning processes at schools. This study was qualitative research conducted by using an ethnographic method. The informants in the study encompassed *Adat* figures, *Adat* stakeholders, and cultural experts who understand the culture of Sasak people. Participant observation, interview, documentation, and field record were the data collecting techniques used in the study. Findings showed the existence of mathematical ideas that are potential to be made as the initial step in learning mathematics contextually.

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1. INTRODUCTION

Mathematics can be found in daily activities, sometimes it goes unaware off. However, most people perceive that mathematics is difficult [1]. Besides, many believe that being unable to do mathematics is not an issue [2]. Such massive changes certainly occurred due to a very structured symptom, namely the impacts of science and technology that continue to grow causing people to consider mathematics narrowly [3]. Clements *et al.* proposed six mathematics competencies required by every culture, namely: counting, measuring, locating, designing, playing and explaining [4]. Cultural activities are developed based on pedagogic principles that are culturally relevant, focusing on the role of mathematics in socio-cultural context. These activities involve ideas and procedures related to ethnomathematics perspective to solve problems [5]. In the context of cultural anthropology, people have adapted various mathematical activities, such as counting, ordering, sorting, measuring, and weighting, with different terms based on each culture. This has encouraged some studies regarding the evolution of mathematics concept in the frame of culture and anthropology. On the other side, there is a correlation among anthropology, cultural experts, and mathematics experts, creating a bridge to connect the three elements to recognize that different thoughts might lead to various forms of mathematics, called as ethnomathematics [6], [7].

School as a key institution to obtain cross-cultural competencies in shaping the future life quality within a multi-ethnic community can support social cohesion, and competencies required for economic and

political integration of people in the future [8]. According to Contini and Maturo, school is an ideal place in introducing cross-cultural knowledge to learn and respect cultural diversity [8]. There are multi-cultural educations that emphasize on the issue of diversity and equality of culture and language, but only few that be integrated into various disciplines [9]. Mathematics is often perceived as a culture-free discipline and not considered as a discipline that is built socially and culturally because the presentation tends to discover a set of facts, objective and universal rules [10]. Teachers need to understand what is meant by knowledge in mathematics and how knowledge is associated with cultural norms and values. In general, conventional learnings rely on the provision of examples, analogies, and artifacts, that are often hard to understand by students [11], [12].

Most of people consider mathematics as an independent science, culture-free, and beyond social values [13]–[15]. If reviewed further, culture can be understood as patterns of meaning, established historically, and transmitted socially, which is embodied in symbols and languages where humans communicate, pass down, and develop their knowledge and understanding about life [16]. Mathematics has to be understood as the product of culture that is built based on the habits that produce languages, beliefs, religions, rituals, food-producing techniques, artifacts, and others. Therefore, we can say that every culture produces mathematics [16]. Thus, culture needs to be accommodated in learning mathematics.

To accommodate a change in mathematics learning, an effort that needs to be done is developing a culture-based pedagogic theory in the critical paradigm through an explicit relationship between the culture of students and the learning materials of schools. In this perspective, mathematics learnings need to link experiences and cultures of students with mathematics contents. Linking students' culture with mathematics contents is a crucial component in the culture-based education because it will provide liberty for teachers to conceptualize mathematics learnings by relating mathematics contents with students' culture and their actual life experience [17]. Artifacts and cultural representation systems are crucial components in mathematics learnings. Cultural artifacts are everything created by the culture of a group of people that can provide information regarding the creation result and the utilization [18]. To explore the architecture of traditional residence philosophically as the part of cultural artifacts, people will consider architecture designs and constructions based on the geographical location [19].

Traditional residence is the building made by referring to the local environmental tradition based on the cultural procedures and values. The residence is a house established based on the local people's character and local condition by referring to *awik-awik* (local rules), local ideological views. Thus, it is always related to the local way of life. Similar to traditional residences in Lombok Island. Traditional residences of Sasak people are unique if seen from the architecture. Their unique *Adat* houses own a belief system on the building location, layouts, spatial patterns, and building materials. The cultural values contained in the concept of Sasak's house architecture is the heritage of nation culture that should be recognized and inherited by the future generation. The architecture concept of *Adat* house, especially its form in terms of spatial division and management is an appealing thing to discover. Therefore, the architecture form as well as cultural values contained within the house is the analysis of this study, which can be made as the initial step in starting mathematics learning in an actual or contextual manner.

Building knowledge by involving students' culture and daily experience as a basic knowledge through artifacts can make learning mathematics to be more meaningful [20]. Besides, the appropriate use of artifacts, teaching, and learning environments are also designed in accordance with students' culture and be implemented in mathematics learnings through new socio-mathematics norms [20]. Through cultural relevance and personal experiences, mathematics learnings help students discover more about reality, culture, community, and themselves [21]. In its turn, these elements will allow students to be more aware, critical, respectful, and confident. It can build new perspectives and syntheses, and find new alternatives, which will support students to change the existing structures and relationships. This study aimed to describe how mathematical ideas in culture can develop sustainable mathematics education; can be made as the learning source; and as an instrument that can create new dialects between school mathematics and actual world.

2. RESEARCH METHOD

This was qualitative research with an ethnographic method. Qualitative study is the comprehension-based research process done by methodologies that studies a social phenomenon in the community. This study can provide the description about world, by using techniques of field record, interview, conversation, photo, recording, and memo. At this stage, qualitative studies involve interpretive, naturalistic approach towards environment [22]. The informants used in the study encompassed five *Adat* figures: two *Adat* stakeholders, two cultural experts, and one traditional builder who understand the culture of Sasak people, in Lombok Island, Indonesia. This method is in line with ethnomathematics studies focusing on mathematics applied by a group of culture [14]. This matter is consistent with the aim of this study.

The data collection was referring to the stages proposed by previous researchers [22], namely participant, observation, interview, documentation, and field record. Data were collected through the stages aforementioned, namely: i) Observations are conducted in traditional villages of Sasak people: *Adat Sade*, *Adat Limbungan*, and *Adat Segenter* villages; ii) Interviews with five *Adat* figures (Moch. Yamin, Raden Gedarif, Lalu Malik Hidayat, Kurdap, and M. Bachri), two *Adat* stakeholders (Ratmanom and Wahid), two cultural experts (Lalu Agus Fathurahman and Lalu Anggawa Nuraksi), and one traditional builder (Amaq Darsih); iii) Documentation, which was conducted by taking photos of objects that were considered supporting the study, especially the form of architecture of the traditional residence of Sasak people; and iv) Creating field notes. Then, data were analyzed through stages: i) Domain analysis, which is aimed to obtain the general descriptions of the research object; ii) Taxonomy analysis, which is describing domains in more details to discover ideas, meanings, and mathematics forms contained in the traditional residence architecture of Sasak people; iii) Component analysis to determine specific characteristics of the research object; and iv) Cultural theme analysis, that finding the relationship among domains that later be stated in themes.

3. RESULTS AND DISCUSSION

Architecture is the manifestation of culture, therefore, architecture is the reflection of culture [23]. Sasak people set a place that is made as the center of cosmos, namely Mount Rinjani. If this location is unreachable, the center point can be moved to a reachable space (meso space), even to the personal space (micro space), where all cosmic processes are directed to build energy [24]. The spatial development pattern of Sasak people is generally orientating on cosmologic values based on belief system and Sasak people's traditions in accordance with the local culture [25]. While the settlement system pattern of residences is based on the kinship system [26].

In their life, Sasak people have their way of socializing with a high spirit of fraternity, thus, people are closer to each other in unique ways. Cultural values are the reference of behaviors for the majority of people that have been embedded in their mind, which are consistent, and do not change easily in any circumstances. In the daily life, people live up to the existence of themselves and God as well as the relationship pattern based on the embraced value through interactions and learning processes with nature. The appreciation regarding the relationship pattern between humans and nature, and between humans and God, produces traditional wisdoms as the image of the community, either as an individual or ethnic community [27]. Involving culture in learnings can motivate students in class discussions, starting questions, accepting authorities, memorizing facts, finding innovative ways of understanding, and many other aspects in class education [5], [28]. Therefore, mathematical aspects of symbols exist in culture can be used in teaching mathematics concepts in a contextual manner [29]. In that order, teachers need to contextualize mathematics learnings by associating mathematics contents with the culture and actual life on students' experience [17].

Sasak people understand every inch of region (*paer*) with everything in it as nature that also contains a specific address (meanings and values) in establishing cosmological harmony. Concepts in building residence, selecting architectural designs, spatial management and selecting building materials are referring to the embraced principles, which are believed as a guideline that is considered as sacred [30]. Such understanding and awareness are expressed in *Adat* rituals specifically associated with nature. The harmony in discussion is connecting three elements, namely the relationship between humans and the Creator, the relationship between humans, and the relationship between humans and nature as the basis in life.

Sasak people believe and convinced that Mount Rinjani is the center of the earth that also works as the earth's axis with cosmological power it has. This belief system created ceremonial and taboo systems as restoration and appreciation efforts of the embodiment of gratitude towards The Creator. The tributes are committed in the forms of traditions, either in social relationship or in the relationship with nature through behaviors and expressions mediated by objects, such as weapons, jewelries or architectures.

In Sasak's architecture, the composition of the building mass is arranged based on these values. This concept is not far from the meaning that it is an expression of love and obedience to The Creator as the Creator of the Universe. This cosmological view is expressed from the development of functional and artificial spaces of house environment, up to regional layouts. In developing artificial areas, there must be a cosmological concept related to the center of the building picture and several other natural considerations.

In Sasak's traditional architectures, the selection of living settlement and residential pattern is highly related to natural factors, such as highland, land contour, water, forest, climate, view, orientation, and others. If looked more specifically, there are three aspects that become the main basis for traditional residential layouts of Sasak people, such as: i) Numerical fingerprint (*sidik numerik*): related to the harmonization of core-periphery that is geometrically measured by the quantity and the number of unit in a residential area, such as triangular, circular, and straight-rectangular or linear buildings; ii) Literal fingerprint (*sidik literir*): related to the naming that shows the location character and the area of traditional layout, each area or location

that has a name is used as a sign, attribute, and symbol; and iii) Genetic fingerprint (*sidik genetik*): related to the hereditary and heritage elements of a community that inhabit an area. Often measured by using anthropometry (human body size) as everything related to human works and creations that reflects the personality of the owner or the dimension of the owner himself.

Sasak's architectures, especially on residential patterns and living settlements are relatively having hereditary basic rules and became the life norms of the community. Such rules and norms are symbolized with "ngawan" book because life should be in order and regulated as is the universe. By construction, the residential architecture of Sasak people consists of 9 to 12 15x15 cm beam-shaped poles, with a sliding door (*lawang*) made of wooden board. The roof is *limasan*-shaped with the position of building against the mountain and located in the mountain area with a high foundation.

3.1. Mathematical ideas

As a basic knowledge of shapes and their orders, geometry has a massive contribution in architectural composition and designing. The composition in architecture starts with elements and their correlations in which geometric shapes work as the element and proportion, while angle and transformation work as the foundation structure [31]. The layout of the traditional village of the Sasak people is generally square-shaped with the residential layout lined up regularly in which the shape and size are relatively similar. The outside area of the village/hut (*gubuk*) is approximately three hectares, the village area is surrounded by ± 6 hectares reserve area for the expansion of the village which is called *due gubuk*. The village (*gubuk*) and *due gubuk* are in the middle of *tanak pecatu Adat*. If viewed mathematically, the village layout forms Venn diagram (subset).

The construction of the traditional residence of Sasak people is generally supported by nine to twelve sitting poles that rest on stone pedestal (*cendi*). These poles are made from wood, square-shape, the wall is made from woven bamboo and the roof is made from thatch grass (*re*). The types of Sasak's traditional residence are differentiated based on the strata of the residents, while the house layout is facing the mountain. In addition to the identity of the people, the existence of Sasak's traditional architecture is also functioned to identify the origin of a nation's identity. According to the residential forms and structures of Sasak people, mathematical forms and elements that were found available to be made as a learning material are presented in Table 1 (see Appendix).

Research results indicate that the layout pattern of the villages and the architectural form of Sasak traditional residence are made from mathematical models. The traditional village layouts of Sasak people that are surrounded by *duwe gubuk* and *tanak pecatu Adat* form mathematical pattern, namely subsets in materials regarding sets. While the concept of residential layouts and building architecture are made from geometric shapes, such as the room blueprint of *dalem bale* that is square-shaped, *sesangkok* blueprint that is rectangular-shaped, *limasan*-shaped roof that is made from trapezium and isosceles triangle, house stairs that are made from the composition of truncated pyramids, and the house door that is the combination of two-dimensional figures, namely rectangle and semi-circle.

The results of mathematical exploration on the traditional residential architecture of Sasak people can be made as the reference in learning mathematics in which the context of culture can be determined as the initial step to grow students' initial knowledge acquired from their environment. Designing students' knowledge by referring to the initial knowledge obtained from the environment becomes the focus of teachers in designing the learning. The crucial component in integrating culture with mathematical learnings is contextualizing learning materials with mathematics contents found by students in culture [17]. As a result, the analysis of students' mathematical knowledge acquired from their environment made researchers to conclude that mathematical knowledge is not only being discovered in formal activities, such as school, but also many found in their own culture and habits [10]. In many cases, learning mathematics in classes are terrifying experiences for students [32], therefore, focusing on socio-cultural experiences are proven to be more positive for students. Socio-cultural experiences obtained naturally by students are the initial knowledge found through the interaction with their own environment [33]. Students can develop their socio-culture experiences through many ways [34]. Ethnomathematics principles do not offer static learning, instead, students consistently develop new knowledge acquired through the interaction with their environment. Humans continuously tell stories or build narrations to understand various experiences they discover within their environment as the part of initial knowledge [35].

Mathematical reasoning can be developed by using the proper learning design and scrupulously-formulated assignments [36]. Mathematical learning outcomes are acquired from socio-cultural interactions, in which relevant ideas consist of facts, concepts, principles, and skills [37]. Therefore, learning designs and assignments are adjusted with the age and experience of students regarding mathematics [38]. However, teachers often find difficulties in designing and providing compatible assignments to students by not giving academic burden, but maintaining the involvement and exploration of mathematics found by them in their environment [39].

3.2. Educational values

House is one of the embodiments of cultural product and the development of human civilization. This cultural product has suprastructure domain and complex structures. In the suprastructure manner, a construction of a house is based on hope and faith that comfort and safety will be acquired in the arms of nature and the protection of The Almighty. Due to that, the selection of materials, construction procedures, and determination of the construction time are based on the belief as the suprastructure driver. The basic rule that needs to be made as the reference for a house is the concepts of *pemolé* (honoring) and *semaiq* (sufficient). Structurally, house is built with the concept underlined in suprastructure (*pemolé* and *semaiq*) by using the materials existing locally. The provision of space, size, and structure, both vertically and horizontally are oriented to meet suprastructure needs. We understand that residential layouts and architectural forms are majorly influenced by a wide spectrum. Residential characteristics are not determined by physical impacts alone, but the results of all socio-cultural factors. House designs are influenced by cultural values and options [40]; house represents rules, norms, and social relation [41], traditional house is full with symbolic meanings [40], [42], [43]. In this context, ethnomathematics can be perceived as the study about the relationship between culture, mathematics, and mathematics education [6]. Ethnomathematics is a term created to explain that every individual uses and capable of learn mathematics [44].

In the construction process, the traditional residence of Sasak people is not only functioned as a living place, but also as an artificial space as the representation of the owner as cosmology, therefore, a house is built to provide comfort and safety for the owner. Due to that matter, the house owner should harmonize the existence of his house with both physical and non-physical environments. According to Memarian and Brown, layouts and architectural forms of traditional residence are mostly constructed based on social values and religious ideologies [45].

The forms and structures of the residence to be built do not only fulfill the aesthetics aspect, but are prioritized more on the philosophy of the residence's form and layout. The architectural form of a traditional house reflects the local culture. If seen from the forms and structures, Sasak's residences also have cultural values. In general, the traditional residential structures of Sasak people consist of three spaces, namely *dalem bale*, *bale dalem*, and *sesangkok* or *ampik*. If seen from its architecture, the traditional houses of Sasak people have *limasan*-shaped roof, there is only one door without windows, the room of *dalem bale* is square-shaped with the size of 3x3 *sikut*, there are three stair-steps towards *dalem bale* in the shape of truncated prism, *sesangkok* or *ampik* is rectangular-shaped, the roof is trapezoidal when viewed from the front and back, and the side-view roof of the house is isosceles triangle-shaped. Philosophically, the educational values exist in the form and architecture of traditional residence of Sasak people can be seen in Table 2.

Table 2. Educational values on the traditional residential architecture of Sasak people

Representations	Objects	Educational values
The direction of a house must not face north or south	House direction	West direction is Qibla. Humans must always respect the Almighty.
The houses face one direction	House direction	The democratic value is reflected in <i>Adat</i> settlements that face one same direction, towards the east/sunrise. The <i>Adat</i> settlements means that people have to follow the leader first, decided through a colloquy.
Houses are lined up regularly with the same form and architecture	House form	The value of harmony in which everything is the same without any noticeable differences.
The roof of the house is in the form of a pyramid pointing upwards with a distance of approximately 1.5 meters from the ground, almost covering the wall	House roof	Live only once and surrender only to God. The distance between the roof and the ground is very low, this reflects that the mind and heart and human steps are always parallel.
There are two stair-steps to <i>sesangkok</i> and three stair-steps to <i>dalem bale</i> . Therefore, there are five stair-steps in total.	House stairs	There are five stair-steps in the house of Sasak people, with a hope that their descendants will always remember that they born Islam and always remember about the five pillars of Islam. There are three stair-steps towards <i>dalem bale</i> , advising that there are three definite stages in human life to go through, namely the realm of the womb, the realm of the world and the afterlife.
There is a door without windows	House door	Every human has the same purpose vertically: getting close to the Creator. Facilitating the supervision, so anyone who comes and goes will be known.
The door made low	House door	Entering the house while lowering the head gives the impression of greeting, and the house owner also greets the incoming guest. Respecting each other and being humble.

Table 2 shows moral messages contained in the form and structure of the traditional residence of Sasak people. The embedded educational messages or values are an advice that can be made as the basis to live the life for their posterity. The form and layout of Sasak people traditional residence provide the character of the people as an identity. Houses that face the same direction show that in togetherness, same purpose is embraced, i.e., obeying the leader. The number of stairs shows the faith towards the embraced religion. The number and shape of doors are the reflection of respect and appreciation towards others. In general, we understand that people honor morality and ethics highly.

Morality and ethics are the part of the way of life, both individually or as a community, which cannot be separated from all other life aspects [46]. Culture exists in the representation inherited by individuals from tribe traditions that contain education value systems associated with various approaches with different levels [47]. Cultural values are related to those that are morally considered as good or bad in the community, but because they are abstract, values are not directly correlated with behaviors; by contrast, relative routines indicate individual behaviors. Cultural values can be categorized into the thought system regarding belief, faith, religion, and custom that becomes the part of cultural identities [48]. The implementation of cultural values in formal education is aimed to improve the moral and character development of students, in which cultural values and education are supported by moral philosophies, moral psychologies, and moral educational practices [49]. Cultural values and education are about inner changes, as spiritual materials and arrive through the universal internalization of religious values [50].

4. CONCLUSION

Mathematics can be found in any activities of life, either in the form of ideas, activities, or cultural artifacts. One of the cultural artifacts that can be found in Sasak people is traditional village. Traditional residence/village of Sasak people is not only be made as the cultural tourism alone, but can also be made as cultural mathematics tourism. As can be seen in the layout pattern and architecture of Sasak traditional residence that are composed of geometric shapes, both flat and spatial geometries. The form of traditional residential architecture of the Sasak people is not only considering the values in terms of aesthetics but also the philosophical values contained therein. In terms of the shape and structure that forms it, the traditional housing of the Sasak people consists of a *limasan*-shaped roof, trapezoidal front and rear roofs, a side roof in the shape of an isosceles triangle and a ladder leading to *dalem bele* in the shape of a truncated pyramid.

Geometric shapes that become the part of traditional residential architecture of Sasak people can be found in mathematics learnings. This study shows that cultural artifacts as the heritage of the ancestors can be made as the initial step in learning real-life mathematics, especially regarding geometric topics. So, the benefit of cultural artifacts of Sasak people can be made as the instrument to motivate students to learn mathematics, and build the meaning of cultural values in mathematics learnings, and mathematics substance aspects. The culture of Sasak people can be made as concrete mathematical objects, the context of mathematical issues, and the example of mathematical application in the daily life. One of the developments of students' creativity can be done through the integration between mathematics and culture in education to grow students' capability in developing cultural values and the present context based on creative-mathematical-thinking skills. One of the factors affecting the children way of learning is the education received from the environment. Mathematical symbols, objects, and contexts found in the community are objects related to historical and social aspects of a culture. The results of this study can also be made as the reference for teachers in Lombok Island, Indonesia to improve the creativity and motivation of students to learn mathematics by integrating their cultures.

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APPENDIX

Table 1. Forms and elements of mathematics on residential architecture

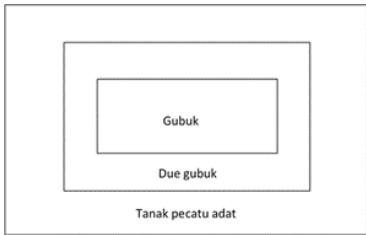
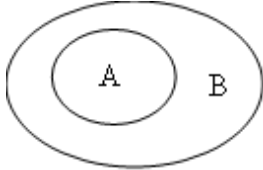
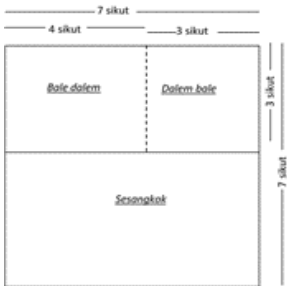
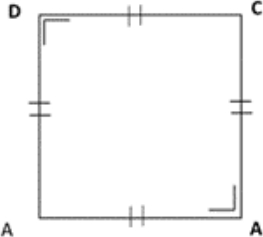
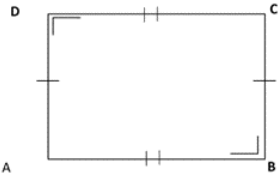

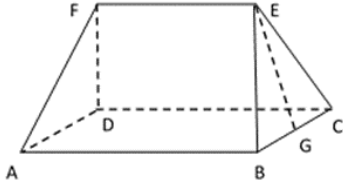

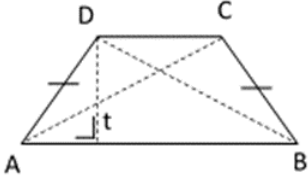

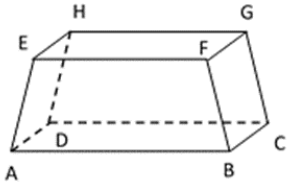

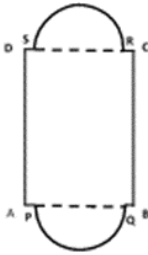



Representation	Objects	Mathematics concepts
<p>The village structure (<i>gubuk</i>) is surrounded by <i>due gubuk</i> and <i>tanak pecatu Adat</i></p> 	<p>The traditional village layout (<i>gubuk</i>) of Sasak people</p>	<p>If every member of A is also the member of B, namely if $x \in A$ and $x \in B$, so A is defined as the subset of B, or A is included in B, and written as $A \subseteq B$</p> 
<p>Residence is divided into two parts, namely: <i>dalem bale</i> and <i>sesangkok</i>. <i>Dalem bale</i> is divided into two parts by using a screen/curtain. The room inside <i>dalem bale</i> is square. <i>bale dalem</i> and <i>sesangkok</i> are rectangular-shaped.</p> 	<p>The layout of traditional residence of Sasak people</p>	 <p>Perimeter=$4s$ Area=s^2</p>  <p>Perimeter=$2(p+l)$ Area=pxl</p>




Table 1. Forms and elements of mathematics on residential architecture (continued)

Representation	Objects	Mathematics concepts
<p>Limasan-shaped roof, built 1.5 meter above the ground.</p> 	House roof	 <p>Perimeter=$AB+BC+AD+CD$ Area=$\frac{1}{2} t (AB + DC)$</p>
<p>The front and rear roofs are trapezoidal.</p> 	The front and rear views of the roof	 <p>Perimeter=$AB+BC+AD+CD$ Area=$\frac{1}{2} t (AB + DC)$</p>
<p>The stairs to <i>dalem bale</i> are in the form of a truncated pyramid that consist of three flats.</p> 	House stairs	 <p>The volume of truncated prism $=\frac{1}{3} t (D + A + \sqrt{DA})$</p> <p>Where: t=height D=base area A=upper area</p>
<p>The door to <i>dalem bale</i> is a rectangular and semicircular combination</p> 	House door	 <p>Rectangle perimeter $= 2 (p+l)-2 \times diameter$ $= 2 (AB+AD)-(2 PQ)$</p> <p>Circumference = $2\pi r = \pi d$ Joint circumference $= 2 (AB+AD)-(2 PQ))+ \pi PQ$ Rectangle area = $p \times l$ $= AB \times AD$</p> <p>Circle area = πr^2 $= \pi \left(\frac{1}{2} d\right)^2$ $= \pi \left(\frac{1}{2} PQ\right)^2$ Joint area=$(AB \times AD)+\pi \left(\frac{1}{2} PQ\right)^2$</p>




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