Geleng, an Earthquake Resistant Sasak Vernacular Building in Lombok, Indonesia

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Abstract

Geleng is a Sasak vernacular building that serves to store agricultural products in a traditional house in the island of Lombok, Indonesia. There are also other names for the Geleng, depending on the village. In the village of Limbungan, it is called Panteq. In Senaru village and in Sembalun village it is called Geleng. In Sade village, it is called Bale Alang. During the magnitude-7 Lombok earthquake, Geleng was able to withstand the earthquake. This fact proved that Geleng has a high resistance to earthquakes.

This study investigates the reasons for the high earthquake resistance of the Geleng building. Data was collected using a survey in the villages of Limbungan, Beleq Sembalun, Senaru, and Sade. The number of Gelengs investigated were: six in Limbungan, one in Sembalun, and three in Senaru. Bale Alang in the Sade village was not included in this study because it has a different roof structure from the Geleng in the other three villages. The dimensions of the Geleng structural elements are measured and the drift ratio capacity is calculated.

The results of this study show that the Geleng structure of Sembalun village has the highest drift ratio capacity, which is 72.0%. This is followed by the Limbungan village at 71.5% and the Senaru village has a drift ratio capacity of 54.5%. This result proves that all the Geleng buildings have a drift ratio capacity that exceed the minimum drift ratio requirement for earthquake-resistant structures, which is 3.5%.

Keywords: Vernacular architecture, Geleng, Drift ratio, Earthquake Resistance

Introduction

Vernacular architecture is one that has developed over a long period of time in an area adapted to local climatic conditions, as well as cultural, economic, and historical contexts in that period (Du, Bokel & Dobbelsteen, 2018). The term vernacular architecture denotes an architectural design that uses locally available resources to meet local needs (Ju, Omar & Ko, 2012), where building owners can participate and build with local materials and techniques (Chang & Chiou, 2018). Vernacular architecture where local wisdom is applied to build is indeed sustainable. This is because sustainable architecture is not only closely related to economic, social, human, and environmental continuity, but should also include architecturally innovative technologies, historical aspects, local culture and efforts in environmental conservation (Susilo, Umniati & Pramitasari, 2019).

Vernacular architecture is produced through a traditional process; namely a hereditary process, be it the object, the method or the 'technology'. Nowadays, there is very little written knowledge about *Sasak* vernacular architecture in the island of Lombok. Most of its existence is still a relic of architectural objects. In the near future, *Sasak* vernacular architecture may become extinct due to the influence of modern technological architectural developments and the influence of the age of architectural objects (Du, Bokel & Dobbelsteen, 2018).

Sasak vernacular architecture located in the island of Lombok, West Nusa Tenggara, exists today only as relics, a legacy from ancestors who used them as a tourism object. Moreover, today's 'modern' Lombok community rarely builds their houses according to their traditions using *Sasak* architecture. From residential buildings in the island of Lombok, it is shown that people prefer 'modern' buildings, which use reinforced concrete technology.

This research on the *Sasak* vernacular architectural model is motivated by the 2018 Lombok earthquake with a magnitude of 7 on the Richter scale which knocked down most of the residential buildings in the island of Lombok (Wikipedia, 2018). However, most of the buildings belonging to *Sasak* vernacular settlements did not collapse. This shows that *Sasak* vernacular architecture has been designed to withstand earthquakes.

Sasak vernacular architecture consists of many buildings and masses arranged to form a traditional housing complex. Two types of mass structures exist in the traditional *Sasak* house, namely the arrangement of the mass of the building on the contoured land surface and the arrangement of the mass on the flat land surface (Susilo and Umniati, 2021). There are five types of buildings in the Sasak traditional house, namely: 1) *Bale Tani* used for housing on a contoured land surface. 2) *Bale Mengina* used for residence on a flat land surface. 3) *Geleng*, a type of building that has high legs and is used to store rice. 4) *Berugaq*, a type of building used for gatherings and various activities. 5) *Sambi*, a type of building used to store rice but has short legs.

Geleng is the type of simple timber building whose appearance is the most prominent in the mass group of *Sasak* traditional houses. Therefore, in this study, *Geleng* becomes the focus of research. The type of *Geleng* building in its development has changed both in terms of shape and name, although in terms of its use it is still the same. The biggest change in shape is found in the *Geleng* in the *Sade* traditional house called *Bale Alang*. The difference between *Geleng* in each village is mainly due to differences in the area of the roof shade. The difference in the area of the roof shade is due to a change in the use of the roof as shown in Fig. 1. The simplest form of *Geleng* is found in the village of *Beleq Sembalun*. In terms of the area of the roof structure, the *Geleng* building in the *Senaru* traditional house has a wider roof structure than that in the *Beleq Sembalun* village. Likewise, the *Geleng* in the traditional house of *Limbungan* village, the roof is even wider when compared to the one in the *Senaru* traditional house whose name has changed to *Panteq* (Susilo, Umniati & Pramitasari, 2020).

A Review of Earthquake Resistant Structure

The principles of planning of earthquake-resistant building structures are based on the level of earthquake strength that occurs, namely low or minor, medium, and strong earthquakes ground motions. They are as follows: a) For minor earthquake ground motions—the structural design allows minimal damage, which does not affect the functionality of the building, b) For moderate earthquake ground motions—the structural design allows damage that may affect functionality of the building. and c) To design earthquake ground motions— the structural design allows major damage but significant falling hazards are avoided; likely loss of functionality of the building (ATC-40, 2017), (FEMA-BSSC, 2015). The resistance of a structure to earthquake loads can be calculated based on how much energy can be absorbed and transmitted by the structure. The amount of energy from an earthquake is indicated by the intensity of the earthquake or from the magnitude of the earthquake. The intensity of an earthquake is the degree of shaking that occurs in a certain place or area. To measure the intensity of this earthquake, several intensity scales are known, including the MMI (Modified Mercalli Intensity) scale or the MM scale, the Mercalli scale which has been modified by Neuman, the MSK scale (Medvedev-Sponheuer-Karnik), and the JMA scale (Japanese Meteorological Agency). While the magnitude of the earthquake is the amount of energy released at the epicenter (hypocenter), the magnitude M is defined by Richter in 1935, and is often used to express the strength of an earthquake. The relationship between the magnitude M (in the Richter scale) and the earthquake energy E (in erg), is expressed in the following equation (Gutenberg and Richter, 1956):

For an earthquake with a shallow epicenter, $\text{Log } E = 11.8 + 1.5\, M_s$ .... (1)
For earthquakes with deep and moderate epicenters, $\text{Log } E = 5.8 + 2.4\, m_B$ .... (2)
Where, E = earthquake energy (in units of erg. 1erg= 1.0168 x 10^{-7} kNmm); M_s = surface wave magnitude; m_B is deep wave magnitude, long period.

$M = \log A$ .... (3)

That is the amplitude A as measured by a Wood-Anderson seismometer, at a distance of 100 km from the epicenter (projection of the hypocenter to the earth's surface). Not always earthquake strength is measured at a distance of 100 km. If measured at any distance, then equation 3 is modified to:

$M = \log A - \log A_0$ .... (4)

Where, A = maximum amplitude measured at a distance to a certain earthquake; A_0 = special amplitude for the selected earthquake as standard.
The complete energy balance of the structure is given by Uang and Bertero (1990) in Symans *et al* (2008) as:

$E_I = E_S + E_K + E_D + E_H$ ………. (5)

Where, at a given moment in time, t, E_I = cumulative input energy; E_S =the instantaneous strain energy stored by the structure; E_K = instantaneous kinetic energy of the moving mass; E_D = cumulative viscous damping energy; and E_H = cumulative hysteretic energy.

At the end of the earthquake time $t=t_f$, the kinetic energy is zero, the strain energy is zero for an elastic system and zero or close to zero for an inelastic system, and the cumulative hysteretic energy is equal to the energy demand i.e., $E_H (t_f)$=E demand. The cumulative hysteresis energy of the structure can be calculated from the area of the relationship curve between the lateral earthquake load and the displacement at the beam column connection. The larger the area of the curve, the greater the earthquake energy, the structure can withstand. If the energy value of E is known, then from equations 1 and 2, it will be possible to calculate the magnitude of the earthquake, the structure can withstand.

The earthquake resistance of a structure can also be shown from the value of its drift ratio capacity. The drift ratio capacity is the amount of displacement, the structure can withstand in a non-collapsed condition divided by the height of the column. It can also be written in the following formula: $DR = \Delta / l_c$ ……….. (6)
Where DR = drift ratio capacity; Δ=displacement capacity; *lc* = column length.

The greater the drift ratio capacity of a structure, the greater the ability of the structure to deform. It can be said that the structure is more flexible and the higher in resistance of the structure to earthquakes (Badan Standarisasi Nasional, 2019).

To increase resistance to earthquakes, the structure of a building can be stiffened with earthquake dampers. There are several types of earthquake dampers in building structures, including bracing installed diagonally at the ends of the columns, or viscous damper, mechanics damper, or friction damper, or many others. In vernacular buildings, some have used earthquake damping systems. Among other things, the Dhajji-Dewari house in Kasmir (Thappa et al., 2022) uses X-bracing between the columns to absorb the seismic forces acting on the beam-column connections and dissipate it to adjacent beams and columns. X bracing had been also used in Nias vernacular architecture, in such a way, during the Nias earthquake, the structure was still intact. (unknown, Nias, 2020).

In the *Sasak* vernacular architecture, the earthquake damping element is the beam-column connection itself. The column is perforated so that the beam can pass through the column. This connection is fastened by dowels. If the earthquake is big enough, these dowels can come out of the hole and even fall. There will be friction between the beam and column and this will cause displacement. The excess length of the beam end passing through the column hole will provide a greater displacement capacity for the column beam connection.

In this study, the *Geleng* building is grouped into three parts, namely the sub-structure or the bottom structure, the middle structure, and the upper structure. The sub-structure consists of pedestal foundations, beams and columns. The middle structure consists of a floor, 4 columns, and 2 *Galang* beams. The upper structure consists of a space structure for storing agricultural products and a roof structure. The non-structural elements in the *Geleng* building consists of wall coverings made of *Gedeg* (woven bamboo slats) and roof coverings made of thatch, which are arranged in tiers.

The column structure is made of logs. It can also increase the earthquake resistance of the *Geleng* structure, as the House in Meghalaya India is earthquake resistant supported by logs wood or bamboo (Vijayalaxmi and Singha, 2021). Tie beams are made of wood with a rectangular cross section. The roof frame uses wood and bamboo, and the roof covering is made of reeds. Hence, the load received by the *Geleng* structure from its weight is relatively smaller when compared to structures made of concrete. When there was an earthquake with a large magnitude (7 SR) in Lombok in 2018 (Wikipedia, 2018), all the types of *Geleng* buildings in the traditional settlements did not collapse. It was found that one *Geleng* was damaged in non-structural elements because it was no longer used. This phenomenon is interesting to study, because even though it was shaken by the Lombok earthquake and its aftershocks, which occurred very often after the first earthquake for a long time, the Geleng structure remained intact, stood upright and did not collapse. Hence, the aim of this study is to investigate the earthquake resistance of the *Geleng* structure.

Fig. 1: (a) geleng in Sembalun village, (b) bale Alang in Sade village, (c) geleng in Senaru village, (d) panteq in Limbungan village
Source: author

Research Method

This study aims to investigate and describe the parts of the *Geleng* structure and the earthquake resistance of the *Geleng* structure in traditional *Sasak* architecture on the island of Lombok. The research used a survey method involving a direct survey in the field. The research variables studied were the *Geleng* parts, both structural and non-structural elements, and the earthquake resistance of the structure. The research parameters measured the dimensions of the structural elements of the *Geleng*, the damage to the structural parts, and the non-structural parts due to the earthquake. 10 *Geleng* samples were examined. Sampling was carried out in traditional houses: 1) Limbungan Barat village, 2) Limbungan Timur village, 3) Beleq Sembalun village, 4) Senaru village. The number of *Geleng* samples in each village are three in Limbungan Barat, three in Limbungan Timur, three in Senaru, and one in Sembalun. The total number was 10 *Geleng*.

Findings

It was found that the *Geleng* structure has the following parts: the foundation, beams, columns, walls, floors, roof structures, and roof coverings. All elements are connected using dowel joints and flexible joints. As mentioned before, the *Geleng* structure is named based on the location of its parts, which are the substructure, the middle structure, and the upper structure. The substructure consists of pedestal foundations, beams, and columns. The middle structure consists of floors, columns, beams, and *Galang* beams. The upper structure consists of a floor structure, a space for storing agricultural products (barn) in the form of a column and beam frame, a plank floor, a wall stiffener frame, and a roof structure. The details are as follows:

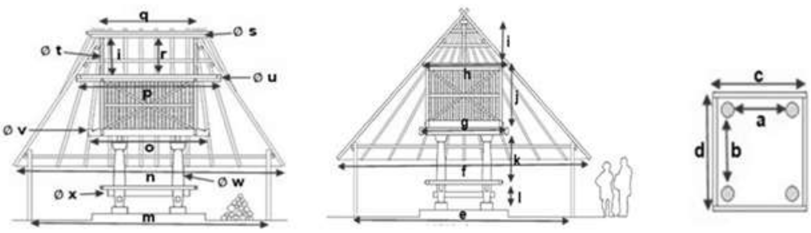

Fig. 2: Kit map and measurement codes
Source: Author

Table 1: Dimension of the elements of Geleng (all units are in cm)
Source: Author

The dimensions of the *Geleng*	CODE	PANTEQ / PAON							GELENG				
		Limbungan Barat			Limbungan Timur				Sembalun	Senaru			
		LBB 2	LBB 4	LBB 6	LBT 2	LB T 4	LB T 6	Mean	SBL	SN 8	SN 9	SN 7	Mean
Short tie beam	a	138	132	133	140	150	133	138	132	120	130	122	124
Long tie beam	b	150	150	155	160	160	157	155	132	135	150	141	142
Short bed	c	280	270	242	246	245	252	256	155	173	220	190	194
Long bed	d	310	300	278	280	270	305	291	155	200	250	200	217
Width of Geleng	e	530	490	521	520	480	545	514	220	0	0	0	0
Width of roof area	f	635	580	535	565	600	610	588	320	500	490	515	502
Galang beam	g	250	250	242	230	220	260	242	259	227	200	240	222
Barn width	h	270	275	245	220	260	245	253	220	250	218	271	246
Nok support pole	i	125	125	132	106	130	134	125	110	110	110	126	115
barn column height	j	157	155	150	136	160	146	151	158	128	130	158	139
Amben to Galang distance	k	110	115	114	105	120	130	116	107	123	110	120	118
Amben to Cendi distance	l	50	57	63	48	52	54	54	49	44	35	47	42
column height		160	172	177	153	172	184	170	156	167	145	167	160
Length of Geleng	m	575	575	521	545	490	564	545					0
Length of roof area	n	650	650	563	625	640	610	623	380	576	510	610	565
Blandar beam	o	292	280	291	270	275	300	285	280	290	290	282	287
Length of Barn beam	p	402	360	388	360	355	412	380	430	426	320	395	380
Nok beam length	q	305	290	227	286	230	285	271	305	246	230	222	233

Nok support pole	r	125	125	132	100	130	134	124	110	110	110	126	115
Nok cross section	s	10x8	12x6	12x6	10x8	10x8	8x6,5	11x7	12x6	7x8	10x8	10,5x9	9x8
Nok support cross section	t	8X8	12x6	9,5x6,5	10x6	7x7	7x6,5	9x7	12x6	8x8	8x8,5	8x8	8x8
Barn beam dimensions	u	12x6/5,5	10x6	12x5,5	10x8	11x6	13x7,5	11x8	12x7,5	15x7	13x7,5	12x7	13x8
dimensions of Galang	v	11x7	15x10	12x8	10x8	13x6,5	11x7	11x8	14x10	11x10	10x11	11x9,5	11x10
kel. Tiang	w	75	80	72	60	70	78	73	70	70	72	74	72
dimensions of tie beam	x	14X10	10x5	11x6	8x6	9x6	11x6	10x6	11x5	4x6	10x8,5	8x5,5	10x8
Diameter of column	y	24	25	23	19	22	25	23	22	22	23	24	23

Bottom Structure

The bottom structure of the *Geleng* is the foundation up to the column and the lower part of the beam-column connection. In the *Geleng* foundation, pedestal foundations are used, consisting of stone with a diameter larger than the diameter of the column, which is supported on this pedestal foundation. Because the column at the bottom of the structure is supported on a pedestal stone, the *Geleng* structure can move. This can also be found in other traditional houses that use stone foundations such as most traditional houses in Indonesia (Kusuma, 2022) and traditional Thai houses in the southern region (Choawkeaw, 2021). Between the pedestal and column foundations, fibers are placed with a thickness ranging from 0 cm - 6 cm. This fiber serves to dampen the loads from the column and forward to the foundation. After the fibers, the four columns of the *Geleng* structure are placed. This column is spherical with column y diameter ranging from 19-25 cm (Table 1). Images of pedestal foundations, layers of fibers, and the bottom columns of *Geleng* in the Limbungan village, the Sembalun village, and the Senaru vilage are shown in Fig. 3.

a b c

Fig. 3: The bottom structure of the Geleng in (a). Limbungan (b). Sembalun (c). Senaru
Source: Author

At a distance of *l* = 35-63 cm from the pedestal foundation (Table 1), the column is tied with tie beams. The beam and column connections are made with dowel connections. This dowel connection is made by punching holes in the column according to the size of the tie beam in the length and width directions (long stitching and short stitching). Then the beam is placed through the hole in the column and given a dowel at the bottom of the beam that enters the column, to strengthen the connection so that it is not loose. The end of the beam that passes through the column is exaggerated with the length of the pass varying between 10-75 cm from the face of the column. This beam-column connection is flexible/non-rigid with the length of the beam and the dowel placed at the bottom of the beam-column connection as shown in Fig. 3.

Middle Structure

The middle structure consists of a floor called *Malak*, which can be used for sitting or lying down columns, and the head of the column, which is wider than the column called *Jelepeng*, and *Galang* beams. This *Galang* beam is placed on top of the *Jelepeng*. In Lombok language, *galang* means pillow. The function of the *Galang* beam is to support the load of the upper structure, namely the barn where agricultural products are stored. This *Galang* beam is placed on top of the *Jelepeng*. The *Galang* beam is passed with the length of the pass varying between 42-63 cm from the center of the column as shown in Fig. 4.

Fig. 4: The middle structure of the Geleng
Source: author

Upper Structure

The upper structure consists of a storage space structure (storage of agricultural products) and a roof structure. Agricultural storage space (barn) consists of floors, walls, and roofs, as shown in Fig. 5. The floor is made of wooden planks laid freely on the *Galang* beam, as shown in Fig. 6. On the edges on all four sides, this plank floor is fastened by *Galang* beams with dowel connections to each other. Above the floor, wall rib straps tied to the columns of this storage room (barn) are installed. The fasteners are provided with holes as wide as the ends of the wall ribs so that the ribs can be inserted directly into the wall rib fasteners. The ribs of the walls are in the form of several wooden slats and wall coverings of woven bamboo. These wall ribs are cut at both ends at an angle and taper off at the ends. They are inserted into the holes in the wooden slats to tie the wall ribs to the top and bottom of the ribs.

Fig. 5: The barn structure of Geleng
Source: author

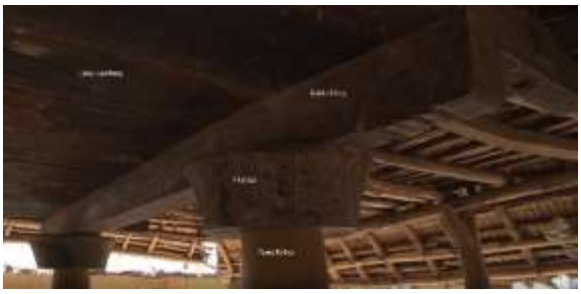

Fig. 6: View under the barn floor
Source: author

A requirement for buildings that are resistant to earthquakes is to have high deformability of more than 3.5. Deformability is the ability of a structure to deform, which can be indicated by the ratio between the ultimate deformation (deformation at maximum load) to the deformation of the elastic limit of the structure (Badan Standarisasi Nasional, 2019). The deformation can be in the form of displacement, stress, and strain. From the results of the survey in the Limbungan village, the Sembalun village, and the Senaru village, the *Geleng* structures which did not collapse after the Lombok earthquake were included. This means *Geleng* structures that could withstand a 7 SR earthquake. This is because the deformation ability of the *Geleng* structure is very high. The *Geleng* can withstand horizontal loads and absorb the earthquake energy it receives and convert it into a form of lateral deformation called displacement. The greater the horizontal load received by a *Geleng*, the greater the deformation that will occur. A *Geleng* can receive a larger horizontal load because it has a high deformation capability which is indicated by the high capacity of *Geleng* drift ratio (Preumont, 2013). This deformation ability is indicated by the value of the drift ratio of the *Geleng* structural elements.

In the substructure, under the column, a pedestal of stone is used which allows the *Geleng* structure to move freely because there is no restraint. The *umpak* foundation has been widely used in traditional houses in Indonesia (Kusuma, 2022) and traditional Thai houses in southern Thailand (Choawkeaw, 2021). Between the columns with the base of the foundation is given a base of fibers that function as an insulator/damper for earthquake forces (loads), as well as an elastomer that dampens the dynamic forces of the bridge. The four sub-structure columns have beam-column connections with high deformability due to the use of dowel connections. In addition, at the end of each tie beam that enters through the column, an additional beam length of varying length is provided so that the drift ratio of substructure of *Geleng* is also different for the three villages, as shown in table 2.

Table 2: The drift ratio capacity of the Geleng sub-structure in 3 villages
Source: Author

No.	Villlage	Average additional beam length (cm)	Height of column (cm)	DR Capacity %	Description
1.	Limbungan	73	54	135.2	>3.5 accepted
2.	Sembalun	55	49	112.2	>3.5 accepted
3.	Senaru	27	42	64.3	>3.5 accepted

We compared the value of the drift ratio capacity of the three villages to the minimum drift ratio value that must be provided for the required minimum drift ratio capacity of 3.5% (Badan Standarisasi Nasional, 2019). It can be concluded that the *Geleng* sub-structures of the three villages have a high deformation capability and that they are resistant to earthquakes. In other words, the higher the drift ratio, the more flexible the *Geleng* structure has. Therefore the *Geleng* structure becomes safe (Tanabashi, http://hdl.handle.net/2433/123698).

In the middle structure, the end of the beam is longer than the column beam connection. The length of this *galang* beam pass also varies in each village so that the drift ratio of middle structure of *Geleng* is also different for the three villages, as shown in table 3.

Table 3: Middle-structure drift ratio capacity of Geleng in 3 villages
Source: Author

No.	Villlage	Average additional beam length (cm)	Height of column (cm)	DR Capacity %	Description
1.	Limbungan	42	116	36.2	>3.5 accepted
2.	Sembalun	63	107	58.9	>3.5 accepted
3.	Senaru	55	118	46.6	>3.5 accepted

From the capacity value of this drift ratio, it is notable that it is also far above the required minimum drift ratio capacity of 3.5%. The gravity load on the upper structure from the self-weight of the barn above the *Galang* beam also reduces the horizontal force/earthquake force that occurs and minimizes the deformation that occurs.

In the upper structure of *Geleng*, the barn floor called the *Gelampar* board is placed freely on top of the *Galang* beam. This *Gelampar* board is bounded by 4 *Belandar* beams on all four sides. At the meeting point of 2 *Belandar* beams in the x and y directions, barn columns are placed and entered in the upper and lower *Belandar* beams. The passing length of the *Belandar* beams is used to calculate the drift ratio capacity of the upper structure of the *Geleng*. The length of the crossing of these beams varies between villages. The drift ratio capacity for Geleng in the Limbungan, Sembalun, and Senaru villages are as in the Table 4.

Table 4: Geleng superstructure drift ratio capacity in 3 villages
Source: Author

No.	Villlage	Average additional beam length (cm)	Height of column (cm)	DR Capacity %	Description
1.	Limbungan	65	151	43.0	>3.5 accepted
2.	Sembalun	71	158	44.9	>3.5 accepted
3.	Senaru	73	139	52.5	>3.5 accepted

The roof consists of roof beams, roof beam supports, bamboo ribs, and roof coverings made of dry thatch leaves, as shown in Fig. 7, tied to wooden or bamboo battens. The pier beams and the support posts for the camouflage beams use dowel connections. The usuk, battens, and roof coverings use ropes from palm fiber, rattan, or bamboo as the straps. Therefore, all connections on the roof use flexible joints. In addition, the material used is lightweight.

Fig. 7: The roof covering made of dried thatch leaves
Source: Author

From the capacity drift ratio for the bottom, middle, and top of the structure as shown in table 2, 3, and 4, the average drift ratio for *Ge*leng can be calculated as shown in the Table 5.

Table 4: Average capacity of Geleng drift ratio
Source: Author

No.	Villlage	Sub Structure DR Capacity %	Middle Structure DR Capacity %	Upper Structure DR Capacity %	Average DR Capacity %
1.	Limbungan	135.2	36.2	43.0	71.5
2.	Sembalun	112.2	58.9	44.9	72.0
3.	Senaru	64.3	46.6	52.5	54.5

From the results of the calculations of the drift ratios, it is seen that all the capacity values for the drift ratios in the lower, middle, and upper *Geleng* structures, and their average values, are far above the minimum drift ratio values specified by standard Codes (Badan Standarisasi Nasional, 2019). Hence, with a very high value of this drift ratio capacity, the *Geleng* is resistant to earthquakes. If a hysteretic loop curve is made that shows the relationship between earthquake loads and displacements, a larger curve will be obtained. The larger the area of the curve, the greater the earthquake energy that can be absorbed (Umniati, *et al.*, 2017).

On the other hand, the *Geleng* structure has high stiffness with a relatively small self-weight. The magnitude of the earthquake force that must be resisted by a structure, called the Base Shear force, can be written in the following equation:

V = Cs x W, Where V is the magnitude of the base shear force; Cs is the seismic response coefficient; W is the total weight of the building (Dalgliesh, 2014).

Thus, by considering the construction materials, the Geleng are made from wooden beams and columns, with woven bamboo walls and thatch roofs, making the self-weight of the *Geleng* structure relatively smaller than that of reinforced concrete structures and steel structures. Hence, by calculating the basic earthquake force of the structure (base shear) using equation V = Cs x W (Badan Standarisasi Nasional, 2019), the base earthquake forces on the Geleng structure will be relatively small compared to reinforced concrete structures and steel structures.

Conclusion

From the findings and the discussion, several conclusions can be drawn as follows:

1. The *Geleng* structure in every *Sasak* traditional village on the Indonesian island of Lombok has different dimensions of structural elements with large variations in the dimensions of the *Geleng*, making it difficult to generalize
2. The *Geleng* structural consists of the bottom structure, the middle structure, and the upper structure. The bottom structure consists of the pedestal foundation, columns, and beams. The middle structure consists of a *Malak* floor, columns, *jelepeng*, and *Galang* beams. The upper structure consists of floor, tie beams, columns, walls, and barn for storing agricultural products, wall stiffening ribs, and roof truss and covering structure.
3. The highest value of the average drift ratio capacity for the *Geleng* structure is achieved by Geleng in the Sembalun village, which is 72.0%, then in the Limbungan village is 71.5% and the lowest is in Senaru village is 54.5%. Thus, all *Geleng* in the villages of Limbungan, Sembalun, and Senaru have met the requirements for the minimum drift ratio capacity value of 3.5%.
4. Since the load from the Geleng self-weight is relatively small compared to reinforced concrete structures and steel structures, the magnitude of the earthquake force that occurs in the Geleng will also be relatively smaller than the two types of structures.

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