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Analysis of the Performance of Tongkonan Traditional House Structure Based on Eco Panel Material Against Earthquake Loads

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ABSTRACT

The Tongkonan building in Toraja is one of many structures in the archipelago that possesses a unique form, structure, and construction. The traditional house of the Toraja tribe located in South Sulawesi Province is called the Tongkonan. This building is made of wood. The traditional house differs from other traditional houses in terms of its structural system, making the Tongkonan a very interesting subject for research. Along with the advancement of time, it is important to study and analyze the structure of Tongkonan in order to enhance its resilience to earthquakes. This research aims to analyze the behavior of the Tongkonan structure under earthquake loads. The structure of the Tongkonan house is modeled in SAP2000 software to obtain the internal forces acting on the structural elements of the Tongkonan house. Then an analysis was conducted on the beam section, resulting in the internal force analysis occurring within the structure. The internal forces of the Tongkonan structural elements refer to the principles of tension and compression members, beam-columns, and flexural members, depending on the internal forces acting on each element. The results of the structural modeling analysis show that Tongkonan I is more resistant to earthquakes, with a minimum axial value of –1385.74 kN, a maximum axial value of 204.14 kN, a minimum shear value of –719.82 kNm^3, and a maximum shear value of 719.82 kNm3. Meanwhile, Tongkonan II has a minimum axial value of –1550.31 kN, a maximum axial value of 457.67 kN, a minimum shear value of –813.23 kNm^3, and a maximum shear value of 813.24 kNm^3.

Keywords: Tongkonan House, earthquake, wood, internal styles.

INTRODUCTION

Indonesia is one of the countries with the highest levels of seismic activity in the world, located at the confluence of four active tectonic plates: the Indo-Australian, Eurasian, Pacific, and Philippine [1]. This makes the Indonesian archipelago highly vulnerable to earthquakes, which can significantly impact the safety of building structures, both modern and traditional. Amidst demands for sustainable development based on local wisdom, traditional houses have become an important object in the study of structural resilience to natural disasters [2].

Traditional houses are part of Indonesia's cultural heritage, inherited from ancestors in each region [3]. Traditional houses are a unique type of housing in Indonesia that reflect the culture and characteristics of the local community [4]. Traditional Indonesian stilt houses consist of three parts: the upper part serves as the roof, the middle part as the building's body, and the lower part serves as the building's base. The load from the roof flows to the body in the middle, and is finally transferred to the base at the bottom through the building's base structure [5]. The traditional house of the Toraja people, located in South Sulawesi Province, is called the Tongkonan house. This building is made of wood and is always built based on the natural environment in which it is located [6]. This traditional house differs from other traditional houses in terms of its structural system, making the Tongkonan a very interesting research object [7].

Over the years, the ancestors of the Toraja people have created an innovative architectural environment. This has made the traditional Toraja house an expressive architectural heritage, even embodying philosophical symbolic elements. Based on its tectonic components, its existence is very unique. Beliefs, culture, customs, climate, environment, architectural form, and structure are unclear. The Toraja Tongkonan building is one of many buildings in the archipelago that has a unique shape, structure, and construction. The development of various connection techniques and different structural forms has created diverse architectural forms [8]. One important element of the Tongkonan structure is its pillars, which are a traditional Toraja architectural form with a roof resembling an upturned boat [9].

As time goes by, it is crucial to study and analyze Tongkonan structures to improve their earthquake resistance. Earthquakes are known to be one of the most destructive natural disasters. Indonesia, an archipelagic country with the longest coastline in the world, is prone to both earthquakes and tsunamis. Although earthquakes cannot be predicted, their impact can be minimized by building earthquake-resistant houses [10]. Numerous incidents demonstrate that errors in selecting the right materials and structural systems can lead to damage, or even total collapse, of structures due to repeated earthquake stress. This is due to the fact that these structures lack high resilience, making them vulnerable to earthquakes and unable to function properly during an earthquake [11]. Steel dampers are components used in building structures to dampen vibrations and energy generated by dynamic loads such as earthquakes [12].

Most available literature focuses primarily on the anthropological and symbolic aspects of Tongkonan, while the engineering performance of structures against lateral seismic forces is still limited. Understanding the dynamic response of these traditional structures is crucial not only for conservation but also as a basis for developing earthquake-resistant vernacular architectural designs. In terms of disaster mitigation, the integration of cultural heritage and earthquake resistance principles is very relevant, in line with the sustainable development program ([13]. Therefore, this study aims to analyze the structural performance of the Tongkonan traditional house against earthquake loads using a numerical analysis approach based on the finite element method (FEM).

The Tongkonan data to be studied is in Tongkonan I, the material used is wood, used as a Toraja Traditional House. located in Ranteaa', Tallang Sura' Village, Buntao' District, North Toraja Regency. The dimensions of the Tongkonan pillars are 295 cm high, 30 cm long, 30 cm wide. The dimensions of the beams/roroan are 18 cm high, 925 cm long, 5 cm wide and the number of pillars is 34. In Tongkonan II Pongtambulibukku, the material used is wood, as a Toraja Traditional House, located in Rantebua Sumalu, Rantebua District, North Toraja Regency. The dimensions of the Tongkonan pillars are 290 cm high, 30 cm long, 30 cm wide. The dimensions of the beams/roroan are 8 cm high, 810 cm long, 5 cm wide, and 34 pillars. Studying the behavior of Tongkonan structures under earthquake loads is crucial for understanding their resistance to lateral forces caused by earthquakes [14].

RESEARCH METHODS

Research Approach and Design

This research uses a quantitative experimental approach based on structural engineering, with the aim of evaluating the performance of Tongkonan traditional houses under earthquake loads. The research is descriptive-analytical, analyzing the structure based on existing conditions through numerical modeling and dynamic loading in accordance with national seismic standards. The primary methods used are static-equivalent structural analysis and dynamic response spectrum analysis based on SNI regulations concerning Earthquake Resistance Planning Procedures for Building and Non-Building Structures [15].

Methods

Research Location and Object

The object of the research is the Tongkonan traditional house structure in North Toraja Regency, South Sulawesi. The location was selected based on the diversity of building age, construction characteristics, and level of use in cultural activities. At least three Tongkonan were analyzed, each representing a group of newly built Tongkonan (less than 10 years old), medium-sized Tongkonan (10–30 years old), and old Tongkonan (over 30 years old). Each building was examined in terms of geometry, wood connection systems, construction materials, and main structural positions (posts, beams, trusses).

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Data Types and Sources

Primary Data

- Field Survey: conducted to observe the actual condition of the structure, the dimensions of the main elements (columns, beams, connections), and visual documentation.

- Structured Interviews: conducted with traditional craftsmen (Tongkonan builders), community leaders, and homeowners to understand traditional construction techniques and the structural modifications made.

- Direct Measurement: using building measuring instruments to obtain data on geometry and structural elements.

Secondary Data

- Literature related to wood construction techniques, earthquakes in Sulawesi, and the resilience of traditional building structures.

- BMKG earthquake zoning maps and local soil data.

- Technical regulations and standards such as the Indonesian National Standard (SNI) on wood structures [16].

Research Stages

- Literature Study

Conducting theoretical studies on earthquake-resistant wood buildings, structural analysis methods, and the construction of traditional Tongkonan houses.

- Data Collection and Verification

Collecting primary and secondary data and conducting field validation of structural dimensions, connection types, and building materials.

- Structural Modeling

A digital model of the Tongkonan structure is built using structural analysis software such as SAP2000 or ETABS. The model includes actual elements, connection configurations, and the properties of local wood materials.

- Seismic Loading: The structure is analyzed for earthquake loads based on:

1. The building's seismic zone [15],

2. Structural parameters: building mass, height, configuration,

3. Static-equivalent lateral loads,

4. Response spectrum analysis if required for dynamic validation.

Structural Behavior Analysis

Evaluation is conducted on:

- Displacement (inter-story drift),

- Internal Forces (moments, shear forces),

- Connection Performance (joint behavior),

- Potential failures (cracking, excessive rotation),

- Ductility and stiffness of the structure.

Evaluation and Interpretation

Calculation results are compared with safe design criteria. Structures are assessed based on whether they meet the elastic limit (limit elastic behavior), deformation capacity and reduction of collapse risk in the design earthquake.

Data Analysis

The structural analysis was conducted using a numerical approach using SAP2000 software. The modeling follows the actual configuration of a traditional Tongkonan house, which consists of a beam-column structural system made from local wood (usually ironwood or similar). The three-dimensional model was built based on primary data from a field survey, which includes element dimensions, connection types, and building height and width. The structural model was created assuming simple support conditions (roller joints), semi-rigid connections at the main structural elements, lateral seismic loads in the dominant direction of the structure (longitudinal axis), and the structure was assumed to be a one-story open frame system. Earthquake load calculations are based on SNI 1726:2019, taking into account:

- Seismic Zone: The building is located in a high seismic zone (South Sulawesi region),

- Earthquake Response Factor (R) and Reduction Coefficient (Cd) according to the wood framing system,

- Design Response Spectrum using the following parameters:

- Peak Ground Acceleration (PGA),

- Site Factor (SS, S1),

- Spectrum Modification Factor (Fa, Fv),

The load combination follows the following rule:

- 1.2D + 1.0L + 1.0E

- 0.9D ± 1.0E

RESULTS AND DISCUSSION

Structural Load Analysis on Tongkonan Houses

Table 1. Loading on Tongkonan House I

Loading	Value
Dead load	Construction load weight (300 kg)
Live load	250 kg/m2
Wind load	1.0
Earthquake load	Spectral response

Table 2. Loading on Tongkonan II house

Loading	Value
Dead load	Construction load weight (300 kg)
Live load	250 kg/m2
Wind load	1.0
Earthquake load	Spectral response

Tables 1 and 2 present loading data on Tongkonan I and II, including a dead load of 300 kg from the main construction weight, a live load of 250 kg/m² according to SNI 1727:2013, a wind load with a coefficient of 1.0, and earthquake loads analyzed using the response spectrum according to SNI 1726:2019. Although the loading values for both buildings are identical, the difference in building age—Tongkonan I, newly constructed, and Tongkonan II, which has been standing since 2011—can affect the structural response to lateral loads, particularly in terms of stiffness, joint weathering, and earthquake resistance.

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Analysis of Tongkonan Structural Elements

Based on Tables 3 and 4, the dimensions of the pillar structural elements in Tongkonan I and II houses show variations in size and configuration, reflecting the structural requirements of each building. In Tongkonan I, the largest element is the Tuaran Uai, measuring 10 x 25 cm and measuring 1,000 cm long. The Patongkon, the main pillar, measures 30 x 30 cm and measures 295 cm long. Conversely, in Tongkonan II, the Patongkon is smaller, measuring 25 x 25 cm, but the Pata' and Kundai elements are larger, measuring up to 1,000 cm and 925 cm in length. These differences indicate variations in the structural design approach, with Tongkonan II tending to use longer and slender elements, which can affect the structure's behavior against lateral forces such as earthquakes. These variations in element shape and size directly impact the stiffness, stability, and load distribution within the overall structural system of the traditional house.

Table 3. Dimensions of Pillar Structural Elements in Tongkonan I

No	Element	Shape	Dimension (cm)	Long (cm)
1.	B 30/30 (Patongkon)	Square	30 x 30	295
2.	B 5/18 (Roroan baba)	Square	5 x 18	440
3.	B 5/18 (Roroan Lambe)	Square	5 x 18	925
4.	B 10/25 (Tuaran Uai)	Square	10 x 25	1000
5.	B 10/30 (Kalaka)	Square	10 x 30	460
6.	B 10/20 (Pangosokan)	Square	10 x 20	440
7.	B 15/20 (Pata’)	Square	15 x 20	460
8.	B 6/12 (Kundai)	Square	6 x 12	440
9.	B 8/12 (Rampanan)	Square	8 x 12	440

Table 4. Dimensions of the structural elements of Tongkonan II pillars

No	Element	Shape	Dimension (cm)	Long (cm)
1.	B 8/12 (rampanan)	Square	8 x 12	925
2.	B 15/15 (bantuli)	Square	15 x 15	925
3.	B 15/20 (pata')	Square	15 x 20	1000
4.	B 25/25 (patongkon)	Square	25 x 25	295
5.	B 5/18 (Roroan Ba’ba)	Square	5 x 18	420
6.	B 15/25 (Kundai)	Square	15 x 25	925
7.	B 6/12 (Tuaran uai)	Square	6 x 12	420

SAP2000 Modeling of Tongkonan Pillar Structures

Model Definition

Table 5. Tongkonan I Model Definition

Section Name	Material	Shape	I23	Area	TorsConst	I33	I22	AS2
			m^4	m^2	m^4	m^4	m^4	m^2
B 10/20	Wood	SD Section	0.000000	0.020000	0.000046	0.000067	0.000017	0.016667
B 10/25	Wood	SD Section	0.000000	0.025000	0.000062	0.000130	0.000021	0.020833
B 10/30	Wood	SD Section	0.000000	0.030000	0.000079	0.000225	0.000025	0.025000
B 15/15	Wood	SD Section	0.000000	0.022500	0.000071	0.000042	0.000042	0.018750

Section Name	Material	Shape	I23	Area	TorsConst	I33	I22	AS2
			m^4	m^2	m^4	m^4	m^4	m^2
B 15/20 (PATA')	Wood	SD Section	0.000000	0.030000	0.000122	0.000056	0.000100	0.025000
B 30/30	Wood	SD Section	0.000000	0.090000	0.001141	0.000675	0.000675	0.075000
B 5/18	Wood	SD Section	0.000000	0.009000	6.197E-06	0.000024	1.875E-06	0.007500
B 6/12	Wood	SD Section	0.000000	0.007200	5.938E-06	8.640E-06	2.160E-06	0.006000
B 8/12	Wood	SD Section	0.000000	0.009600	0.000012	0.000012	5.120E-06	0.008000

Table 6. Model defenition Tongkonan II

Section Name	Material	Shape	I23	Area	TorsConst	I33	I22	AS2
			m4	m2	m4	m4	m4	m2
B 12/6	Wood	SD Section	0.000000	0.007200	5.938E-06	8.640E-06	2.160E-06	0.006000
B 15/15	Wood	SD Section	0.000000	0.022500	0.000071	0.000042	0.000042	0.018750
B 18/5	Wood	SD Section	0.000000	0.009000	6.197E-06	0.000024	1.875E-06	0.007500
B 20/15 (PATA')	Wood	SD Section	0.000000	0.030000	0.000122	0.000056	0.000100	0.025000
B 25/15	Wood	SD Section	0.000000	0.037500	0.000176	0.000195	0.000070	0.031250
B 25/25	Wood	SD Section	0.000000	0.062500	0.000550	0.000326	0.000326	0.052084
B 5/10	Wood	SD Section	0.000000	0.005000	2.864E-06	4.167E-06	1.042E-06	0.004167
B 8/12	Wood	SD Section	0.000000	0.009600	0.000012	0.000012	5.120E-06	0.008000

The discussion of Tables 5 and 6 shows that the structural elements of Tongkonan I and II houses have varying cross-sectional characteristics, with differences in cross-sectional area (Area), moments of inertia (I22, I33), and torsional constants (TorsConst) that affect the stiffness and structural response to lateral loads such as earthquakes. In Tongkonan I, the B 30/30 element has the highest moment of inertia value (I33 = 0.000675 m^4), indicating its primary role as the main support element. Conversely, Tongkonan II shows the dominance of the B 25/25 element with a cross-sectional area of 0.0625 m^2 and a moment of inertia I33 of 0.000326 m^4, indicating efforts to optimize dimensions to support taller or longer structures. These differences in flexural and torsional stiffness values significantly determine the dynamic behavior of the building, especially in responding to earthquake vibrations. This confirms that the selection of dimensions and mechanical properties of wood in each traditional house is carried out by considering the specific structural needs and existing conditions of the building.

Model Geometry Tongkonan

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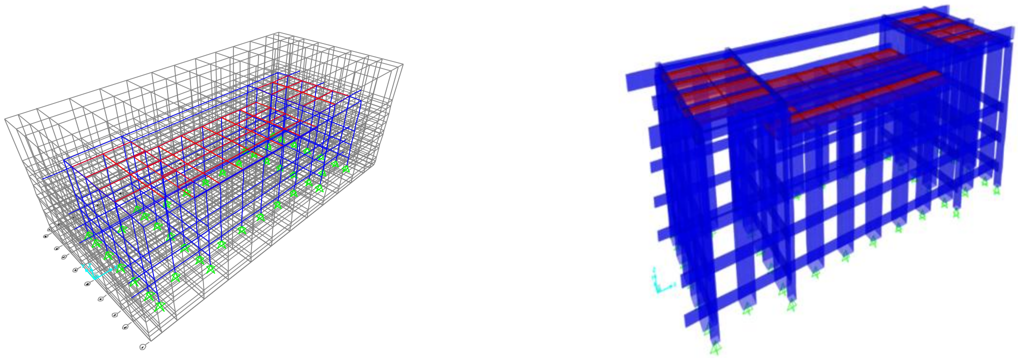

Figure 1. Model 3D SAP2000 tiang Tongkonan I

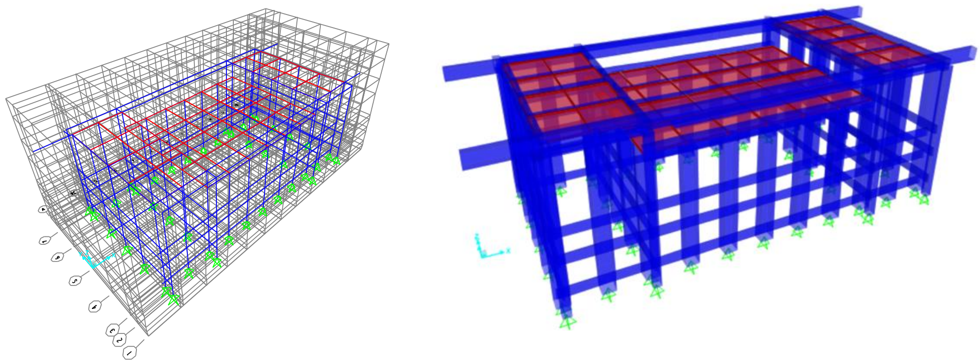

Figure 2. Model 3D SAP2000 tiang Tongkonan I

Figure 2. SAP2000 3D Model of Tongkonan II Pillar
SAP2000 Calculation Results for Tongkonan I Structure

Table 7. Analysis Results for Tongkonan I Structure Modeling

No	Element	Moment (Nm)	Displacement (N/m^2)	Sagging (kNm^3)	Axial (kN)	Torque (Nm)
1.	B 5/18 (Roroan)	-5.22	14.48	8.511	-6.76	-0.20
2.	B 6/12 (Kundai)	-45.00	127.94	-0.000017	57.11	-8.699E-03
3.	B 8/12 (Rampanan)	-227.58	275.63	0.017	-78.56	8.458E-04
4.	B 10/20 (Pangosokan)	-19.59	82.06	0.000000	66.97	1.75
5.	B 10/25 (Tuaran uai)	131.22	-44.41	0.000077	-29.81	-0.11
6.	B 10/30 (Kalaka)	0.69	-2.07	5.451	37.25	0.25
7.	B 15/15 (Bantuli)	-89.84	79.59	-0.000023	-384.19	-10.63
8.	B 15/20 (Pata')	-26.81	-115.54	0.000014	72.85	6.632E-04
9.	B 30/30 (Patongkon)	-45.85	64.69	-6.732	-674.89	1.65

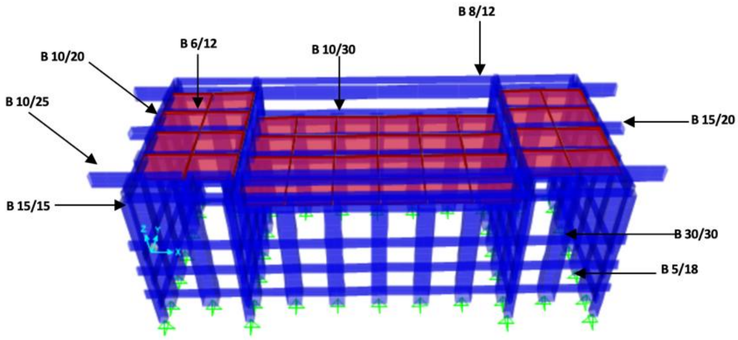

Figure 3. Structural elements of Tongkonan I

Table 8. Element forces – frames (moments) of Tongkonan I

Frame	Station	OutputCase	CaseType	P	V2	V3	T	M2	M3	FrameElem	ElemStation	KET
74	0	COMB2	Combination	182.14	-719.82	-0.0007894	-0.0003204	0.0001701	-640.99	74-1	0	
74	0	COMB3	Combination	182.14	-719.82	-0.0007894	-0.0003204	0.0001701	-640.99	74-1	0	Momen
79	0.85	COMB2	Combination	182.16	719.82	-0.0007228	-0.0003204	0.000169	-640.99	79-1	0.85	Minimum
79	0.85	COMB3	Combination	182.16	719.82	-0.0007228	-0.0003204	0.000169	-640.99	79-1	0.85	
76	0.85	COMB2	Combination	204.12	-49.21	-0.002134	-0.0003204	0.0001931	339.52	76-1	0.85	
76	0.85	COMB3	Combination	204.12	-49.21	-0.002134	-0.0003204	0.0001931	339.52	76-1	0.85	Momen
77	0	COMB2	Combination	204.14	49.21	-0.0004957	-0.0003204	-0.0002736	339.52	77-1	0	Maksimum
77	0	COMB3	Combination	204.14	49.21	-0.0004957	-0.0003204	-0.0002736	339.52	77-1	0	

Table 9. Element forces – frames (geser) Tongkonan I

Frame	Station	OutputCase	CaseType	P	V2	V3	T	M2	M3	FrameElem	ElemStation	KET
74	0	COMB2	Combination	182.14	-719.82	-0.0007894	-0.0003204	0.0001701	-640.99	74-1	0	Geser
74	0	COMB3	Combination	182.14	-719.82	-0.0007894	-0.0003204	0.0001701	-640.99	74-1	0	Minimum
79	0.85	COMB2	Combination	182.16	719.82	-0.0007228	-0.0003204	0.000169	-640.99	79-1	0.85	Geser
79	0.85	COMB3	Combination	182.16	719.82	-0.0007228	-0.0003204	0.000169	-640.99	79-1	0.85	Maksimum

Table 10. Element forces – frames (aksial) Tongkonan I

Frame	Station	OutputCase	CaseType	P	V2	V3	T	M2	M3	FrameElem	ElemStation	KET
441	0	COMB2	Combination	-1385.74	-131.32	0.02158	0	1.11E-17	0	441-1	0	Aksial
441	0	COMB3	Combination	-1385.74	-131.32	0.02158	0	1.11E-17	0	441-1	0	Minimum
77	0	COMB2	Combination	204.14	49.21	-0.0004957	-0.0003204	-0.0002736	339.52	77-1	0	
77	0.425	COMB2	Combination	204.14	128.17	-0.0004957	-0.0003204	-0.00006295	306.23	77-1	0.425	
77	0.85	COMB2	Combination	204.14	207.13	-0.0004957	-0.0003204	0.0001477	230.58	77-1	0.85	Aksial
77	0	COMB3	Combination	204.14	49.21	-0.0004957	-0.0003204	-0.0002736	339.52	77-1	0	Maksimum
77	0.425	COMB3	Combination	204.14	128.17	-0.0004957	-0.0003204	-0.00006295	306.23	77-1	0.425	
77	0.85	COMB3	Combination	204.14	207.13	-0.0004957	-0.0003204	0.0001477	230.58	77-1	0.85	

In the test results of the tongkonan I structure above, the values of moment, shear, deflection, axial and torque were obtained. in each beam. In the 5/18 beam, a moment of -5.22 Nm, a shear-force of 14.48 N/m2, a deflection of 8.511 kNm3, axial -6.76 kN and a torque of -0.20 Nm. In the 6/12 beam span, the moment that occurred was -45.00 Nm, a shear-force of 127.94 N/m2 and a deflection of -

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0.000017 kNm3, axial 57.11 kN and a torque of -8.699E-03 Nm. The 8/12 beam experienced a moment of -227.58 Nm, a shear of 275.63 N/m2, a deflection of 0.017 kNm3, an axial force of -78.56 kN, and a torque of 8.458E-04 Nm. The 10/20 beam experienced a moment of -19.59 Nm, a shear of 82.06 N/m2, a deflection of 0.000000 kNm3, an axial force of 66.97 kN, and a torque of 1.75 Nm.

The 10/25 beam experienced a moment of 131.22 Nm, a shear of -44.41 N/m2, a deflection of 0.000077 kNm3, an axial force of -29.81 kN, and a torque of -0.11 Nm. In the 10/30 beam, the moment is 0.69 Nm, shear -2.07 N/m2, deflection of 5.45, axial 37.25 kN and torque 0.25 Nm. In the 15/15 beam, the moment is -89.84, shear 79.59 N/m2, deflection -0.000023 kNm3, axial -384.19 kN and torque -10.63 Nm. In the 15/20 beam, the moment is -26.81 Nm, shear -115.54 N/m2 and deflection 0.000014 kNm3 and axial 72.85 kN and torque 6.632E-04 Nm. In a 30/30 beam, the resulting moment is -45.85 Nm, shear 64.69 N/m2, deflection -6.732 kNm3, axial -674.89 kN, and torque 1.65 Nm.

SAP2000 Calculation Results for Tongkonan II Structure

Table 11. SAP2000 Calculation Results for Tongkonan II Structure

No	Element	Moment (Nm)	Displacement (N/m^2)	Sagging (kNm^3)	Axial (kN)	Torque (Nm)
1.	B 6/12 (Tuaran uai)	233.44	-136.95	0.001737	57.80	1.810E-04
2.	B 15/15 (Bantuli)	-53.34	-41.95	-0.000120	-364.04	-3.21
3.	B 5/18 (Roroan)	-5,90	-17,22	-6,334	-0.31	-0.14
4.	B 15/20 (Pata')	-71,84	179,61	0,000017	155.27	-2.718E-03
5.	B 15/25 (Kundai)	-22.54	-103.51	-1.812E-07	138.32	6.58
6.	B 25/25 (Tiang)	-29,46	50,99	-2,160	-947.13	11.72
7.	B 8/12 (Rampanan)	-189,17	249,69	0,011424	-949	-0.12

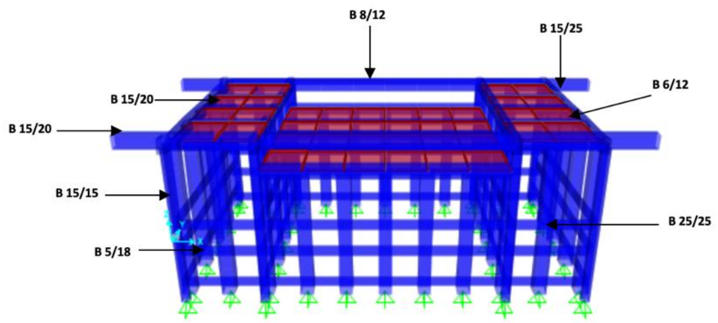

Figure 4. Structural elements of Tongkonan II

Table 12. Element forces – frames (moments) of Tongkonan II

Frame	Station	OutputCase	CaseType	P	V2	V3	T	M2	M3	FrameElem	ElemStation	KET
4366	0.77	COMB2	Combination	106.97	809.92	-0.13	-0.00006592	0.03999	-679.75	4366-1	0.77	
4366	0.77	COMB3	Combination	106.97	809.92	-0.13	-0.00006592	0.03999	-679.75	4366-1	0.77	Momen
4373	0.77	COMB2	Combination	106.97	809.92	0.13	0.0000368	-0.04013	-679.75	4373-1	0.77	Minimum
4373	0.77	COMB3	Combination	106.97	809.92	0.13	0.0000368	-0.04013	-679.75	4373-1	0.77	
3972	2.4	COMB2	Combination	-493.34	645.8	32.84	-14.62	6.26	420.88	3972-5	0	Momen
3972	2.4	COMB3	Combination	-493.34	645.8	32.84	-14.62	6.26	420.88	3972-5	0	Maksimum

Table 13. Elemen forces – frames Tongkonan II

Frame	Station	OutputCase	CaseType	P	V2	V3	T	M2	M3	FrameElem	ElemStation	KET
4293	0	COMB2	Combination	235.22	-813.23	0.002101	-0.0003093	0.0007566	-664.14	4293-1	0	Geser
4293	0	COMB3	Combination	235.22	-813.23	0.002101	-0.0003093	0.0007566	-664.14	4293-1	0	Minimum
4298	0.77	COMB2	Combination	233.81	813.24	0.001144	-0.0003093	0.0002346	-664.17	4298-1	0.77	Geser
4298	0.77	COMB3	Combination	233.81	813.24	0.001144	-0.0003093	0.0002346	-664.17	4298-1	0.77	Maksimum

Table 14. Elemen forces – frames (axial) Tongkonan II

Frame	Station	OutputCase	CaseType	P	V2	V3	T	M2	M3	FrameElem	ElemStation	KET
4293	0	COMB2	Combination	235.22	-813.23	0.002101	-0.0003093	0.0007566	-664.14	4293-1	0	Geser
4293	0	COMB3	Combination	235.22	-813.23	0.002101	-0.0003093	0.0007566	-664.14	4293-1	0	Minimum
4298	0.77	COMB2	Combination	233.81	813.24	0.001144	-0.0003093	0.0002346	-664.17	4298-1	0.77	Geser
4298	0.77	COMB3	Combination	233.81	813.24	0.001144	-0.0003093	0.0002346	-664.17	4298-1	0.77	Maksimum

Based on the table of results of the tongkonan II structural test above, the values of moment, shear, deflection, axial and torque were obtained on each beam. In the 6/12 beam, the moment was 233.44 Nm, shear force was -136.95 N/m2, deflection was 0.001737 kNm3, axial 57.80 kN and torque was 1.810E-04 Nm. In the 15/15 beam span, the moment was -53.34 Nm, shear force was -41.95 N/m2 and deflection was -0.000120 kNm3, axial -364.04 kN and torque was -3.21 Nm. The 5/18 beam experienced a moment of -5.90 Nm, a shear of -17.22 N/m2, a deflection of -6.334 kNm3, an axial force of -0.31 kN, and a torque of -0.14 Nm. The 15/20 beam experienced a moment of -71.84 Nm, a shear of 179.61 N/m2, a deflection of 0.000017 kNm3, an axial force of 155.27 kN, and a torque of -2.718E-03 Nm.

The 15/25 beam experienced a moment of -22.54 Nm, a shear of -103.51 N/m2, a deflection of -1.812E-07 kNm3, an axial force of 138.32 kN, and a torque of 6.58 Nm. The 25/25 beam experienced a moment of -29.46 Nm, a shear of 50.99 N/m2, a deflection of -2.160 kNm3, an axial force of -947.13 kN, and a torque of 11.72 Nm. The 8/12 beam experienced a moment of -189.17 Nm, a shear of 249.69 N/m2, a deflection of -0.011424 kNm3, an axial force of -9.49 kN, and a torque of -0.12 Nm.

Tongkonan Structural Analysis Results

Table 15. Comparison of Tongkonan Structural Analysis Results

No	Element Tongkonan I	Moment (Nm)	Displacement (N/m^2)	Sagging (kNm^3)	Axial (kN)	Torque (Nm)
1.	B 5/18 (Roroan)	-5.22	14.48	8.511	-6.76	-0.20
2.	B 6/12 (Kundai)	-45.00	127.94	-0.000017	57.11	-8.699E-03
3.	B 8/12 (Rampanan)	-227.58	275.63	0.017	-78.56	8.458E-04
4.	B 10/20 (Pangosokan)	-19.59	82.06	0.000000	66.97	1.75
5.	B 10/25 (Tuaran uai)	131.22	-44.41	0.000077	-29.81	-0.11
-6.	B 10/30 (Kalaka)	0.69	-2.07	5.451	37.25	0.25
7.	B 15/15 (Bantuli)	-89.84	79.59	-0.000023	-384.19	-10.63
8.	B 15/20 (Pata')	-26.81	-115.54	0.000014	72.85	6.632E-04
9.	B 30/30 (Patongkon)	-45.85	64.69	-6.732	-674.89	1.65

Table 16. Comparison of Tongkonan Structural Analysis Results

No	Elemen Tongkonan II	Moment (Nm)	Displacement (N/m^2)	Sagging (kNm^3)	Axial (kN)	Torque (Nm)
1.	B 6/12 (Tuaran uai)	233.44	-136.95	0.001737	57.80	1.810E-04
2.	B 15/15 (Bantuli)	-53.34	-41.95	-0.000120	-364.04	-3.21

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3.	B 5/18 (Roroan)	-5,90	-17,22	-6,334	-0.31	-0.14
4.	B 15/20 (Pata')	-71,84	179,61	0,000017	155.27	-2.718E-03
5.	B 15/25 (Kundai)	-22.54	-103.51	-1.812E-07	138.32	6.58
6.	B 25/25 (Tiang)	-29,46	50,99	-2,160	-947.13	11.72
7.	B 8/12 (Rampanan)	-189,17	249,69	0,011424	-949	-0.12

The structural element tables of Tongkonan I and II show significant variations in the values of bending moments, shear forces, deflections, axial forces, and torques, reflecting the role of each element in resisting lateral and vertical loads due to the earthquake. In Tongkonan I, element B 30/30 (Patongkon) experiences the highest axial force of -674.89 kN, indicating its primary function as the main vertical support, although with a large negative deflection (-6.732 kNm³). Conversely, in Tongkonan II, element B 25/25 (Pillar) shows the highest axial value of -947.13 kN, indicating its crucial role in the vertical stability of the structure. The highest torque value is also found in this element (11.72 Nm), indicating a high tendency for torsion due to lateral loads. Elements B 6/12 and B 8/12 in both models show significant positive deflections, indicating the flexibility of small elements to earthquake-induced deformation. These results demonstrate that element dimensions, structural position, and cross-sectional stiffness significantly influence the mechanical performance of Tongkonan houses and are key to designing earthquake-resistant traditional houses while maintaining traditional architectural values.

CONCLUSION

Based on the analysis of the Tongkonan I and II structures, it can be concluded that the behavior of the Tongkonan structure when subjected to earthquake loads in the SAP 2000 model moved entirely in line with the horizontal direction of the earthquake and showed no signs of structural failure, such as broken columns or beams. No significant changes were found in the critical areas of the structure due to dead loads and earthquake loads. This is because the primary connections are found at the joints between columns and beams. Traditional connection techniques, such as dowel and tie connections, are designed to provide the strength and flexibility necessary to withstand various loads. These connections are also designed to absorb dynamic forces such as earthquake vibrations, reducing the risk of damage at critical points. The presence of redundancy in the structure ensures that if one element fails, other elements can take over the additional load, preventing total collapse. Ultimately a structural system safely transfers all the loads of the structural parts to the foundation (rock foundation) to the ground.

REFERENCES

[1] Simons, M., Minson, S. E., Sladen, A., Ortega, F., Jiang, J., Owen, S. E., ... & Fielding, E. J. (2007). *A shallow subduction zone earthquake with widespread tsunami generation*. *Science*, 308(5725), 1127–1131. https://doi.org/10.1126/science.1109792

[2] Pratama, M. R., & Wahyuningtyas, A. (2024). Identifikasi kearifan lokal terhadap desain rumah tradisional tahan gempa: Studi kasus pada rumah Suku Baduy. *Jurnal Menara*, *12*(3), 1–12. https://doi.org/10.37817/jurnalmenara.v12i3

[3] Teiko, Y., Wabang, Y. S., Bekata, H. M., Doni, P. M. T., Karfing, M., Maiateng, W., Karmating, Y., Laa Ull, Y. M., & Anideng, A. (2025). Rumah adat Suku Alor Besar sebagai representasi identitas budaya dan warisan leluhur Desa Alor Besar Kecamatan Alor Barat Laut. *Journal of Community Dedication*, *5*(1), 284–293.

[4] Angkasa, Z. (2017). Penerapan konsep arsitektur rumah panggung di lingkungan perkotaan. *Jurnal Arsir*, *1*(2), 175–185

[5] Rifai, A. J. B. (2010). Perkembangan struktur dan konstruksi rumah tradisional Suku Bajo di pesisir pantai Parigi Moutong. *Ruang: Jurnal Arsitektur*, *2*(1), 1–10

[6] Stephany, S. (2009). Transformasi tatanan ruang dan bentuk pada interior Tongkonan di Tana Toraja, Sulawesi Selatan. *Dimensi Interior*, *7*(1), 28–39.

[7] Pakan, M. S. L., Pratiknjo, M. H., & Mamosey, W. E. (2018). Rumah adat "Tongkonan"

orang Toraja kabupaten Tana Toraja propinsi Sulawesi Selatan. HOLISTIK, Journal of Social and Culturef Social and Culture, XI (22), 1–16.

[8] Ben, B., & Dahlan, M. (2023). Fungsi sosial rumah adat Tongkonan di Desa Sillanan, Tana Toraja. *ALLIRI: Journal of Anthropology*, *5*(1), 1–10.

[9] Patriani, S. R. (2019). Perubahan visual desain arsitektur rumah adat Toraja. *GESTALT: Jurnal Seni Rupa dan Desain*, *1*(1), 113–124

[10] Marwati. (2014). Studi rumah panggung tahan gempa Woloan di Minahasa, Manado. *Jurnal Teknosains*, *8*(1), 95–108.

[11] Musthafa, N. F., & Hindaryanto, A. (2021). Bangunan tinggi dan bencana gempa bumi. *Journal of Economic, Business and Engineering (JEBE)*, *3*(1), 50–60

[12] Ampangallo, B. A., Parung, H., Irmawaty, R., & Amiruddin, A. (2024). Effective stiffness and damping analysis of steel damper to lateral cyclic loading. *Civil Engineering Journal, 10*(7), 2344–2356.

[13] UNDRR. (2019). *Global assessment report on disaster risk reduction*. Geneva: United Nations Office for Disaster Risk Reduction. https://www.undrr.org/publication/global-assessment-report-disaster-risk-reduction-2019

[14] Rio, A. M., Syaidina, A. R., Asdar, M. Q., Nurfatimah, N., Mangalla, Y. R., Pratiwi, E., Irdahardini, I., Baci, M. I., Sunandar, I., Wantisa, Y. E., & Taba, I. (2025). Menggali sejarah dan makna filosofis rumah adat Tongkonan Ke'te Kesu di Toraja Utara. Discourse: Journal of Social Studies and Education, 2(2), 118–132. https://doi.org/10.69875/djosse.v2i2.189

[15] Badan Standardisasi Nasional. (2019). *SNI 1726:2019 – Tata cara perencanaan ketahanan gempa untuk struktur bangunan gedung dan non-gedung*. Jakarta: Badan Standardisasi Nasional.

[16] Badan Standardisasi Nasional. (2013). *SNI 7973:2013 – Spesifikasi desain untuk konstruksi kayu*. Jakarta: Badan Standardisasi Nasional.