

Rapid report of seismic damage and consequence analysis in the 2025 M 6.8 Dingri earthquake



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ABSTRACT

On January 7, 2025, a M 6.8 earthquake occurred at Dingri County, Shigatse City, Xizang Autonomous Region, which is the most largest earthquake in this region in the most recent five years. The maximum recorded peak ground acceleration in this earthquake is 0.43 g, which is significantly higher than the local design basis earthquake intensity level. This report focuses on the post-earthquake seismic damage investigation of rural self-built houses and local public buildings, which shows quite different seismic performance. Collapse and heavy damage of rural self-built houses without seismic resistant measures were observed, while the masonry houses with seismic resistant measures show good seismic performance against collapse. The structural systems of public buildings with proper seismic design suffered slight seismic damage. Different form slight structural damage, the seismic damages of non-structural components, which resulted in the interruption of public building functionality were highlighted in this report. With the investigation results of seismic damage suffered by local houses and buildings, the casualty distribution and causes were analyzed in detail.

1. Introduction and overview of the earthquake effects

On January 7, 2025, a M 6.8 earthquake occurred at Dingri County (28.50° N, 87.45° E), Shigatse City, Xizang Autonomous Region at 9:05 a.m. Beijing time. The epicenter is located in Cuoguo Town, Dingri County, with an average altitude of about 4 471 m within 10 km of the epicenter, and a housing area of about 5 168 800 square meters within 50 km of the epicenter. The depth of hypocenter is 10 km and this earthquake is the most largest earthquake in the region in the most recent five years.

According to the intensity map announced by the Ministry of Emergency Management of China on January 10, 2025 (Ministry of

Emergency Management of the People's Republic of China (2025)), the maximum intensity based on an extensive field survey was IX on a modified Mercalli (MM) scale (GB/T 17742-2020 (2020)) covering a region of 411 km². The intensity IX area mainly involves five town in Dingri County, namely Changsuo Town, Quluo Town, Cuoguo Town, Nixia Town and Jiacao Town. The intensity VI zone and above cover an area of 23 986 km². A total of 126 people died and 61 500 people were affected in the earthquake. A total of 27 248 houses were damaged, of which 3 612 houses collapsed. As of 8:00 on January 14, a total of 3 614 aftershocks were monitored. A M 5.0 aftershock occurred on January 13, which is the highest one (<https://data.earthquake.cn/>).

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Following the earthquake, the research group arrived at Dingri County immediately for earthquake damage assessment. This report focuses on seismic damage of local houses and buildings, and the casualty causes of this earthquake. The investigated area of this report is shown in Fig. 1 and a detailed discussion of the post-earthquake investigation results will be given in the following Sections.

2. Strong ground motion records

According to the fourth generation seismic ground motion parameters zonation map of China (2001.8–2016.5) (GB 18306-2001 (2001)), the epicenter is located in the Intensity 7 seismic fortification area. According to the fifth generation zonation map (from June, 2016 until now) (GB 18306-2015 (2016)), the epicenter is located in the Intensity 8 seismic fortification area. Based on the requirement in GB 18306-2015 (2016), 13 townships in Dingri County are located in the seismic fortification zone with DBE level Peak Ground Acceleration (PGA) of 0.10g (Intensity 7) - 0.20g (Intensity 8), as listed in Table 1. It should be noted that DBE represents the design basis earthquake intensity in China and the corresponding exceedance probability of DBE in 50 years is 10%.

The Station XZ.D0007 (29.09° N, 87.63° E) located near the epicenter recorded the three-component strong ground motion acceleration time histories, as shown in Fig. 2. Among all the available stations, Station XZ.D0007 was closest to the epicenter and recorded the largest PGA values. The peak values of the acceleration and velocity time histories, filtered by a bandwidth of 0.1 Hz–25 Hz, of the records are listed in Table 2. According to the requirements in GB 18306-2015 (2016), the DBE level PGA demand for Lazi Town of Lazi County is 0.20 g. It corresponds to Intensity 8 for seismic design of buildings as per the Code for Seismic Design of Buildings in China (GB 50011-2010 (2016)). The corresponding PGA demand at the maximum considered earthquake (MCE) level is 0.40 g, with an exceedance probability in 50 years of 2%–3%. The PGA recorded by Station XZ.D0007 in this earthquake is 0.37 g, 0.43 g and 0.30 g in east-west (EW), north-south (NS) and vertical (UD) direction, respectively, which are significantly higher than the local DBE level value. The pseudo-acceleration response spectra of the records are also compared with the respective local design spectra at the DBE and MCE levels in Fig. 2. It is worth noting that the corresponding parameters of 5% damping ratio, Class II and Group 3 site were used for generation of the design spectra. The corresponding

Table 1

Ground motion parameter zoning of investigated towns at Shigatse City, Xizang Autonomous Region (Note: PGA represents peak ground acceleration, T_g represents characteristic period of the site).

No.	Town name	PGA (g)	T_g (s)	Seismic fortification intensity	Evaluated intensity
1	Xiegeer Town	0.15	0.45	7	VI
2	Gangga Town	0.15	0.45	7	N.A.
3	Zhaxizong Town	0.2	0.4	8	VI
4	Rongxia Town	0.2	0.45	8	N.A.
5	Qudang Town	0.2	0.45	8	VII
6	Cuoguo Town	0.2	0.4	8	IX
7	Quluo Town	0.2	0.4	8	VIII
8	Changsuo Town	0.2	0.4	8	IX
9	Nixia Town	0.2	0.4	8	VII
10	Zhaguo Town	0.15	0.45	7	VI
11	Kema Town	0.1	0.45	7	N.A.
12	Penji Town	0.1	0.45	7	VI
13	Jiacuo Town	0.15	0.45	7	VI
14	Lazi Town	0.2	0.4	8	VII

characteristic period value of this site classification is 0.45 s. The design spectra of both intensity 7 and 8 areas are included here. The EW and NS components recorded at Station XZ.D0007 are higher than the designed response spectra of MCE level of Intensity 8 in the period of 0.1 s–0.35 s, which covers most of the vibration periods of local houses and buildings. However, the spectra values were significantly lower than the design response spectra of MCE level of Intensity 8 when the period goes beyond 0.35 s. Station XZ.D0004 (28.37° N, 87.78° E) is another station, which recorded comparable PGA values, however, still much smaller than the recorded values at Station XZ.D0007. The acceleration response spectra of Station XZ.D0004 are comparable with the DBE level design spectra of intensity 7 for short-period range but lower than the DBE level design spectra of Intensity VII when the period goes beyond 0.35 s.

With the strong ground motion records as a background, the next three sections summarize the seismic damage of rural self-built houses and public buildings, and the casualty causes will be analyzed.

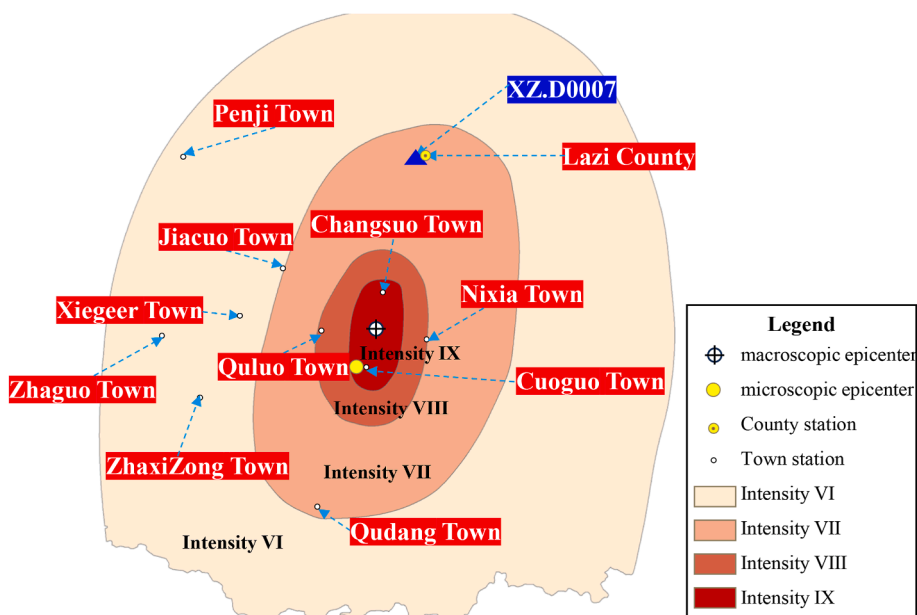


Fig. 1. Investigated area of damage buildings.

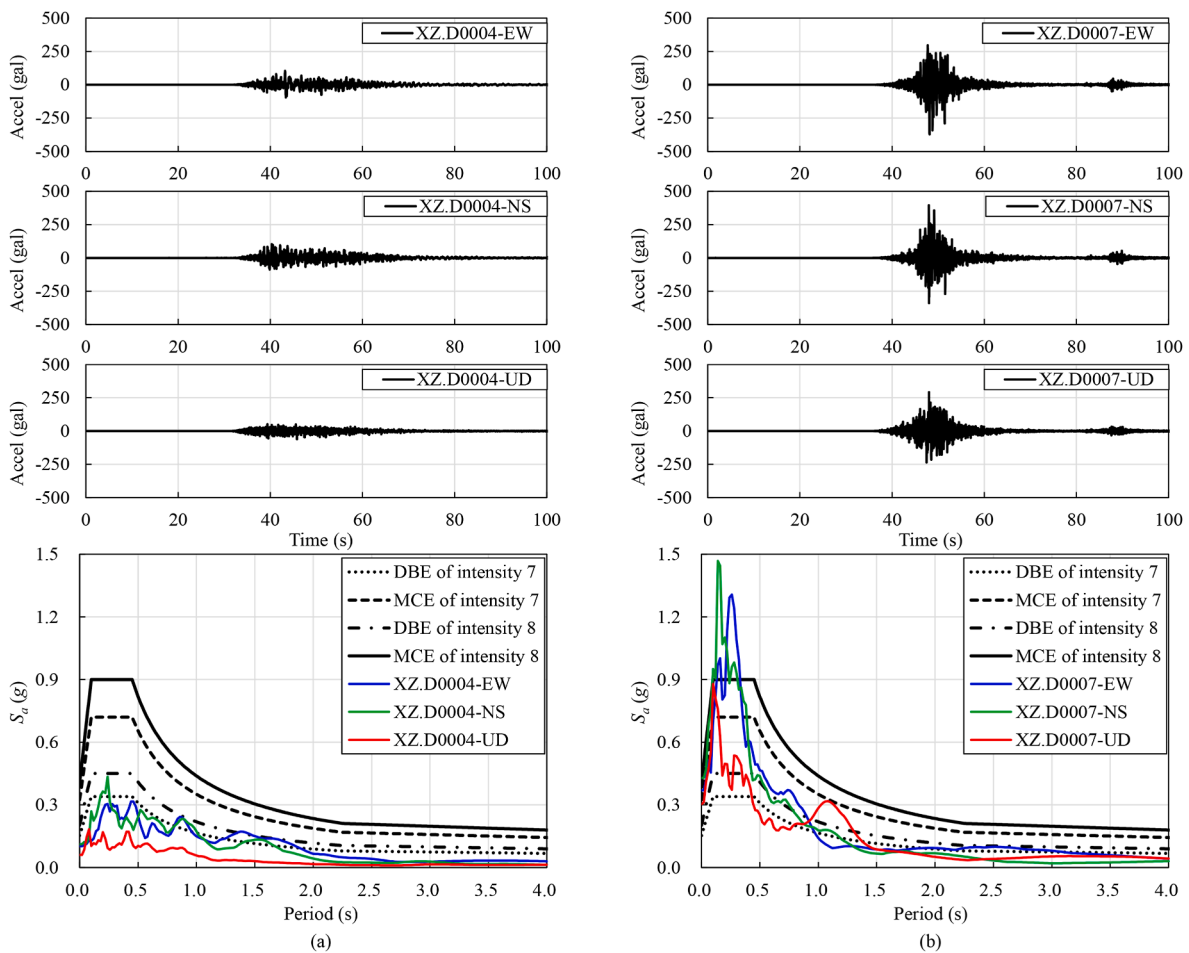


Fig. 2. Acceleration time histories and corresponding acceleration response spectra (5% damping ratio, Class II Group 3 site for design spectra), (a) Station XZ.D0004, and (b) Station XZ.D0007.

Table 2

Peak ground acceleration (PGA) and peak ground velocity (PGV) of recorded ground motions.

Station ID	PGA (g)			PGV (cm/s)		
	EW	NS	UD	EW	NS	UD
XZ.D0004	0.10	0.11	0.06	13.34	8.66	4.93
XZ.D0007	0.37	0.43	0.30	25.69	19.22	15.31

3. Seismic damage of rural self-built houses

3.1. Timber houses without seismic resistant measures

Limited by local conditions and traditional accommodation habits, rural self-built houses usually use local materials, and most self-built houses are timber structures with mud bricks or stones (Fig. 3) with poor seismic performance. During this earthquake, building collapse was concentrated in un-engineered rural houses, which is similar to the seismic damage observed in the 2022 *M* 6.8 Luding earthquake, China (Qu et al. (2023)). A large number of rural self-built houses collapsed near the epicenter. The walls of rural self-built houses are basically made of mud bricks and stones, with low strength and almost no bonding effect but large mass, which resulted in poor seismic bearing capacity. In addition, most of them have no seismic resistant measures such as ring beams and structural columns, and the mixed use of different materials and specifications (coarse stone, rubble stone, cement mortar blocks, adobe, etc) is common. There was no reliable structural connection

between the walls of different materials in the two orthogonal directions, which weakened the integrity of the houses. Most of the roofs of self-built houses were laid by wood purlin, stone, and clay. The integrity and stiffness of these roofs are usually poor, and it is difficult to effectively transmit the horizontal earthquake effect to the walls when an earthquake occurs. These self-built houses can basically maintain stability under vertical load when there is no earthquake. However, when the earthquake occurs, the ability of these houses to resist the horizontal earthquake effects is low and they are easily damaged.

3.2. Masonry houses with seismic resistant measures

For masonry houses with efficient seismic resistant measures, the seismic performance is much better than the above discussed timber structures without seismic resistant measures. As shown in Fig. 4, the seismic performances of structural system of these masonry houses were proved acceptable during this earthquake. As we discussed with the villagers during the reconnaissance, the villagers said that the investments of these seismic resistant measures have helped them away from house loss and kept the post-earthquake safety. However, the furniture inside the houses still suffered from heavy damage, e.g., overturning of the cabinets and falling down of some dishes and home appliances from the tables. And the collapse of roof parapet walls were still commonly found in this earthquake. In addition, apart from the traditional masonry parapet walls, the roof was usually stacked with a circle of “cow dung parapets”. The sun-dried cow dungs are usually used for making fire and heating in local villagers’ daily life. It was found that most of these “cow dung parapets” falling down after earthquakes as a



Fig. 3. Seismic damage of rural self-built houses in Changsuo Town (Intensity IX area).



Fig. 4. Seismic damage of masonry structures with efficient seismic resistant measures.



Fig. 5. Seismic damage of reinforced concrete frame houses at Quluo Town (Intensity VIII area).



Fig. 6. Seismic damage of bottom frame structure houses.

result of low connection with the structures under seismic effects. Considering the big weight of these “cow dung parapets”, there is a life-safety threat if some passengers are next to the houses during earthquakes. It is suggested to adopt some connection measures to fix these “cow dung parapets” to the roof firmly if it is necessary to posit them on the roof.

3.3. Reinforced concrete frame houses

A two-story reinforced concrete frame structure located at Quluo Town was found collapsed at the first story, as shown in Fig. 5. After a detailed investigation, it was found that the construction quality of this

frame structure was quite poor for the following aspects. (1) The concrete aggregates were all exposed after the earthquake. (2) The construction of the reinforcement bar was not standardized and it was found that there were no stirrups at some beam-column joints. (3) The beam section height of the first story is obviously larger than that of the column section. After check with the residents, it was confirmed that this house is self-built without seismic design. The concrete construction quality of this house was extremely poor and the anchoring, connection, lap joints of the steel bars were non-standard, which leads to the formation of a weak story at the bottom and causes the overall collapse. During the earthquake, the first story collapsed and the failure mechanisms of “strong beam-weak column” and “strong component-weak

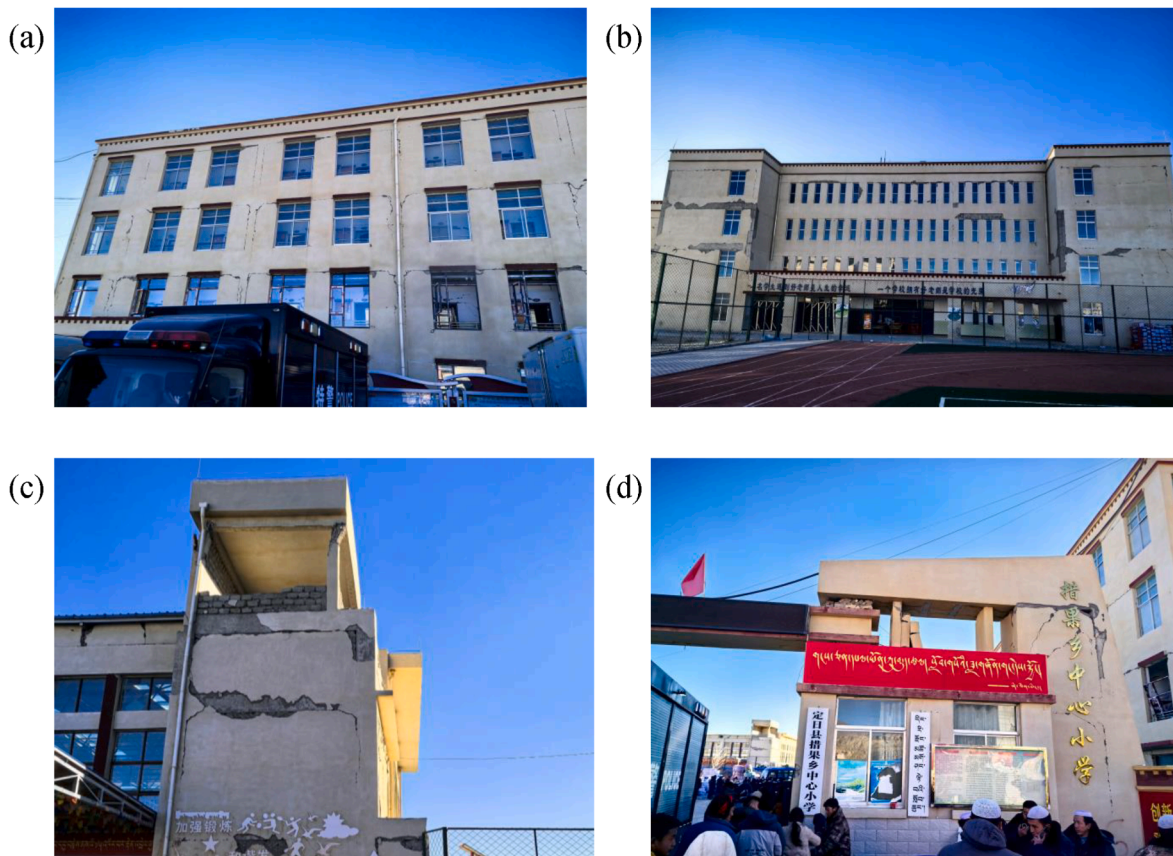


Fig. 7. Structural damages of Central Primary school in Cuoguo Town, (a) teaching building, (b) office building, (c) gymnasium, and (d) school gate.



Fig. 8. Structural damages of public buildings in Changsuo Town, (a) the town government office building, (b) the health center outpatient building, and (c) the health center dormitory building.

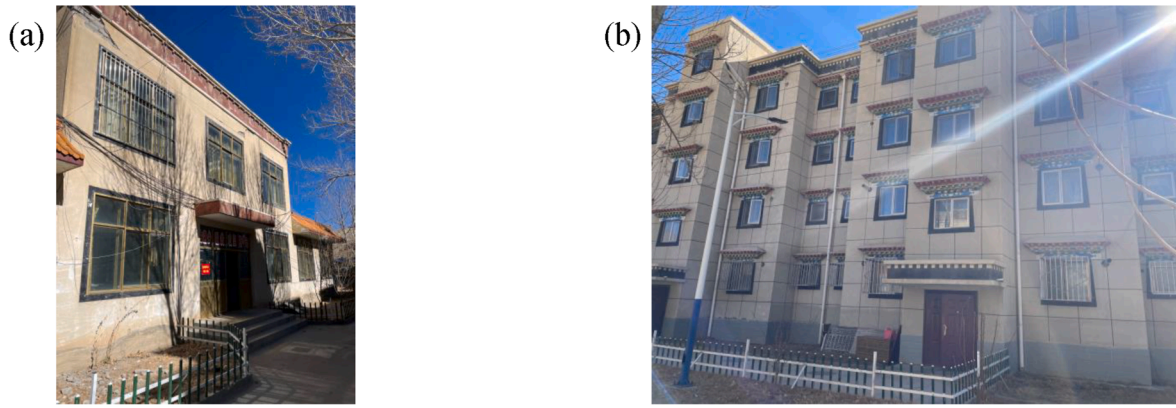


Fig. 9. Structural damages of public buildings in Quluo Town, (a) town government office building (two-story masonry structure), and (b) town government dormitory building (five-story masonry structure).

joint” were observed, while such failure mechanisms are not permitted in seismic design code (GB 50011-2010 (2016)). Excessive deformation demands at the first story columns in the presence of weak-story mechanisms under the seismic inputs led to the collapse of this house. The top and bottom reinforcement bars of the columns were pulled out and the concrete was crushed. And significant seismic damages of the beam-column joints were found. Such seismic damage of reinforced concrete frame structures was frequently observed during past earthquakes although the seismic design codes required ductile design with “strong column-weak beam” systems to ensure the building safety (GB

50011-2010 (2016); Zhao et al. (2009)). In addition, the parapet walls at the roof all collapsed and the roof light steel frame was almost collapsed. The parapet walls, as enclosure components located at the edge of the roof in building structures, are in a special position at the top of the building. The roof accelerations of the building will be increased due to the whipping effect under earthquakes. The parapet walls are highly vulnerable to damage during earthquakes, e.g., loosening or even falling off. Especially in this earthquake affected areas, the parapet walls of houses are generally built with masonry bricks. Local yellow mud is often used as the adhesive to simply build a circle of parapet walls



Fig. 10. Seismic damage of suspended ceiling systems, (a) government office building in Changsuo Town (Intensity IX area), (b) health clinic building in Changsuo Town (Intensity IX area), and (c) central primary school in Quluo Town (Intensity VIII area).

around the roof. The connection between parapet walls and the main structure is usually quite weak, which results in the collapse of parapet walls, as shown in Fig. 5.

3.4. Bottom frame structure houses

Bottom frame structure refers to the mixed load-bearing house with frame structure at the bottom story and masonry structure at the top. Such structure system is widely used in the street facing buildings of small towns in China. This type of structure is a hybrid structure composed of two different lateral force resistance systems with varied stiffnesses in the vertical direction and is usually rigid at the top while soft at the bottom, which was reported to be easily damaged during earthquakes (Sun and Deng, 2015). Benefit from the small column spacing, there was no collapse at the first story for the investigated bottom frame structure houses. However, the second story masonry walls cracked significantly with billboards fell from walls, as shown in Fig. 6. Such seismic damage differences of the two stories were owing to the vertical stiffness difference of bottom story frame structure and second story masonry structure. In addition, the roof parapet walls were found suffered from partial or complete collapse, as shown in Fig. 6. The causes of roof parapet wall damage were the same as those discussed in Section 3.3.

4. Seismic damage of public buildings

Different from the above-mentioned seismic damage and collapse of rural self-built houses in villages and towns, the lateral resisting system, i.e., the structural components and system of public buildings are usually without damage or suffer from slight damage in this earthquake. However, the non-structural components (NSCs) of the investigated

public buildings are severely damaged. The typical seismic damage characteristics will be summarized and causes of the damage to public buildings will be analyzed in this Section.

4.1. Structural damage

The Central Primary School in Cuoguo Town is located in the Intensity IX area. The teaching and office buildings are all 4-story reinforced concrete frame structures with infilled walls. It was found that the main structures of these two buildings suffered slight seismic damage. The beams, columns and joints showed no obvious damage, as shown in Fig. 7a and b. However, the concrete-bent structure of the gymnasium suffered significant seismic damage to the roof due to the whipping effects. Typically, the top of the reinforced concrete column was seriously damaged. The roof infilled walls collapsed completely and several heavy cracks of the infilled walls can be observed at the lower stories, as shown in Fig. 7c. In addition, the arch over a gateway of the Central Primary School in Cuoguo Town was damaged, as shown in Fig. 7d.

Fig. 8 shows the structural damage of public buildings in Changsuo Town (Intensity IX area). The town government office building (four-story reinforced concrete frame), outpatient building (four-story reinforced concrete frame), and dormitory building (four-story masonry structure) of the town health center were almost undamaged from the inspection of structural components. In Quluo Town (Intensity VIII area), the structural systems of the local public buildings including the town government office building and the town government dormitory building suffered almost no damage, as shown in Fig. 9.

The structural damages of most public buildings involved in this earthquake were relatively slight, which benefited from the good seismic performance of reinforced concrete frame structure systems and masonry structures with formal seismic design. The ability of such



Fig. 11. Seismic damages of exterior facade walls, (a) health center outpatient building in Changsuo Town, (b) central primary school #1 teaching building of Quluo Town, and (c) central primary school #2 teaching building of Quluo Town.

structures to resist the earthquake that reach or exceed their seismic fortification intensity can be ensured.

4.2. Nonstructural damage

4.2.1. Suspended ceilings

Although the seismic design code in China, e.g., GB 50011-2010 (2016), prescribes seismic forces for seismic design of suspended ceiling systems, the construction standard that prescribes seismic detailing or installation is still limited. In addition, according to the statistical data of Miranda et al. (2012), the construction cost of a seismic-resistant suspended ceiling system is approximately 20% higher than a non-seismic ceiling system in Chile. Similar cost ratio can be applied to ceiling systems in China. Therefore, most ceiling systems in Xizang, China, lack adequate seismic-resistant installation as a result of budget-limitation, which resulted in significant seismic damage to ceilings in this earthquake.

For the investigated public buildings, seismic damage to suspended ceiling systems are frequently observed. The seismic damages can be classified as the damage or breakage of the main tee, cross tee connections, perimeter angle, and the falling of the lay-in ceiling panels. All floors of the government office building in Changsuo Town (Intensity IX area) suffered from significant ceiling falling damage. In general, the falling percentage of ceilings increased with the increase in floor height. For the conference room on the top floor, all the ceiling panels fell after the earthquake, as shown in Fig. 10a. The main reason is that the ceiling panels were floating on the channels and perimeters, and the ceiling system was not equipped with seismic clamps and an effective seismic fastener connection. Moreover, the seismic inputs from the ground will

be amplified due to the amplification effect of the floor acceleration response of the supporting structure (Wang et al., 2021; Shang et al., 2022). Therefore, the seismic force suffered by the ceiling connections will have a higher probability of exceeding the connection bearing capacity, which caused the damage of the connections and led to a large area of ceiling panels. The falling of these ceiling panels significantly affected the functionality of public buildings, especially for hospitals and schools with a large number of patients and students, as shown in Fig. 10b and c. The falling of these ceiling panels may also impact people passing through during the earthquake. It should also be noted that different types of suspended ceiling systems all suffered from heavy seismic damage (Fig. 10b and c) during this earthquake. Similar seismic damages of suspended ceiling systems were also reported in the 2013 M 7.0 Lushan earthquake, China (Wang et al., 2016).

4.2.2. Exterior facade walls

The exterior facade walls of public buildings were found to be easily damaged in this earthquake. Both horizontal and vertical cracks were found at the exterior facade walls of the teaching building and office building of the Central Primary school in Cuoguo Town, as shown in Fig. 7a and b. Most of the cracks were found at the connection of the walls and beams, or columns of the structures, especially at the wall positions next to windows. Cracks or even falling off were found at various positions of the plaster skin coats on the exterior facade walls, mainly due to the disharmony of deformation between the surface and the main structure. The shear failure of the bonding interface occurred under a small inter-story drift ratio. Similar cracks of exterior facade walls were also observed at public buildings in Changsuo Town and Quluo Town, as shown in Fig. 11. It should be noted that out of plane



Fig. 12. Seismic damages of infilled walls, (a) spalling of plaster of infilled wall at town government office building in Changsuo Town, (b) shear cracks of infilled wall at town government office building in Changsuo Town, (c) shear cracks of infilled wall at central primary school #1 teaching building of Quluo Town, and (d) spalling of plaster at central primary school #1 teaching building of Quluo Town.

damage and partial collapse of the top floor exterior facade wall were observed at central primary school teaching building of Quluo Town (Fig. 11b). Such damage was also found at the roof exterior facade walls of gymnasium building at the Central Primary school in Cuoguo Town, which suffered serious overall collapse under the amplified acceleration responses at the top of the structure, as presented in Fig. 7c.

4.2.3. Infilled walls

The seismic damages of infilled walls are commonly observed in earthquakes. The observed damage types in this earthquake include horizontal and vertical cracks that occur at the interface between the infilled walls and the structural beams or columns, shear cracks at the walls and wall limbs at the door and window openings, spalling of plaster and falling bricks. The observed damage examples of infilled walls were given in Fig. 12. According to previous earthquake damage investigation experience and quasi-static test results of frame structures with masonry filled walls, cracks of masonry infilled walls usually first appear at the junction of the infilled walls and frame beam or column components, and shear cracks will appear when the deformation increases. The laboratory test results from Xie et al. (2022) indicated that the initiation of small cracks in masonry, mainly concentrated in bed and head joints in plaster or along the interfaces with the columns and/or the top beam of the frame will occur under a low later drift ratio of 0.068% with a probability of 50%. The observed damages of infilled walls can confirm that the lateral deformation of the buildings in this earthquake is not too large, which also explained that why the main structure systems are usually basically undamaged.

4.2.4. Stairwell walls

The seismic damage phenomenons of stairwell walls are similar to those observed for the infilled walls mentioned above, as shown in Fig. 13. The reason for serious cracks of the stairwell walls is that the

inclined plate and inclined beam of the stair segment increased its horizontal stiffness, which results in greater seismic force distributed to the stair. And the stairwell wall is relatively high and has no floor slab support. In addition, the stair treads embedded in the wall further weaken the wall section. It is worth noting that the spalling of plaster and falling bricks of the stairwell walls and infilled walls seriously blocked the passage of the route of emergency escape, which may get the passengers injured.

4.2.5. Contents

Seismic damage to the inside contents was predominated by the sliding and overturning of cabinets, projector displays, medical carts, and oxygen tanks, and falling of indoor air conditioner units, as shown in Fig. 14. The cabinets, projector displays, medical carts, and oxygen tanks are usually free-standing on the floors without any anchor measures for seismic protection. Based on the shaking table test data from Shang et al. (2023), the median overturning peak floor acceleration (PFA) is 0.366 g for hospital cabinets located on ceramic tile flooring. A rigid block analysis of single window freestanding hospital cabinets by Di Sarno et al. (2019) indicated that the median overturning PFA is 0.38 g, as shown in the seismic fragility curves in Fig. 15. The overturning of these inside contents is mainly due to the fact that they were not anchored to the floor or the wall. The large aspect ratio resulted in a high center of gravity, which aggregated the seismic risk. In addition, the investigation results indicated that for higher floors in a building, the overturning of inside contents became heavier due to the amplified floor acceleration responses, which are the seismic inputs of these contents. Considering the large magnitude of this earthquake and the floor amplification effects, the seismic inputs of these contents may exceed the overturning limitation and therefore resulted in the seismic damage presented in Fig. 14. Apart from the overturning damage, the failure of wall-mounted monitors (Fig. 14d) and air conditioner unit (Fig. 14e)

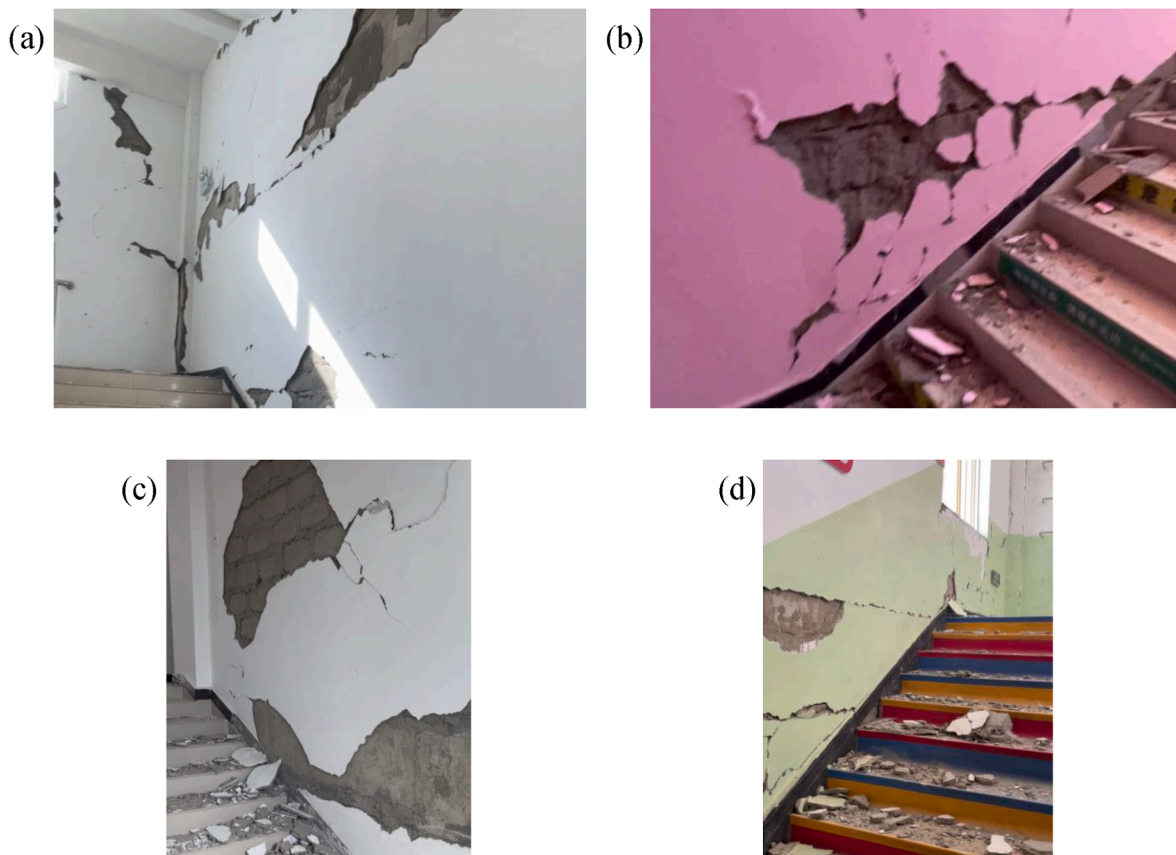


Fig. 13. Seismic damages of stairwell walls, (a) town government office building in Changsuo Town, (b) health center outpatient building in Changsuo Town, (c) town government office building of Quluo Town, and (d) central primary school #1 teaching building of Quluo Town.



Fig. 14. Seismic damages of inside contents, (a) overturning of cabinet at town government office building in Changsuo Town, (b) overturning of projector displayer at town government office building in Changsuo Town, (c) overturning of oxygen tank and sliding of medical cart at health center outpatient building in Changsuo Town, (d) almost falling monitors at health center outpatient building in Changsuo Town, (e) falling of wall-mounted air conditioner unit and cabinet contents, and (f) overturning of cabinets at central primary school #1 teaching building of Quluo Town.

were also observed. The falling down of such equipment may also threaten the life safety of surrounding passengers.

4.3. Seismic damage level classification of public buildings

Based on the observed structural damage and non-structural damage of the investigated buildings, the post-earthquake seismic damage levels of these buildings were evaluated as per GB/T 24335-2009 (2009). A total of 14 public buildings were investigated, and the structural systems are mainly reinforced concrete frame structures and masonry structures. An illustration of seismic damage level classification standard for reinforced concrete frame structures after earthquakes is listed in Table 3. Based on the structural damage, most of these buildings are classified as

basically intact or slight damage. However, most are in moderate damage state if the non-structural damage and post-earthquake building functionality were considered. The proportion of evaluated damage levels was shown in Fig. 16. 64.3% of the investigated public buildings were in moderate damage level after this earthquake, and 7.1% were in heavy damage level. After the earthquakes, people in these buildings were all evacuated urgently and suffered partial loss of functionality. It should be noted that due to the limited human, material and time resources during the post-earthquake emergency period, the investigation didn't cover all the buildings in the earthquake-affected area, resulting in a relatively small sample size. However, for seismic damage of public buildings, the onsite investigation results are similar as discussed in Sections 4.1 and 4.2.

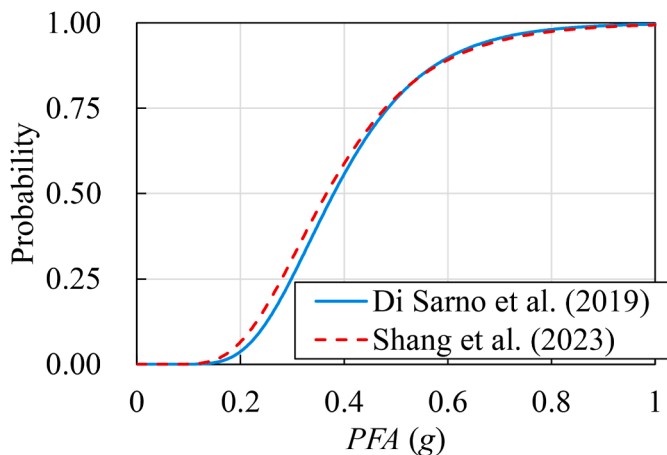


Fig. 15. Seismic fragility curves of freestanding inside contents.

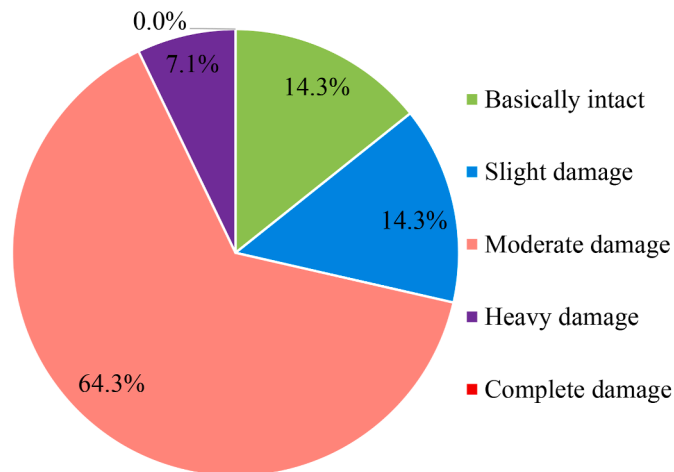


Fig. 16. Proportion of evaluated damage levels for investigated public buildings.

5. Casualty distribution and analysis

5.1. Spatial distribution characteristics of the death

A total of 126 people died during the earthquake, and the spatial distribution shows an obvious aggregation trend. 123 died people were distributed in several towns of Dingri County near the epicenter, including Changsuo Town, Cuoguo Town, Quluo Town, Qudang Town, and Xiegeer Town. And three died people distributed in Lazi County, as shown in Fig. 17. Changsuo Town is located in the intensity IX area of this earthquake and 94 people died, which accounts for 75.2% of the total death number. Apart from the seismic damage of rural self-built houses, another important reason for the large number of deaths in Changsuo Town is the strong fault activity in this area. From the surface fracture tracking investigation in Changsuo Town, it can be seen that there exists significant vertical dislocations, up to 3.0 m (Liang et al. (2025)). Fourteen people died in Cuoguo Town (IX degree zone), 13 people died in Quluo Town (VIII degree zone), one person died in Qudang Town (VII degree zone), and one person died in Xiegeer Town (VI degree zone), as presented in Fig. 17b.

5.2. Age and gender distribution characteristics of the death

The age and gender of 123 people who died in this earthquake in Dingri County were summarized in Fig. 18. Most of the earthquake deaths were female, specifically 70 females, accounting for 56.9% of the

deaths in Dingri County, and 53 males, accounting for 43.1% of the deaths in Dingri County. For different age groups, the death of 24–60 years old accounted for the highest proportion (33.3%), followed by 0–7 years old children (30.9%). 8–14 and 15–23 years old people accounted for 17.1% and 6.5% of the total death.

5.3. Causes of death

The population density in the earthquake area is relatively low, but the local population is concentrated. Although the average population of 20 km per square kilometer near the epicenter is only 7 people, there are 3 township government offices, 29 villages, 3 medical institutions, and 3 primary schools, with a total population of 9 300, which is a relatively densely populated area in Xizang. According to the statistical data of population distribution, the earthquake occurred in a densely populated area, and most of the permanent residents are left-behind elderly and children, which are not beneficial to self-rescuing and mutual rescuing. Changsuo Town, Cuoguo Town, and Quluo Town are located within 20 km of the earthquake epicenter. Among them, Cuoguo Town is only 3.2 km from the epicenter with a total population of more than 4 200 people, of which 99% are from Xizang. Changsuo Town is 15.7 km from the epicenter with a population of more than 4 000. Dingjie County and Dingri County are located within 50 km of the earthquake epicenter. Dingjie County is 34 km away from the epicenter and has a total population of more than 20 000 people. Dingri County is 36 km from the

Table 3

Seismic damage level classification standard of reinforced concrete frame structure after earthquakes (GB/T 24335-2009 (2009)).

Damage level	Structural Components	Non-structural components	Building functionality
Basically intact	The frame beam and column components are in good condition.	A few (less than 10%) NSCs are slightly damaged, e.g., minor cracks of a few infilled walls or at the junctions with the frame, and minor damages to some decorations.	The building functionality is normal and can continue to be used without repair.
Slight damage	Minor cracks appeared in a few frame beam and column components.	Some (10%–50%) NSCs have minor damages, or a few have obvious damages, e.g., obvious cracks of some infilled walls or at the junctions with the frame.	The basic functionality of the building remains unaffected. It can continue to be used with minor repairs or no repairs at all.
Moderate damage	Most (more than 50%) of the frame beam and column components have minor cracks, some have obvious cracks, and the concrete at the ends of a few beams and columns spalled off.	Most NSCs have obvious damages. For example, most infilled walls have obvious cracks, and a few have severe cracks.	The basic functionality of the building has been affected to a certain extent. It can be used after repair.
Heavy damage	The frame beam and column components were severely damaged. The concrete at the ends of most beams and columns spalled off, the main bars were exposed, and the main bars of a few columns were compressed and buckled.	NSCs were severely damaged, including most of infilled walls suffered heavy damages and partial collapsed. Or the structure is obviously inclined.	The basic functionality of the building has been severely affected, and it is difficult to repair or having no repair value.
Complete damage	The frame beams and columns were severely damaged, and the structure was on the verge of collapse or had already collapsed.	Most NSCs were almost completely damaged.	The building functionality no longer exists and there is no possibility of repair.

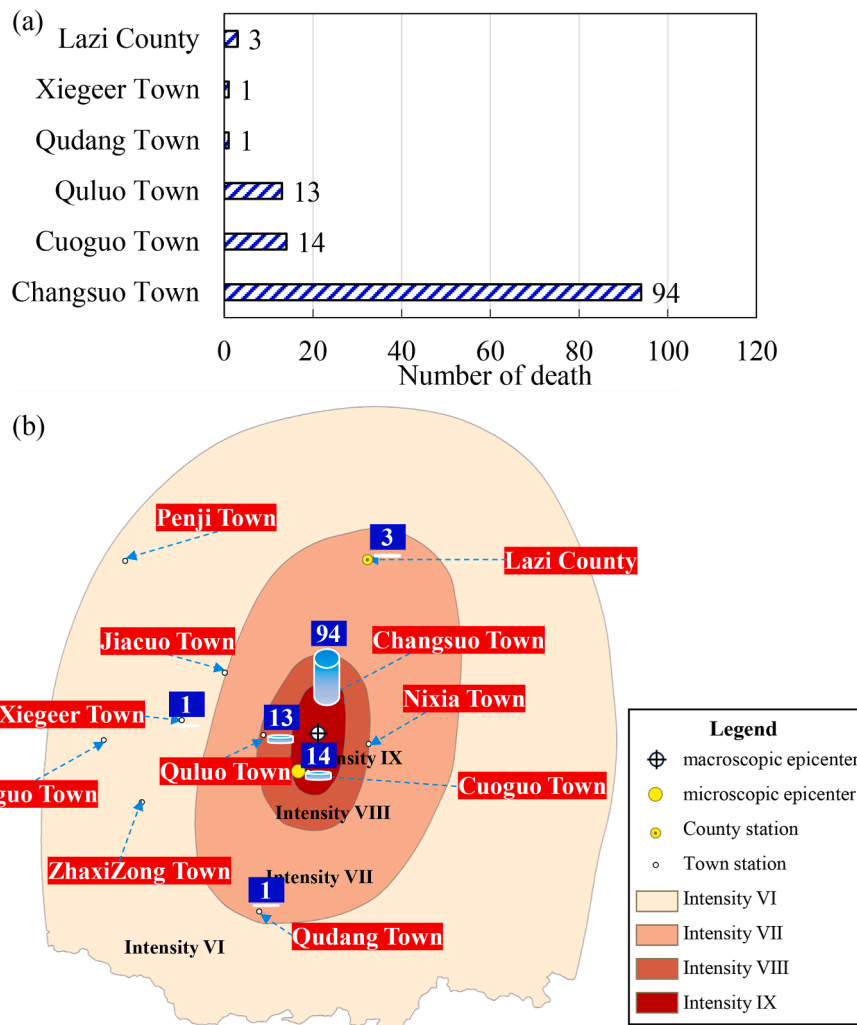


Fig. 17. Casualty distribution, (a) statistical data, and (b) spatial distribution.

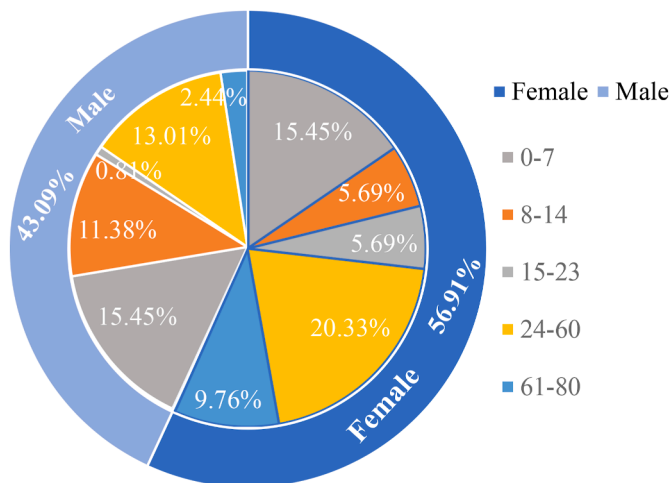


Fig. 18. Age and gender distribution of the death.

epicenter with a population of more than 60 000, making it the most populous county in the Xizang border region. A detailed investigation and analysis on the causes of death of the 6.8 magnitude earthquake in Dingri County were conducted and the causes of death are mainly summarized in this Section.

5.3.1. Earthquake magnitude and intensity

The earthquake affected area has a tectonic background of frequent earthquakes. Since 1900, there have been 40 earthquakes of magnitude 3.0 or larger within 50 km of the epicenter, of which two were 6.0–6.9 magnitude and seven were 5.0–5.9 magnitude, while the largest one is this earthquake. The recorded earthquake intensity is larger than the local basic fortification intensity, as discussed in Section 2. The PGA of the earthquake recorded by the station 67 km from the epicenter was 0.43 g, which means that the seismic intensity of the epicenter is far more than the local DBE level (with PGA values of 0.2 g). Such seismic intensity may cause serious damage to local buildings especially for rural self-built houses, which account for most of the local buildings. A discussion of poor seismic performance of local houses without proper seismic design under this earthquake is provided in Sections 3 and 5.3.3. As for public buildings with reasonable seismic design, the seismic damage mainly concentrates on NSCs, as discussed in Section 4.

5.3.2. Seismogenic fault and vertical dislocations

Another important reason is the strong fault activity in this area. The epicenter is located in Cuoguo Town, Dingri County. The type of this earthquake is normal fault, mainly unilateral rupture. The earthquake rupture is about 55 km and the rupture lasted 27 s with a maximum displacement of 1.4 m. There are significant vertical dislocations with a maximum vertical dislocation of about 3.0 m (Liang et al. (2025)). The rupture passes north through Changsuo Town and the maximum displacement location is near Changsuo Town. The rupture duration and

length are obviously larger than the earthquake of the same magnitude with a larger earthquake destructive power. In addition, the area near the epicenter is in the sedimentary area of river and lake, which has the site amplification effect and further intensifies the destructive power. The nearest village to the rupture surface is Gurong Village, Changsuo Town, which locates about 2 km away. The earthquake spread to buildings without sufficient distance attenuation, resulting in the collapse of a wide range of houses in Changsuo Town and 94 people died. For Gurong Village, all the 34 houses collapsed and resulted in 23 people died, making this area the most severely affected by the earthquake.

5.3.3. Seismic performance of local houses

There are many old timber structure houses with mud bricks or stones in the countryside near the epicenter. There is generally no systematic seismic design and the structural system of the houses is usually unreasonable, which results in poor seismic performance. In addition, the freezing and thawing cycle in the winter in high cold area is easy to lead to more significant damage and even collapse of these houses. The proportion of old timber structure houses with mud bricks or stones with poor seismic performance is 97% and 88% for Intensity IX and Intensity VIII areas. The walls were usually constructed with raw adobe masonry and the roofs were usually thick for heating demand, which are prone to brittle damage under seismic inputs and usually result in collapse. The overall collapse rate of the Intensity IX area is more than 60% (Ministry of Emergency Management of the People's Republic of China 2025). The collapsed heavy roofs and walls can easily cause smashing and burying people, which is one of the main factor causing heavy casualties in this earthquake.

5.3.4. Sleeping habits of residents

From the analysis of residents' habits, it was found that residents like to sleep against the wall in winter for warming themselves. However, such sleeping habits will lead to a worse situation once the collapse of houses occurred. Sleeping against the wall means that people are next to the wall and there is almost no response time to run away once the collapse of the wall happened. The consequence is that people will get buried and trapped when earthquake occurs, especially when the houses collapse. Such sleeping habit is also an important cause of the death in this earthquake.

5.3.5. Earthquake occurrence time

According to the statistics of the death in Dingri County, it was found that most residents were in their sleep, and there was almost no response time to escape when the earthquake occurred at 9:05 on January 7, Beijing time. This time is not production time in winter in Xizang, when most residents were in their sleep. Once the wall and roof fell due to house collapse instantly, the people were basically buried and died in their sleep. It was found that the elderly (61–80 years old) and children (0–7 years old) accounted for a relatively higher proportion (43.1%) of deaths.

5.3.6. Local temperature and altitude

The earthquake affected area located in the high altitude area of the plateau with an average altitude of more than 4 300 m. And the earthquake occurred in winter. The local temperature is significantly low as the local minimum temperature reached minus 18 °C. The low temperature has a great impact on the survival rate and health status of buried and trapped people. The injured people will have fast physical consumption and the body's tolerance will be reduced, e.g., the physiological functions will decline, the heartbeat and breathing will slow down, the blood pressure will decrease, and even will be in confusion and other symptoms of hypothermia. If the buried one cannot get timely rescue, they will be in coma or even death. In addition, due to the scattered distribution of villages, it was difficult to collect earthquake information, the rescue arrival time was not timely, and the death rate of

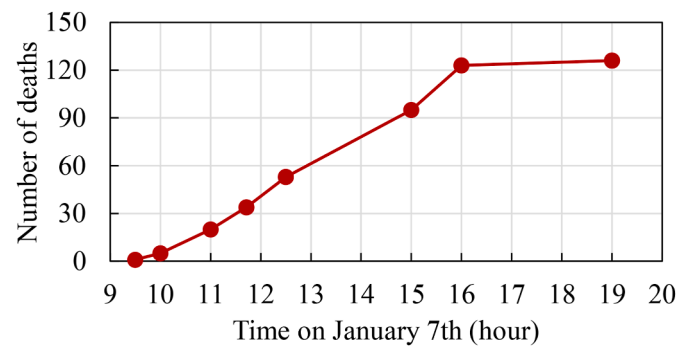


Fig. 19. Increase trend of casualty number with time.

injured people trapped under low temperature conditions increased significantly. The increase of death number after the earthquake occurrence is presented in Fig. 19. It can be found that the number of death almost increased linearly with the time. The casualty number increased to 126 at 10 hr later after the earthquake occurrence. Therefore, the rescue time is usually quite short for post-earthquake emergency rescue at high altitude and low temperature areas, which reminds that the emergency response should be as quickly as possible for buried and trapped people rescue.

6. Conclusion

On January 7, 2025, a M 6.8 earthquake occurred at Dingri County. This report discusses the seismic damage of local houses and buildings, and the casualty characteristics and causes of this earthquake. The main results can be summarized as follows:

- (1) For rural self-built one-story or two-story timber structure houses, the seismic performance is usually poor and suffered significant damage. Collapse was widely found for such type of houses due to poor integrity of the structure system, low strength of building materials, poor construction quality and lack of necessary seismic structural measures. In addition, a two-story reinforced concrete frame house was found collapsed at the first story due to poor construction quality and no seismic design.
- (2) For local public buildings with proper seismic design, the structural components are basically undamaged or suffer slight damage, which shows good seismic performance. However, the non-structural components including the suspended ceilings, exterior facade walls, infilled walls, stairwell walls and building-inside contents are severely damaged. Such seismic damage not only resulted in significant economic losses, but also led to building functionality interruption, especially for public buildings like hospitals and schools.
- (3) Based on the seismic damage characteristics and causes of the non-structural components, it is suggested to focus on whether the structural measures of various non-structural components in public buildings of high intensity areas meet the requirements of the seismic design codes in post-earthquake inspection and strengthening of local buildings. Strengthening the connection between non-structural components and the main supporting structure to improve their seismic performance is important to achieve seismic protection of non-structural components, and avoid building functionality interruption.
- (4) This earthquake caused 126 death and most of the died people were distributed in several towns of Dingri County near the epicenter, among which 56.9% were female. The elderly (61–80 years old) and children (0–7 years old) accounted for a relatively higher proportion (43.1%) of deaths. The causes of death were owing to several factors including the collapse of houses due to

high earthquake magnitude and high seismic intensity, seismogenic fault and significant vertical dislocation effects, and poor seismic performance of local houses. In addition, when the earthquake occurred, residents were in sleep with no time to escape which resulted in a lot of people get buried and trapped under low local temperature. All of these factors resulted in such harrowing consequence.

It should be noted that possible reasons that may cause the reported damage and casualty were determined based on the field investigation results. Detailed numerical analyses are still needed in future studies.

CRediT authorship contribution statement

Qingxue Shang: Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Zhongyi Zhou:** Writing – review & editing, Writing – original draft, Resources, Methodology, Investigation, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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