Survey Report on the Areas Affected by the Earthquake with Epicenter in Southeastern Turkey

School of Architecture, Mukogawa Women's University, Japan

Shigeyuki Okazaki, *Dean, Professor*
Kazuhiko Yanagisawa, *Head of Architecture Department, Professor*
Shigeki Tosu, *Professor*
Hiroyuki Tagawa, *Professor*

Kobe City, Japan

Yukio Tanaka, *Executive Director, Building Guidance Department, Construction and Housing Bureau*
Masayoshi Nose, *Director, Crisis Management Office*

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Preface

On February 6, 2023, there was a major earthquake in the areas straddling southeastern Turkey and Syria. In fact, there was also a severe earthquake in 2011 in the vicinity of Lake Van, which is located to the east of the affected area. After the Van earthquake, myself, two Kobe City officials, one former Kobe City official, and one structural researcher from E-Defense conducted a field survey of the damage with then Dean of the Faculty of Architecture and Design Ahmet Eyüce and Professor Murat Dündar of Bahçeşehir University in Istanbul. After the survey, we held a public symposium in Istanbul. Mukogawa Women's University signed an exchange agreement with Bahçeşehir University in 2008, and the schools of architecture at both universities have conducted short-term exchange programs almost every year, as well as jointly hosting the International Conference on Archi-Cultural Interactions through the Silk Road.

Again, immediately after the earthquake, we were in contact with Professor Murat Dündar, the current Dean of the Faculty of Architecture and Design at Bahçeşehir University, who provided us with comparative photos of historical and cultural buildings and townscapes before and after the earthquake, as well as topographical maps of the entire affected area. Subsequently, at the invitation of Bahçeşehir University, we decided to conduct a survey of the affected areas together with the City of Kobe.

On April 12, three professors from the School of Architecture at Mukogawa Women's University and two Kobe City officials left for Turkey to survey earthquake disasters in southeastern Turkey. On the 11th, the day before their departure, a press conference was held in Kobe City. The three members from Mukogawa Women's University were Professor Yanagisawa, head of the architecture department and a professor of architectural design, Professor Tagawa, a professor of earthquake-resistant engineering, and Professor Tosu, a professor of structural design, while the two members from Kobe City were Executive Director Tanaka of the Construction and Housing Bureau and Director Nose of the Crisis Management Office. Professor Murat Dündar planned the survey cities and itinerary, and guided them throughout the entire tour.

With the full support of Bahçeşehir University, the group flew to the affected areas early in the morning of the day after their arrival in Istanbul, conducted surveys in Kahramanmaraş, Hatay, and other areas that were most severely damaged, and after returning to Istanbul, held a press conference and exchanged opinions with researchers from Bahçeşehir University. The five returned to Japan on April 20, and held a debriefing session at the West Hall of Mukogawa Women's University Koshien Hall on May 1, inviting TV stations and newspapers.

The three reporters were from Mukogawa Women's University and two from Kobe City. And Prof. Murat Dündar participated online. The entire cost of the research in Turkey was supported by Bahçeşehir University. Travel expenses for all participants from Mukogawa Women's University were supported by Hyogo Prefecture.

Prof. Yanagisawa reported on the overall damage, Prof. Tagawa on the magnitude and characteristics of the earthquake and the damage, Prof. Tosu on the damage caused by the form of buildings and their relationship with adjacent buildings from a structural design perspective, and Mr. Tanaka and Mr. Nose of Kobe City on the importance of building administration in dealing with earthquake damage and their visits to the mayors in the affected areas. Dean Murat reported on the problems of the inspection system for architectural design and renovation work in Turkey, and on the plan to open a disaster prevention center at Bahçeşehir University.

Prof. Dr. Shigeyuki Okazaki

Dean of the School of Architecture
Mukogawa Women’s University

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1．Overall Overview

On February 6, 2023, an earthquake centered in southeastern Turkey caused extensive damage in the region and surrounding areas. At the request of Bahçeşehir University in Turkey, three faculty members with expertise in architectural structure and design from Mukogawa Women's University (MWU), which has a general exchange agreement with Bahçeşehir University, and two officials in charge of architectural guidance and crisis management from Kobe City, which experienced the Great Hanshin-Awaji Earthquake, were sent to the affected areas to conduct on-site surveys for reconstruction.

1-1．Members

Japan Side Planner

Prof. Dr. Shigeyuki Okazaki, *Dean, School of Architecture, MWU*

Dispatch Members

Prof. Dr. Kazuhiko Yanagisawa, *Head of Architecture Department, School of Architecture, MWU* (Architectural Design and Planning)

Prof. Dr. Shigeki Tosu, *School of Architecture, MWU* (Architectural Structure Design)

Prof. Dr. Hiroyuki Tagawa, *School of Architecture, MWU* (Architectural Structure Engineering)

Mr. Yukio Tanaka, *Executive Director, Building Guidance Department, Construction and Housing Bureau, Kobe City*

Mr. Masayoshi Nose, *Director, Crisis Management Office, Kobe City*

1-2．Dispatch Schedule

Dispatch period: April 12 (Wed.) - April 20 (Thu.)

Date	Contents	Place to stay
Apr. 12 (Wed.)	Departure from Japan	
Apr. 13 (Thu.)	Visit to Bahçeşehir University	İstanbul
Apr. 14 (Fri.)	Visit to the Mayor of Çukurova, Adana Visit to the Mayor of Onikişubat, Kahramanmaraş Visit to Onikişubat and Dulkadiroğlu, Kahramanmaraş	İskenderun
Apr. 15 (Sat.)	Visit to Antakya, Hatay Visit to the Hatay Metropolitan Municipality Mayor Visit to Samandağ, Hatay	İskenderun
Apr. 16 (Sun.)	Visit to İskenderun, Hatay Visit to the Mayor of Payas, Hatay Tours of temporary housing, etc in Payas, Hatay	İstanbul
Apr. 17 (Mon.)	Roundtable at Bahçeşehir University	İstanbul
Apr. 18 (Tue.)	Visit to İstanbul	İstanbul
Apr. 19 (Wed.)	Departure from İstanbul	
Apr. 20 (Thu.)	Arrival in Japan	

1-3．Survey Summary

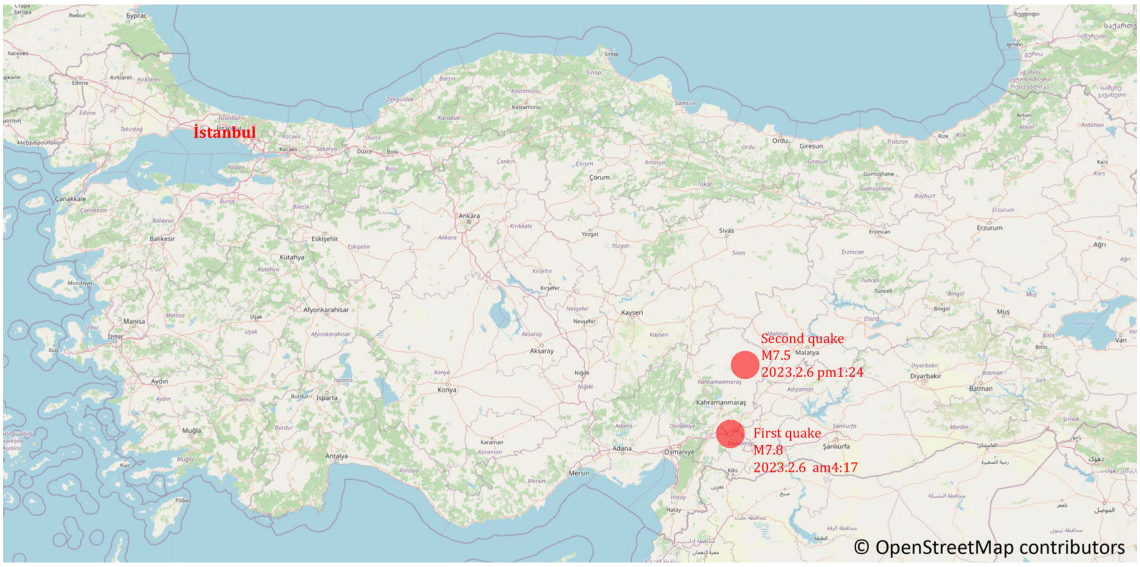

Fig. 1-1　Location of epicenters

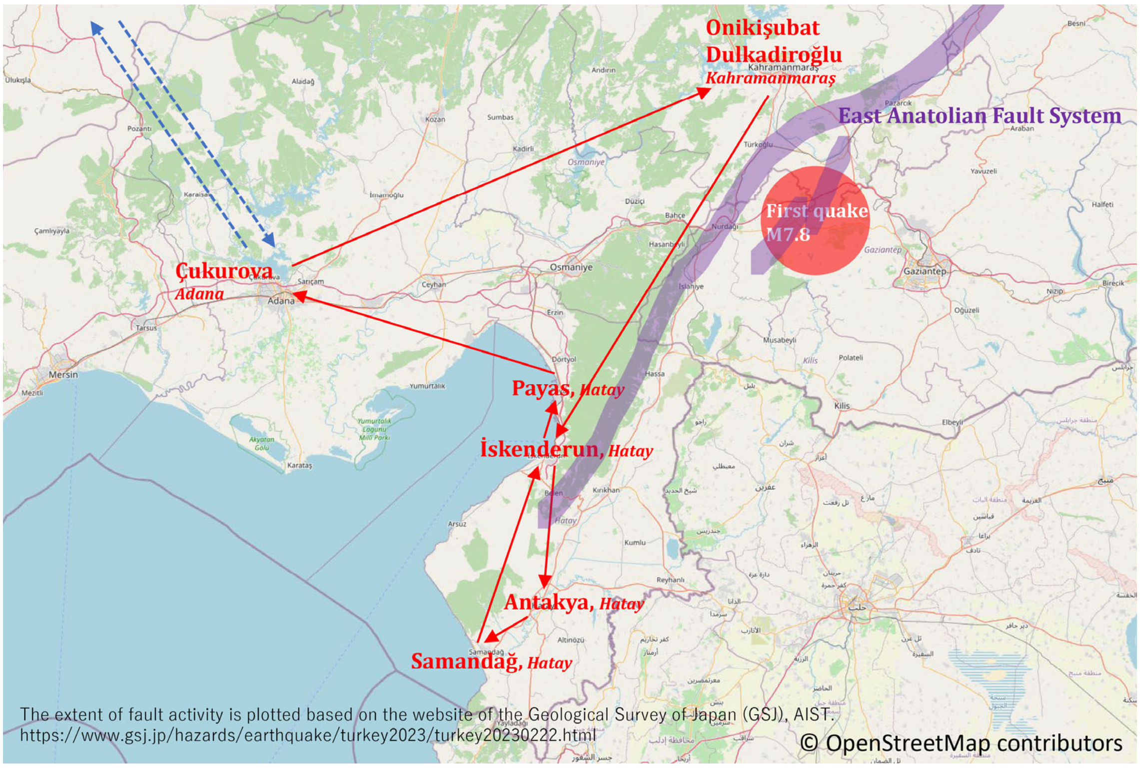

Fig. 1-2　Destinations

On April 14 (Fri.), we arrived in Adana from İstanbul, visited Adana, Kahramanmaraş, and Hatay provinces, and returned to İstanbul on April 16 (Sun.) On April 17 (Mon.), at Bahçeşehir University, with the presence of local media, we provided information on the history and efforts of architectural structures in Japan, and on the efforts of Kobe City, which experienced the earthquake, and opinions were exchanged on this earthquake.

1-3-1. Apr. 14 (Fri.) Adana and Kahramanmaraş Provinces

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Photo 1- 2　Visit to the Mayor of Onikişubat, K.Maraş.

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Peeling of exterior walls of apartment buildings.

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Drone shot of apartment buildings in Photo 1-4.

Photo 1-6 Onikişubat, K.Maraş.
Three 10-story buildings were destroyed.
Debris has already been removed in many places.

Photo 1- 7 Onikişubat, K.Maraş.
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HACI HUSEYIN KARA CAMARA CAMII.
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HACI HUSEYIN KARA CAMARA CAMII.
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Photo 1-10 Onikişubat, K.Maraş. Hz. Yunus Cami. Collapse of minarets.

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Photo 1-12 Dulkadiroğlu, K.Maraş.
Falling exterior wall blocks.

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Beyoğlu Disaster Relief Center.

1-3-2．Apr. 15 (Sat.) Antakya and Samandağ Districts, Hatay Province

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Hürriyet Street.

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Greek Orthodox Church Gate Street.

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Greek Orthodox Church Gate Street.

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Greek Orthodox Church Gate Street.

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Hatay Sanayici ve İş İnsanları Derneği（HASiAD）

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Site where an extension building collapsed.

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Peeling of exterior walls of apartment buildings.

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In the back, a 12-story apartment building collapsed.

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Apartment buildings to be demolished.

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4-story buildings are safe.

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Photo 1-72 Prof. Dr. Murat Dündar,
being interviewed by TV station.

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being interviewed by TV station.

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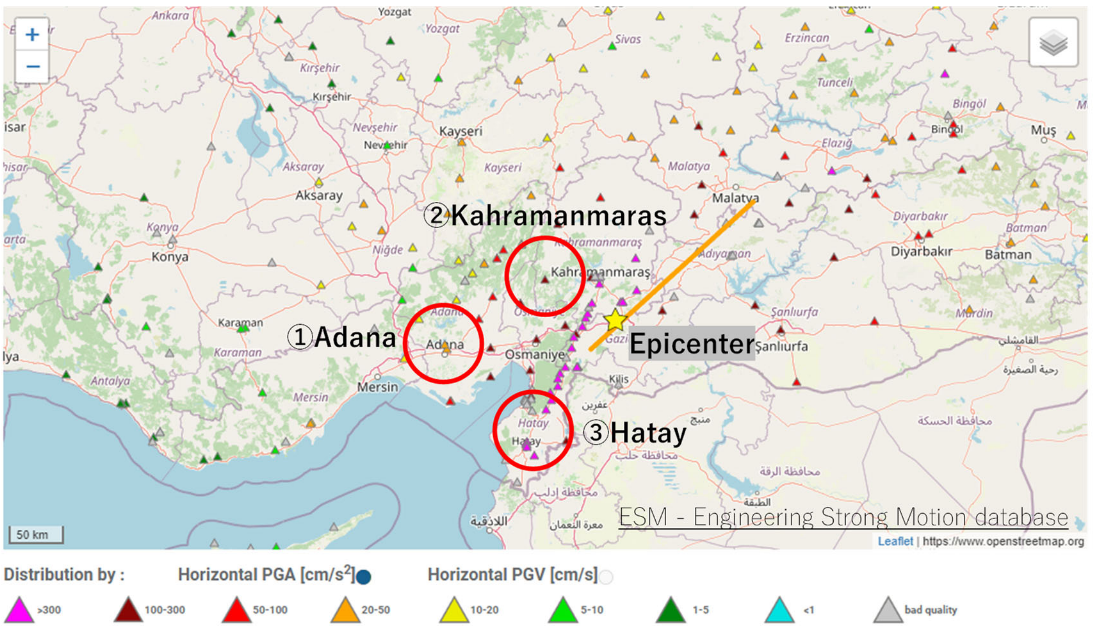
being interviewed by TV station.

Photo 1-75 A commemorative photo with paper cranes
in everyone's hands

Photo 1-76 A roundtable was held at Bahçeşehir University with the presence of local media. In addition to providing information on the history and efforts of architectural structures in Japan and the efforts of Kobe City, which experienced the earthquake, we exchanged opinions on this earthquake. We also discussed how the Disaster Prevention Center, which is scheduled to be newly established at Bahçeşehir University, should be established.

2. SURVEY REPORT I　Seismic Intensity and Observed Damage：From a Perspective of Seismic Structure

The seismic damage of structures is determined by seismic intensity, demand, and the seismic performance of structures, capacity. In this chapter, the seismic intensity in the three provinces, Adana, Kahramanmaras, and Hatay, as well as the observed seismic damage in the three provinces, are described. The geographical positions of these provinces, Adana, Kahramanmaras, and Hatay, are illustrated in Fig. 2-1. This figure presents the epicenter and fault line of the initial earthquake, transpiring at 4:17 a.m. (local time) on February 6, 2023. The figure symbolizes the observation station's location with the triangular symbol (△), which is color-coded to indicate the range of maximum ground motion acceleration. The observation stations marked with pink (△) exemplify ground motions with a maximum acceleration exceeding 300 gal and are situated in proximity to, and along, the fault line.



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△ represents observation station and the color represents the level of the maximum acceleration of observed ground motions.
https://esm-db.eu/#/event/INT-20230206_0000008

Fig. 2-1 Locations of three provinces visited and surveyed

2-1. Adana Province

The ground motion intensity recorded and seismic damage observed in the province of Adana are described. Fig. 2-2 illustrates the observation stations situated within the urban area of Adana. Two stations, namely TK0118 and TK0123, are depicted. The ground motion recorded at TK0118, situated close to the Cukurova municipal office, which we visited, has been utilized. The time-history of ground accelerations (in the east-west, north-south, and up-down directions) is presented in Fig. 2-3. The maximum ground accelerations are 38.2 gal in the east-west direction, 49.7 gal in the north-south direction, and 23.3 gal in the up-down direction. Although it might be reasonable to convert and represent pulse-type near-fault ground motions in the strike-normal direction, perpendicular to the fault line, and in the strike-parallel direction, the data in the east-south and north-south directions is displayed in this report. The instrumental seismic intensity, as defined by the Japan Meteorological Agency, is 4.0. It should be noted that the instrumental seismic intensity for TK0123 is 3.7.

To express the impact of ground motions on the seismic response of structures, the response spectrum is typically employed. Ground motions are input into single-degree-of-freedom oscillator models with varying natural periods, consisting of one mass, one spring, and one dashpot, and the maximum values of acceleration, velocity, and displacement responses are computed and plotted against the natural period. The maximum values of the time-history response are computed with single-degree-of-freedom oscillator models with natural periods ranging from 0.04 to 3.0 seconds, with a viscus damping ratio of 5%, and subjected to the TK0118 ground motion acceleration. The acceleration, velocity, and displacement spectra in the horizontal and vertical directions are presented in Fig. 2-4. In this figure, the values of the response spectra in the horizontal direction are derived as the maximum value of the square root of the sum of the squared responses in the east-west and north-south directions at each time step. Additionally, the response spectra for the JMA-Kobe ground motions recorded during the 1995 Hyogo-ken Nunbu Earthquake are provided for comparison. Notably, the instrumental seismic intensity of the JMA-Kobe ground motions measures 6.4. The acceleration, velocity, and displacement spectra for TK0118 are evidently smaller than those of the JMA Kobe ground motions.

Fig. 2-5 presents the demand response spectra, known as the Sa-Sd plot, where the displacement response spectra (Sd) is plotted on the X-axis, and the acceleration response spectra (Sa) is plotted on the Y-axis. Here, the viscous damping ratio is also set to 5%. If the load-displacement curve, known as the capacity spectrum, of the substitute single-degree-of-freedom oscillator model is plotted over the Sa-Sd plot, the seismic performance of a structure can be quickly assessed. This methodology, recognized as the Capacity Spectrum Method (CSM), forms the foundation for calculating the response and limit strength using the substitute linearization method. It is noteworthy that the Substitute Structure Method was originally proposed in the paper by Gulkan and Sozen (1974), and Polat Gulkan, the author of the paper, is a renowned seismic engineering researcher from Turkey.

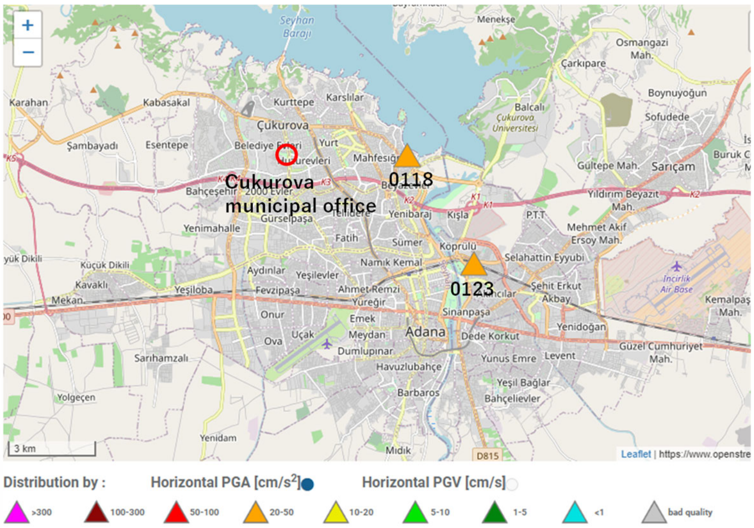


Fig. 2-2 Observation stations in Adana urban area

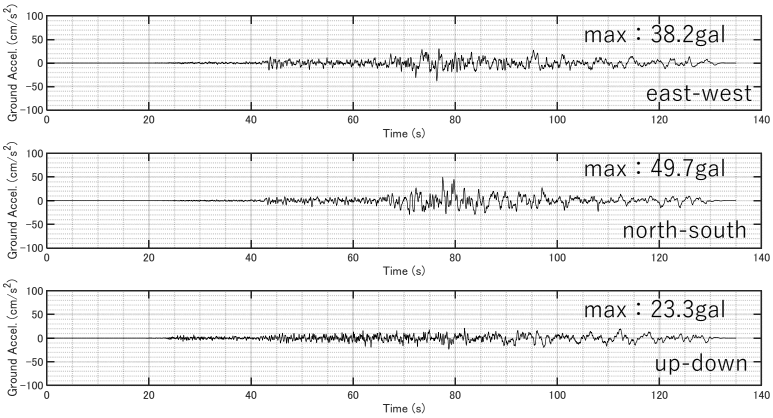


Fig. 2-3 Time-history of ground acceleration (TK0118)

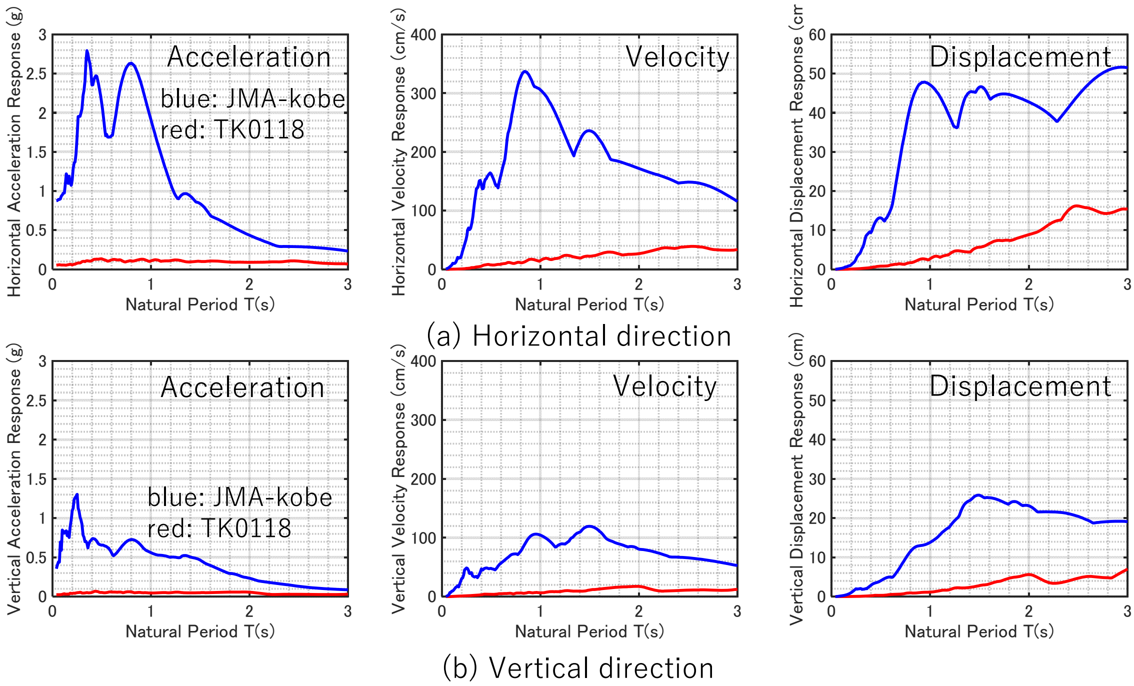


Fig. 2-4 Acceleration, velocity, displacement response spectra (TK0118)

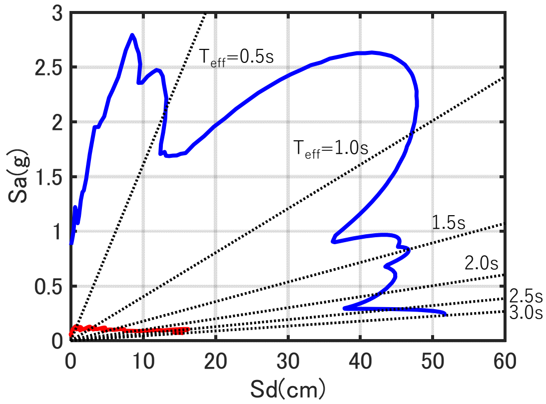


Fig. 2-5 Demand response spectra (TK0118)

The seismic damages observed in the urban area of Adana are presented in Photo 2-1. This photograph captures the vicinity of the Cukurova municipal office, where numerous reinforced concrete (RC) high-rise apartment buildings line the main road. Cracks are discernible on the exterior walls of many buildings, constituting non-structural damages. Additionally, there is evidence of a partial eave collapse. However, during a cursory inspection of the urban area from a moving vehicle, no instances of building collapse resulting from the earthquake were observed. Nevertheless, as per a conversation with the headman of Cukurova and a news report from Japan, it has come to light that a 14-story RC apartment building suffered complete collapse as a consequence of the earthquake, as shown in Photo 2-2. Moreover, approximately 12 RC high-rise apartment buildings in Cukurova have also collapsed, which poses a critical issue. The precise locations of these collapsed apartment buildings have not been specified, making it challenging to accurately determine the intensity of the ground motions they were subjected to. However, presuming that the instrumental seismic intensity of the TK0118 and TK0123 observation stations in the Adana urban area is 3.7 and 4.0, respectively, a similar level of intensity can be inferred for these apartment buildings. It is postulated that critical design flaws contributed to the total collapse of the high-rise apartment buildings under this intensity level of ground motions.

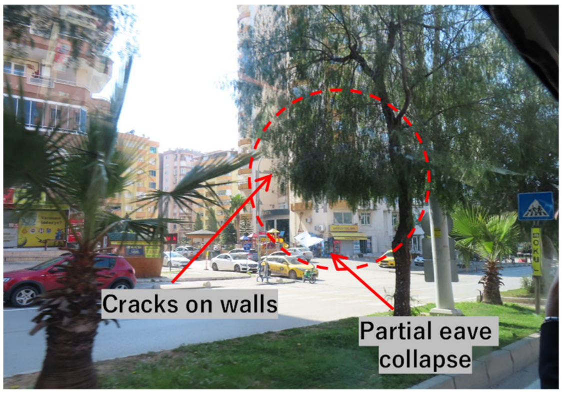


Photo 2-1 Seismic damage in Adana


Photo 2-2 Collapse of 14-story apartment

(Photo 2-2 reference：https://www.jiji.com/jc/article?k=2023020800195&g=int)

2-2. Kahramanmaras Province

The intensity of the ground motions recorded and the seismic damage observed in the Kahramanmaras province, which is situated closest to the epicenter, are described. The observation stations for ground motions in Kahramanmaras are presented in Fig. 2-6. There are a total of 5 observation stations, although data from two of them were not accurately recorded. The ground motions recorded at stations TK4617 and TK4620, which are in closest proximity to the locations we visited, are utilized. The time-history of ground motion accelerations at TK4617 is presented in Fig. 2-7. The maximum ground motion acceleration reaches 112.7 gal in the east-west direction, 145.6 gal in the north-south direction, and 111.8 gal in the up-down direction. The instrumental seismic intensity at TK4617 is 4.7. The acceleration, velocity, and displacement response spectra for TK4617 are presented in Fig. 2-8, while the demand response spectrum is presented in Fig. 2-9. Conversely, the time-history of ground motion accelerations at TK4620 is presented in Fig. 2-10. The maximum ground motion acceleration reaches 316.6 gal in the east-west direction, 298.2 gal in the north-south direction, and 176.6 gal in the up-down direction. The instrumental seismic intensity at TK4620 is 5.0. The acceleration, velocity, and displacement response spectra for TK4620 are presented in Fig. 2-11, while the demand response spectrum is presented in Fig. 2-12. It is evident that the response spectra for the recorded ground motions at TK4617 and TK4620 are generally smaller than those of the JMA-Kobe ground motion across most of the natural period ranges.

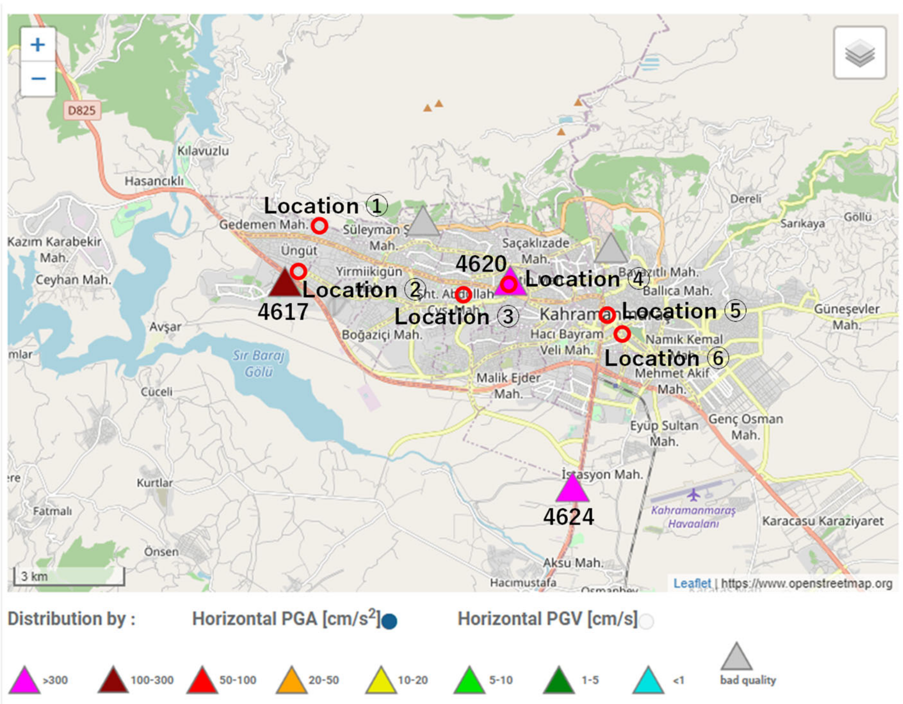


Fig. 2-6 Observation stations in Kahramanmaras urban area

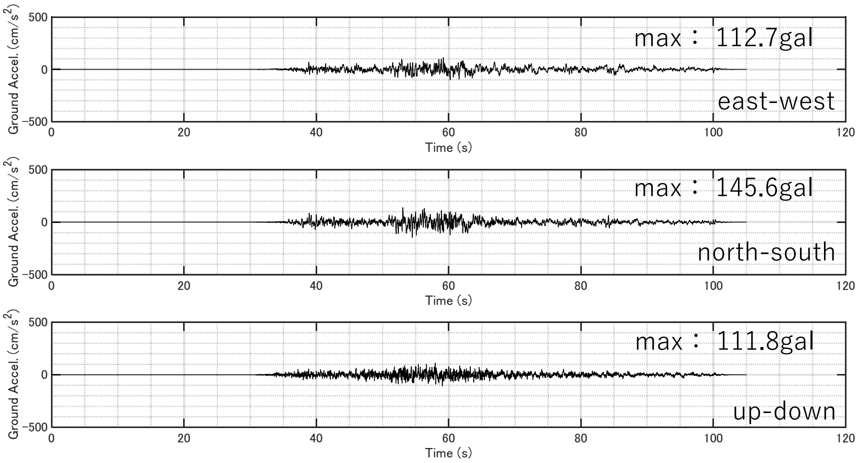


Fig. 2-7 Time-history of ground motion acceleration（TK4617）

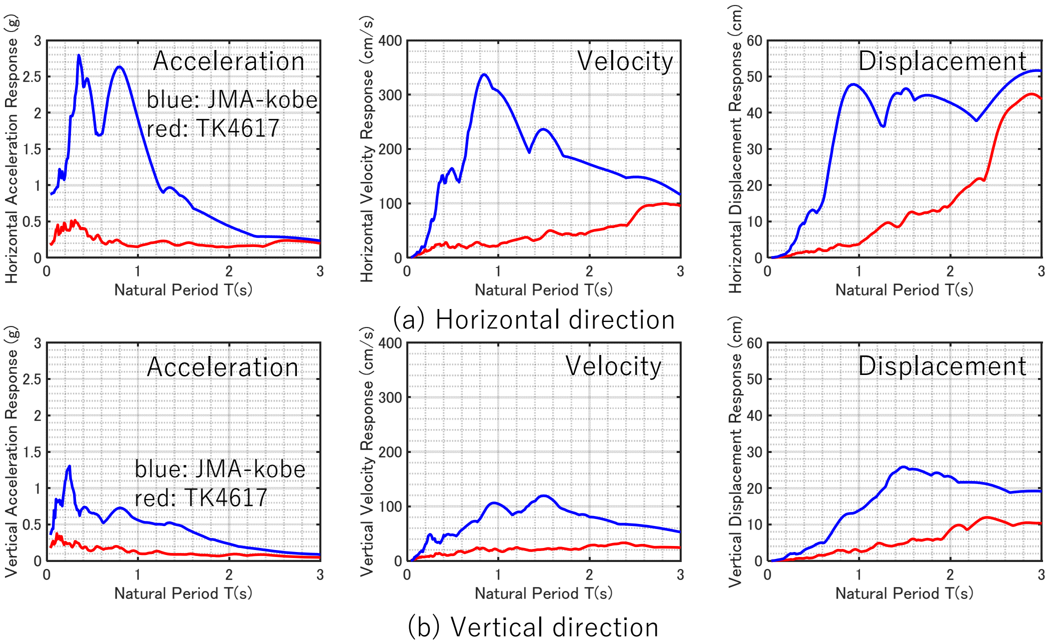


Fig. 2-8 Acceleration, velocity, displacement response spectra（TK4617）

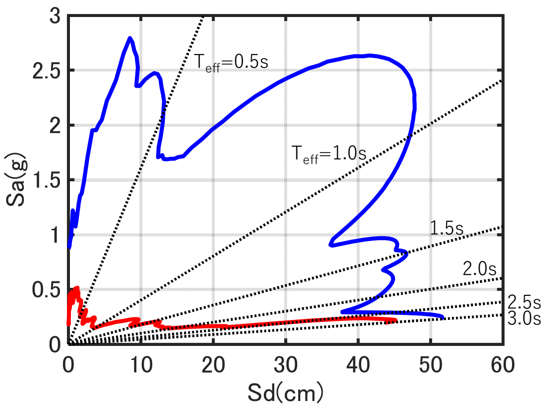


Fig. 2-9 Demand response spectrum（TK4617）

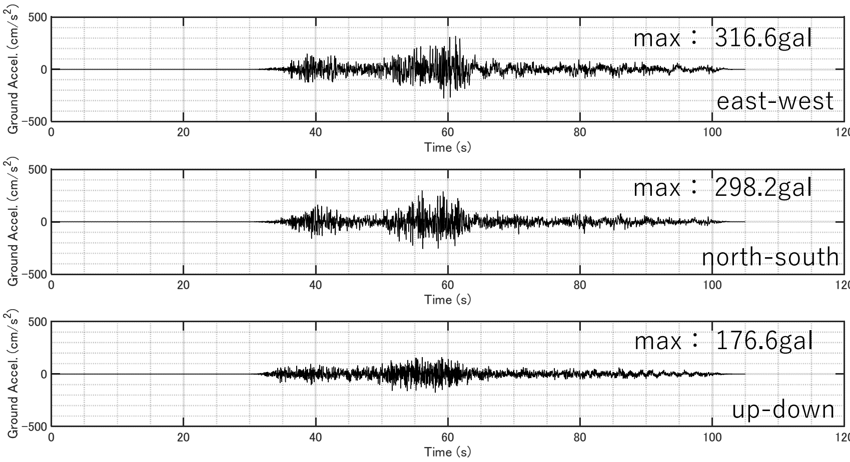
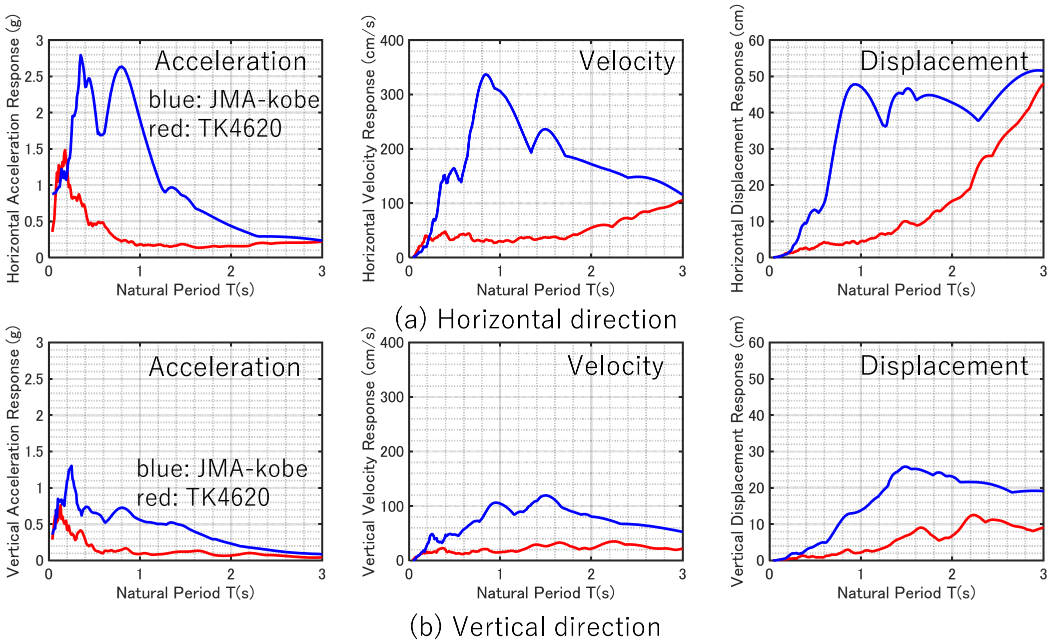


Fig. 2-10 Time-history of ground motion acceleration（TK4620）



(a) Horizontal direction

(b) Vertical direction

Fig. 2-11 Acceleration, velocity, displacement response spectra（TK4620）

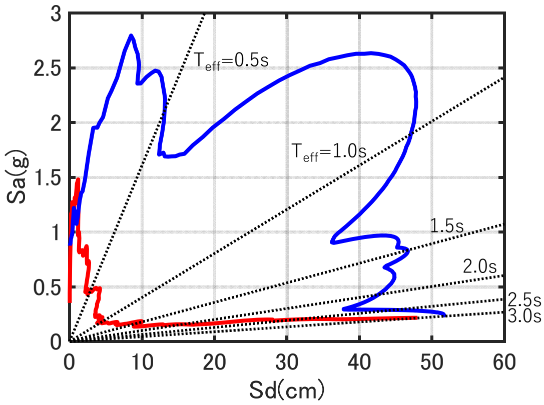


Fig. 2-12 Demand response spectrum（TK4620）

The seismic damages resulting from the earthquakes at the six locations (① to ⑥) visited during the survey in the urban area of Kahramanmaras are presented in Photo 2-3 to 2-8. These six locations are illustrated in Fig. 2-6. The damage conditions at locations ① and ② are described. Location ① is where the Onikisubat municipal office is situated. Location ② is in close proximity to the observation station TK4617 and is believed to have experienced ground motions with an instrumental seismic intensity of approximately 4.7. As shown in Photo 2-3 on the left, the four-story RC building of the Onikisubat municipal office does not exhibit any structural damage. However, as shown in Photo 2-3 on the right, a portion of the dry external wall has collapsed. At the location ②, near the Onikisubat municipal office, as seen in Photo 2-4 in the left, recently constructed high-rise apartment buildings stand side by side. Concrete walls without reinforcements have fallen in an out-of-plane direction. Additionally, as shown in Photo 2-4 on the right, exterior walls have collapsed towards the entrance. If individuals had been present at the time of the collapse, severe human casualties would have occurred. Generally, at Locations ① and ②, while structural members may have experienced damages, non-structural members, such as exterior wall damage, are more prominent.

Photo 2-3 Seismic damage in Kahramanmaras (Location ①)

Photo 2-4 Seismic damage in Kahramanmaras (Location ②)

It is postulated that Locations ③ and ④ experienced ground motions with an instrumental seismic intensity of approximately 5.0, given their proximity to observation station TK4620. At Location ③, three ten-story residential complexes underwent structural collapse, and as shown in Photo 2-5 on the left, debris had been cleared, leaving cleared construction sites. There was scarce evidence available to ascertain the causes and types of the building collapses. Nevertheless, steel reinforcements of considerable diameter were discovered protruding from the ground as shown in Photo 2-5 on the right, which were presumed to be main reinforcements at the lower levels. Both deformed and round steel reinforcements were identified. The influences of round steel reinforcements as a contributing factor to the building collapse cannot be definitely determined. However, the AIJ standard for the structural calculation of reinforced concrete structures specifies that primary reinforcements should be deformed reinforcements exceeding a diameter of D13, as stated in Article 13, and that more than four primary reinforcements should be deformed reinforcements with a diameter greater than D13, as outlined in Article 14. A few buildings suffered complete collapses, while concurrently, as shown in the background of Photo 2-5 on the left, numerous medium and high-rise structures appear to have withstood the event without any discernible structural damage, based on their external appearance. At Location ④, as shown in Photo 2-6 on the left, the upper portion of a minaret belonging to the Yunus Cami Mosque collapsed, and as shown in Photo 2-6 on the right, stacked stones plummeted to the ground or onto the mosque's roof. It is worth noting that Location ④ is nearly indistinguishable from the ground motion observation station TK4620.

Photo 2-5 Seismic damage in Kahramanmaras (Location ③)

Photo 2-6 Seismic damage in Kahramanmaras (Location ④)

Locations ⑤ and ⑥ experienced exceptionally severe seismic damage within the urban area of Kahramanmaras, as shown in Photo 2-7 on the left, presenting a profoundly devastating state throughout the district. These locations, in close proximity to observation station TK4620, exhibited significantly more extensive seismic damage compared to the district encompassing Locations ③ and ④. While it is postulated that this disparity could be attributed to unfavorable soil conditions leading to seismic amplification and the dense arrangement of commercial and residential buildings, quantitatively verifying these factors may prove challenging. At Location ⑤, as shown in Photo 2-7 on the right, a column with substantial spacing between hoops, which serve as shear reinforcements, was observed. Although the hoops should have been more densely arranged around the beam-column joint, they were spaced widely, resembling the configuration seen in the central section of a beam.

At Location ⑥, as shown in Photo 2-8, a bustling downtown area characterized by a dense congregation of commercial and residential structures along major throughfares suffered extensive building collapses. In many buildings, the ground floor consists of shops, while the stories above the second-floor house residential units. The shops on the ground floor feature large openings, resulting in an eccentricity in the stiffness distribution across the height of the structures. Moreover, the building layout itself exhibits significant eccentricity due to the protrusion of balconies and the irregular arrangement of columns and walls. It is conjectured that such an imbalance in the overall structural system contributed to the collapses, emphasizing the importance of considering stiffness distributions across the height and the building plan, as well as the fundamental concept of seismic design, including the utilization of designated design routes such as routes 2 and 3 employed in Japan.

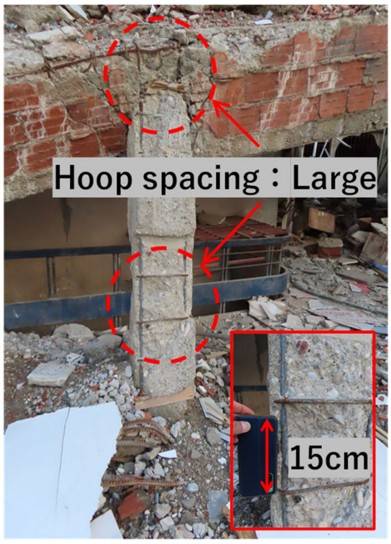


Photo 2-7 Seismic damage in Kahramanmaras (Location ⑤)

Photo 2-8 Seismic damage in Kahramanmaras (Location ⑥)

2-3．Hatay Province

The ground motion intensities measured and seismic damage observed in the province of Hatay are described. Specifically, three urban areas in Hatay province, namely Antakya, Samandag, and Iskenderun, were visited and surveyed. The locations of the observation stations in Hatay province are illustrated in Fig. 2-13. The data recorded in Samandag is of poor quality. Similarly, a significant portion of the data recorded in Iskenderun is also of poor quality, with the exception of one station located far from the urban area. Consequently, the ground motions recorded in the Antakya urban area are utilized. The locations of the observation stations in the Antakya urban area are illustrated in Fig. 2-14. There are four observation stations in the Antakya urban area, and the ground motions recorded at TK3123, which is in close proximity to the visited and surveyed location, as well as TK3124, situated in the district exhibiting extensive damage visible from aerial photographs, are considered.

The time-history of ground motion accelerations at TK3123 is presented in Fig. 2-15. The maximum acceleration recorded is 585.8 gal in the east-west direction, 652.1 gal in the north-south direction, and 842.6 gal in the up-down direction. The instrumental seismic intensity of TK3123 is 6.3. The acceleration, velocity, and displacement response spectra at TK3123 are presented in Fig. 2-16, while the demand response spectrum is presented in Fig. 2-17. Conversely, the time-history of ground motion accelerations at TK3124 is presented in Fig. 2-18. The maximum acceleration recorded is 624.3 gal in the east-west direction, 571.4 gal in the north-south direction, and 572.7 gal in the up-down direction. The instrumental seismic intensity at TK3124 is also 6.3. The acceleration, velocity, and displacement response spectra at TK3124 are presented in Fig. 2-19, and the demand response spectrum is presented in Fig. 2-20. It is noted that the response spectra of both recorded ground motions, TK3123 and TK3124, in Antakya exhibit a comparable level to that of the JMA-Kobe ground motions. The trends of the response spectra for TK3123 and TK3124 are similar, and in the horizontal direction, both TK3123 and TK3124 exhibit greater velocity and acceleration spectra compared to the JMA-Kobe ground motions for natural periods exceeding 1.0 sec. In the vertical direction, within the range of shorter frequencies, both TK3123 and TK3124 exhibit higher acceleration responses than the JMA-Kobe ground motions.

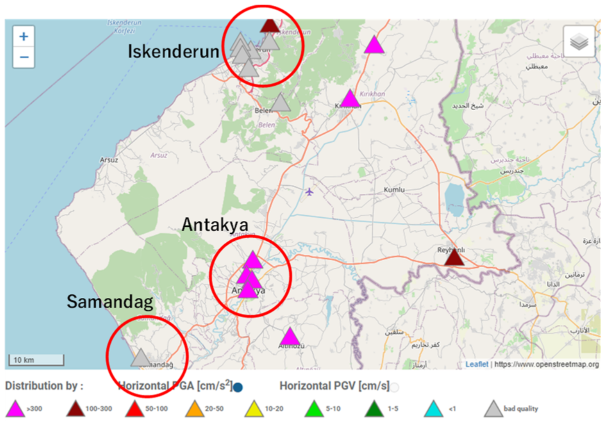


Fig. 2-13 Observation stations in Hatay province

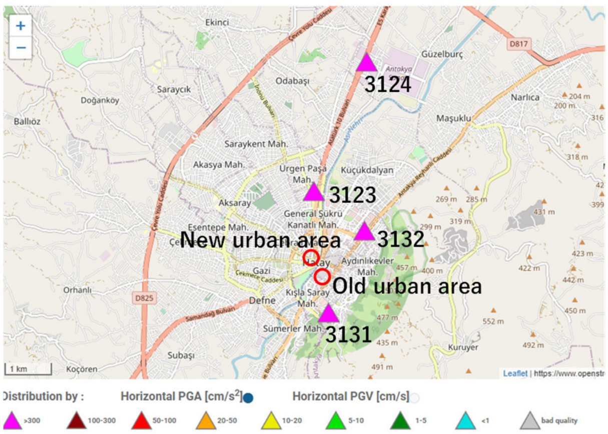


Fig. 2-14 Observation stations in Antakya urban area

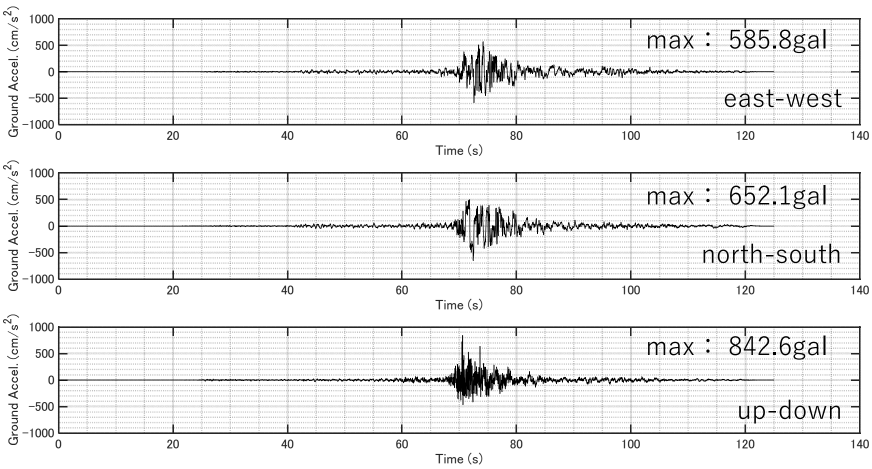


Fig. 2-15 Time-history of ground motion acceleration (TK3123)

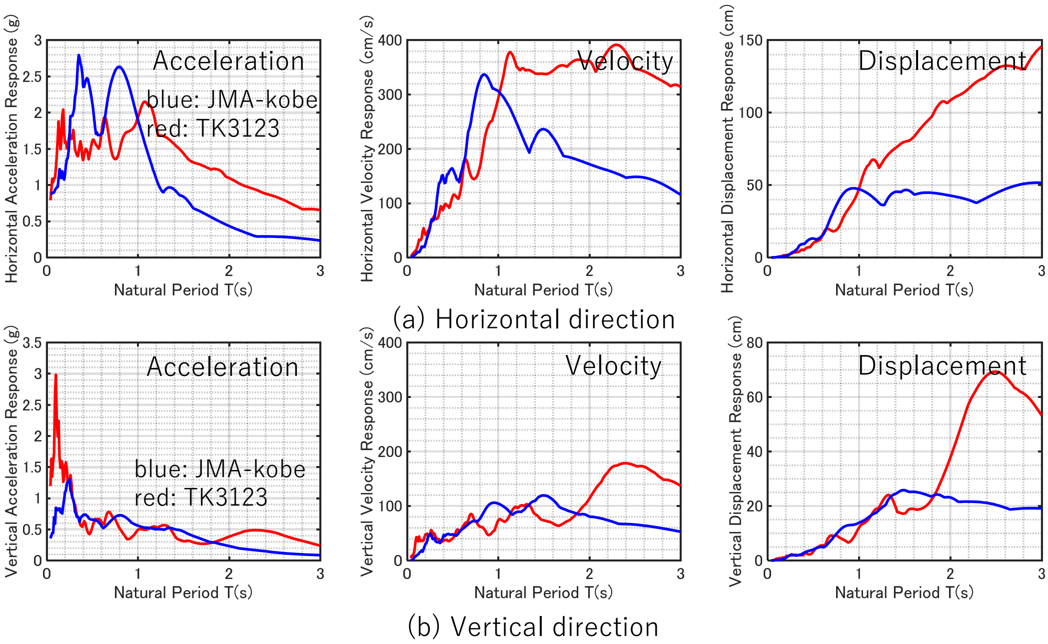


Fig. 2-16 Acceleration, velocity, displacement response spectra (TK3123)

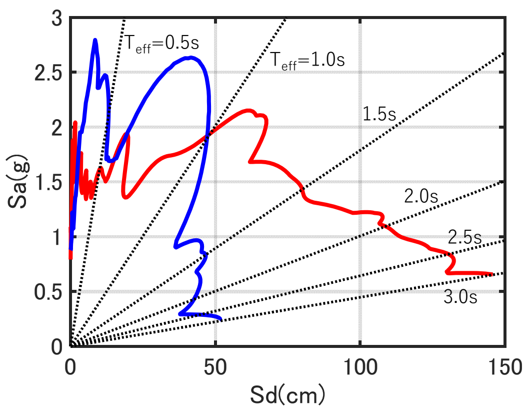


Fig. 2-17 Demand response spectra (TK3123)

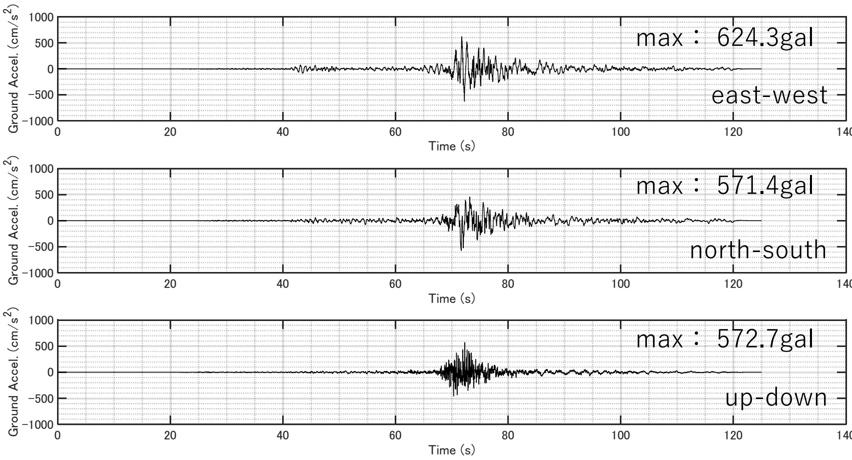
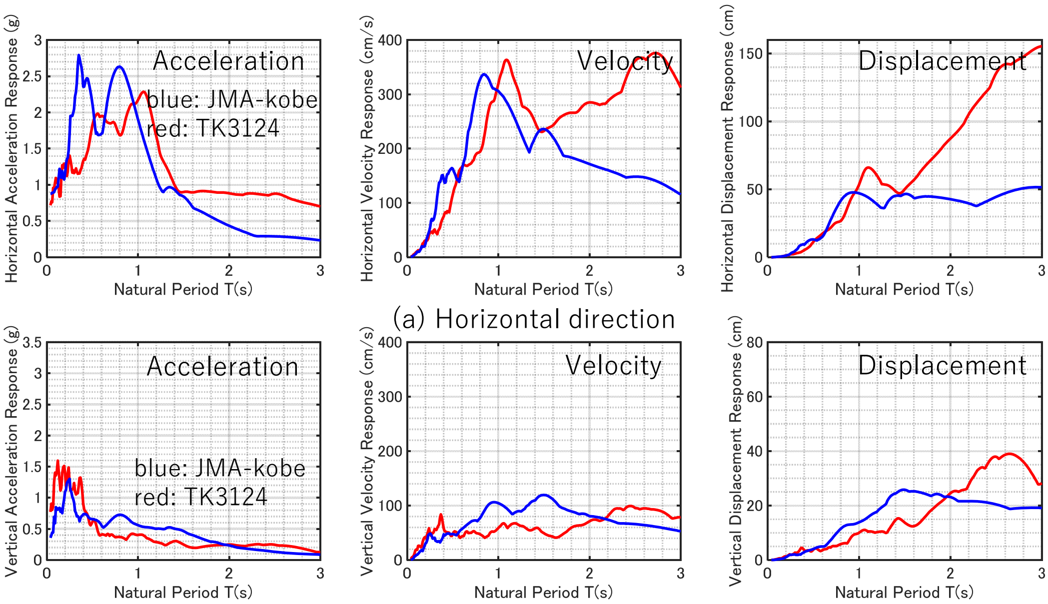


Fig. 2-18 Time-history of ground motion acceleration (TK3124)



(a) Horizontal direction

(b) Vertical direction

Fig. 2-19 Acceleration, velocity, displacement response spectra (TK3124)

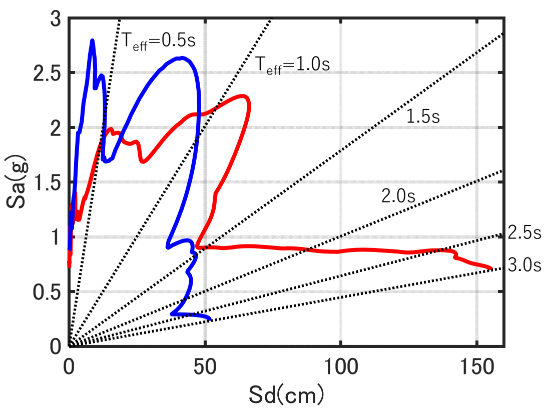


Fig. 2-20 Demand response spectra (TK3124)

Photos 2-9 and 2-10 illustrate the seismic damage observed in the new and old urban areas of Antakya, respectively. The locations visited and surveyed in both the new and old urban areas of Antakya are indicated in Fig. 2-14. In the new urban area of Antakya, as shown in the left image of Photo 2-9, numerous medium- and high-rise reinforced concrete (RC) building structures suffered collapses, with debris having been cleared from the sites. In the right image of Photo 2-9, even among the standing buildings that did not collapse, the exterior brick walls experienced significant out-of-plane displacement, resulting in substantial damage and a ruinous appearance. The specific structural distinctions between the collapsed and non-collapsed buildings are not clearly evident. Notably, the left image of Photo 2-9 reveals that the non-collapsed buildings exhibit a predominantly regular configuration, with beam and column moment-resisting frames being prominently featured. Moving forward, it is imperative to elucidate the mechanisms and factors contributing to the collapses of the affected buildings.

Conversely, in the old urban area of Antakya, as shown in Photo 2-10, numerous masonry structures constructed with stones and bricks suffered collapses. Additionally, some wooden structures also experienced failures. Debris still remains at the sites. It is noteworthy that the stacked stones and bricks slipped due to the seismic forces and furthermore, slipped due to the overturning moments, known as P-Delta effects, leading to loss of stability and cascading collapse. Considering this, the structural integrity throughout the height of masonry structures is of paramount importance.

Photo 2-9 Seismic damage in Antakya new urban area

Photo 2-10 Seismic damage in Antakya old urban area

The seismic damage observed in Samandag is shown in Photo 2-11. Within the residential district of Samandag, a three-story apartment building experienced a collapse with the story mechanism. While the second and third stories sustained minimum damage, as evident from the spacing between adjacent buildings, the first story exhibited a significant inclination. This phenomenon can be attributed to the distinctive weak-story collapse mechanism, wherein the drift is concentrated in the first story. This is clearly the weak-story collapse mechanism with the drift concentration in the 1st story. As shown in the right image of Photo 2-11, plastic hinges formed at the top and bottom of the columns within the first story, leading to the occurrence of the story collapse mechanism. Conversely, the beams and floors remained largely undamaged. It is imperative to consider global collapse mechanisms that prioritize beam yielding before column yielding, accounting for the relative strengths of the columns and beams, or employ multi-story seismic walls to mitigate the occurrence of the story collapse mechanism.

Photo 2-11 Seismic damage in Samandag

In the urban area of Iskenderun, as shown in the left image of Photo 2-12, tall apartment buildings collapsed in their entirety. Numerous cracks marred the walls of these high-rise structures, resulting in significant damage, and it appeared that the entire structures exhibited a slight inclination. These sites are situated along the coastline, and it is evident that liquefaction played a role in these occurrences. Among them, three medium- and high-rise apartment buildings experienced a pancake-style collapse. As shown in the right image of Photo 2-12, the debris had already been cleared, leaving cleared construction sites. The pancake collapse entails a progressive sequence of failures, wherein certain structural members succumb to the earthquake-induced shaking, subsequently causing a chain reaction that leads to the failure of other members, resulting in an overall loss of structural stability. One common characteristic among these collapses is the absence of redundancy. It is highly desirable to incorporate redundant design principles, wherein additional members that remain intact during seismic events are implemented or other members possess the capacity to bear the load, even if one member fails.

Photo 2-12 Seismic damage in Iskenderun

2-4. Collapse Mechanism and Prevention

In the design guidelines for earthquake-resistant reinforced concrete buildings based on inelastic displacement concept by the AIJ (Architectural Institute of Japan), as shown in Fig. 2-21, the column yielding mechanism, wherein the top and bottom of columns yield prior to the yielding at beam ends, is deemed perilous. Conversely, the beam yielding mechanism, where beams yield at the ends, is recommended. This recommendation is based on the understanding that the column yielding mechanism may give rise to the story mechanism, while the beam yielding mechanism facilitates a global yielding mechanism. The building structure presented in Photo 2-11, depicting seismic damage in Samandag, exhibits the column yielding mechanism. To mitigate the occurrence of the story collapse mechanism, the addition of multi-story seismic wall frames is recommended. These seismic wall frames help ensure a more uniform distribution of story drift angles across the structural height during earthquake motion, thus reducing the concentration of drift in specific stories and effectively preventing the story collapse mechanism.

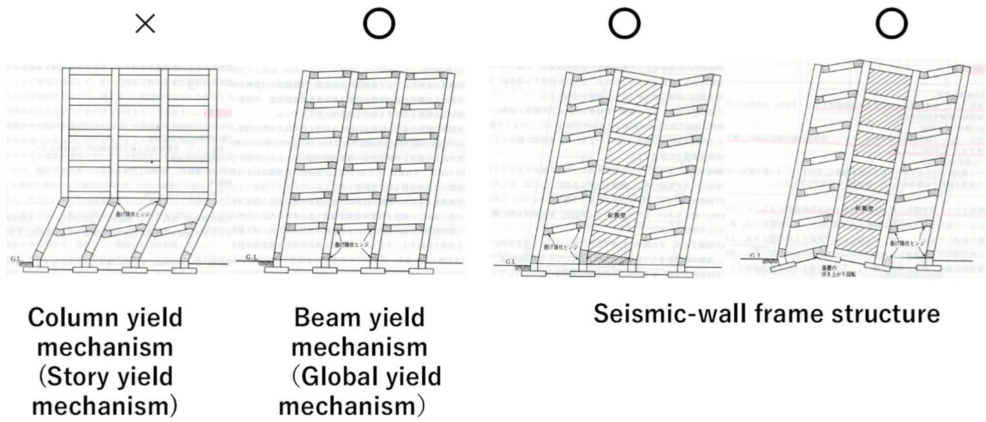


Fig. 2-21 Collapse mechanism and prevention

In future endeavors pertaining to seismic strengthening and retrofitting in Turkey, diverse methodologies will be taken into account. As shown in Fig. 2-22, potential options encompass seismic control approaches involving continuous columns and walls, such as rocking multi-story seismic walls, as well as seismic isolation methods that concentrate deformations within a seismic isolation story.

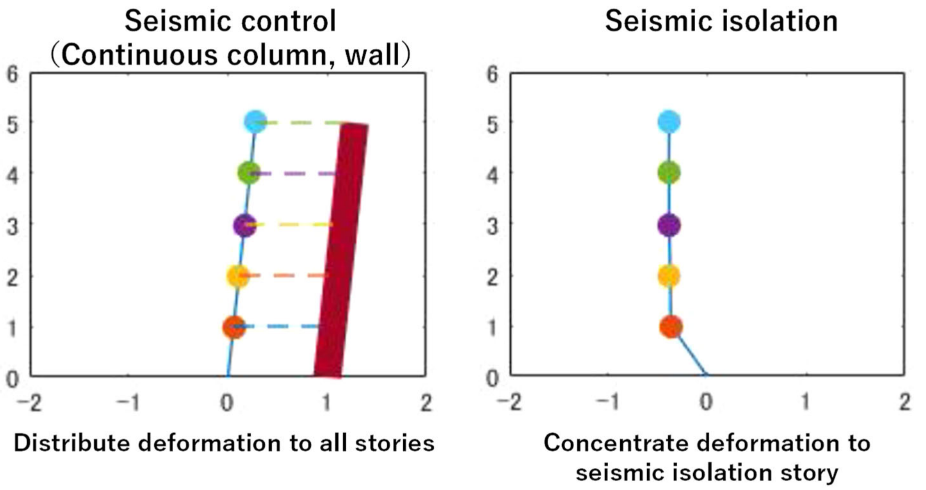


Fig. 2-22 Seismic control with continuous members and seismic isolation

3. SURVEY REPORT II Specific Building Forms and Damage Conditions : From a Perspective of Structural Design

3-1. Introduction

Even in modern architecture, its construction techniques are rooted in history, climate, culture, and customs. While it cannot be said that Japan's seismic technology has universal applicability internationally, this allows for a different perspective when examining the situation of earthquakes compared to seismic technology in Turkey.

3-2. The Impact of Adjacent Building Spacing on the Expansion of Seismic Damage

The seismic forces occurring in individual buildings are designed under the assumption that each building bears its own load. However, in urban areas of Turkey, where building walls are located on property boundaries and adjacent buildings are closely attached, it is believed that a cluster of buildings within a city block behaved as a unified entity in response to seismic horizontal motion. On the other hand, the construction periods of individual buildings vary, and it is speculated that there were buildings with insufficient seismic resistance considering the current seismic standards. Therefore, it is presumed that the seismic horizontal forces of the interconnected cluster of buildings led to concentrated destruction in certain buildings, and further, the horizontal forces concentrated on the next building, resulting in a chain reaction of destruction and the expansion of damage.

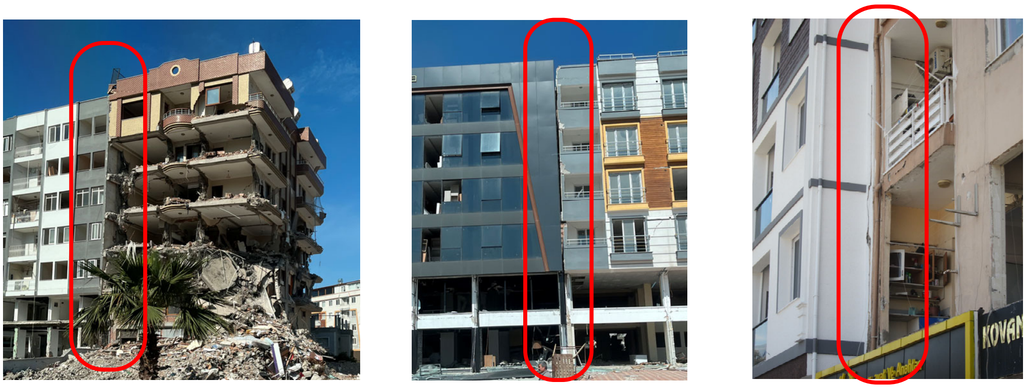


Photo 3-1 Adjacent buildings in close contact

By the way, in Japan, the setback of building walls from property boundaries is regulated by the Civil Code (established prior to the Building Standards Law). As a result, even if adjacent buildings experience horizontal displacement during an earthquake, it is ensured that they do not collide with each other.

3-3. The Commercial Use of Lower Levels in Mid-Rise and High-Rise Buildings and its Relationship to Seismic Damage

Photo 3-2 Buildings with Commercially Used Lower Levels and Mezzanine Floors

Photo 3-3 Column Flattened in the Storefront Direction

In the case of high-rise and mid-rise buildings in urban areas of Turkey. The lower levels are predominantly used for commercial purposes. As a result, the lower levels often lack walls and some have mezzanine floors with high ceilings. Furthermore, to create open storefronts facing the streets, the column width in the direction of the storefront is narrow. Consequently, the lower levels exhibit lower stiffness in the direction facing the street, leading to a structural configuration (commonly known as piloti system) where seismic energy tends to concentrate in the lower levels, resulting in damage. Additionally, the column width is wide in the depth direction but narrow in the storefront direction (same as the beam width), which makes the structure prone to column bending yielding and collapse in the storefront direction. It is presumed that damage occurred due to this type of rigid-jointed structure. It is worth noting that the current Turkish seismic design code, TBEC-2018, includes considerations for non-uniform horizontal stiffness and mezzanine floors.

3-4. The Unreinforced Masonry Infill Walls in RC Buildings and Seismic Damage

Based on the observation of the remaining buildings, collapsed buildings' debris, or buildings under construction in urban areas of Turkey following the earthquake, it can be seen that the high-rise reinforced concrete (RC) buildings have RC rigid-jointed structures, with external and internal walls made of unreinforced insulated concrete blocks or brick masonry. Consequently, these buildings were unable to follow the inter-story displacement of the RC rigid-jointed structures during the earthquake. They collapsed or suffered partial collapses and dislodgment prior to the structural collapse, leading to an increased risk of casualties.

Photo 3-4 The Damaged RC Buildings (Left) and Under-Construction RC Buildings (Center/Right)

By the way, in Japan, the Building Regulations for Urban Areas were revised in the year following the occurrence of the Great Kanto Earthquake (1924). The revised regulations stipulated that masonry infill walls should be reinforced with steel and connected to the structural frame. As a result of this provision, the infill walls were integrated into the reinforced concrete (RC) structure as rigid-jointed elements, leading to the development and widespread adoption of Japan's unique RC construction method known as "seismic wall-attached rigid-jointed structure." In Japan's capacity design and allowable stress design methods, masonry infill walls are considered not to significantly affect the seismic performance of the structural frame. However, the inherent period of the building is calculated using an approximation formula that provides a conservative evaluation (shorter period than the actual) for safety assessment. It is worth noting that the current Turkish seismic design code, TBEC-2018, also incorporates considerations for the influence of infill walls on horizontal stiffness.

3-5. The Qualification System for Structural Designers in Turkey and Current Seismic Design Codes

In Turkey, holders of a Bachelor's degree in Civil Engineering (4-year program) are eligible to perform the structural design of buildings, regardless of their scale. There is no licensing system or renewal system for architectural structural designers, and practical experience is not required. Furthermore, there is no system in place to ensure the maintenance and improvement of technical skills.

On the other hand, the current seismic code in Turkey, TBEC-2018, which was revised in 2018, complies with Eurocode-8 and is generally equivalent to Japan's new seismic standards (either horizontal-load-carrying-capacity or response-limit-capacity based design). As a result, seismic regulations and seismic design have become more advanced, and structural calculations are performed using structural analysis software. However, it is not easy to verify the adequacy of the structural calculation report generated by the software, including the suitability of the structural analysis program, the validity of structural modeling, and the consistency with the design drawings.

There is a possibility that deficiencies in the experience, technical skills, or professional ethics of structural designers, as well as the inadequate capabilities of structural design reviewers, may lead to flaws in the structural design.

In Japan, to engage in architectural structural design, it is required to obtain a national qualification established by the Architect Act, and there are penalty provisions for misconduct by qualified individuals. Specifically, one must graduate from the architectural department of a university, have more than 2 years of design work experience, and pass the national examination for first-class architects. To perform the structural design of large-scale buildings, an additional 5 years of structural design work experience is required, followed by completion of a certified course designated by the government and obtaining the national qualification of first-class architectural structural designer. Additionally, first-class architectural structural designers are required to attend regular courses for first-class architects and regular courses for structural design first-class architects every 3 years.

3-6. Others

The current seismic code in Turkey, TBEC-2018, the International Building Code (IBC-2018) in the United States, and Japan's response-limit capacity-based design are the latest seismic standards that may ultimately lead to the adoption of ductile and flexible structures in building construction. However, Japan's seismic standards for reinforced concrete (RC) low-rise and mid-rise buildings have historically favored strong and rigid structures since their establishment in 1924, leading to the widespread use of Japan's unique seismic wall-bearing rigid frame structures. As a result, the columns in Japanese RC buildings are noticeably thicker compared to those in Europe and the United States, and the cross-sectional area (wall volume) of vertical members such as columns, seismic walls, and wing walls in RC structures is also larger. Increasing the wall volume not only enhances the horizontal resistance of the structure but also increases its vertical support capacity. This has been demonstrated by earthquake damage surveys, showing that buildings with larger wall volumes tend to experience smaller seismic damage.

4．SURVEY REPORT Ⅲ　Visits to Mayors of the Affected Municipalities and Tours of Tents and Container Temporary Housing, etc.

4-1．Results of Hearing with Mayors of the Affected Municipalities

Hearings were held with visits to the Mayor of Çukurova, Adana and the Mayor of Onikişubat, Kahramanmaraş on April 14 (Fri.), the Hatay Metropolitan Municipality Mayor on April 15 (Sat.) and the Mayor of Payas, Hatay on April 16 (Sun.). Below are the main comments obtained.

・As the mayor, I have decided to demolish many of the damaged buildings in the future.
・In some of the collapsed buildings, the owners had removed the columns without permission.
・We would like you to share with us your experiences of recovery and reconstruction after the earthquake in Japan. We would like to consider sending our engineers to Japan.
・We have newly decided to prohibit high-rise buildings and limit them to 5 stories or less in principle as a post-earthquake urban development standard, and to set the following building standards: (1) stop using mezzanine floors, (2) provide basement floors, and (3) strengthen ground inspections and provide guidance on ground improvement.

・Instead of simply rebuilding the damaged buildings, we will carefully consider a reconstruction plan for community development.
・Food and other daily commodities are sufficient. There is a lack of temporary housing for disaster victims and accommodations for recovery workers.
・Infrastructure such as water, electricity, and gas is fine. It was restored about a week after the earthquake.
・Earthquake forecasts had been made even before the earthquake, but countermeasures were not taken in time.

・We are thinking with universities and experts about new town planning for the future.
・Our thoughts are as follows (1) To know the reality of the earthquake. And to remember that reality. (2) Make concrete plans based on the reality of the disaster. (3) Social education about the disaster is necessary, and support from various fields is needed. (4) Steadily implement the recovery plan, including the necessary financial planning.
・We would very much like to learn about Japan's experience in earthquake recovery. Furthermore, we would like to ask for your support, including financial support.

・In our district, there were few buildings that collapsed, but there are more than 1,000 damaged buildings.
・Checks on the damaged buildings were completed within a week.
・Our district had begun removing dangerous buildings with low earthquake resistance before the earthquake. Three of these buildings could not be removed due to a court case, but they collapsed in the earthquake, killing more than 400 people. The residents who were able to remove the buildings and relocate were grateful. I was reminded once again of the importance of preparation before an earthquake strikes.
・Japan has a strong image of always developing while experiencing disasters.
・I had visited the city of Kobe in 2000 following the 1999 Turkish earthquake. The people of Kobe City explained to me the situation of the city and the rescue efforts.

From the above comments, the following points, among others, are the main commonalities

(1) We want to create a disaster-resistant community, not simply rebuild buildings.

(2) In order to achieve this, we would like to ask for Japan's support in a variety of ways, including sharing of knowledge and experience in earthquake recovery, quake-resistant technology, and funds.

4-2. Tours of Tents and Container Temporary Housing, etc.

On April 14 (Fri.), we visited the disaster relief center provided by Istanbul Beyoğlu in Kahramanmaraş Dulkadiroğlu; on April 16 (Sun.), we visited a tent village in Hatay İskenderun, two container temporary housing sites in Hatay Payas, and a field hospital provided by Qatar in Hatay Payas.

4-2-1. Beyoğlu Disaster Relief Center in Kahramanmaraş Dulkadiroğlu

Photo 4-1 Converting a soccer field into the disaster relief center.

Photo 4-2 Providing clothing.

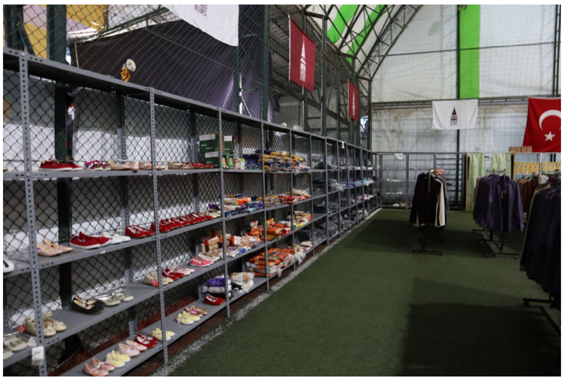


Photo 4-3 Providing shoes.

Photo 4-4 Serving meals for 15,000 people daily.

4-2-2. Tent Village in İskenderun Provided by the National Government, Municipalities, and Turkish Red Crescent, etc.

Photo 4-5 Entrance to the tent village. It can accommodate up to 2700 people. At the time of our visit, 2050 people were living in 450 tents. They were gradually moving into container temporary housing nearby.

Photo 4-6 Meals provided by Turkish Red Crescent.

Photo 4-7 Ramadan meal tent provided by Üsküdar district, İstanbul.

Photo 4-8 Same as on the left. Serving meals for 4,000 people.

Photo 4-9 Tent for children's mental health care.

Photo 4-10 Mobile libraries (tent and bus).

Photo 4-11 Residential tent. Heat was becoming a problem.

Photo 4-12 School by military tents.

4-2-3．Container Temporary Housing, etc. in Payas

Photo 4-13 335 container temporary housing units to be completed next week. There were laundry containers, hospital containers, school containers, etc.

Photo 4-14 There was also a soccer field and a gymnasium. Photo shows the soccer field.

Photo 4-15 Container appearance.

Photo 4-16 Inside the container.　21 ㎡
A kitchen was attached.

Photo 4-17 Inside the container.
Toilet, shower and hand wash.

Photo 4-18 Container temporary housing currently in use was also visited.

Photo 4-19 Field hospital provided by Qatar.

Photo 4-20 Inside the field hospital provided by Qatar.

5．SURVEY REPORT Ⅳ　Status of Damage to Historic Buildings

Since we had special access to the courtyard of Ulu Camii (15C) in the Dulkadiroğlu district of Kahramanmaraş, in 5-1 we present photographs of the damage to Ulu Camii taken there. In 5-2, photos of damage to other major historic buildings are posted.

5-1．Kahramanmaraş Ulu Camii

Photo 5-1 The minaret collapsed and stones were lying on the ground. The entrance area was damaged.

Photo 5-2 The entrance area was damaged.

Photo 5-3 Damaged portico.

Photo 5-4 Damaged portico.

Photo 5-5 Arch section of portico

Photo5-6 Arch section of portico

Photo 5-7 The minaret was cracked.

Photo 5-8 Stone mortise in collapsed minaret.

Photo 5-9 Steel tie connecting the stones of the collapsed minaret.

Photo 5-10 Shot by drone.

Photo 5-11 Shot by drone.

Photo 5-12 The building was damaged by the minaret collapsing and falling stones.

Photo 5-13 Staircase inside the minaret.

Photo 5-14 The surrounding corridor was safe.

Photo 5-15 Cracks in exterior wall.

Photo 5-16 Cracks in exterior wall.

5-2. Other Major Historical Buildings

Photo 5-17 Antakya, Hatay. Ulu Cami.
The famous minaret was erected near the tree in front, but it was completely destroyed along with the building.

Photo 5-18 Antakya, Hatay. Former Parliament building.
Hatay Devleti döneminde meclis binası.

Photo 5-19 Antakya, Hatay. Greek Orthodox Church.

Photo 5-20 Antakya, Hatay.
Protestant Church.

Photo 5-21 Antakya, Hatay. Sarımiye Camii.
The minaret collapsed.

Photo 5-22 Antakya, Hatay. Habib-i Neccar Camii
The minaret and dome collapsed.

Photo 5-23 Antakya, Hatay. Mahremiye Camii.
The minaret collapsed.

Photo 5-24 İskenderun, Hatay.
Greek Orthodox Church.

Photo 5-25 Payas, Hatay. Sokullu Mehmet Paşa Külliyesi designed by Mimar Sinan.
The minaret collapsed.

6. Recommendations Based on the Survey Reports

Based on the above survey reports, we make the following eight recommendations in this report.

Ⅰ. Verification of the Validity of the Current Seismic Code TBEC-2018

It is necessary to verify whether buildings designed according to TBEC-2018 experienced any seismic damage or issues, even for buildings under construction where significant damage may not have occurred but where unreinforced masonry infill walls and partition walls may have been damaged or fallen.

Furthermore, the strong ground motion records of this earthquake were recorded at observation stations of the Turkish National Strong Motion Network, but the records from several stations were incomplete. While AFDA is currently investigating the cause, it is necessary to conduct a comprehensive inspection of all observation stations.

Ⅱ. Seismic Performance of Non-Structural Elements (Cladding, Ceilings, Building Facilities, etc.)

Non-structural elements should remain undamaged during moderate earthquakes (at the damage limit) and should not collapse, detach, or fall during major earthquakes (at the safety limit). It is also important to prevent the toppling of furniture and fixtures.

Ⅲ. Reinforcement of Masonry Filling Walls in RC Buildings

Reinforcement with steel bars or other means is necessary to prevent the collapse or detachment of masonry filling walls during earthquakes. Additionally, the conversion of RC filling walls into seismic walls or load-bearing walls is desirable. RC filling walls not only enhance the horizontal resistance of the building but also increase its vertical support capacity, reducing the risk of collapse.

Ⅳ. Lightweighting of Non-Structural Elements

Masonry filling walls, even with reinforcement, have limited seismic performance and can be unclear in structural analysis. On the other hand, masonry filling walls are heavy and increase the seismic forces acting on the structure. Therefore, lightweight alternatives such as drywall partitions should be used for interior walls. Lightweight materials like ALC panels are also desirable for non-structural exterior walls. The most straightforward approach to improving seismic performance is to lighten the building's weight.

V. Ensuring Reliable Isolation or Integration with Adjacent Buildings

When buildings are in close proximity, there is a higher risk of chain collapse, where buildings with different vibration characteristics or seismic resistance interact and collapse together. Therefore, it is necessary to provide spacing between adjacent buildings to prevent collision in the event of horizontal displacement caused by seismic forces. However, achieving this while maintaining the plot ratio can be challenging. One potential solution is the integration of adjacent buildings, although this raises issues related to land ownership and usage rights. By integrating buildings, two adjacent columns that would be in close proximity can be merged into a single larger column, and two adjacent infill walls can be combined into a single seismic wall, resulting in a highly seismic-resistant structure. Additionally, shared facilities such as stairs and elevators can be rationalized and used.

VI. Development of Seismic Strengthening Methods for Masonry Minarets

In all of the traditional mosques that we were able to inspect, the minarets had collapsed. In addition, in the Kahramanmaraş Ulu Camii, it was confirmed that the building was damaged due to collapsed minarets. The development of seismic reinforcement methods for masonry structures is urgently needed to protect cultural heritage buildings, and among them, the promotion of seismic reinforcement of minarets is expected to have a very immediate effect in protecting cultural heritage buildings.

Methods such as the Hoop-Iron construction (developed by foreign architects hired in Japan in the late 19th century) for seismic reinforcement of brick structures (M. Horiuchi: "A Study on The Hoop-Iron Construction Adopted in The Old Building of The Ministry of Justice," J. Archit Plann. Environ. Eng., AIJ, No.499, pp. 193-198, Sep., 1997) or the stone and steel prefabrication method proposed and adopted by Arup Group Limited for the construction of the spires of the Sagrada Família church can provide inspiration.
(https://www.arup.com/projects/sagrada-familia)

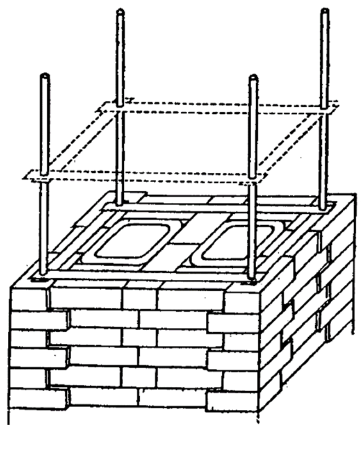


Fig. 6-1 Reinforcement Method for Brick Chimneys by R. Seel (M.Horiuchi, 1997)

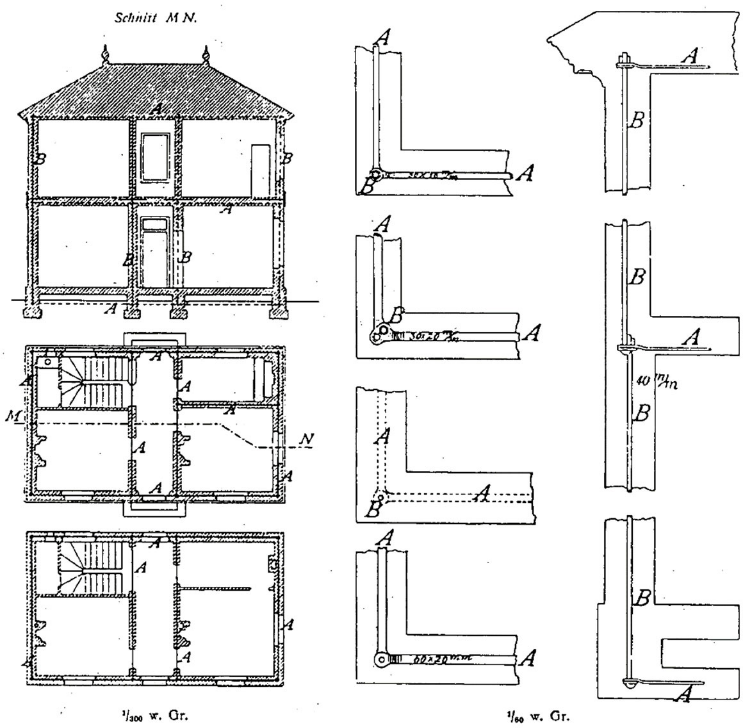


Fig. 6-2 Illustration of J. Lescasse's Brick Construction Method（M.Horiuchi, 1997）

Ⅶ. Establishment of an international mechanism to share experiences of disaster-affected municipalities

From the interview with the mayors of the affected municipalities, several of them commented that they would like to share information with Japan, which is also an earthquake-prone country like Turkey. An international mechanism to share the various efforts and experiences of affected municipalities in Japan, Turkey, and other countries is required to be established.

Ⅷ. Fostering and raising public awareness about the earthquake disaster

In the wake of the recent earthquake in Turkey, it is necessary for the entire population, not just the government and experts, to once again recognize and act on the need to prepare in advance to protect the lives and property of the people against earthquakes. Education and awareness-raising about housing for all ages is of utmost importance for this purpose. For example, educational institutions such as Bahçeşehir University could collaborate with the government and local authorities to promote educational programs.

7．List of Media Coverage

7-1．Turkey

- https://twitter.com/sonercetin01/status/1646796971519221762?t=OErXPhdMo_66HoICPHtOwQ&s=19
- https://www.instagram.com/p/CrAqP9GIaiu/?igshid=MDJmNzVkMjY=
- https://8gunhaber.com/Mobile.aspx?go=habergoster&hid=59544
- https://penceretv.com/belediyelerimiz/chpli-savas-hatayi-yapilandiracagiz-258549h
- https://www.yenimanset.com.tr/haber/japon-kobe-belediyesi-hataya-birikimini-aktaracak-356.html
- https://www.havadishaber.net/japon-belediye-hataya-birikimini-aktaracak/
- https://www.iha.com.tr/istanbul-haberleri/hirosima-magduru-japon-kiz-sadakonun-bin-turna-kuslu-origami-dilegi-turk-depremzedelere-4287782/
- https://www.dha.com.tr/yerel-haberler/istanbul/merkez/hirosima-magduru-japon-kiz-sadakonun-bin-turna-2237584
- https://www.gercekgundem.com/guncel/hirosima-magduru-japon-kiz-sadakonun-bin-turna-kuslu-origami-dilegi-turk-depremzedelere-419524
- https://www.bizimsamsun.net/hirosima-magduru-japon-kiz-sadakonun-bin-turna-kuslu-origami-dilegi-turk-depremzedelere/
- https://www.gunestv.com/infinite-haber-devam-60254-haberi
- https://www.dha.com.tr/yerel-haberler/istanbul/merkez/hirosima-magduru-japon-kiz-sadakonun-bin-turna-2237584
- https://www.bursasondakika.com.tr/m/gundem/hirosima-magduru-japon-kiz-sadakonun-bin-turna-kuslu-origami-dilegi-h153966.html
- https://haberton.com/hirosima-magduru-japon-kiz-sadakodan-turna-kuslu-dilek/
- https://www.batiantalya.com.tr/hirosima-magduru-japon-kiz-sadakonun-bin-turna-kuslu-origami-dilegi-turk-depremzedelere
- https://www.memleket.com.tr/hirosima-magduru-japon-kiz-sadakonun-bin-turna-kuslu-origami-dilegi-turk-2211881h.htm
- https://beyazgazete.com/haber/2023/4/18/hirosima-magduru-japon-kiz-sadako-nun-bin-turna-kuslu-origami-dilegi-turk-depremzedelere-6777314.html
- https://www.medyaege.com.tr/sadakonun-origamisi-umut-olacak-217726h.htm
- https://www.bizimizmir.net/hirosima-magduru-sadako-nun-bin-turna-kuslu-origami-dilegi-turk-depremzedelere-54843
- https://www.ekoiq.com/japon-heyeti-deprem-bolgesinin-toparlanmasi-icin-isbirligi-sart/?amp=1
- https://www.dha.com.tr/gundem/hirosima-magduru-japon-kiz-sadakonun-bin-turna-kuslu-origami-dilegi-turk-depremzedelere-2237588
- https://www.gayrimenkulhaber.com/guncel/prof-dr-murat-dundar-turkiyede-sadece-binalar-cokmemis-yapi-denetim-sistemi-de-cokmustur/

・https://youtu.be/DrDGsWkvUGY

・https://youtu.be/VRmDX67GNnc

7-2．Japan

・https://www3.nhk.or.jp/kansai-news/20230412/2000072752.html

・https://sun-tv.co.jp/suntvnews/news/2023/04/11/66142/

・https://www.youtube.com/watch?v=jtfl7IIKqJA

・https://nordot.app/1018447022640136192

・https://mainichi.jp/articles/20230413/ddl/k28/040/245000c

・https://info.mukogawa-u.ac.jp/publicity/newsdetail?id=4348

・https://www3.nhk.or.jp/kansai-news/20230502/2000073391.html

・https://www3.nhk.or.jp/lnews/kobe/20230502/2020021764.html

・https://www.yomiuri.co.jp/world/20230503-OYT1T50088/

・https://www.tiktok.com/@ytvnews/video/7228156199231917314

・https://www.kobe-np.co.jp/news/kobe/202305/0016337257.shtml

・https://info.mukogawa-u.ac.jp/publicity/newsdetail?id=4365

・The Yomiuri Shimbun, Wednesday, April 12, 2023

・The Asahi Shimbun, Wednesday, April 12, 2023

・The Kobe Shimbun, Wednesday, April 12, 2023

・The Sankei Shimbun, Wednesday, April 12, 2023

・The Yomiuri Shimbun, Wednesday, May 3, 2023

・The Kobe Shimbun, Thursday, May 11, 2023

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In Turkey, we received a lot of support and cooperation from Bahçeşehir University. We would also like to thank many local governments for their cooperation in conducting this survey. We would like to express our gratitude and sincerely pray for the earliest possible recovery and reconstruction of the affected areas.

The dispatch of the three Mukogawa Women's University faculty members to the site was supported by the Hyogo Prefecture "Turkey Earthquake Recovery and Reconstruction Support Project". We would like to express our gratitude for their support.

【Special Contribution】

Problems that increased the destruction caused by the Kahramanmaraş-centered earthquake

Prof.Dr. Murat Dündar
Dean of Faculty of Architecture & Design,
Bahçeşehir University

The earthquake occurred in the city of Kahramanmaraş in Turkey on February 6, 2023 and the subsequent earthquakes in the same region caused great destruction that would affect a total of 11 cities in the region, and many people lost their lives. As it is always said, it is not the earthquake itself that causes loss of life, but the instability of man-made structures.

When we look at the buildings that were heavily damaged or destroyed in the last earthquake, we can say that it is possible to make an assessment in 4 categories in general:

1. **Old Buildings/ Historical buildings:** Buildings over 25 years old, built according to the zoning regulations valid before 1998,
2. **New Buildings:** Relatively new buildings built according to updated zoning regulations after the 1999 earthquake (including the 2007 and 2018 updates),
3. **Illegally constructed buildings:** Buildings that were built illegally without being bound by any law, regulation or legislation, but were legalized through zoning amnesties generally applied by the state in the pre-election periods, and the project and production processes are completely disabled,
4. **Buildings with unauthorized structural changes:** Buildings with structural interventions such as column, beam cutting, etc. that the users perform in line with their needs without any technical support.

The first official Earthquake Regulation in Turkey was published in 1975 and has been updated 3 times in 1998, 2007 and 2018 based on the experiences gained in the following earthquakes.

The static calculation methods used in the construction sector in Turkey are generally similar to those used in European Union countries and the United

States. Eurocodes are widely used as a reference for static calculations in the construction sector in Turkey.

Some of the commonly used static calculation software programs in Turkey include SAP2000, ETABS, Sta4CAD, AxisVM, Robot Structural Analysis, and ProtaStructure. Each program has its unique features, advantages, and disadvantages, so the choice of which program to use may vary depending on the project's specifications and needs.

The journey of a construction process in Turkey from capital to building is summarized in the schematic description shared in Fig.1. The process starts with the application of the investor/property owner to the relevant municipality with a petition in order to learn about the construction rights of the land they intend to build.

The relevant unit of the municipality is obliged to provide the investor with the documents needed for the project in accordance with the provisions of the Master Zoning Plan and Implementation Development Plan in effect regarding the land. With the submission of the relevant documents to the project team, the project phase, which includes architects and engineers, begins.

After obtaining the preliminary consent from the municipality, in which the studies on the architectural project and the rights to build are confirmed, the architectural application project, ground survey, static, mechanical, electrical, etc. all other projects are completed with the coordinated work of the relevant professionals, and all projects are first approved by the Building Inspection Firm; and then the process continues by submitting it to the municipality's license unit for construction phase approval. The projects for which the license has been obtained are delivered to the contractor company, which will undertake the construction, as a package, and the construction process is started. At this stage, the construction process is taken under control by 3 different mechanisms: The first audit is the self-audit carried out by a professional assigned by the construction company; It is the inspection carried out at the construction site by the officials of the Building Inspection Firm, which was assigned as the second inspection center; the last one is the inspections for control purposes carried out at the construction site at regular inspection visits by the relevant department of the Municipality.

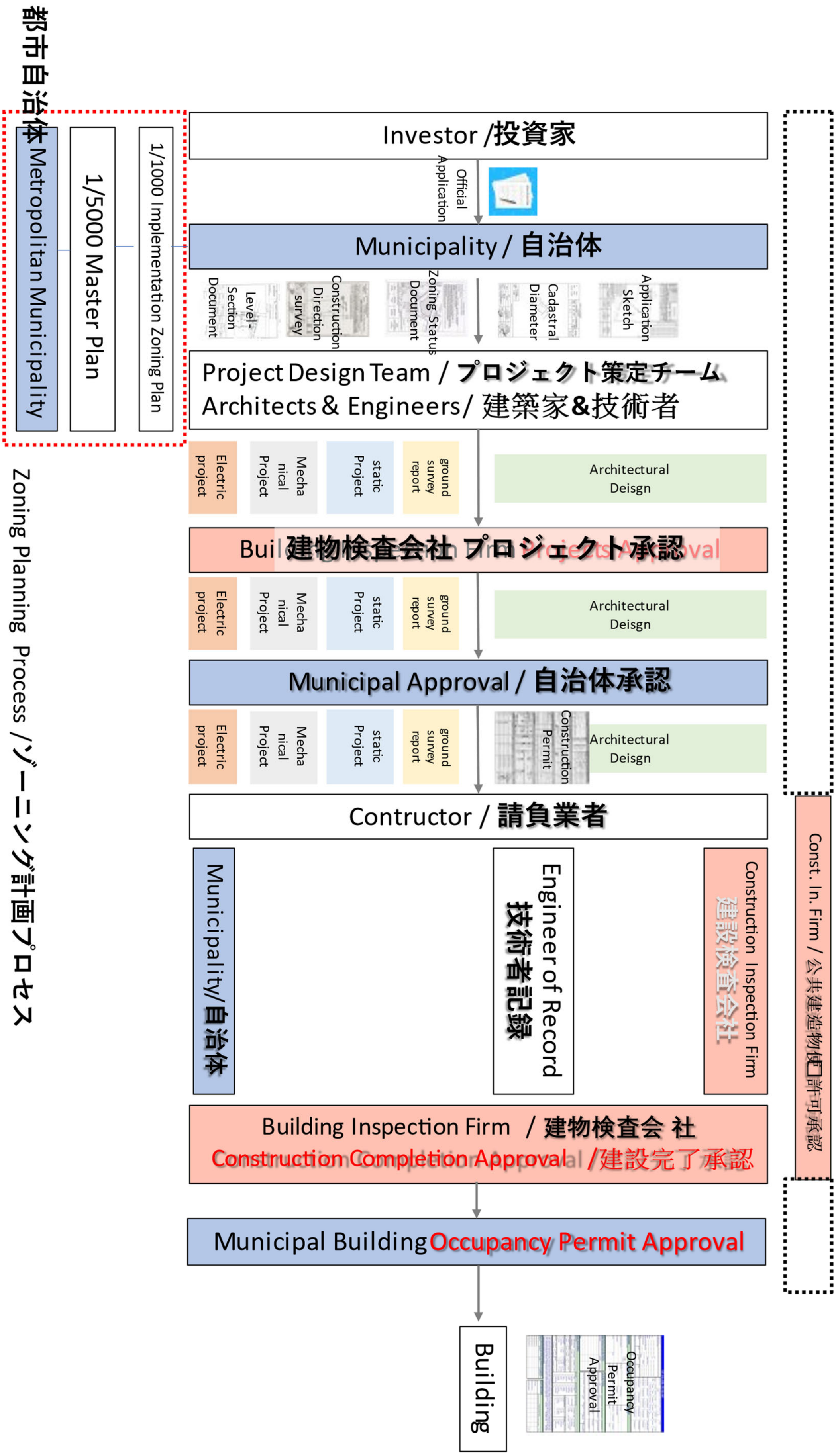

Figure 1: Construction permit phases and inspection mechanism officially implemented in Turkey

When the construction process is over, firstly, after the Building Inspection Firm gives its approval that the construction is completed, the construction control unit of the municipality makes the final visit to confirm that the construction has been carried out in accordance with the project, and the process is completed by giving the occupancy (building occupancy permit) to the property owner.

As it can be understood when the whole process is examined, the entire process is repeatedly audited in the system itself, which is currently in effect, and it can be continued by obtaining conformity approvals.

Within the scope of the observations and examinations made in the earthquake region, the main causes of structural damage in urban areas are similar to the earthquake damage experienced in the past which can be summarized as follows:

- In attached buildings, the floor and beam alignments are at different levels compared to the adjacent building, and the destructions due to the hammering effect that occurs during the earthquake.
- Possible negligence in the inspection of productions following the start of the construction process, (Inadequacy of technical staff and lack of supervision in the fields of professional expertise,)
- Damages caused by interventions made during the usage process,
- Zoning plans and plan amendments made without considering disaster data, and opening of agricultural lands and soils with low carrying capacity for construction,

There is no doubt that the problems experienced especially in new buildings would have been significantly reduced if the rules that have already been set in both the legal legislation and the project design and permitting processes were properly implemented and inspected.

As a justification for this view, we can show that a small number of buildings that implement these processes correctly are still standing. Although they are few in number when we compare them in areas where destruction is intense, it is seen that there are old and new buildings that did not receive any visible or less damage in this severe earthquake.

The most basic problem in the processes is not the laws, regulations or the projects created in accordance with them, but the lack of awareness of responsibility in the people who will implement them. In summary, the main factor in the growth of the disaster is that the awareness of the disaster spread throughout the society was not embraced as much as it should be by all the stakeholders of the process.

In this context, all institutions and organizations, especially universities, should make an intense and programmed effort in order to spread an approach in which the concept of creating disaster-resilient cities is handled sensitively, internalized and become a collective consciousness, in a way that covers the whole society.