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Overview of Aseismic Design of Subway System against Hidden Fault in Osaka and Damages by Kobe Earthquake in terms of Almaty Subway

Abstract. *Fault may cause not only ground motion but also ruptures and displacement of ground surface where various important lifeline systems have been installed. In Almaty, the largest city in Kazakhstan, many hidden faults are shown in microzonation map for earthquake damage. The Kobe Earthquake of 1995 showed damage of subway system due to severe ground motion. Osaka, Japan, has also hidden fault just beneath the downtown of the city. Recent subway construction in Osaka adapted a design procedure against the fault movement. This paper shows the damage of subway in Kobe during the Kobe Earthquake and describes the fault and geotechnical condition of Osaka with the adopted design as well as basic characteristics of the hidden faults in Almaty known to the authors.*

Keywords: *earthquake, faults, motion, damage, subway,structures.*

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Introduction. Osaka basin has been considered as tectonically sinking part surrounded by active faults along which reverse faults creating mountains, as shown in Figure 1. Beneath flatlands, existence of hidden faults also has been found. One of them is the Uemachi fault having relatively high probability of earthquake occurrence. So far the active faults have been considered only as the source of strong earthquake motion (see Kobe example below), and the ground deformation and gap caused by the fault displacement have not been deeply discussed. In this paper, the ground deformation problem caused by the fault displacement is taken into account and as an example its effect on the subway shield tunnel as well as needed counter measures are discussed.

Damage to the subway during 1995 Kobe earthquake was one of the amazing event, because underground structures have been considered to be relatively safe from earthquake effects compared to structures above the ground. In many design specifications for the underground line-shaped structures, aseismic design is not usually considered in the transverse direction. The reason for this is that the underground structures are assumed to follow the deformation of the ground during an earthquake and the apparent unit weight of the structure is much smaller than that of the subsoils. Yoshida and Nakamura (1996) investigated heavy damage on the Daikai station. We review their results as an example of subway damage during earthquake.

Almaty locates at the north side of the Tien-Shan Mountains that is the largest seismogenic zone in Central Asia and is considered as the most earthquake prone region in Kazakhstan, which is result of highly intensive orogenic processes. Two major thrust faults, Zailiisky and Chilik- Kemin faults, hosting potential earthquakes M8 and more, are located south of the city. Other faults, M7 Almaty fault and Boroldaisky fault, are hidden faults located just under the city. A world famous series of strong earthquakes, including 1887 Vernyi earthquake and 1911 Kemin earthquakes that destroyed city, were generated by these faults. A M8 segment of Zailiisky fault east of Almaty in the immediate vicinity has been left un-ruptured. These fault segments, including hidden faults under city are most dangerous for Almaty.

Similarly to Osaka basin, Almaty depression, hosting Almaty city, is considered as tectonically sinking part. Thick layers of sediments are accumulated here. Basin-like structure shall give severe effects on the strong ground motion amplification and ground displacements. It is already investigated in detail by many different methods, see e.g. Microzoning Map of Almaty.

Aseismic Design of Subway System against Hidden Fault for Nakanoshima Subway Line in Osaka. In order to link Nakanoshima Island, public and business center of Osaka, from Kyoto, a new branch subway line, so- called Nakanoshima Line, was constructed. One of the various important technical problems was to consider possible counter measures for the shield tunnel against the flexure deformation due to the displacement of the fault under the east end of subway line.

Seismic Reflection and Geological Studies for the Fault. The active Uemachi fault (Figure 2) had been long recognized along the western edge of Uemachi Upland by topographical feature. In 1980, a seismic reflection study was carried out along a riverbank of the river Okawa in West-East direction and the result is shown in Figure 3. The Uemachi fault was identified under a flat surface ground condition, as hidden fault. Continuous deformation known as flexure structure near the surface is strongly related to the fault.

Figure 1. Osaka Basin and Surrounding Mountains.

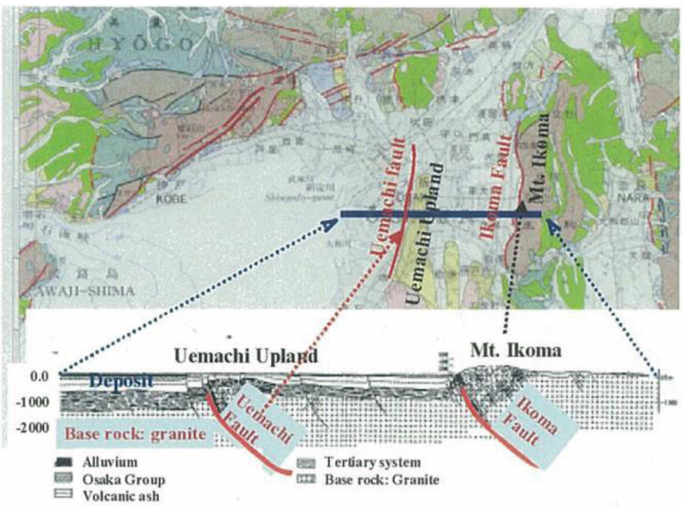

Figure 2 Geological Profile in West-East Direction Through Osaka City.

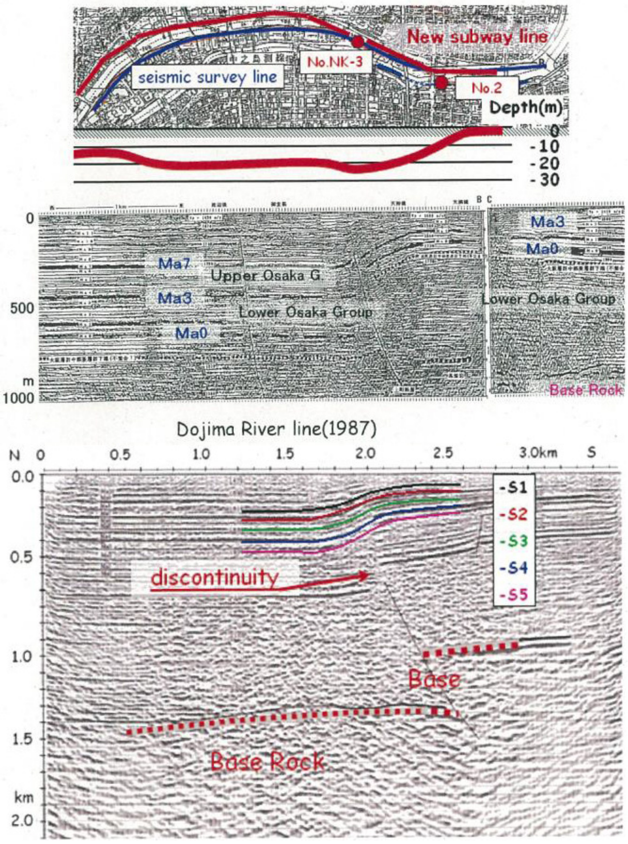

Figure 3 Seismic Reflection Study and Results along the South Bank of River Okawa: Hidden Uemachi Reverse Fault and Flexure Structure above the Fault.

The underground geology in Osaka is sedimentary formation in Quaternary called as Osaka Group, consists of alternation of sand and clay layers marked by Ma, which stands for «marine clay layer.» e.g. Ma0, Ma3, and Ma7 are identified as marine clay layers deposited in 0.98, 0.77, and

0.44 million years before present respectively. As shown in Figure 4, the uppermost layer in the eastern side was Ma7 of Osaka Group; the same marine clay formation in the western part was expected to be at about GL-300m. To confirm the Ma7, a deep drilling of 300m was carried out until some key tuff layer above the Ma7 was sampled out to identify it.

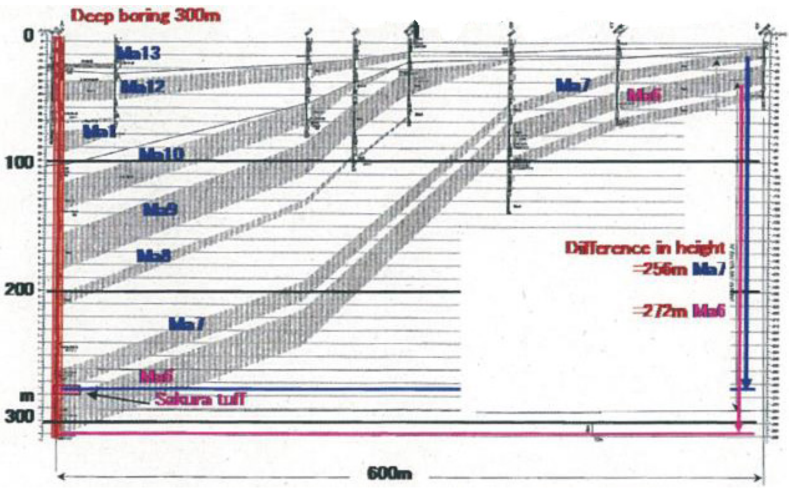

Figure 4 Uemachi Flexure Based on Boring Studies. The rate of the vertical fault displacement was estimated from the difference in the depths between 256m for Ma7 and 272m for Ma6 and the

time period after the depositions of these layers: 0.44m/103year. Sugiyma (2003) reported that the last event along the Uemachi Fault is estimated about 9,000 years ago. Possible release of the vertical displacement for one earthquake is 0.44m/103year x 9,000years = 4m. This fault displacement is assumed for the design of Nakanoshima line.

Flexure Deformation Due to the Uemachi Fault. Seismic reflection surveys give us clear characteristics of flexure deformation caused by the hidden fault in Osaka. The fault deformation can be characterized by a hyperbolic tangent curve normalized by maximum throw in vertical axis and by the reference width in horizontal axis (see Figure 5). Example is plotted in Figure 6, where two cases of flexures are shown. Hyperbolic tangent curve is used to search the best fit with seismic as well as boring data to obtain the deformation curve for Ma6 layer of Uemachi Flexure. Deformation curve and radius of curvature of Ma6 layer, estimated from these data, are further used to estimate by FEM modelling the reference width and dip angle of the fault. The reference width was obtained as 300m and dip angle is 60 degrees towards East. Figure 7 shows example of FEM numerical simulation of flexure for a set of physical parameters of ground estimated in boreholes. Linear constitutive law was assumed in this case.

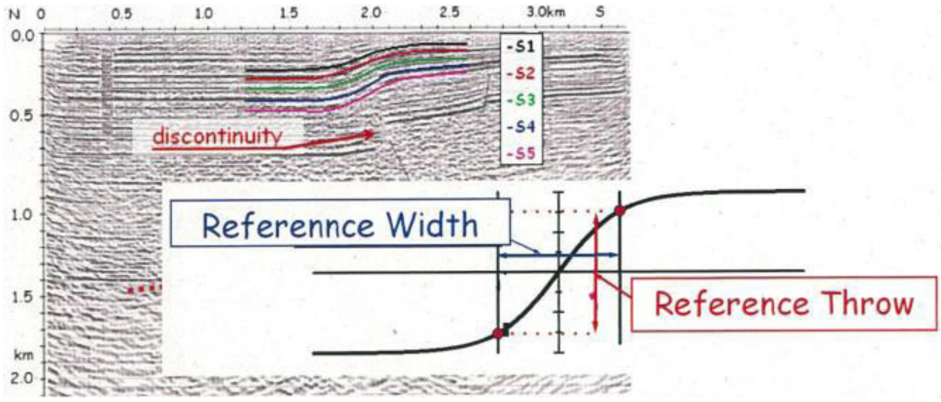

Figure 5 Characteristics of Flexure.

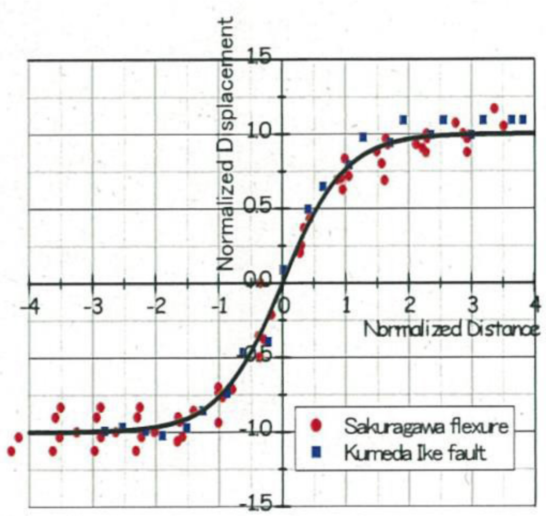

Figure 6 Normalized Flexure Deformation.

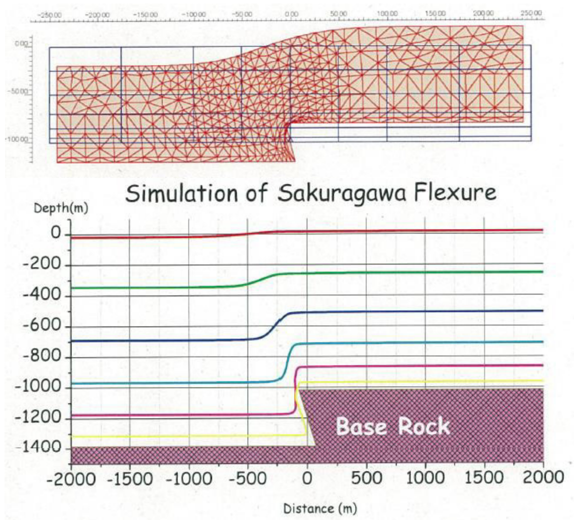

Figure 7 Example of Numerical Simulation of Uemachi Fault Flexure.

Expected Behavior of Shield Tunnel due to the Fault Displacement. Based upon the study of several cases with different fault displacements and their effect, it was concluded that two types of emergency plan for the countermeasure should be prepared against two different magnitudes of fault displacements. As shown in Figure 8, in one of the section of the subway, the vertical alignment had to be designed using steep inclination of 4% so as to run under the riverbed with enough cover to keep the safe tunnel construction. The inclination value 4% is the allowable maximum value for train operation in Japan. Whenever the next Uemachi fault displacement shall cause the same amount of deformation for the Uemachi flexure as in the past earthquake, the maximum inclination of the subway exceeds the critical value of 4% and the railway operation shall be forced to terminate.

However, if the fault displacement is some value less than 4m, the railway vertical alignment can be adjusted to keep the inclination less than 4% if tunnel inner cross-section has set up some room. For instance, if tunnel inner cross section is widened about 10cm vertically and the fault displacement is less than 1m, it can adjust the inclination within the allowable value as shown in Figure 9 and the railway to continue its service even after the earthquake.

At any rate, the section of the shield tunnel of 700 m was assigned as affected by the fault displacement. Among various considerable countermeasures to avoid damage of the shield tunnel, it was decided to adapt the ring segments made by ductile steel (DC) rather than precast reinforced concrete (RC) as given in Figures 8 and 9. The moment strength of DC is about 2.5 times larger than that of RC.

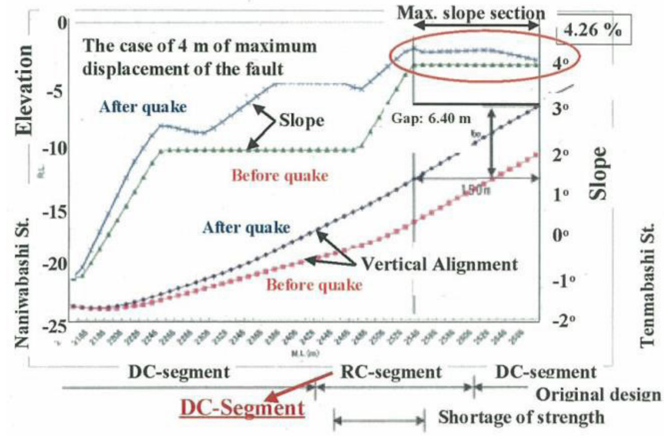

Figure 8 Subway Vertical Alignments Before and After Fault Displacement of 4 m

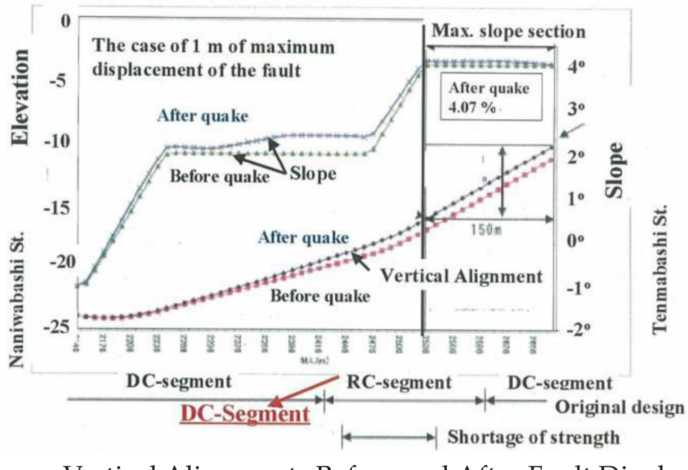

Figure 9 Subway Vertical Alignments Before and After Fault Displacement of 1 m

Table 1 shows the performance level of railway during and after earthquake based upon «Earthquake Resistance Design Manual for Railways in Japan (1999)» and Table 2 give the results of investigation on performance level of Nakanoshima subway line against the Uemachi fault displacement. As seen in these Tables, even in the case of 4m of fault displacement, the tunnel was designed as never collapse and to secure safety for passengers.

Table 1

Performance Level of Railway during and after Earthquake.

Performance Level I	After earthquake, structure is safe and unstable without retrofitting
Performance Level II	After earthquake, safety of structure is recovered with in short time and usable without retrofitting
Performance Level III	During earthquake, structure does not fail or collapse

Table 2

Performance Level of Nakanoshima-line Against Fault Displacements.

Performance Level I	-	-
Performance Level II	Disp.<1m	Designed as to keep safety against displacement less than 1m inclination of railway is adjusted as lower or equal to 4%
Performance Level III	Disp.=4m	Designed to avoid structure failure when the displacement becomes 4m to prevent human loss. Residual deformation may require large retrofitting of the tunnel

Example of Subway Damage by 1995 Kobe Earthquake. Here we follow study of Yoshida and Nakamura (1996). Damage to the subway during 1995 Kobe earthquake was one of the amazing event, because underground structures have been considered to be relatively safe from earthquake effects compared to structures above the ground. Figure 10 shows the location of the damaged subway and damage patterns. The general damage pattern is damage to columns.

In many design specifications for the underground line- shaped structures, aseismic design is not usually considered in the transverse direction. The reason for this is that the underground structures are assumed to follow the deformation of the ground during an earthquake and the apparent unit weight of the structure is much smaller than that of the subsoils.

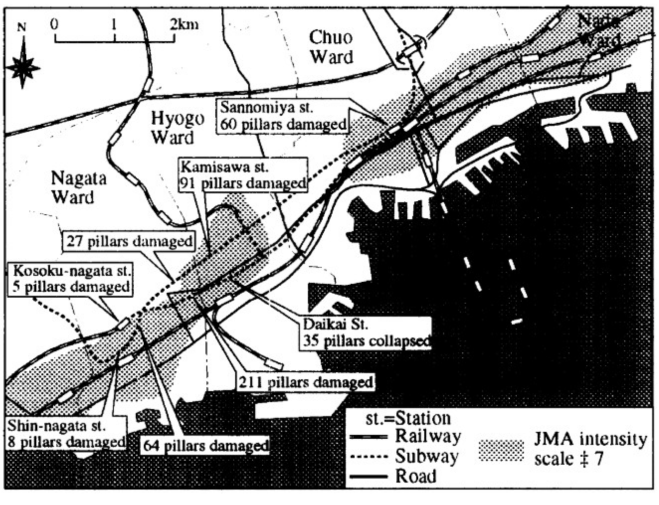

Figure 10 Location of damaged subways and damage.

Design and Geological Setting of Daikai Station. The Daikai station was constructed by the cut-and-cover method and has two story reinforced concrete underground structure with columns at the center. The thickness of the overburden soil is about 2-5m. The frame was designed based on a consideration of the weight of the overburden soil, lateral earth pressure, and weight of the frame under ordinary loading conditions, but the earthquake load was not taken into account.

The depth of the base ground (SPT-N value > 50) that consists of silty or clayey stiff soil is about 15m from the surface. Above the base there are alternating sand and clay soft layers.

Damage due to Earthquake. According to the damage level, the station structure was divided into 3 zones: A, B, and C.

Damage was the most severe at zone A, in the Nagata side zone. Almost all of the center columns completely collapsed and the ceiling slab fell down. As a result, the original box frame structure was distorted to an M-shaped section as shown in Figure 11(a). Typical damage to the center columns is shown in Photo 1. The ceiling slab kinks and cracks 150 to 250 mm wide appeared in the longitudinal direction about 2.15 to 2.40 m from the center line of the columns. In addition, the separation of cover concrete was observed over almost the entire area near the haunch and the intersection between the lateral wall and ceiling slab. In zone B, as shown in Figure 11(b), the collapse of the column occurred in the upper portion and reinforcing steel buckled into a symmetrical shape for columns 24 and 25. The upper longitudinal beam connecting the center columns was bent at a point between columns 25 and 26. The small separation of the corner concrete of the center columns is observed at the mountain side of upper portion and at sea side of lower portion, in columns 26, 27 and 28.

Although the structural system in zone C was the same as that for zone A, damage was less in zone C compared with that in zone A.

In the lateral wall, separation of cover concrete was observed near both of the top and the bottom haunches. According to the investigation of the exterior surface, wide cracks in the longitudinal direction were observed along the intersection with the haunch. Under the platform, a significant separation of cover concrete was observed on the both side lateral walls. There are several walls in the transverse direction: both of the ends, electric facility room, switching station room, etc. Diagonal cracks typically shown in Figure 11(d) and Photo 2 were observed in all the walls in the transverse direction.

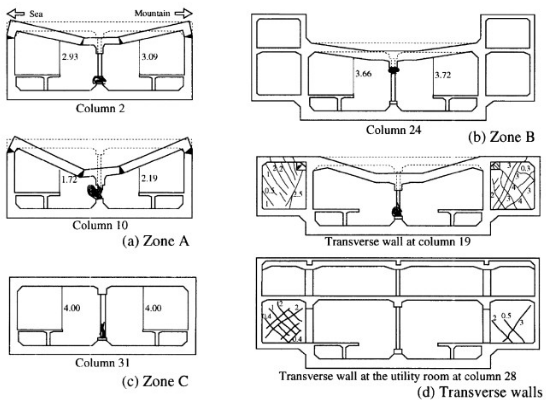

Figure 11 Schematic figure showing the damage pattern in the transverse direction.

Photo 1 Collapse of no. 10 column in Zone A.

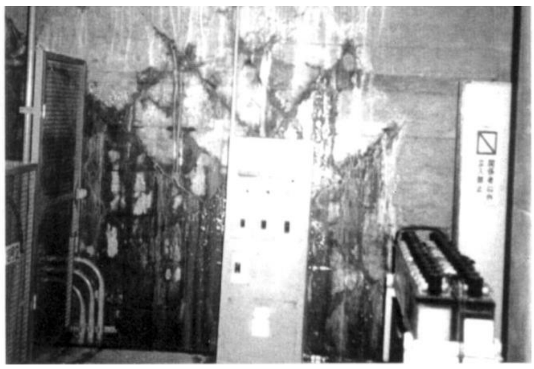

Photo 2 Cracks in the transverse wall in electric facility room.

Based on the observation of the damage to these columns and walls, the mechanism of the damage of the collapsed column in zone A is evaluated to be as follows: 1) Due to strong horizontal force, the member reaches its strength under the combination of bending moment and shear force acting near the end of the column, which resulted in collapse of the end of the column. 2) The load carrying capacity of the box frame was reduced, and therefore excess relative horizontal displacement occurred.

Analysis. Two step analyses were carried out each of which considered either nonlinear behavior of subsoils or that of the structure. At the first step, in order to appropriately estimate the dynamic response of the structure during the earthquake, dynamic response analysis of soil-structure system was conducted using two dimensional finite element method considering nonlinearity of soil by equivalent linear method. Based on the behavior of the dynamic response, static nonlinear analysis was conducted to estimate the damage process of the frame.

Estimation of dynamic response of structure Both horizontal motion and vertical motions observed at Kobe University were applied as the input motion. Dynamic response analysis was first carried out under the horizontal input motion. Then, using converged nonlinear characteristics (shear modulus and Poisson's ratio), dynamic response was calculated by linear analysis under both horizontal and vertical input motion.

Soil-structure model used in the first step analysis is shown in Figure 12. Energy transmitting boundary and viscous boundary are used along the lateral and base boundaries, respectively. Structural members are modeled to elastic beam elements considering rigid zone. The rigidity of each member is evaluated by considered the property of both concrete and reinforced bar.

Peak acceleration distributions in both horizontal and vertical directions are shown in Figure 13 at a length of 14.15, 26.15 and 42.15 meters from the center of structure. Acceleration at the ground surface is more than 400 cm/s2, which correspond to the JMA seismic intensity 7 (MM intensity 10 or more) around this area. The relationship between axial force and bending moment at the bottom of center column is shown in Figure 14. Here, axial force is the sum of the dynamic response value and initial force under ordinary load condition. In the figure, the ultimate bending moment under given axial force is shown as a chained line. The maximum axial force (sum of forces under ordinary load and increment due to earthquake) is about 1520 kN (13300 kN/m2), which is higher in comparison with the strength of concrete. Response bending moment at the bottom of the center column exceed the ultimate bending moment twice, at around 5.3 and 8.13 seconds, respectively. The same tendency is observed at the response of lateral wall, ceiling and base slab. The ductility of the center column is a very small value, 1.3. Therefore, center column was possible to collapse just after the bending moment exceed the yield bending moment. Furthermore, the ratio of the shear strength of center column calculated by the Standard Specification of Reinforced Concrete (JSCE, 1991) to the converted shear force from the ultimate bending moment is less than 1.0. Therefore, center column was also possible to collapse under shear. Figure 15 shows distribution of external load considered for Daikai station.

Based on detailed reconnaissance survey of the damage and nonlinear analyses, the mechanism of the collapse of the station is concluded to be as follows:

The B2 floor of the station was subjected to a strong horizontal load from the adjacent subsoil, which caused deformation of the box frame structure. In zone A where amount of wall in the transverse direction is small, center columns initially collapsed due to a combination of bending and shear resulting in the deformation of the box frame. Then, as a result of the relative displacement between the top and bottom of the columns, additional moment by gravity of the overburden soil became predominant resulting in the failure of the column. Since the walls in the transverse direction carry most of the horizontal force in zones B and C, damage to columns was much smaller compared with that in zone A. Instead, many diagonal cracks appeared on the walls in the transverse direction, such as walls at both ends of the station and walls in the utility rooms.

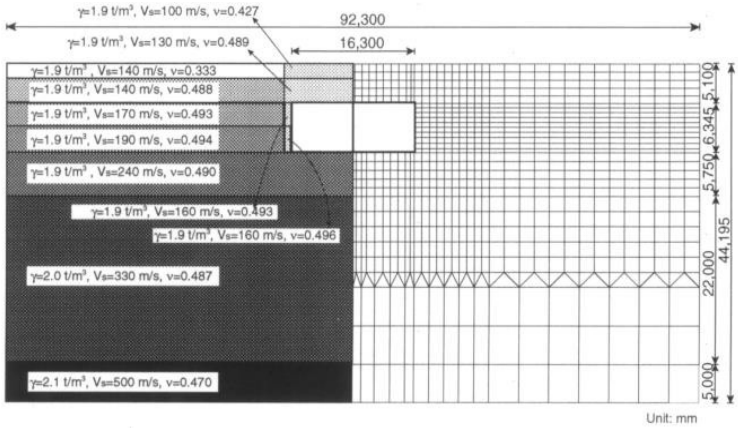

Figure 12 Soil-structure system used in the dynamic response analysis.

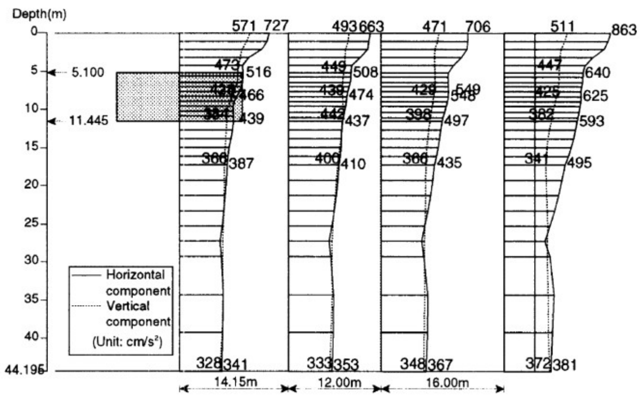

Figure 13 Peak acceleration distributions

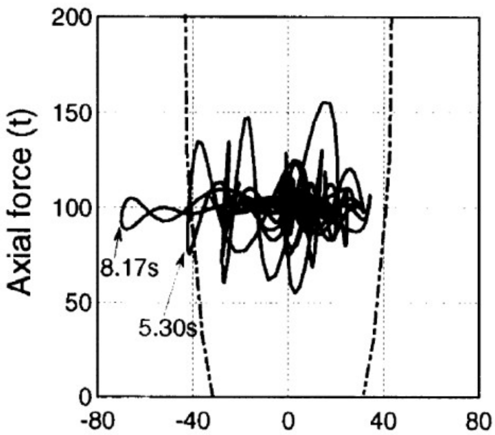

Figure 14 Bending moment-axial force relationship at the bottom of the center column.

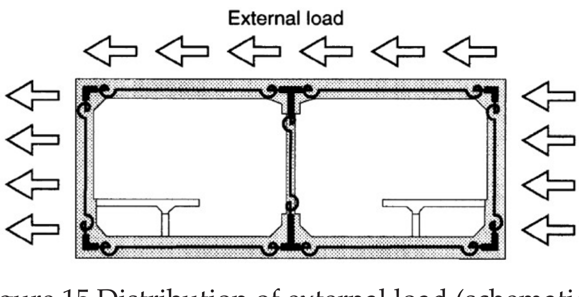

Figure 15 Distribution of external load (schematic).

Overview of the fault system and seismicity around Almaty and subway lines. Almaty locates at the northern foot of Tien-Shan Mountains of the largest seismogenic environment in Central Asia and the most earthquake prone area in Kazakhstan, which is result of highly intensive orogenic processes, 3000m uplift in Zailiisky Alatau and 1000m subsidence in Iliisky-Alamaty depression (Neotectonic Map of Kazakhstan). Two major thrust faults, Zailiisky and Chilik-Kemin faults, hosting potential earthquakes M8 and more, are located south of the city. Other faults, of M7 Almaty fault and Boroldaisky fault, are located just under the city. A world famous series of strong earthquakes, including 1887 Vernyi earthquake and 1911 Kemin earthquakes that destroyed city, were generated by these faults. A M8 segment of Zailiisky fault east of Almaty in immediate vicinity, left un-ruptured.

According to the Seismic Zonation Map of Kazakhstan Republic, seismic intensity 9 in adopted in Kazakhstan MSK scale (approximately equivalent to Amax=400cm/s/s) is expected in Almaty once in 1000 years. Starting from macro-seismic survey after 1887 Vernyi and 1911 Kemin earthquakes, it was noticed by many observations, that due to ground conditions local seismic intensity can increase in Almaty approximately from north-west to south-east: from -1.0 to +1.0 in seismic intensity scale. This is reflected in seismic microzoning map of Almaty, see Figure 17.

In addition, microzoning map reflects traces of faults across the city. Major faults are Almatinsky fault in central part of city, and Boroldaisky fault in northern part of city without any known historical earthquakes yet. Basement of Almatinsky fault is overlapped with thick, 2-3 kilometer sediments. Nevertheless, fault zone is clearly mapped by vertical movement on the repeating leveling profiles (e.g. Zhunusov and Uzbekov, 2011).

Figure 16 shows location of working, constructed and planned lines of Almaty Metro (subway), overlapped to the seismic microzoning map of Almaty and traces of active faults. Three lines of planned Metro system are crossing Almatinsky fault, and a few others are crossing secondary faults. There is a danger of destructive deformations of the tunnel structures in case of earthquake.

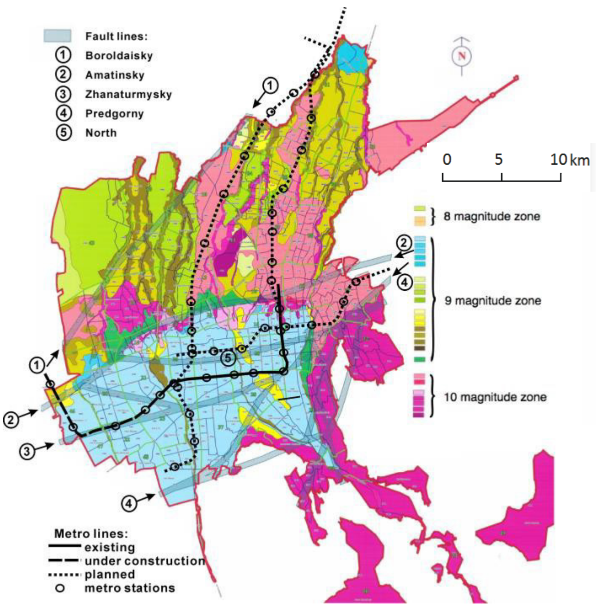

Figure 16 Seismic microzoning map of Almaty and Metro (subway) system.

Conclusions. This paper introduced structural safety of subway system against earthquake problems of fault displacement and ground motion.

Nakanoshima subway line in Osaka was planned to construct crossing Unemachi hidden fault. By adopting the material for the ring segments made by ductile steel rather than precast reinforced concrete, even in the case of 4m of fault displacement, the tunnel was designed as to be never collapsed and to secure safety for passengers.

Based on detailed reconnaissance survey of the damage and nonlinear analyses at the Daikai station, the mechanism of the collapse of the station is reproduced. It is concluded that ceiling slab failed by the lack of the load carrying capacity against shear at center column, due to a strong horizontal force that was imposed on the structure from the surrounding subsoils.

Almaty is known as earthquake prone area because of strong ground motion from nearby big earthquake with hidden fault beneath the city. It is worthwhile to evaluate aseismic design not only the ground motions but also ground deformation that is anticipated by hidden faults system.

References

1 Design Standards and Manuals for railway and related Structures, Shield Tunnel, Railway Research Institute, 1997.

2 Sugiyama et al. Complementary study of the Uemachi fault system in the Osaka Basin (2)-Evaluation of the fault activity based on supplementary boring and re- interpretation of S-wave seismic reflection data, Active Faults and Ancient Earthquakes, - 2003.-№3, - P. 117-143.

3 Yoshida, N., and S. Nakamura Damage to Daikai subway station during the 1995 Hyogoken-Nunbu earthquake and its investigation, 11th World Conference on Earthquake Engineering, -1996. - P. 2151.

4 Zhunusova Zh.K., and Uzbekov R.B. Исследование геологических условий, особенности разломной тектоники и сейсмического режим Алматинского сейсмоактивного района для оценки сейсмической ситуации. Вестник Кокшетауского технического института МЧС Республики Казахстан, -2011. -№ 3. - P.27-32

References

1 Design Standards and Manuals for railway and related Structures, Shield Tunnel, Railway Research Institute, 1997.

2 Sugiyama et al. Complementary study of the Uemachi fault system in the Osaka Basin (2)-Evaluation of the fault activity based on supplementary boring and re- interpretation of S-wave seismic reflection data, Active Faults and Ancient Earthquakes, 2003. №3. P.117-143.

3 Yoshida, N., and S. Nakamura Damage to Daikai subway station during the 1995 Hyogoken-Nunbu earthquake and its investigation, 11th World Conference on Earthquake Engineering, 1996. P. 2151.

4 Zhunusova Zh.K and Uzbekov R.B. Issledovanie geologicheskih uslovij, osobennosti razlomnoj tektoniki i sejsmicheskogo rezhim Almatinskogo sejsmoaktivnogo rajona dlya ocenki sejsmicheskoj situacii. Vestnik Kokshetauskogo tehnicheskogo instituta MChS Respubliki Kazahstan [Study of geological conditions, features of fault tectonics and seismic regime of the Almaty seismically active region to assess the seismic situation. Bulletin of the Kokshetau technical Institute of the Ministry of emergency situations of the Republic of Kazakhstan]. 2011 №3. P 27-32.

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Алматы метрополитені тұрғысынан Осакадағы жасырын ақауға және Кобе жер сілкінісінен болатын зақымға қарсы Метрополитен жүйесін Асейсмикалық жобалауға шолу

Аңдатпа. Ақаулық тек топырақтың қозғалысына ғана емес, сонымен қатар, тіршілікті қамтамасыз етудің әртүрлі маңызды жүйелері орнатылған жер бетінің бұзылуына және жылжуына әкелуі мүмкін. Қазақстанның ең ірі қаласы Алматыда көптеген жасырын жарылыстар жер сілкіністерінің шағын аймақтық картасында көрсетілген. 1995 жылы Кобе жер сілкінісі метро жүйесінің қатты жер қозғалысына байланысты зақымдалғанын көрсетті. Осака, Жапония, сонымен қатар, қала орталығының астында жасырын ақаулық бар. Жақында Осакадағы метро құрылысы ақаулық қозғалысына қарсы жобалау процедурасын бейімдеді. Бұл жұмыста Кобе қаласындағы жер сілкінісі кезіндегі Кобе метрополитенінің зақымдануы көрсетілген және қабылданған құрылымы бар Осаканың жарылу және геотехникалық жағдайы, сондай-ақ, Алматыдағы авторларға белгілі жасырын жарылыстардың негізгі сипаттамалары қарастырылған.

Түйін сөздер: жер сілкінісі, ақаулар, қозғалыс, зақым, метро, құрылыстар.

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Обзор асейсмического проектирования системы метрополитена против скрытого разлома в Осаке и повреждений от землетрясения в Кобе с точки зрения Алматинского метрополитена

Аннотация. Неисправность может привести не только к движению грунта, но и к разрывам и смещению земной поверхности там, где были установлены различные важные системы жизнеобеспечения. В Алматы, крупнейшем городе Казахстана, многие скрытые разломы показаны на микрозональной карте землетрясений. Землетрясение в Кобе в 1995 году показало повреждение системы метро из-за сильного движения грунта. В Осаке (Япония) также имеется скрытый разлом прямо под центром города. Недавнее строительство метро в Осаке адаптировало процедуру проектирования против движения разлома. В данной работе показаны повреждения метрополитена в Кобе во время землетрясения и описаны разломное и геотехническое состояние Осаки с принятой конструкцией, а также основные характеристики известных авторам скрытых разломов в Алматы.

Ключевые слова: землетрясение, разломы, движение, повреждения, метро, сооружения.

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