Significant issues posed by the 2016 Kumamoto earthquake with regard to active fault assessment and disaster mitigation

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After the Kumamoto earthquake, it was necessary to critically examine the efficiency of evaluation by the Headquarters for Earthquake Research Promotion of Japan for implementation of disaster mitigation countermeasures. Was the headquarters successful in predicting the earthquake? Was the information provided by the headquarters effective in mitigating damages? What should the headquarters and research institutes learn from this earthquake?

Many residents in Kumamoto said that they knew the existence of the Futagawa-Hinagu fault and were aware that the probability of an earthquake was "relatively higher," prior to the earthquake. This can be regarded as a significant achievement for the headquarters after having devoted 22 years since 1995 to predict the occurrence of an earthquake. However, there is doubt whether these efforts actually led the residents to employ countermeasures.

The behavior of the fault during the Kumamoto earthquake was not consistent with the fault classification assumed in the evaluation. Another remarkable feature of the Kumamoto earthquake was that the "severely damaged zones" were generated along the active fault. A seismic intensity of 7 was recognized officially only in Mashiki town and Nishihara village. However, severe damages indicated that the seismic intensity in most areas along the earthquake fault was equivalent to 7. Although the Ministry of Land, Infrastructure and Transport issued a policy to not revise the Building Standards Law, the current standard is regarded only as a minimum requirement, and is not sufficient for a seismic intensity of 7. This leads to the conclusion that there should be a need to identify areas where the seismic intensity could reach 7.

In addition, various surface ruptures were generated during the Kumamoto earthquake. There were (1) narrowly defined earthquake faults, which were judged to be surface appearances of the seismic fault itself, (2) secondary faults induced with the seismic faulting, (3) gravitating landslides having no relation with the seismic fault. Are they clearly distinguishable at present? It is important to clarify the mechanism of ruptures and improve the hazard assessment of various ground displacements.

There were several unsolved problems such as determining a relationship between damages and faulting, even in the 1995 Hanshin Awaji earthquake. One of the reasons as to why these problems were unsolved is the lack of inter-disciplinary research. After the Kumamoto earthquake, it is necessary to develop a new inter-disciplinary research promotion system, considering all the risks posed by the earthquake.

Keywords: Kumamoto earthquake, active fauls assessment, disaster mitigation

Landslides in urban residential region induced by the 2016 Kumamoto earthquake

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Recent destructive earthquakes in urban regions, such as the 1978 Miyagiken-oki earthquake the 1995 Kobe earthquake, and the 2011 Tohoku earthquake have destabilized many of the gentle slopes in residential areas around large cities in Japan. Beyond the serious danger to residents of the earthquake affected areas, these landslides revealed the weaknesses of urban development in cities of Japan. The 2016 Kumamoto earthquake induced serious damages in the suburbs of Kumamoto city. The strong motion along the earthquake fault across the urban region caused slope damages, that are building deconstruction, collapse of houses, and landslides of artificial steep slopes, but also the ground condition controlled their distribution and landslide mechanism.

Keywords: Fill, Residential developments

Building Damage on Surface Faulting of 2016 Kumamoto Earthquake, and Counter Measures

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This paper reports the results for investigating building damage near the surface faulting of the 2016 Kumamoto earthquake, and counter measures of building. The results of the building investigation indicated that most of severe damage occurred in those directly above the surface faulting, because of its slip deformation. And, almost all severe damaged buildings were very old wooden houses/apartments, whereas new wooden or RC buildings showed very minor damage. In the Shimojin area, for examples, the ground motion was probably not strong enough to cause severe damage, and thus, the highest damage was Grade 3. All of them were very old wooden buildings and directly above the surface faulting. Even though the best counter measure for buildings near active faults is to avoid them, it is unrealistic to prohibit regular buildings in such areas shown in this study, because the exact locations of the surface faulting are very difficult to identify. In fact, they differed from those of the actual surface faulting, because of the young alluvial/volcanic sediments and the artificial land development. In addition, the recurrence intervals of the active faults are extremely long (usually several thousand years), as compared with the lifetime of a building. And the most importantly, various safety counter measures are effective, even for the building directly above the surface faulting. For example, the new wooden houses with the mat foundation of RC could prevent the slip deformation from reaching the building, and the combinations of the shear wall and light roofs prevented severe damage. On the other hand, the old Japanese traditional houses generally suffered severe damage, but their structural flexibilities could prevent collapsing by following the slip deformation. The collapsed buildings were generally very old and lacked both the sufficient earthquake-resisting structural members and the effective connections among them.

Keywords: 2016 Kumamoto Earthquake, Surface Faulting, Damage and Counter Measures of Building

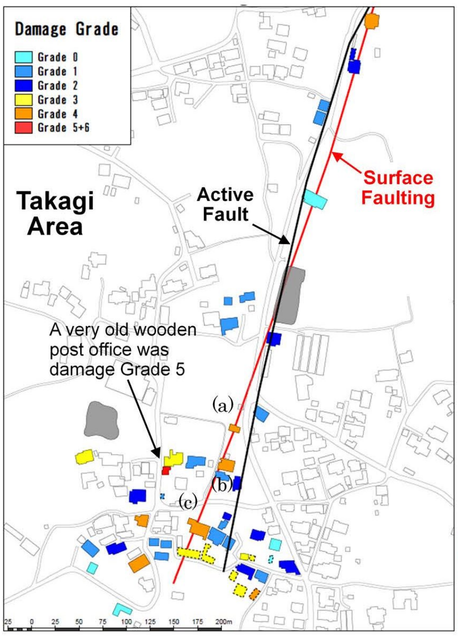

図１　地表地震断層近傍の建物被害分布（高木地区）

表１　地表地震断層近傍の建物被害統計（高木地区）

構造	棟数	割合
木造	35	90%
S造	3	8%
RC造	1	3%
合計	39	100%

築年	棟数	割合
30年以上	17	44%
30～10年	12	31%
10年以下	10	26%
合計	39	100%

古い建物

被害度	棟数	割合
Grade 0	0	0%
Grade 1	6	50%
Grade 2	3	25%
Grade 3	1	8%
Grade 4	2	17%
Grade 5	0	0%
Grade 6	0	0%
合計	12	100%
全壊	2	17%
倒壊	0	0%

非常に古い建物

被害度	棟数	割合
Grade 0	0	0%
Grade 1	5	29%
Grade 2	5	29%
Grade 3	2	12%
Grade 4	4	24%
Grade 5	1	6%
Grade 6	0	0%
合計	17	100%
全壊	5	29%
倒壊	1	6%

断層直上のみ

被害度	棟数	割合
Grade 0	1	14%
Grade 1	1	14%
Grade 2	2	29%
Grade 3	0	0%
Grade 4	3	43%
Grade 5	0	0%
Grade 6	0	0%
合計	7	100%
全壊	3	43%
倒壊	0	0%

断層直上以外

被害度	棟数	割合
Grade 0	3	9%
Grade 1	15	47%
Grade 2	7	22%
Grade 3	3	9%
Grade 4	3	9%
Grade 5	1	3%
Grade 6	0	0%
合計	32	100%
全壊	4	13%
倒壊	1	3%

(1) 古い在来木造住宅　(2) 新しい軽量鉄骨住宅　(3) 非常に古い伝統木造住宅

写真１　御船町高木地区における地表地震断層直上の建物被害の例

Consideration of uncertainty in strong-motion prediction and seismic hazard analysis

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The Kumamoto earthquakes were earthquakes that were long-term evaluated by the headquarters of earthquake research promotion of Japan. The earthquakes occurred in a part of the Futagawa fault zone and the Hinagu fault zone where the seismic hazard maps with specified seismic source fault were published. Based on the knowledge obtained from the analysis of the Kumamoto earthquake, we will consider problems in strong-motion prediction and seismic hazard analysis, especially handling of uncertainty in prediction of future events. We classify the uncertainty in assessment into aleatory variability and epistemic uncertainty. The aleatory variability is evaluated as a random variable, and the epistemic uncertainty is evaluated using a logic tree.

(1) Consideration of uncertainty in setting earthquake magnitude (seismic moment)
a) Consideration of epistemic uncertainty about the concept of model setting of fault geometry
Considering the epistemic uncertainty with respect to the setting of the size of source fault, it is necessary to consider the following model in addition to the basic model according to the current ‘recipe’.
1) Model assuming that the source fault length is longer than the surface fault length.
2) Model assuming that depth of lower end of fault slightly deeper than the lower limit of the seismogenic layer.
3) Model with the top of the source fault at 0 km (ground).
4) Model considering uncertainty in setting dip angle.

b) Consideration of uncertainty concerning outer source fault parameters
It is important to properly consider the epistemic uncertainty accompanying the selection of the equation and the aleatory variability included in the prediction in parameter setting of the source fault model using the empirical formula.
1) Epistemic uncertainty on selection of empirical formula in L-Mo relation and Mj-Mw relation.
2) Aleatory variability in Mo-S relation and Mo-A relation.

(2) Consideration of uncertainty in modeling position and shape of source fault
In the strong-motion evaluation, the emphasis was mainly on modeling of short period strong-motion generation, the source fault was within the seismogenic layer, and its upper end was not 0 km (surface). In order to predict the strong ground motion in the very vicinity of the fault, detailed modeling of the position and shape of the source fault with the top end depth of 0 km is necessary. It is necessary to consider the uncertainty concerning detailed modeling of position and shape.

(3) Consideration of uncertainty in inner parameters of source fault model
In the strong-motion prediction by simulation using the fault model, it is necessary to evaluate both "average ground motion level" and "variation of ground motion due to model uncertainty". For that purpose, it is necessary to consider the uncertainty in the inner parameters of source fault model. It is important to consider the uncertainty concerning starting point of rupture, asperity position, inhomogeneity of effective stress of asperity, the setting of slip velocity time function in the shallower part than the seismogenic layer. In the prediction using simulation, it is necessary to clarify relationship

between the reproduction model of the past earthquake and the model for prediction.

(4) Consideration of uncertainty in subsurface structure model
The uncertainty of underground structure model is hardly considered compared with the modeling of source fault. A model based on dense observation data is being developed in the land area, but there is large uncertainty in the ocean floor area. In order to cover up to about 1 to 2 Hz, it is necessary to consider aleatory variability due to random inhomogeneities. In the evaluation of the amplification factor by the shallow ground, consideration of the epistemic uncertainty due to the lack of data is a future subject.

(5) Consideration one size smaller earthquakes than the characteristic earthquake
The earthquake on April 14 (M6.5), which is thought to be a smaller earthquake than the characteristic one, but the maximum seismic intensity 7 is observed. Modeling magnitude and occurrence frequency of smaller earthquakes than the characteristic one is an important issue.

Keywords: strong-motion prediction, seismic hazard analysis, uncertainty, variability

Reconsideration of earthquake disaster countermeasures based on the experience of the Kumamoto earthquake

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The 2016 Kumamoto earthquake caused twice strong shakes of 7 degree of JSI with interval of 28 hours. The first strong shake killed 9people and the second shake killed 41 people in midnight. The number of earthquakes as aftershock which occurred 1 degree of JSI and more reaches more than 4,200. About 230,000 of people were evacuated in shelters due to the repeated aftershocks. As the result of it, the number of the related death reached more than of 150 persons as three times as number of the direct death victims. The experience of the Kumamoto earthquake clarified the various problem of the Japanese countermeasures for earthquake, such as evacuation system, regulation system of fault zone, anti-earthquake standard of building of important facilities, countermeasure against repeated aftershocks, care of the elderly in shelter for decrease of the related dearth, the supply of temporary houses, and so on in the emergency and quick recovery period, to be re-considered. This one year after the earthquake was expensed for only making a reconstruction plan, but implementing reconstruction projects for sufferers.

S-wave velocity measurement across active faults and the effect of basin geometry on site response, California, USA

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We measured S-wave velocity (Vs) profiles at eleven sites in the east San Francisco Bay area using surface wave methods. The sites were placed around the Hayward fault and the Calaveras fault (Figure 1). The 30-year probabilities of magnitude 6.7 or greater earthquakes on the Hayward-Rodgers Creek and Calaveras faults have been estimated at 32 % and 25 %, respectively. These faults run through densely populated areas and knowledge of a detailed two- or three dimensional Vs structure along the faults is needed in order to estimate local site effects due to a potential earthquake. This presentation summarizes data obtained by the surface wave methods, shows Vs profiles calculated by inversion, and discusses the effect of 2D Vs structure on surface ground motion. Data acquisition included multichannel analysis of surface waves using an active source (MASW), a passive surface-wave method using a linear array of geophones (Linear-MAM), and a two station spatial autocorrelation method (2ST-SPAC) using long-period accelerometers. Maximum distance between stations ranged from several hundred meters to several kilometers, depending on the site. Minimum frequency ranged from 0.2 to 2 Hz, depending on the site, corresponding to maximum wavelengths of 10 to 1 km. Phase velocities obtained from three methods were combined into a single dispersion curve for each site. A nonlinear inversion was used to estimate Vs profiles to a depth of 200 to 2000 m, depending on the site. Resultant Vs profiles show significant differences among the sites (Figure 2). On the west side of the Hayward fault and the east side of the Calaveras fault, there is a low velocity layer at the surface, with Vs less than 700 m/s, to a depth of approximately 100 m. A thick intermediate velocity layer with Vs ranging from 700 to 1500 m/s lies beneath the low velocity layer. Bedrock with Vs greater than 1500 m/s was measured at depths greater than approximately 1700 m. Between the Hayward Fault and the Calaveras Fault, thicknesses of the low velocity layer and the intermediate velocity layer are less than 50 m and 200 m respectively, and depth to bedrock is less than 250 m. To evaluate the effect of a lateral change in bedrock depth on surface ground motion due to an earthquake, a representative Vs cross section perpendicular to the Hayward fault was constructed and theoretical amplification was calculated using a viscoelastic finite-difference method. Calculation results show that the low frequency (0.5 to 5 Hz) component of ground motion is locally amplified on the west side of the Hayward fault because of the effect of two-dimensional structure. The results of this investigation indicate that the phase velocity information obtained using the 2ST-SPAC method with a limited number of high quality sensors provides valuable Vs information over a wide depth range. It offers a robust alternative to widely-used single station methods such as the horizontal to vertical spectral ratio. Though the 2ST-SPAC method and other passive surface wave methods using an anisotropic or linear array cannot equal the performance of an isotropic array in the case of strongly anisotropic ambient noise, they do provide an effective alternative for many urban environments where ambient noise is relatively isotropic and potential sites for array deployment are limited to corridors along roadways. The inversion of surface wave data is essentially non-unique and we cannot remove uncertainty from analyses, the effect of the uncertainty depends on the purpose of investigation and the use of the data. Several different velocity profiles that yield almost the same theoretical phase velocities were examined to evaluate the effect of uncertainty of inversion on amplification calculation. The results shows that the site amplifications calculated from Vs profiles are relatively insensitive to uncertainties in the velocity profiles.

Keywords: Active fault, S-wave velocity, Surface-wave method, Micro-tremor array measurements, Site amplification, Basin edge effect

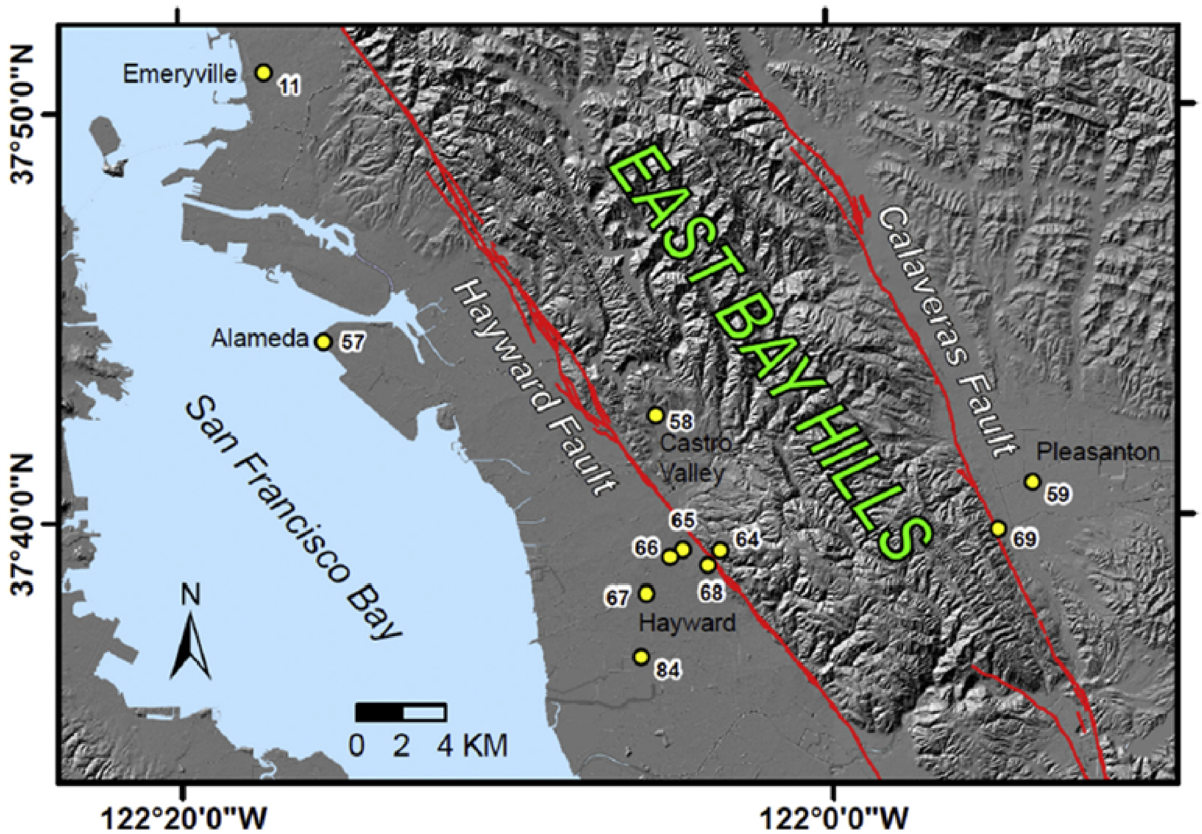

Figure 1. Sites of investigation. 11 : Emeryville, 57 : Alameda, 58 : Castro Valley, 59 : Pleasanton, 64 : CSU East Bay, 65 : Charles Ave, 66 : Huntwood Ave, 67 : Southgate Park, 68 : Cemetary, 69 : Alviso Adobe, 84 : Eden Shores Park.

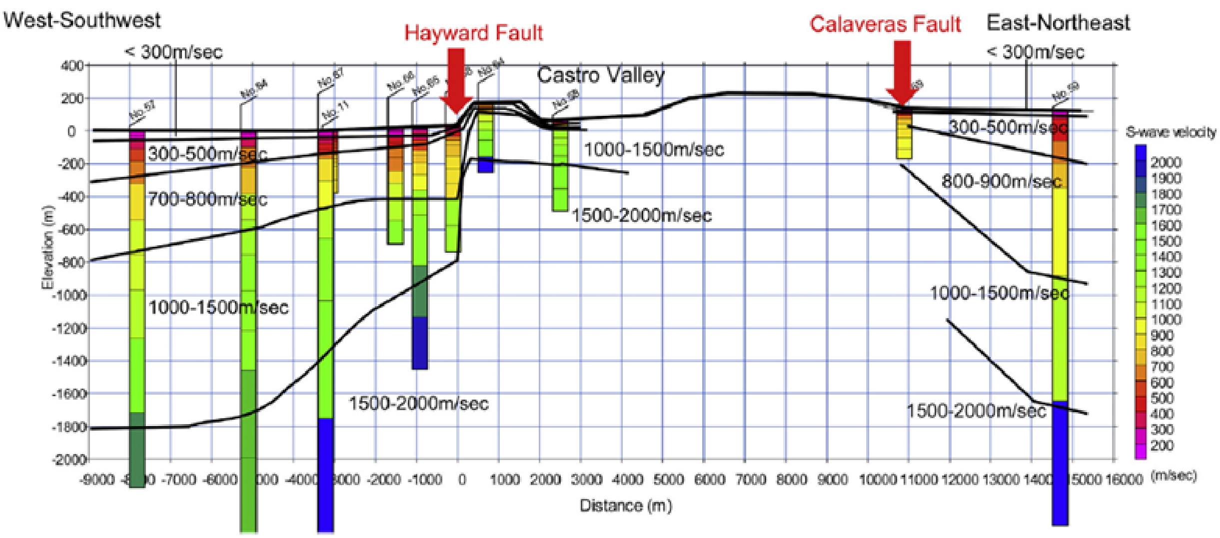

Figure 2. Schematic S-wave velocity section based on the S-wave velocity profiles obtained in this study.

Geotechnical aspect of damage found along seismic fault that appeared in the 2016 Kumamoto Earthquake

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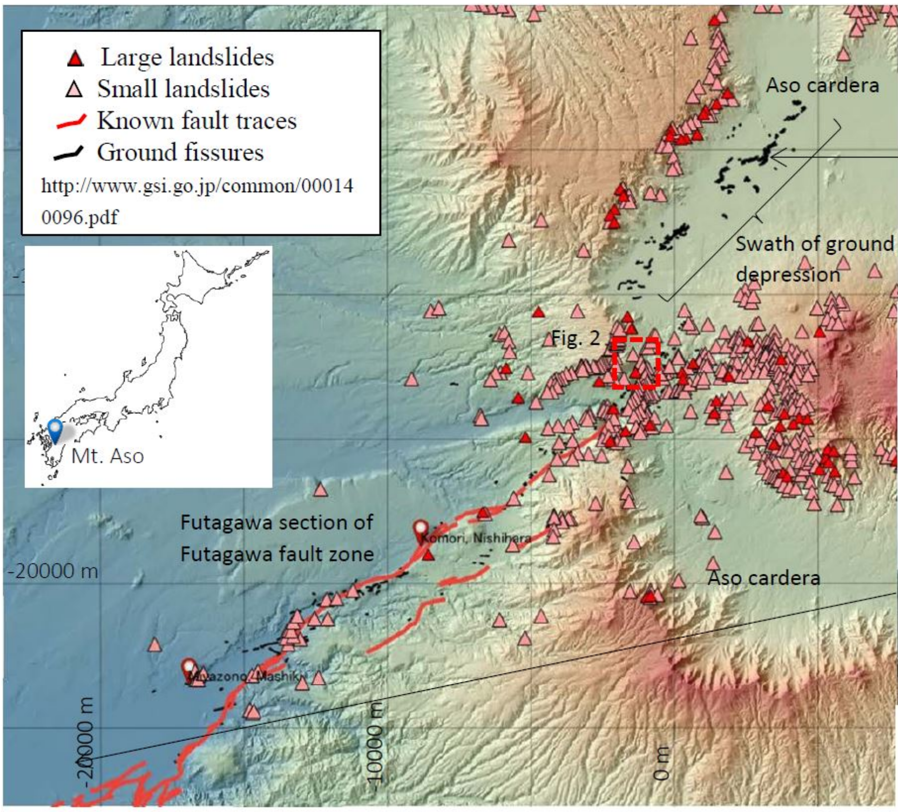
Starting with a magnitude-6.5 foreshock on April 14, 2016, a series of major earthquakes including the magnitude-7.3 main shock on April 16 have hit the central Kumamoto area of Kyushu, Japan, causing deaths, injuries and widespread damage to various facilities. The activity of the fault, whose right-lateral offset appeared in the main shock along the previously known section of the Futagawa fault zone, caused extensive damage to roads, bridges, a tunnel and a dam. The observed features of the damage again showed that not only intense shakes but also ground deformations such as landslides, lateral spread of embankments and levees, soil liquefactions etc., which can be found within a swath along the fault trace, can be equally or often more responsible for devastations. Moreover close to 500 millimeters of rain fell on some parts along the quake-hit areas on June 20 and 21, causing further extensive landslides and flooding, highlighting the difficulty to cope with earthquake-flood multi hazards.
LiDAR, Laser based altimetry, can penetrate through tree canopy, revealing detailed feature of bare earth left behind by past natural hazards, and the LiDAR image of the mountain slope along the outer rim of the Aso crater shows evidence of past landslides as well as the most recent one that has hit an important location for traffic. Moreover cracks are seen along the exposed scar indicating future risk. As long as clear evidence for past large soil deformation was there in LiDAR images, landslides/active fault maps etc., we could bring potential hazard to light and take necessary actions. However these pieces of evidence can be often buried beneath surface soil deposits particularly when they are near an active volcano. Because large ground deformations can be repeated in any extreme natural events as can be seen in the past major earthquakes, they are to be recorded in a quantitative manner.

Keywords: Kumamoto Earthquake of 2016, Geotechnical hazard, earthquake-flood multi hazards



House hanging a little over the northwestern offset of the ground at N32.9568°, E131.0368

Tilted RC housing of pump for Akita clean water well No. 2 at N32.7670°, E130.7786 °: A low lying area east of this housing is found sunken by more than a meter

Geomorphological and geological features of landslide deposits caused by the 2016 Kumamoto earthquake at the western part of Aso Volcano

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The Kumamoto earthquake (Mj=7.3) on April 16, 2016 triggered many landslides at the slope of Aso Volcano. The main shock triggered more than 100 landslides of loam deposits. Earthquake-induced earthflow deposits consists of loam blocks flowed relatively long distance along the San-odani River.

Keywords: Kumamoto earthquake, Aso volcano, landslide

Reserach on active faults in urbanized area of Mashiki Town by the City Bureau, MLIT and its significance

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1. Senshu University, 2. Geospatial Information Authority of Japan

The Urban Development and Improvement Division, City Bureau, Ministry of Land Infrastructure, Transport and Tourism researched to specify the location of active faults including pitting (see photo) in urbanized area of Mashiki Town, which utterly devastated by the Kumamoto Earthquake of 2016, for the purpose of supporting the reconstruction of urbanized area. The author introduce the result of the research and discuss the significance of the active fault reserch in the area where small surface deformations arised in urbanized area.

Consideration of existence of active faults in the Reconstruction Plan of Mashiki Town

*Hiroshi Une[1]

1. Geospatial Information Authority of Japan

The Mashiki Town, utterly devastated by the 2016 Kumamoto Earthquake, established “the Reconstruction Plan of Mashiki Town” in December 2016 aiming to revive from earthquake disaster and reconstruct disaster-proof town. The questionnaire survey to the residents which was carried out in the process of drafting of the plan revealed that a majority of the residents were in fear for the existence of active fault and the occurrence of future earthquake. In parallel with this planning, the City Bureau of Ministry of Land, Infrastructure, Transport and Tourism conducted the research and analysis of the background elements of the damage such as fault and soil condition and the consideration of measures to rebuild disaster-proof town, and provided the results to support the Town. It assumed that at least three east-west active faults run below the town center of the Mashiki Town, and proposed to take special consideration for the land use on active faults from the viewpoint of avoidance of damage risk while implementing land readjusting project in town center. Although concrete land use planning has not started yet, this is a remarkable policy based on fair understanding of the nature of active faults aiming at the coexistence with active faults.

Keywords: Reconstruction Plan of Mashiki Town, land use on active fault, coexistence with active fault

益城町市街地内における活断層の位置

国土交通省

層位置の推定方法

以下の4点から総合的に判断

①同一地層の標高差の有無
②明瞭な段差地形の有無
③活断層の繰り返しにより柔らかくなった地盤の有無
④地表に現れる連続的な亀裂の有無

○ 益城町市街地において、3本の活断層(A・B・C)が存在。
○ 今回の地震では、活断層Aが主体に活動し、益城町市街地では、最大35cmの右ズレ及び最大15cm程度の上下変位(南落ち)を確認。
(活断層B,Cのズレは活断層Aに比べて微量)

国土交通省都市局(2017):「熊本地震からの益城町の市街地復興に向けた安全対策のあり方等に関する中間報告」より

Earthquake faults along the Kiyomasa-kodo and in the northwestern part of the Aso caldera during 2016 Kumamoto Earthquake

*Mitsuhisa Watanabe[1], Takashi Nakata[2], Hideaki Goto[3], Kei Tanaka[4], Yasuhiro Suzuki[5], Keita Takada[6]

1. Faculty of Sociology, Toyo University, 2. Emeritus professor, Hiroshima University, 3. Graduate school of letters, Hiroshima University, 4. Japan Map Center, 5. Nagoya University, 6. Fukken Co. Ltd.

A large number of ruptures appeared along the Futaenotoge seismic zone and its extension during 2016 Kumamoto earthquake. There are right-lateral earthquake faults along the Kiyomasa-kodo (Seishoko-do). The narrow “severely damaged zone” indicates that the upper cutoff depth of seismogenic layer is very shallow. The remarkable surface ruptures aligned in ENE-WSW direction intermittently in the northwestern part of the Aso caldera. The locations of the ruptures are not coincided in space with soft grounds, and strong tremor did not attack the areas. The tectonic ruptures in the form of grabens caused the lateral ground displacements in these areas.

Keywords: earthquake fault, right-latera fault, normal fault, Kiyomasa-kodo, Aso caldera, 2016 Kumamoto earthquake

Ground motion amplification on heavily damaged zone in the Mashiki town during the 2016 Kumamoto Eartuquake

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1. Disaster Prevention Research Institute, Kyoto University, 2. National Institute of Advanced Industrial Science and Technology, 3. Osaka University

Severe ground motion damages occurred in the downtown area of the Mashiki town, Kumamoto Prefecture, during the 2016 Kumamoto earthquake, Japan, and several heavily damaged zone appeared in the center of the downtown. Nonlinear site response for the first (14th Apr., 2016) and main shocks (16th Apr., 2016) is important factors to explain the reason why the heavily damaged zone appeared. We analyzed the soil nonlinearity by using the surface and borehole records at KiK-net KMMH16 (Mashiki) station. Optimal S- wave velocity models clearly depended on the amplitude of input ground motions. Strain dependent shear stiffness and damping ratio were estimated to explain the S-wave velocity dependence on the input motion amplitudes. We conducted nonlinear analyses at KMMH16 site on the basis of the nonlinear model. The synthetic surface ground motions agreed well with the observed ones, especially at S-wave amplitude and phase for the first and main shocks. In addition, we also conducted the same analyses at TMP3 site, which was located in the heavily damaged zones. The synthetic motions well represented the observed ones, and difference of spectral accelerations was well explained by the analyses. The results indicated that the soil nonlinearity played a big role to cause the difference of ground motions, and thus the damaged zone appeared in the downtown of the Mashiki town.

Keywords: 2016 Kumamoto Earthquake, Ground amplification, Mashiki town

Clarification of the relationship between the damage distribution and surface cracks caused by the 2016 Kumamoto earthquake

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In the 2016 Kumamoto earthquake, catastrophic damage concentrates along active faults. At the time of the earthquake, various cracks appeared on the surface. I will discuss surface displacement and damage caused by the earthquake.
Clear surface earthquake faults appeared along the line where the active fault position was recognized before the earthquake. In the part where the fault passed, the retaining wall was broken in the range of several meters wide due to fault displacement. However, there are no houses collapsed by fault displacement. The wooden house existing on the surface earthquake fault twisted and deformed, but it did not collapse. In the old wooden house built at the point where the fault passed beside the fault, there was no falling of the roof tile and it was not damaged.The catastrophic damage concentrated in the center of Mashiki- machi. A surface earthquake fault appeared on a part of it, displacing the paved road up to 40 cm. However, the line where the surface earthquake fault appeared and the distribution of the collapsed houses are not finely matched.
A surface earthquake fault appeared also in the western part of the Aso caldera. A part of the fault displaced the houses, but the houses has not collapsed. In the Aso Valley, a linear collapse area crack occurred. Analysis of the surface displacement vector from the DEM before and after the earthquake showed that the blocks with a major diameter of 1 to 2 km moved 2 to 5 m in the north - northwest direction in the three areas along the Kurokawa river (Mukaiyama et al. 2016). As a result of the underground exploration conducted in the Matoishi which is one of the three districts, I confirmed the existence of a low velocity layer of about 10 m in thickness right under the crack. According to the testimony of the elderly, the linear cracked parts ware that the yellow soil was collected before 1940.
In summary, devastating damage concentrates along the active fault in the 2016 Kumamoto earthquake. However, focusing only on damage caused by fault displacement, it was shown that the range of damage is extremely limited.

Keywords: 2016 Kumamoto earthquake, active fault

Geometry of surface fault ruptures of the 2016 Kumamoto earthquake and house damages

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During the Kumamoto earthquake (Mw 7.3) on April 16, 2016 severe house damages were caused by the strong shaking and surface fault rupture along active fault known as the Futagawa-Hinagu fault in central Kyushu, southwest Japan and near-by faults some of which were not known before. Main surface fault ruptures with right-lateral slip appeared along northern part of the Futagawa-Hinagu
Severe house damages appeared in narrow zones several hundred meters from the surface fault traces, and destructive house damages were unevenly distributed and concentrated in the both ends of the main surface fault rupture as observed Mashiki town and Minami-Aso village. Along the main surface fault rupture sever house damages were locally concentrated in the places where surface fault ruptures make steps and bends, while house damages were relatively small along the areas where surface fault ruptures extends straight except for the damages on the fault traces. House damages along the surface fault ruptures with normal slip were rather small suggesting that ground shaking was not so strong.

Keywords: Kumamoto earthquake, fault geometry, house damage

Real-time Damage Estimations for the 2016 Kumamoto Earthquakes by J-RISQ

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The National Research Institute for Earth Science and Disaster Resilience (NIED) is developing a real-time earthquake information system for damage estimation and situation assessment (J-RISQ) as a Cross-ministerial Strategic Innovation Promotion Program (SIP). J-RISQ is able to immediately estimate earthquake damage by combining methods for predicting ground motion using amplification characteristic data for subsurface ground, basic information on population and buildings, damage assessment methods for buildings using fragility functions, and observation data such as real-time strong motion data obtained by K-NET, KiK-net, local governments, and JMA. A part of J-RISQ information is published as a "J-RISQ Report" on http://www.j-risq.bosai.go.jp/ immediately after the occurrence of an earthquake. In this study, we describe the estimations by J-RISQ for the 2016 Kumamoto earthquakes (M6.5 event and M7.3 event) with maximum seismic intensity of 7 caused great damage to human beings, buildings, and infrastructures.
J-RISQ issued the first report 29 seconds after the M6.5 event occurred and a total of seven reports for about 10 minutes. Finally the system estimated that population exposed to seismic intensity of 6 lower or larger was 620,000 and that of 6 higher or larger was 290,000. The estimated results of building damage showed that completely destroyed buildings were between 6,000 and 14,000. The distribution of estimated completely destroyed buildings spread 7 km long by 1 km wide in Mashiki town.
For the M7.3 event occurred about 28 hours after the M6.5 event, the system distributed the first report 29 seconds after the M7.3 event occurred and a total of eight reports for about 11 minutes. Finally the system estimated that population exposed to seismic intensity of 6 lower or larger was 1,130,000 and that of 6 higher or larger was 660,000. The estimated results of building damage showed that completely destroyed buildings were between 12,000 and 31,000. The distribution of estimated completely destroyed buildings spread in Mashiki town similar to the result of the M6.5 event and Kumamoto city. However, this result of damage building is out of consideration of the effect of the earthquakes including M6.5 event before M7.3 event.
The estimated spatial distribution of the belt-shaped region at Mashiki town qualitatively agrees with the actual damage status; however, the estimated results tend to overestimate the actual damage. Therefore, we aim to verify the precision of the estimated damage through a detailed investigation of damage to buildings and to make improvements to enhance precision. Building damage caused by the Kumamoto earthquakes may be attributed to the decreased strength of buildings because of repeated strong motion originating from the large foreshock, mainshock, and subsequent active seismic activity. We also plan to investigate real-time damage estimation methods taking into account such changes in building strength.

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Keywords: Kumamoto earthquake, Real-time Damage Estimation, J-RISQ

Modeling of the subsurface structure from the seismic bedrock to the ground surface for a broadband strong motion evaluation during 2016 Kumamoto earthquake.

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On April 16, 2016, a Japan Metrological Agency Magnitude (MJMA) 7.3 earthquake struck the Kumamoto Prefecture on the island of Kyushu in southwest Japan. This earthquake followed the MJMA 6.5 earthquake, which struck on April 14. Both the earthquakes registered a reading of 7 on the Japan Metrological Agency seismic intensity scale (IJMA), which is the highest reading on the IJMA, in the town of Mashiki approximately 6.5 and 5.5 km from the hypocenters of the main shock and foreshock, respectively.

The tendency damage is concentrating at the earthquake fault neighborhood confirmed the building damage distribution. However, even if damage is away from a little location and the fault even if it's right above the gap, the location where damage is big relatively is also confirmed. There is also comment with a high possibility caused by soil structure for these phenomena. We put it around Kumamoto plain in the fault neighborhood, collected borehole data and built initial stage geologic model, and a microtremor observation and seismography record were collected.

And secondary S-wave velocity model built highly precise ground model and did comparison and consideration with the building damage distribution.
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Keywords: Strong motion evaluation, S-wave velocity structure model, Microtremor array, Borehole data, Predominant period