Mr. Yuminamochi's photographs depicting ongoing liquefaction disaster during the 1964 Niigata earthquake
1964 年新潟地震に際して液状化発生と震災直後の市内の状況を映像記録した弓納持福夫氏の業績

Ikuo Towhata[1], Nozomu Yoshida[2]

1　Visiting Professor, Kanto Gakuin University 関東学院大学客員教授
2　Visiting Professor, Tohoku Gakuin University 東北学院大学客員教授

ABSTRACT

Mr. Fukuo Yuminamochi, who was a professional photographer and living in Niigata, took still photographs and motion pictures of ongoing liquefaction and the damaged Niigata City from the air at the onset of and immediately after the 1964 Niigata earthquake. This earthquake was an epoch-making disaster after which liquefaction has been attracting significant engineering concerns. Obviously, Mr. Yuminamochi's imageries helped concerned people understand this phenomenon correctly and were unforgettable achievement. It is important that Mr. Yuminamochi was able to take those imageries as a consequence of remarkable combination of miracles that he was ready to do his business with cameras, films, aircrafts, fuels and supporters ready. In 2023, he transferred all of his imageries to the care of the Japanese Geotechnical Society so that they might be open to free use. In this context, the present paper explains the photographs with, if available, more information added. As an open resource, Mr. Yuminamochi's products can be used by anybody for good purposes without acquiring the permission of the Society. Only one requirement is that the photographs are presented with a credit that they were taken by Mr. Yuminamochi and that they are now preserved by the Japanese Geotechnical Society.

1964 年の新潟地震の発生に際し、新潟在住の写真専門家である弓納持福夫氏が、液状化発生の瞬間から地震直後の新潟市の被災状況までを、地上と航空機の両方から、静止画像と 8 ミリ動画で明確に記録されたことは、すでに広く知られている。液状化現象が自然災害の一種として工学的な対応を迫られるきっかけとなったのがこの新潟地震であり、それと同時に早くも現象の実態が画像として明瞭に記録されたことは、その後の技術の発展において極めて有意義であった。弓納持氏がそのような業績を残すにあたっては、同氏が地震発生の瞬間に装備、飛行機など諸条件がすべて整った状態で現場に存在した、という偶然の組み合わせに、後世の人間は驚かされる。2023 年、弓納持氏は映像すべてを地盤工学会の管理に寄託されることとなり、学会としては誰でも自由に利用できるよう、学術的な意義説明を合わせて、JSTAGE の機構を通じてすべての映像を一般公開することにした。この趣旨に沿って本論文は、弓納持氏撮影の映像にその後の知見を合わせて説明を加えるとともに、必要に応じて他の情報をも追加して、読者の理解に資することにした。文中でも記述しているが、公開された弓納持氏の映像は、撮影者として同氏のお名前、そして管理者として地盤工学会の名前を明記することを条件として、誰でも許諾申請無しに使用することができる。斯界の発展に永く役立てば幸いである。

KEYWORD: liquefaction, 1964 Niigata earthquake, photographs　液状化、1964 年新潟地震、記録写真

1. Introduction

The 1964 Niigata earthquake of Mw=7.6 occurred at 1:01:40 PM on June 16th and severely affected the City of Niigata at an epicentral distance of around 40 km. Because Niigata City was a modern city equipped with a variety of lifelines, this earthquake provided an important opportunity in which the seismic resilience of a modern city was examined. Although liquefaction phenomenon had occurred many times before this earthquake, it happened mostly in free fields where there was little urban development. Hence, engineers had not paid much attention to it. In contrast, the subsoil liquefaction in Niigata exerted a profound influence on operation of not only buildings, bridges, quay walls and railways but also embedded pipelines. The pipeline damage resulted in the loss of lifeline services that were providing water and gas as well as collecting sewage.

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Among a variety of damage types, the most striking was the liquefaction and the induced loss of bearing capacity in loose sandy ground (Fig. 1) that had been considered, until 1964, free of consolidation problem and favorable soil condition. After this earthquake, the public sectors made efforts to develop and implement liquefaction-prevention measures such as densification of sand and relevant design codes. Thus, the liquefaction phenomenon in 1964 was an epoch-making event. It was fortunate that two people, namely Mr. Fukuo YUMINAMOCHI (a professional photographer) and Mr. Yutaka TAKEUCHI who was a student of Meikun High School, visually recorded the liquefaction disasters on the same day when the earthquake occurred by means of still photographs and a motion picture[1), 2), 3), 4)].

The present paper aims to introduce all the still photographs and the famous motion picture of liquefaction taken by Mr. Yuminamochi who donated all his photographs and motion picture of the Niigata earthquake to the Japanese Geotechnical Society. In commemoration of his good will, this paper was written so that, in combination with his imageries, the future generation of liquefaction researchers and practitioners may understand the liquefaction phenomenon clearly and precisely. Mr. Yuminamochi's photographs were previously published without detailed information by JGS[1), 2)] but this time relevant and additional explanations are added of his activities before and after the disaster. On the other hand, the still photographs by Mr. Takeuchi were published by the Japan Association for Earthquake Engineering in 2014[3)] as well and is out of scope of this paper. The following sections attempt to reproduce what Mr. Yuminamochi experienced at the time of the Niigata earthquake on the basis of the authors' interview that took place in 1998 and on May 13th, 2023. To shed more light to the details, the present paper uses more imageries from different sources that are available to the authors.

Fig. 1. Overturned apartment building in Kawagishi-Cho, Niigata, that was situated on loose sandy ground without pile foundation (Reconnaissance team, University of Tokyo) ゆるい砂地盤上に設置された川岸町アパートの倒壊（東京大学土木工学科教官調査団撮影）

2. Before the earthquake

Mr. Yuminamochi was born in 1936 and was educated to be a professional photographer. In 1957, he started his career as a TV cameraman. In 1964 when he was 27 years old, he was in charge of commercial photography in a private firm. Thus, when the Niigata earthquake happened, he had an ample experience and skill in taking photos for media and also from the air.

As is well known, two most important features of Mr. Yuminamochi's photographs on Niigata earthquake are that they were taken exactly when liquefaction and sand ejection started in the Niigata Airport and that many aerial photographs were then taken from a Cessna light airplane that immediately took off from the airport. The pilot of the airplane was Mr. Masatoshi SATO who had a long professional career for more than 20 years (Fig. 2). Mr. Yuminamochi met this experienced pilot for the first time one month before the earthquake when he was waiting for another aircraft coming from Tokyo. He was supposed to take air photos for a mission of a printing company but the aircraft could not take off from Tokyo due to bad weather. At this moment, Mr. Sato, who was also in the airport,

offered help for Mr. Yuminamochi. Fortunately, the weather in Niigata was getting better. After this successful collaboration, Mr. Sato asked Mr. Yuminamochi to solve his problem that he and his technicians had to leave their dormitory in Niigata but could not find the next place to live because the national sports festival was scheduled soon in early June and accommodations were fully booked in the city. Mr. Yuminamochi was delighted to arrange for them an apartment room owned by his friend. Thus, their friendship started.

Mr. Yuminamochi got another air-photo business that was scheduled on the day of the earthquake and decided to hire Mr. Sato's Cessna aircraft again because his plane was available in Niigata and was less expensive than calling another aircraft from Tokyo.

Fig. 2. Mr. Yuminamochi (left) and Mr. Sato (right), the pilot, in Niigata Airport on June 27, 1984 弓納持福夫氏（左）とパイロットの佐藤正敏氏（右）（1984年6月27日新潟空港にて撮影）

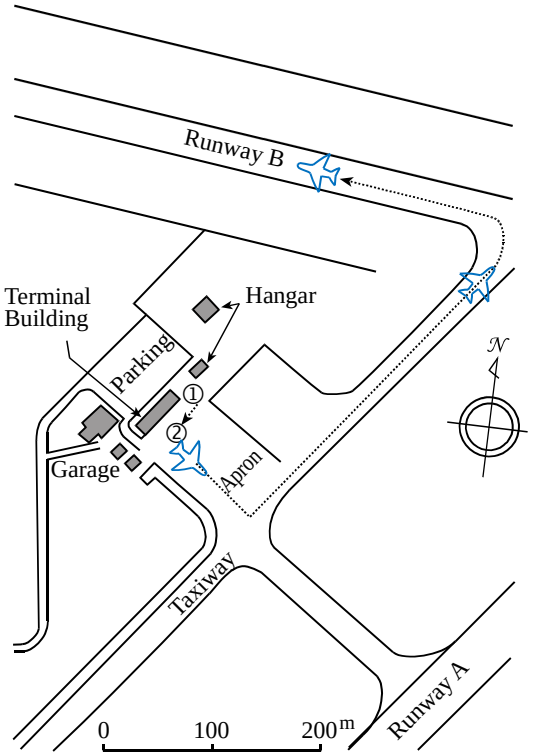


Fig. 3. Plan view of Niigata Airport and its terminal building (① Mr. Yuminamochi's location of taking motion picture, ② location of his aircraft) 当時の新潟空港平面図とターミナルビルディングの位置

3. At the Niigata Airport on the day of the Niigata earthquake

Five people were on board who were Mr. Yuminamochi, his assistant (Mr. Kazunori TAMAKI, 19 years old, 田巻一徳氏 [5]), the pilot (Mr. Sato), an aviation mechanic, and an operator of aerial survey devices (Mr. Katafumi, OHNO, 大野賢文氏). Because the major mission of this aircraft was aerial survey, the device (camera) for this mission was heavy. This issue became important later on the same day. When the earthquake shaking started, Mr. Sato was visiting the control tower to submit his flight plan but the officers there had gone to a safer place and nobody was there.

On the other hand, Mr. Yuminamochi was staying in front of the terminal building (Fig. 3) when the ground shaking started. He could not stand up under strong shaking and squatted on the ground. He felt that the shaking was slow and large as if staying on a floating island. He then realized that he had to record the disaster as a professional and prepared one of his still cameras (Fig. 4). Nothing was happening around the terminal building. Then, suddenly people rushed out of the building (Fig. 5), shouting that the building was sinking. Two still photographs were taken and Mr. Yuminamochi realized that taking still photos required film setting and many time-consuming procedures. To record more information within a short time, he decided to take a motion picture. This was the time when sand ejection started in front of him. Figs. 6 to 11 were captured from the motion picture. In Fig. 6, ejection is not yet visible but probably a part of black color shown by an arrow indicates the beginning of ejection. It became clear and impactful quickly in Fig. 7.

In 2005, Mr. Yuminamochi reviewed the elapsed time during his experience[6], saying

- he was trying to take the earthquake photograph by his Speed Graphic camera for one to two minutes but could not take any interesting one,
- one to two minutes after the onset of shaking, people came out of the building and one of them shouted that the building was sinking,
- he took two still photos and realized that the Speed Graphic photo was time consuming and that motion picture was better,
- he had been recording the overall situation of the terminal building but the slow subsidence was not clearly recorded,
- therefore, he decided to zoom at the entrance of the building,
- when he started his motion picture, sand ejection suddenly started (Figs. 6 and 7), and
- the ejection occurred at several places one after another, each lasting for 10 seconds or so.

It seems reasonable that approximately 2.5 to 3 minutes was elapsed between the onset of ground shaking and the beginning of water ejection. Moreover, both still photos and motion picture were taken in a standing position. The ejected water level reached slightly above his knees and the water was not warm. The two still photographs were submitted to a newspaper company in Tokyo and were not returned.

Soon after this moment, Fig. 8 of black smoke in the sky was taken. This smoke likely came from the fire in the oil refinery in the airport vicinity. Mr. Yuminamochi intended to record the timing of the fire by this photograph, saying that the smoke was recorded about three minutes after the onset of shaking[6]. Therefore, it is reasonable that the fire started approximately at the same time as the onset of ground shaking. Then, Figs. 9 and 10 indicate that the ejected water spread rapidly into the airport apron where two aircrafts were ready to take off. Out of them, the smaller one was what Mr. Yuminamochi was going to take. Fig. 11 illustrates the terminal building again wherein the building is substantially submerged in the ejected water but no structural damage is seen in walls, columns and windows. The rate of motion picture was 18 frames per second. After these experiences, the pilot, Mr. Sato, told Mr. Yuminamochi to get aboard the aircraft to escape from this dangerous place.

Fig. 4. Mr. Yuminamochi's Nikon 8-mm movie camera (left) and Linhof Technika still large-format camera (right) for color photographs with 4'×5' film with 150-mm lens (he had two more cameras that were Speed Graphic for black-and-white 4'×5' photographs with 127-mm lens and Asahi Pentax with 35-mm and 135-mm telescope lenses) (photograph provided by Mr. Yuminamochi) 弓納持氏の使用したニコン8ミリ撮影機とリーンホフ・テクニカカメラ（弓納持氏提供の写真）

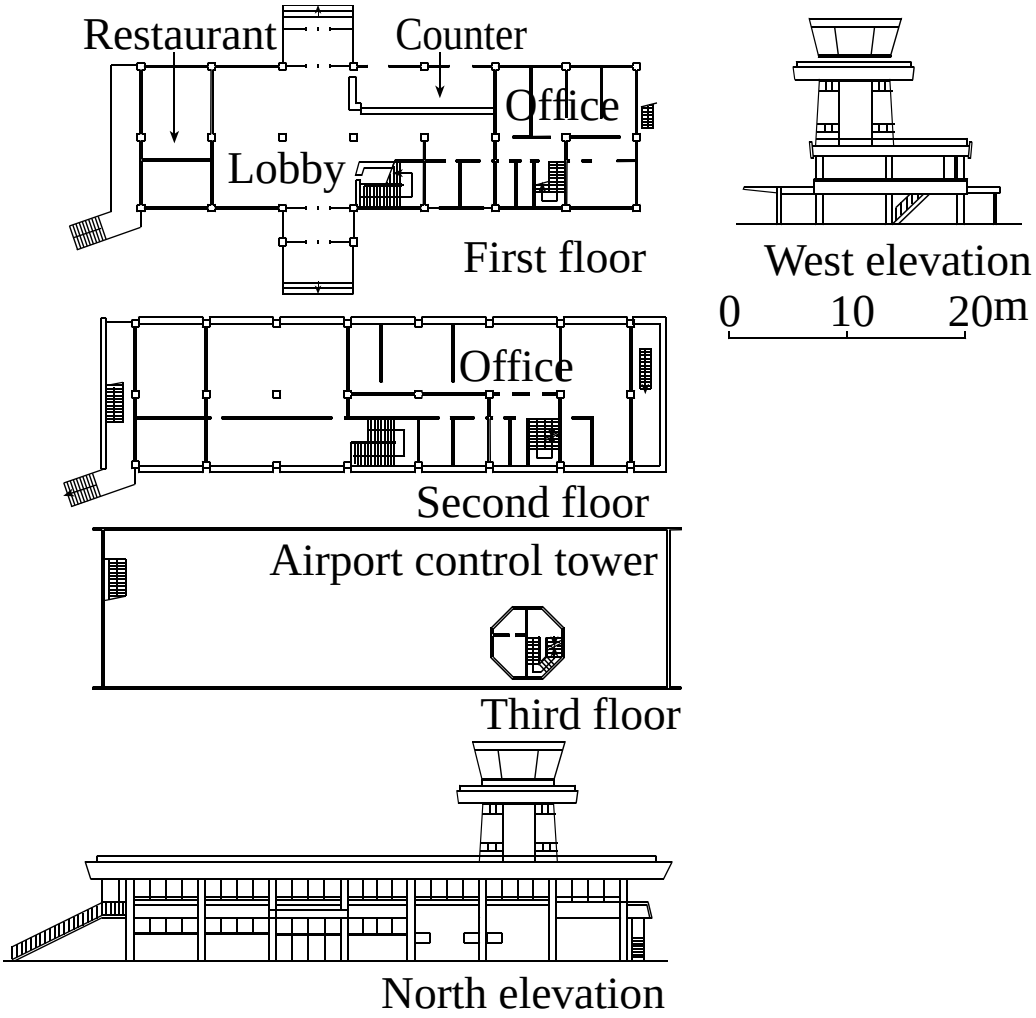


Fig. 5. Conceptual sketch of the terminal building in Niigata Airport (the liquefaction-induced subsidence of the first floor under the ground surface) 新潟空港ターミナルビル地震前の状況のスケッチ

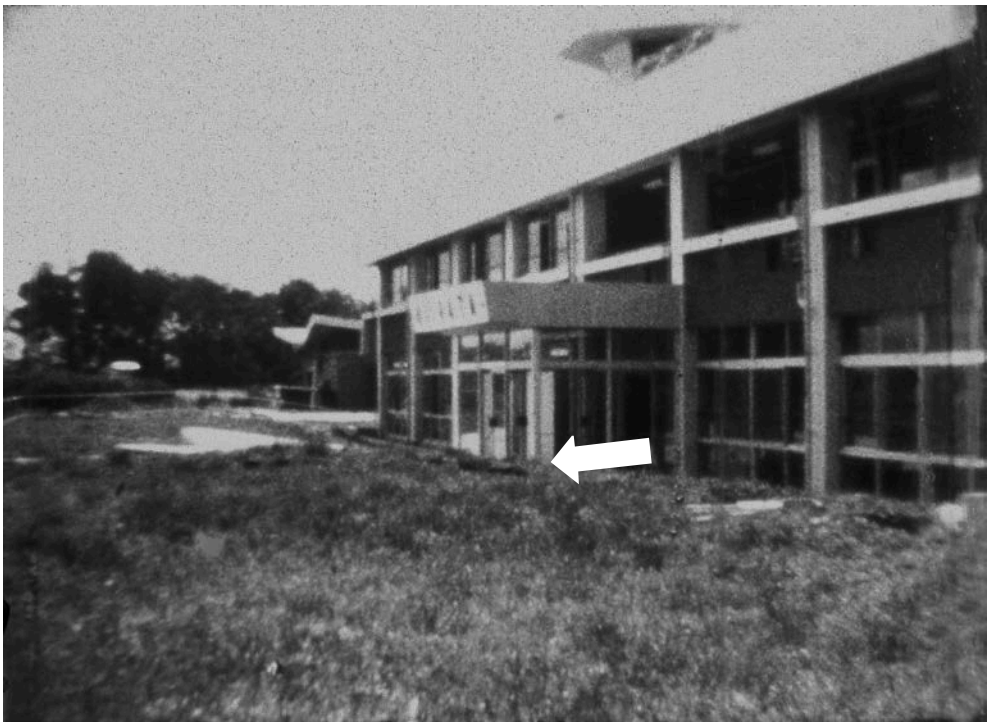


Fig. 6. First scene of Mr. Yuminamochi's motion picture in which sand ejection has not yet started with an arrow suggesting heaving of ground surface 液状化動画の冒頭部、まだ噴砂は始まっていない、矢印は地表の膨張らしき状況を示す

Fig. 7. Beginning of ejection of sand and water in front of the terminal building (captured from Mr. Yuminamochi's motion picture) 噴砂噴水の始まり

Fig. 8. Black smoke coming from the oil refinery (captured and enlarged from Mr. Yuminamochi's motion picture) 製油所から上る黒煙

Fig. 9. Ejected water spreading into the airport apron (1) (captured from Mr. Yuminamochi's motion picture) エプロンに広がる噴出水(1)

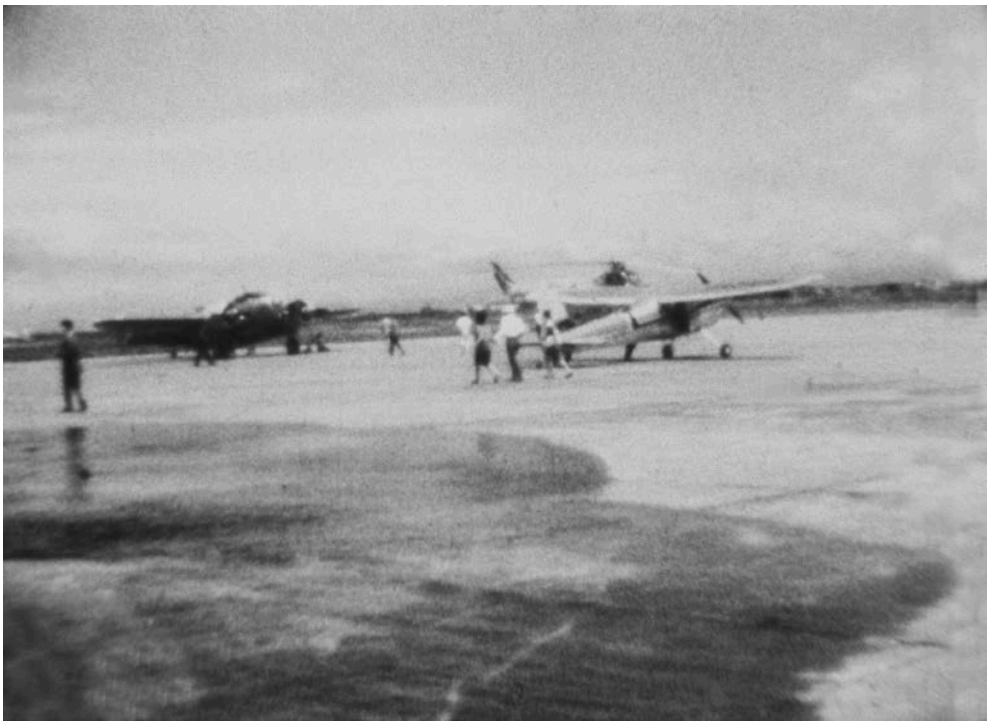


Fig. 10. Ejected water spreading into the airport apron (2) (captured from Mr. Yuminamochi's motion picture) エプロンに広がる噴出水(2)

Fig.11. Terminal building inundated by deeper ejected water (captured from Mr. Yuminamochi's motion picture) 水没しつつある空港ビル

4. Combination of miracles at the Niigata Airport

The Niigata earthquake was the first dramatic event that demonstrated the importance of engineering studies on liquefaction, as stated before. Upon this epoch-making occasion, Mr. Yuminamochi's aerial photographs and motion picture together with the abovementioned photographs by Mr. Takeuchi provided the 'real' view of liquefaction disaster. Moreover, Mr. Yuminamochi's photographs were made possible by the miraculous combination of the followings;

(1) Mr. Yuminamochi was a skilled professional photographer,

(2) he had a mission of aerial photographing and came to the airport,

(3) he had a professional still cameras with films together with an 8-mm movie camera (Fig. 4),
(4) although his business did not require it, Mr. Yuminamochi had his movie camera by accident simply because, a few days before, he had had another mission of taking a motion picture of a ferry that Emperor had taken during the Royal visit to Sado Island off Niigata.
(5) he had bought 8-mm films in the airport building shortly before the onset of the earthquake.
(6) The Cessna aircraft was fully fueled, with the pilot, the mechanic and the assistant on board, waiting for Mr. Yuminamochi, and a flight plan had been approved. Thus, the aircraft was ready to take off at any time.

When the Cessna aircraft came to the runway, its surface had been flooded by liquefaction water and a bigger plane (Fig. 10) was reluctant to go. The bigger plane was afraid of possible runway depression and was trying to communicate with the control tower. Mr. Sato, the Cessna's pilot, had visited the tower and knew that there was nobody in the tower. So, he told the bigger aircraft to just go. After confirming its successful take-off, the Cessna aircraft followed.

5. Aerial photographs taken by Mr. Yuminamochi

This section introduces the still photographs that were taken by Mr. Yuminamochi from the Cessna aircraft. When the Cessna aircraft took off, Mr. Yuminamochi, who had just got the first baby 10 days before, was upset, worrying about the safety of his family. The knowledge of the 1923 Kanto earthquake, that totally devastated Tokyo by fire and claimed one hundred thousand victims, was clear to him and the same disaster could have been repeated in Niigata. At this moment, the pilot, Mr. Sato, encouraged him to take this extremely rare and important opportunity as a professional photographer. Then, the first target that Mr. Yuminamochi was interested in was the fire in the oil refinery and proposed the pilot to approach the fire. However, this idea was declined because of the high risk of updraft wind. Then, the second idea was the route, passing near the fire, and flying over the city along the Shinano River (Fig. 12).

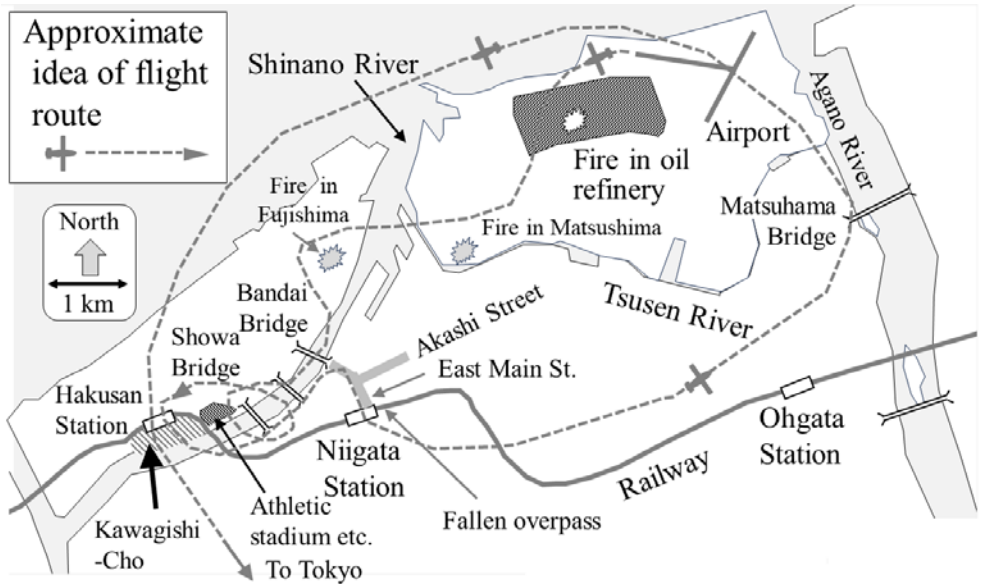


Fig. 12. Route of Mr. Yuminamochi's flight above Niigata City (IITT Imagery Bank) 当日飛行ルートの概要

5.1 Fire in oil refinery

The still photographs are explained in what follows. Fig. 13 shows the fire in the oil refinery that is located between the airport and the Shinano River mouth (Fig. 12). Figs. 13 and 14 show that the surface of the airport was covered by liquefaction-ejected water. Note here that Mr. Yuminamochi got seated on the left side of the aircraft throughout his flight.

Fig. 13. Fire of oil refinery as seen from the airport area (still photo taken by Mr. Yuminamochi) 機内左側座席に着席した弓納持氏による製油所火災の情景

Fig. 14. One of the two runways of Niigata Airport towards the right from which the aircraft took off (still photo taken by Mr. Yuminamochi) 噴出水に覆われつつある滑走路

The oil refinery was affected by two fires[7), 8)]. The first fire started at 1:02 PM, which was one minute after the onset of the earthquake. This fire was initiated by collision of metal members of the tank and affected 21 houses. This fire lasted for 15 days. Figs. 15 to 18

indicate the fire from shorter distances. Note herein that the fire occurred in the inland area, with no influence of tsunami inundation. The second fire near the sea area (Fig. 18) started later at 6 PM on the same day[8)] and had not yet started when the photographs were taken. The second fire triggered explosions of many oil tanks. Until it was extinguished at around 5 PM on June 20th, 27 families lost their houses in addition to the abovementioned explosion of oil refinery facilities. The reason of the delayed occurrence of the second fire is unknown. Because the affected area was inundated by tsunami water, it is likely that the burning oil was transported into a bigger areas by the flow of water.

Fig. 15. Fire of oil refinery from short distance (1) (still photo taken by Mr. Yuminamochi) 製油所の火災

Fig. 16. Fire of oil refinery from short distance (2) (still photo taken by Mr. Yuminamochi) 製油所の火災

Fig. 17. Fire of oil refinery from short distance (3) (still photo taken by Mr. Yuminamochi) 近距離から撮影した製油所の火災

Fig. 18. The area of what was going to be the second fire of oil refinery near the sea (not yet started) in front of the first fire (still photo taken by Mr. Yuminamochi)
手前は夕刻になって発生することになる第二火災の現場

5.2 Fires in the city

After viewing the oil refinery, the aircraft came into the city area. Two fires in Fig. 19 occurred near the Tsusen River (shown in Fig. 12), which is a minor canal today but used to be the bigger main channel of the Agano River until its flood in 1731. These two fires

Fig. 19. Fires in Matsushima-2 on the north bank of Tsusen River (still photo taken by Mr. Yuminamochi) 通船川北岸松島二丁目の火災

Fig. 20. Fire in Fujishima-3 on the left bank of Shinano River (still photo taken by Mr. Yuminamochi) 信濃川北岸藤島三丁目の火災

were extinguished by firefighters[7), 8)] but recalled Mr. Yuminamochi of the catastrophic fire in Tokyo triggered by the 1923 gigantic Kanto earthquake. The fire in Fig. 20 on the left (north) bank of the Shinano River recalled him again of the disaster in 1923; his wife and a new-born baby remained in the city. Fortunately, the area of this fire near the Shinano River was flooded later by the water of tsunami that, at least partially[7), 8)], extinguished the fire and helped the city avoid catastrophic disaster.

5.3 Urban development of Niigata as shown in old city maps

Prior to discussion on liquefaction, the present paper describes the sand filling of the former channel of the Shinano River. The catchment of this river is 11,900 km^2 and caused floods in the Echigo Plain of Niigata frequently in the past. The width of the channel in Niigata City used to be 400 m or more and water transportation in this big river supported the trading business of Niigata City that was situated at the river mouth and served connection between ocean and river transportations. The nearby Agano River (Fig. 12) was another transportation route (catchment area = 770 km^2) and benefited the business of Niigata as well. This river caused many flood disasters as well.

In 1922, a drainage channel was installed at Ohkozu, approximately 60 km in the upstream direction of the Shinano River, and, since then, substantial amount of flood water has been discharged directly into the ocean. Thus, it became possible to reduce the river width in Niigata and to expand the city area by filling the channel with the river bed deposit together with dune and beach sands that were available near the city. Fig. 21 illustrates the city, Hakusan-ura Cove of the river channel, and the beach in 1849. The sand filling took place from 1929 to 1939[9)] and consisted of disposal of fine uniformly-graded sand into water without compaction, thus producing highly liquefaction-prone sandy ground. This cove area was renamed Kawagishi-Cho that literally meant riverside town. After land filling along the river channel, the river width decreased to 200 m.

The map in Fig. 22 was published in 1883 in which the filling project had not yet started and the cove is found near the left edge. There is no bridge across the Shinano River yet. Fig. 23 is another map dated 1889. The major change from the previous map is the Bandai Bridge of the first generation (toll bridge) which was a wooden structure. Note further in Figs. 22 and 23 that the commercial town in their center had many canals that were later filled with sand. After the earthquake in 1964, Niigata University carried out detailed reconnaissance investigation on location of sand ejection and tilting buildings over the city and, in the former commercial district, such phenomena were concentrated along these abandoned canals[10)].

Fig. 21. Old map of Niigata in 1849 (IITT Imagery Bank) 1849年の新潟

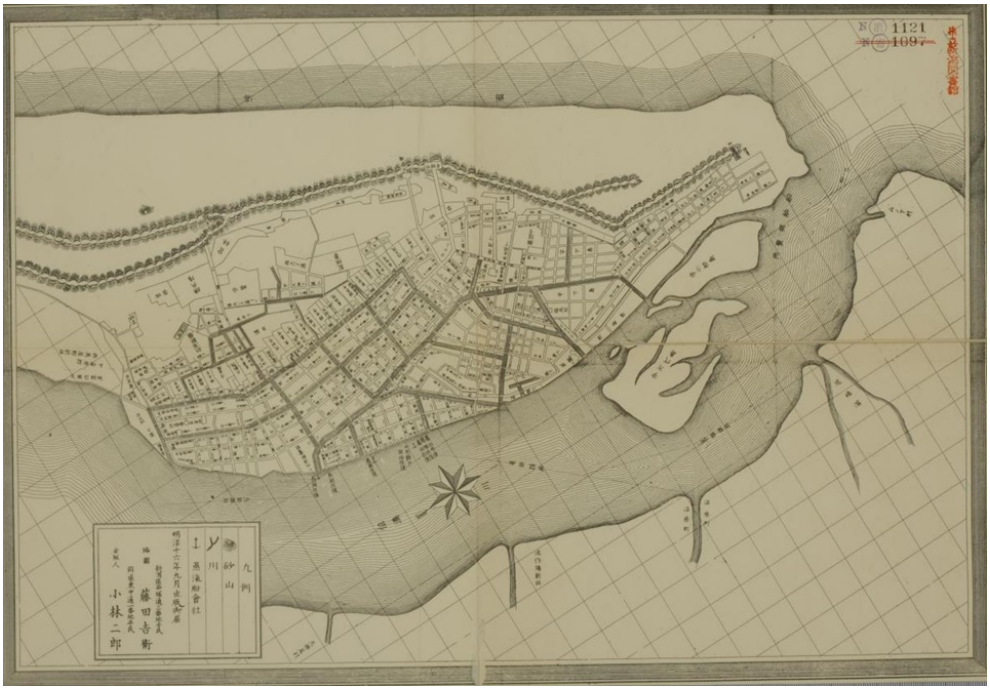


Fig. 22. Old map of Niigata published in 1883 (IITT Imagery Bank) 1883年の新潟

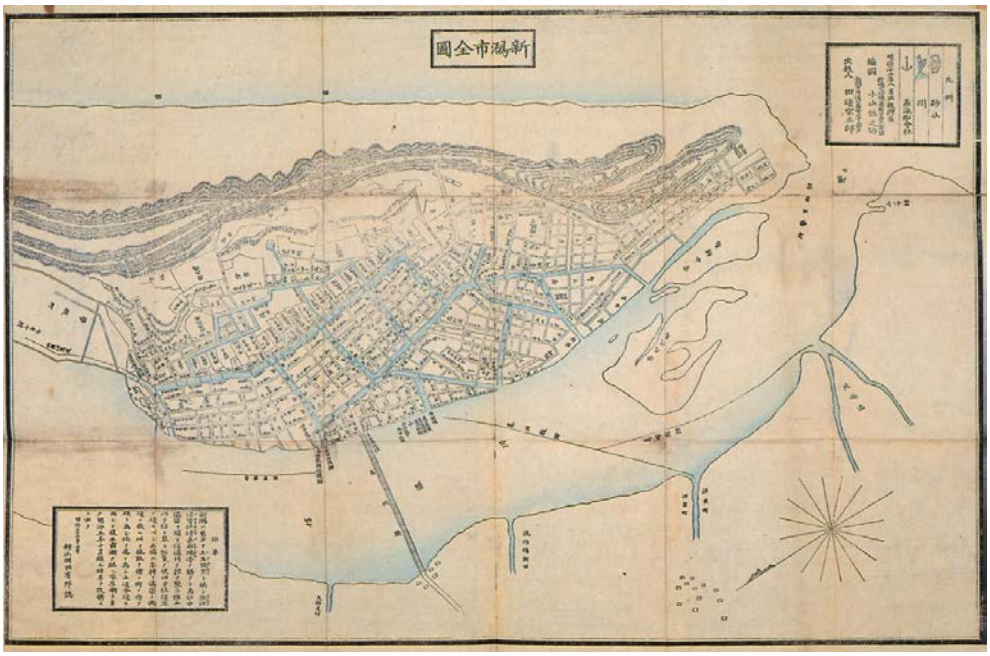


Fig. 23. Old map of Niigata published in 1889, showing the Bandai Bridge across the river (IITT Imagery Bank) 1889年の新潟、萬代橋が架橋された

5.4 Bandai Bridge

Figs. 24 and 25 show the Bandai Bridge of the second generation that was constructed in 1929 after the river width was reduced and is an RC arch bridge. This bridge survived the earthquake and served for evacuation of people during the aftermath. Nevertheless, the approach road suffered a big crack in the longitudinal direction (Fig. 25). The timbers in the water imply that they were transported by flow of tsunami water from the timberyard in the more downstream area and that these photos were taken after arrival of tsunami. Tsunami arrived at Niigata after 1:35 PM and reached Kawagishi-Cho 3-chome[11), 12)]. Note that the revetment wall along the river totally fell down and induced lateral displacement of the backfill surface (Fig. 25). Consequently, the revetment wall around the northern end of the bridge distorted to be curved (Fig. 26) because the rigid Bandai Bridge prevented the lateral displacement of the wall in its vicinity only.

Fig. 24. Bandai Bridge (1) (still photo taken of the south bank of the river by Mr. Yuminamochi) 万代橋の地震後の状況(1)

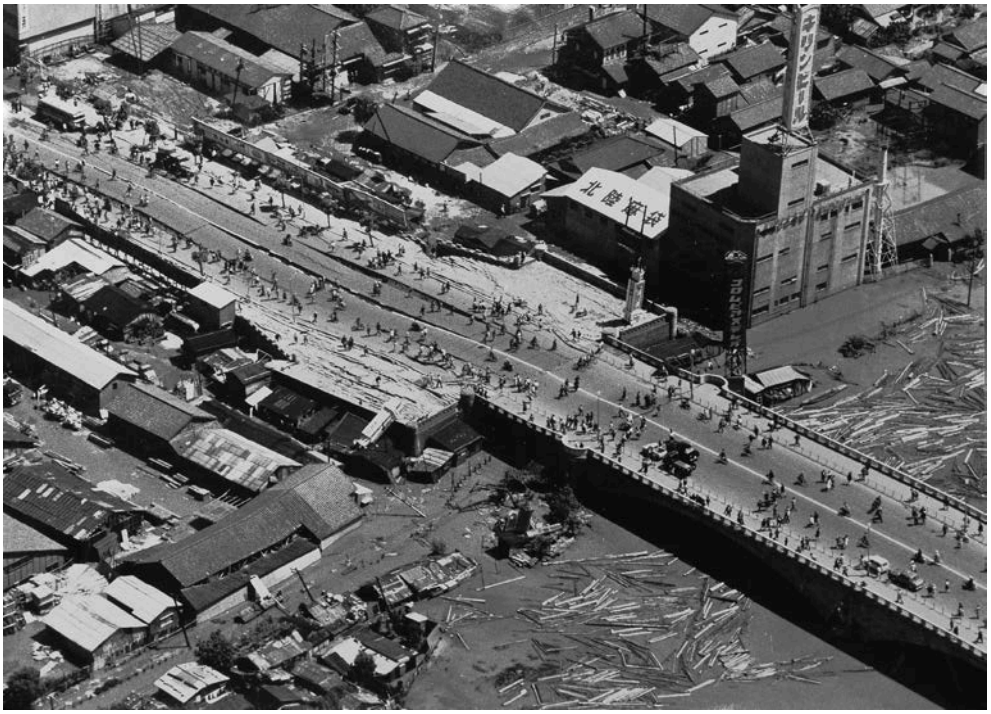


Fig. 25. Bandai Bridge (2) (still photo taken of the south bank of the river by Mr. Yuminamochi) 万代橋の地震後の状況(2)

Fig. 26. Distorted shape of the revetment wall in 2003 at the northern side of the Bandai Bridge (IITT Imagery Bank) 万代橋北たもとの護岸の曲線型変状

5.5 Showa Bridge and its vicinity

Figs. 27 and 28 show the collapse of the Showa Bridge that had been completed only a few weeks before the earthquake when the national sports festival took place in Niigata. The athletic stadium for this festival is seen as well at the top right corner of Fig. 27a. Five spans of the bridge fell down into the river. Moreover, the revetment wall along the Shinano River collapsed and triggered lateral displacement of liquefied ground behind the wall. Fig. 27b demonstrates the detailed situation in the Hakusan Elementary School in which the swimming pool near the river was sheared laterally, perpendicular to the river, and the surface of the school yard was covered by liquefaction ejecta. The road in front of the school (right-hand side) was covered by whitey liquefied sand. The access-road embankment of the Showa Bridge developed several longitudinal cracks as a consequence of its lateral extension (Fig. 27b).

Figs. 29 and 30 were taken when the aircraft was flying near the Showa Bridge. This photographic view towards the downstream area recognizes three fires; white smoke on the northern side (left side) of the river came from the fire in Fig. 20. The dark smoke came from more downstream areas and seems to be a mixture of the fires in the oil refinery (Fig. 18) and the fire in factories (Fig. 19). Fig. 29 appeared in the New York Times on June 17[13].

(a) Arrow showing Hakusan Elementary School in which ejected ground water is visible as a patch on the surface　矢印は被災した白山小学校の位置を示す

(b) Details of liquefaction damage in the Hakusan Elementary School　白山小学校被災の詳細

Fig. 27. Fall of Showa Bridge and the substantial damage of the revetment wall along the river (1) (river flow towards the bottom of photo) (still photo taken by Mr. Yuminamochi) 昭和大橋周辺の状況

Fig. 28. Fall of Showa Bridge and the substantial damage of the revetment wall along the river (2) (downstream to the left) (still photo taken by Mr. Yuminamochi) 昭和大橋近隣の護岸の被害

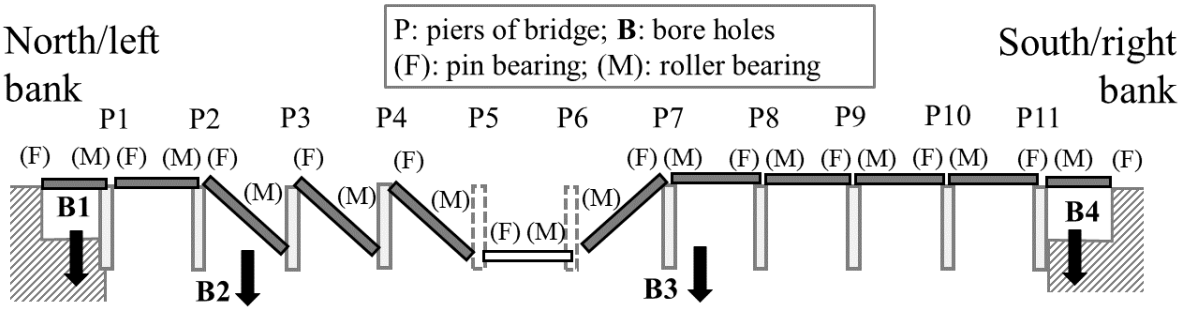
Fig. 29. Aerial view from the Showa Bridge towards the mouth of the Shinano River (1) in which the three bridges are the fallen Showa Bridge on the front side, the Yachiyo Bridge in the middle and the Bandai arch bridge at the far distance (still photo taken by Mr. Yuminamochi) 昭和大橋上空から信濃川河口方向を望む

Fig. 30. Aerial view from the Showa Bridge towards the mouth of the Shinano River (2) (still photo taken by Mr. Yuminamochi) 昭和大橋上空から信濃川河口方向を望む

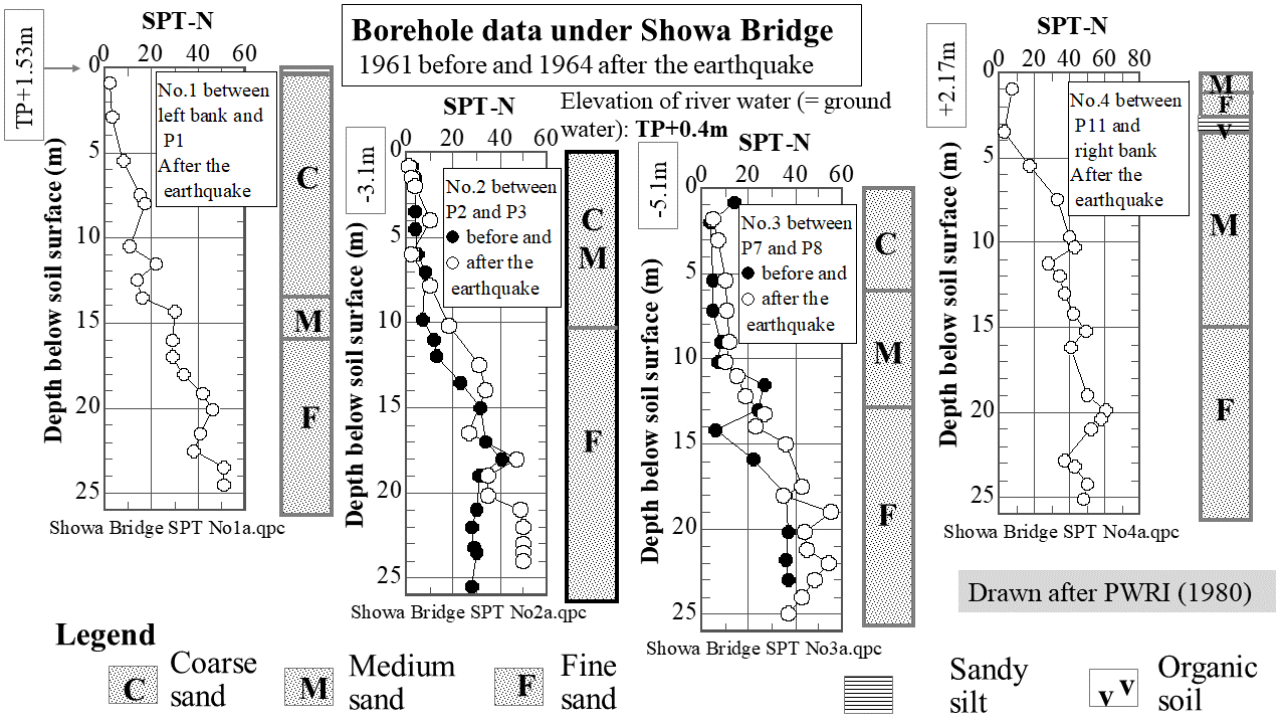
Fig. 31 exhibits the *SPT* (Standard Penetration Tests) cross sections under the Showa Bridge published in 1980[14]. Two profiles were obtained before the earthquake (●), whereas four were after the earthquake (○). There were and are loose material down to approximately 10 meters below the river bed, which is shallower than the depth of the pier foundations. It seems that SPT-*N* increased to a certain extent after the earthquake. Further note that finer sand dominates at lower elevation, while coarser material prevails near the surface.

Interview with eyewitnesses strongly suggested that the bridge fell down after shaking[15), 16)], indicating that the earthquake-induced inertial effect was not the causative mechanism, whereas more important roles were played by the loss of rigidity and lateral flow of liquefied subsoil. It should be borne in mind that those eyewitness remarks addressed the end of 'felt' strong shaking and do not necessarily mean the end of weaker but prolonged displacement oscillation. It was also reported that black columns appeared at the river surface[15)], which may imply substantial liquefaction in the river bed.

Fig. 32a presents the view of the upstream direction from the Showa Bridge. The sports facilities just beyond the bridge (northern bank, right-hand side in this photograph) are seen clearly. The railway bridge at a far distance appears less damaged than the Showa Bridge. As stated before (Fig. 14), Mr. Yuminamochi was seated on the left side of the aircraft. Since the route of the flight was counterclockwise in principle above the city (Fig. 12), he could not take photos of the upstream area except this photograph. Only Fig. 32 captured the famous tilting of the Kawagishi-Cho Apartment Buildings. The portion of the apartment buildings was extracted, therefore, and magnified in Fig. 32b. Taking this photograph, Mr. Yuminamochi did not recognize this famous tilting.



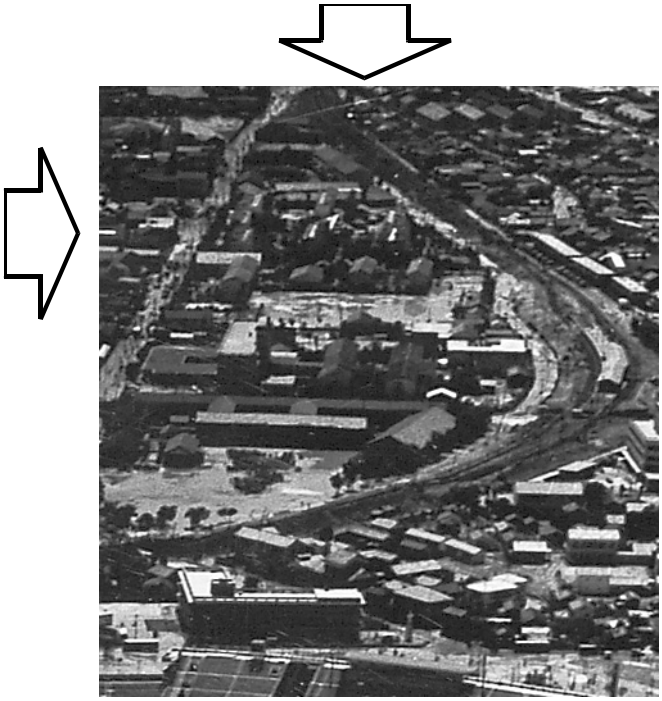
(a) Location of bore holes at Showa Bridge site 昭和大橋サイトの地盤調査地点[14)]



(b) Four bore hole profiles along the Showa Bridge; piers reached 19 m below the river bed 昭和大橋地点の標準貫入試験結果[14)]

Fig. 31. SPT-*N* profiles along the Showa Bridge 昭和大橋のサイトにおける標準貫入試験結果

(a) Entire view (the Echigo Railway Bridge at far side survived the earthquake) 全体写真



(b) Extraction of the part of the tilting Kawagishi-Cho apartment buildings (location indicated by arrows) 矢印は川岸町アパートの部分の拡大写真

Fig. 32. Aerial view of the upstream direction from the Showa Bridge area (still photo taken by Mr. Yuminamochi) 昭和大橋から信濃川上流方向を望む

Niigata Prefecture hosted the national sports festival from June 6th to 11th of this year. For this big event, many sports facilities were constructed and the liquefaction-prone area along the Shinano River (Fig. 12) was the most important place of construction. Only five days after the closing ceremony of this event, the constructed facilities were affected by the earthquake. Fig. 33 indicates the view after liquefaction damage, while more details are shown in Figs. 34 and 35. It was fortunate that the athletic stadium in Fig. 35 avoided structural damage, as is the common case with structures resting on liquefied subsoil, and has been used since then.

Fig. 33. Liquefaction around the sports complex near the Showa Bridge (still photo taken by Mr. Yuminamochi)　競技場地区

Fig. 34. Liquefaction in and around the baseball stadium (still photo taken by Mr. Yuminamochi) 野球場周辺の被害状況

Fig. 35. Athletic stadium that was just completed for the national sports festival in June 1964 (still photo taken by Mr. Yuminamochi) 陸上競技場の被災状況

Fig. 36. People seeking for dry place near the Hakusan Station of Echigo Railway (still photo taken by Mr. Yuminamochi) 越後線白山駅周辺で、水におおわれていない場所に避難する人々

Fig. 37. People seeking for dry evacuation place (still photo taken by Mr. Yuminamochi) 乾いた地面に避難する人々

Fig. 38. Subsidence and lateral spread of the Echigo Line railway embankment (Shinano River and Kawagishi-Cho Apartment Buildings located to the left of this picture) (photograph by University of Tokyo) 越後線盛土の変状

Figs. 36 and 37 depict the situation in the residential district near the Hakusan Railway Station. People are seeking for the areas that are not flooded by water (Fig. 36). The water in Fig. 37 came probably from liquefaction, whereas the other possible water source is inundation under tsunami water. The railway embankment in Fig. 36 was distorted significantly due to its subsidence into liquefied subsoil (Fig. 38).

5.6 Towards the Niigata Railway Station

From Fig. 39 on, the views are presented on the situation near the Niigata Station on the southern side of the Shinano River. First, Fig. 39 depicts the situation along the East Main Street from the Bandai Bridge (below the bottom of this picture) towards the south. In the middle of this picture, the road surface is entirely flooded (by liquefaction water, tsunami inundation, or their mixture). To the further south, Fig. 40 illustrates a similarly affected situation in the area of the East Main Street and the Akashi Street. Pay attention to the tilting of an RC building. This building is more closely presented in Figs. 41, 42 and 43. In spite of its substantial subsidence and tilting, there is no structural damage; walls, columns and windows are intact. It deserves attention in Fig. 40 that other buildings did not undergo noticeable tilting or subsidence. Possibly, local soil conditions were different from place to place but there is no further evidence. Fig. 42 illustrates a clear contrast in damage extents of this RC modern building and a more classical wooden two-storey house. The latter exhibits virtually no subsidence probably because its contact weight (weight per unit footprint area) was lighter than that of the RC building and was less likely to subside into the liquefied ground. The direction of tilting of the RC building (Fig. 42) was towards its back side most likely due to the eccentricity of its gravity center, as suggested by the additional roof structure. Fig. 43 clearly demonstrates the subsidence of this building into liquefied subsoil. The intact glass of window is noteworthy, implying that liquefaction unlikely causes structural damage of buildings and houses.

Fig. 39. View on the south bank of the Shinano River; from the Bandai Bridge along the East Main Street, towards the Niigata Railway Station (still photo taken by Mr. Yuminamochi) 万代橋上空から新潟駅方向を望む

Fig. 40. Akashi Street near the Niigata Station in which the road surface is flooded by liquefaction ejecta 明石通りの液状化被害

Fig. 41. Tilting of RC building in Akashi Street resting on liquefied subsoil (still photo taken by Mr. Yuminamochi)　傾斜したビルディング

Fig. 42. Contrast in damage extents of heavier RC building and lighter wooden two-storey house[17] (this photograph can be used for academic/engineering purposes freely with reference to the literature 17; no request for permission needed) RC ビルの傾斜と木造家屋の無被害（軽微な変状か）との対比

Fig. 43. Damage detail of the tilted building in Figs. 41 and 42 (Reconnaissance team of Civil Engineering Department, University of Tokyo) ビルディングの傾斜状況の詳細

Fig. 44 indicates the northern side of the Niigata Central Railway Station. The dark color on the surface implies the ejected liquefied sand and water, but another possibility is the leakage from broken water pipelines. A more serious problem happened to the east of this station where an overpass bridge fell down onto a train (Figs. 45 to 49). Substantial distortion and probably buckling of rails are visible in these photos. It is also found in Fig. 45 that the ground surface in the station is covered by grayish materials that are most probably liquefaction sand ejecta. A similar material is also found in Fig. 46 to 49 on both sides of the railway track. Any relationship between liquefaction and the damage of the overpass is not known.

Fig. 44. Bandai Exit on the north side of the Niigata Station (still photo taken by Mr. Yuminamochi) 新潟駅北側万代口

Fig. 45. View towards the east of Niigata Central Station (still photo taken by Mr. Yuminamochi) 新潟駅東方の鉄道線路の状況

Fig. 46. Damage of railway overpass bridge (1) (still photo taken by Mr. Yuminamochi) 東跨線橋の落下(1)

Fig. 47. Damage of railway overpass bridge (2) (still photo taken by Mr. Yuminamochi) 東跨線橋の落下(2)

Fig. 48. Damage of railway overpass bridge (3) (still photo taken by Mr. Yuminamochi) 東跨線橋の落下(3)

Fig. 49. Damage of railway overpass bridge (4) (still photo taken by Mr. Yuminamochi) 東跨線橋の落下(4)

5.7 Matsuhama Bridge on the Agano River

Leaving the station area, the aircraft came to the Matsuhama Bridge on the Agano River in the eastern suburb of the city. This bridge was a wooden old bridge (completion in 1943) and had been destroyed by flood in 1943[18] and again in 1958[19], followed by restoration

Fig. 50. Fall-down of Matsuhama Bridge across the Agano River (a new bridge was under construction next to this old one at the time of the earthquake) (still photo taken by Mr. Yuminamochi) 阿賀野川に架かる松浜橋（旧橋）の落橋

Fig. 51. Small boat helping people from a taxi on the Matsuhama Bridge (still photo taken by Mr. Yuminamochi)　松浜橋に取り残された自動車乗客を助ける小舟

as a wooden bridge again[18]. When the earthquake occurred in 1964, its replacement was nearly completed. When the earthquake occurred, two vehicles were left on the old bridge and were involved in a trouble (Figs. 50 and 51). One span of the new bridge collapsed as well (Fig. 52) but was restored and set out its service in December, 1964[18]. The old bridge was washed away by tsunami one hour after the earthquake[20].

Fig. 52. Collapse of both old and new Matsuhama Bridge (the new bridge in front was under construction) (still photo taken by Mr. Yuminamochi) 工事中の松浜橋新橋も1スパン落橋

5.8 Niigata Airport again

After recording the damage of the Matsuhama Bridge, the aircraft came back to the airport area where the ground surface had been totally flooded by the probable mixture of liquefaction-ejected water and tsunami water (Fig. 53). As stated before, the buildings in the airport did not have structural damage (Fig. 54). Nevertheless, the unacceptably large subsidence of 1.2 m made impossible the normal operation of the terminal building (Fig. 55). The airport authority continued the operation by using only the upper floor in place of the original ground floor and demolished the building in spring of 1965.

A question arises why this subsidence happened in spite of the pile foundation of the building. Fig. 56 compares the SPT-*N* profile obtained before the earthquake and the length of the timber piles. It may be possible that the piles were slightly too short to reach a good stable soil layer. However, it is unlikely that pile driving practice was stopped before hitting a hard soil stratum. Cracks of the runway are illustrated in Fig. 57.

Fig. 53. Inundation of the Niigata Airport, viewed after flying over the city (still photo taken by Mr. Yuminamochi after his flight over the city) 水没した新潟空港エプロン

Fig. 54. No structural damage in the airport building in spite of its substantial liquefaction-induced subsidence (still photo taken by Mr. Yuminamochi) 甚大な液状化に比して構造物に被害の無いことが特徴

Fig. 55. 1.2-meter subsidence of airport building caused by liquefaction (no damage in structure and window glasses) (University of Tokyo)　後日撮影した空港ビルの沈下状況

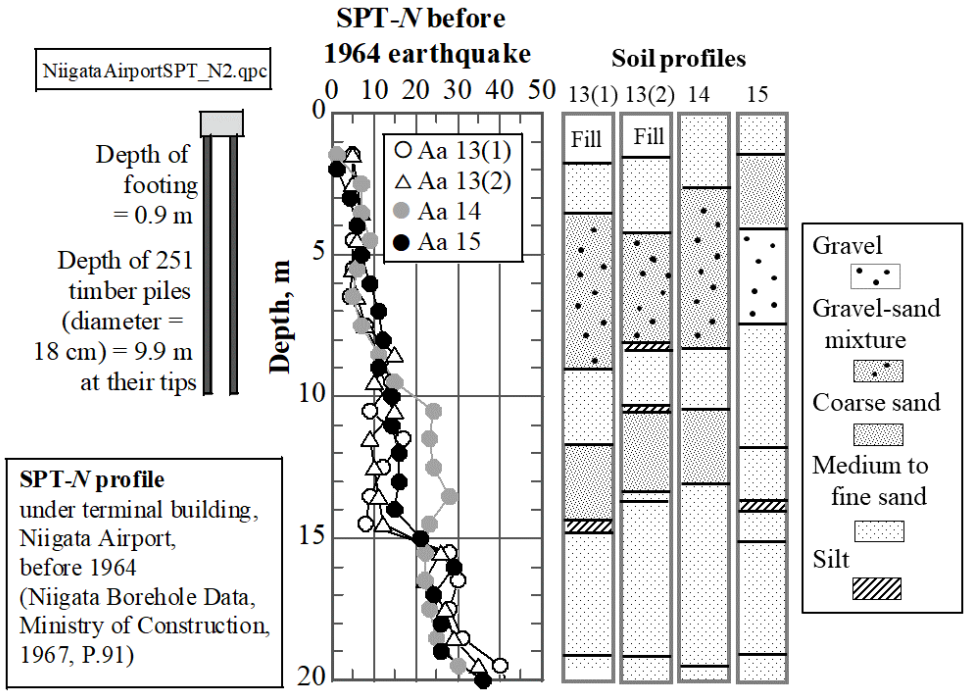


Fig. 56. Pre-earthquake borehole profiles at the site of the subsided terminal building[21)]　新潟空港ビル地点の地盤調査結果（地震前に実施）

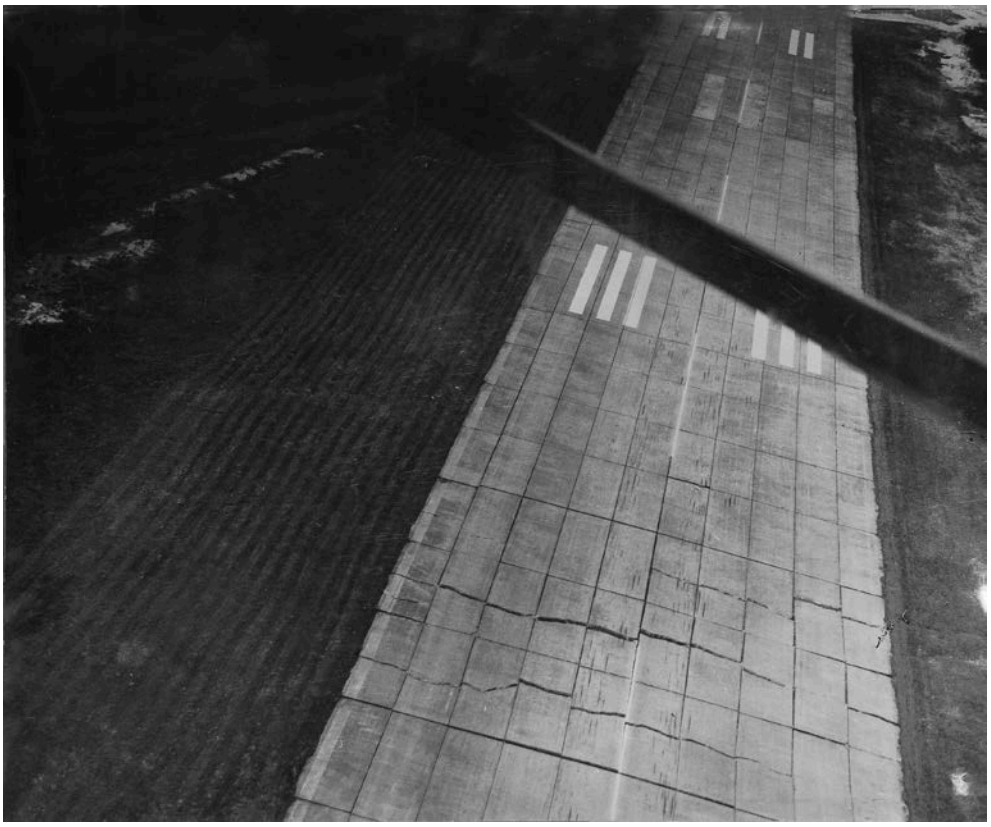


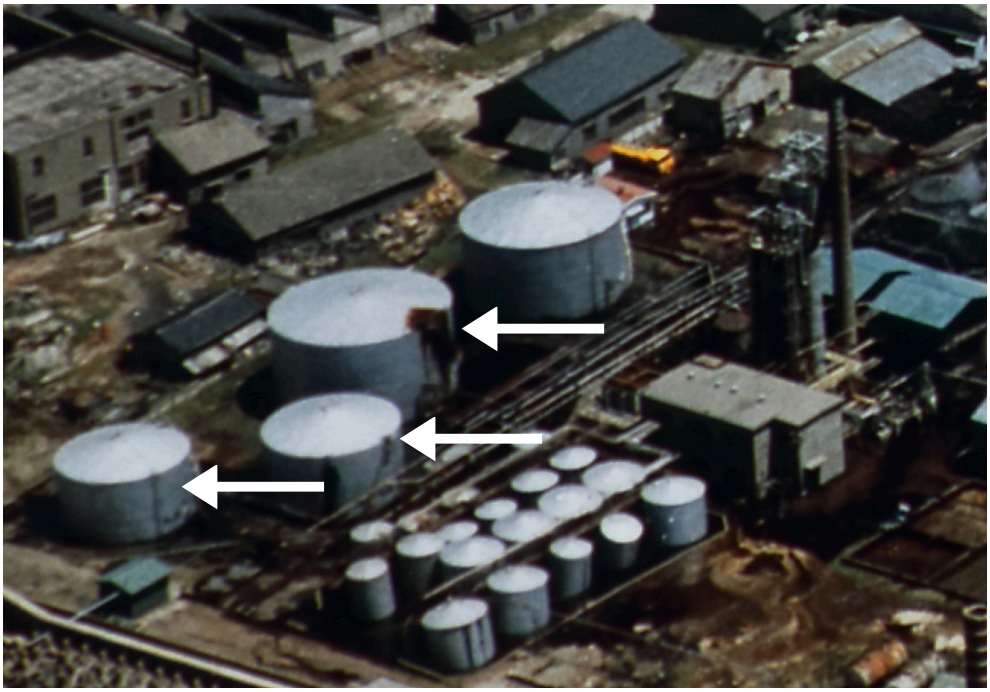
Fig. 57. Cracks and distortion of the airport runway due to heterogeneous subsidence after liquefaction (still photo taken by Mr. Yuminamochi) 滑走路の変状

5.9 Oil refinery again

The photo taking was concluded thereinafter by visiting again the oil refinery (Figs. 58 to 59) where the first fire was still going on, but the second fire had not started. The details of Fig. 58a are presented in Figs. 58b and 58c. In Fig. 58b, the roof of the tanks are distorted, suggesting the strong shaking and, possibly, the collision of the roof and the wall of the tank that set out fire. Fig. 58c shows brown smears or blots on the tank surface (shown by arrows), which are possibly the evidence of oil leakage. The leaked oil was set on fire later on the same day and probably initiated the second fire later in the evening of the same day.

(a) Overall view 製油所火災全体像

(b) Broken roof of oil tanks (partially enlarged photograph) タンクの被害



(c) Possible oil leakage shown by brown smear on tank walls (partially enlarged photograph) タンク側面の茶色い部分は油漏れを意味するのか

Fig .58. First fire in the oil refinery (1) (magnification of still photo taken by Mr. Yuminamochi) 製油所の状況(1)：タンク側壁に茶色い染みが見える

Fig. 59. First fire in the oil refinery (2) (still photo taken by Mr. Yuminamochi) 製油所の状況(2)

Fig. 60. Last photograph of Niigata after which the aircraft departed for Tokyo (still photo taken by Mr. Yuminamochi at around 2 PM after flying over the city)
新潟を飛び去る前の最後の写真

6. Flight to Tokyo

After taking Fig. 60, Mr. Yuminamochi asked the pilot to fly to Tokyo (Fig. 61). This long flight was possible because the fuel was still

enough to go straight to Tokyo. It was essential for a professional photographer to submit his products to media (TV and newspaper) in time for the evening news. One problem was the weight of the aircraft with a heavy aerial survey device with which the small aircraft might not be able to fly over the high Mikuni Pass (1233 m above sea level) en route; see Fig. 61. Thus, the pilot preferred to fly first to Nagano, get fueled there and fly over the Usui Pass that was 956 m a.s.l., which is lower than the Mikuni Pass. After negotiation, the pilot gave up his time consuming idea and agreed to fly directly to Tokyo on the condition that the photographs should be given to a newspaper that was an important business client of his aircraft company. The flight kept low altitude and followed narrow valleys, flied over the Mikuni Pass, and safely arrived at Tokyo Haneda Airport. Landing was at 3:30 PM which was just 2 hours and half after the onset of the earthquake.

7. After arrival in Tokyo

The films of still photograph were handed over to and developed by the aforementioned newspaper and, to the pride of Mr. Yuminamochi, one of the photographs (Fig. 29) was used by the New York Times[13]. In contrast, a difficult decision was made of the motion picture. Although color films were used, its colored development was possible only in a factory in Ashigara (Fig. 61) at 65 km from the Tokyo Haneda Airport. The travel time to carry the films there and return to Tokyo was estimated to be several hours (there was no express motorway in 1964) and was too long for broadcasting them during the evening news at 7 PM. Therefore, all the motion pictures were developed in a black-and-white manner in Tokyo. Nevertheless, all the still photographs and the motion picture deeply impressed everybody who saw them. There is no question that they also impressed the engineers, researchers and people who were concerned with liquefaction, the new type of natural disaster. Next day (June 17th), Mr. Sato and his survey colleague (Mr. Ohno) flew back to Niigata to take more photographs[22].

Fig. 61. Flight route from Niigata to Tokyo 東京への飛行経路

8. Conclusions

On the occasion that the imageries of the 1964 Niigata earthquake is donated to the Japanese Geotechnical Society,

Mr. Yuminamochi's contribution to the geotechnical engineering is appreciated. To make his imageries beneficial to concerned people as much as possible, this paper attempts to describe their significance and implication, adding more knowledge that has been obtained after the earthquake. Although it is not an idea to draw any conclusion, the major issues in this paper are listed in what follows;

(1) The imageries that consist of still photos and motion pictures are products of a combination of several miracles that, upon the earliest liquefaction as a disaster to a built environment, a professional photographer was prepared to take photographs with necessary devices and aircraft ready at the airport site of liquefaction. Although an 8-mm movie camera was not required for the mission of that day, Mr. Yuminamochi incidentally had it and had films purchased in the airport shop.

(2) Scenes of several well-known liquefaction events were recorded, including those at the Niigata Airport, Showa Bridge, revetment walls along the Shinano River, sports facilities near Kawagishi-Cho and a tilted building near the Niigata Station. Even the tilting of the Kawagishi-Cho apartment buildings are seen in one of the photographs, although not very clear.

(3) The recorded imageries were immediately transported to Tokyo in time for the evening news. This flight was not very easy due to the weight of the aircraft and the altitude of the pass on the route.

(4) Due to time limitation, the motion picture was developed in black-and-white manner, although the original was recorded in a color film. This, however, does not affect the value of the picture.

弓納持福夫氏の新潟地震記録映像が地盤工学会に寄託されるのを機に、映像利用者の便を図るため、本論文を作成して映像の意味するところについて説明を試みた。個々の写真の説明がすべてであり、屋上屋的な結論を挙げることは必要ではないが、簡単なまとめを付記するとすれば、次のようになる。

(1) 液状化現象が「災害」であることは、新潟地震においてはじめて認識された。その最初の現場に弓納持氏という写真専門家が装備を所持して存在され、しかも飛行機が出発準備を整えて待機していたことは、奇跡的な出来事であった。しかも重要な動画を撮影した８ミリ写真機は当日の業務には必要ではなく、たまたま所持されていたのである。さらに、8 ミリフィルムもたまたま購入したばかりであったことも、奇跡的である。
(2) 新潟空港、昭和大橋、信濃川護岸、競技場、傾斜したビルなど、よく知られている液状化被害現場が、地震直後に撮影されている。川岸町アパートも遠景に、かすかではあるが、判別される。
(3) 撮影の済んだフィルムはそのままただちに飛行機で東京へ運搬され、当日夕方に新聞とテレビとで公開された。山越えの飛行は容易ではなかった。
(4) 液状化の動画はカラーフィルムに記録されたのだが、夕刻のテレビニュースに間に合わせるため、やむを得ず白黒で現像された。しかしこのことは映像の価値を減ずるものではない。

Acknowledgment

In 2023, Mr. Yuminamochi (Fig. 62) transferred his copyright of his still and motion pictures to the Japanese Geotechnical Society in 2023. His kindness is deeply appreciated by the Society. Those photographs are designated in this report by a remark of “still photo taken by Mr. Yuminamochi” and likes. As an open resource, any concerned person can use his imageries for good purposes and no third-party permission is necessary. Only one requirement is to show a statement that the photographs were taken by Mr. Yuminamochi and are now preserved by the Japanese Geotechnical Society.

弓納持氏は 2023 年、新潟地震を記録した画像を、静止画と 8 ミリ動画ともに、地盤工学会へ寄託された。地盤工学会は、そのご趣旨に深く感謝するとともに、画像がすべての人に広く利用できる途をこしらえることにした。それらの写真は、本報告で(still photo taken by Mr. Yuminamochi)のように表示されているものである。公開された画像を使用するにあたっては、地盤工学会の許諾は不必要である。使用料金も発生しない。ただし、画像が弓納持福夫氏の撮影に係ること、地盤工学会が管理していることの二つを、写真の題目に明示していただくことだけが、条件である。

Fig. 62. Mr. Yuminamochi and his Nikon 8-mm movie camera that recorded the ongoing liquefaction (during the authors’ interview on May 13, 2023, in Niigata) (IITT Imagery Bank) 液状化の動画を撮影した8ミリカメラを持つ弓納持氏（2023年5月13日新潟市内にて）

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