Considering the Extent of Damage in Ishinomaki from a Civil Engineering Perspective

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JOINT INVESTIGATION IN ISHINOMAKI

As a research group member of the Japan Society of Civil Engineers (JSCE), I conducted an interview survey in the disaster-hit area of the Great East Japan Earthquake from April 29 through May 2, 2011. Here, I will report on the conditions of Ishinomaki City（石巻市）, Miyagi Prefecture, to which I was assigned[1]. At that time, since only a month and a half had passed after the devastation, I could not talk directly to quake-stricken residents. Today, I would like to give a general overview of the extent of the damage to the city.

Normally, research members of an academic society such as this restrict their attention to the realm of civil engineering. However, on this occasion, academics from various disciplines, including geologists that deal with the physical aspects of disaster, and fields related to agriculture and fishing, participated in the research. For this reason, in this research, we were able to broaden our perspectives and understand the earthquake disaster from a comprehensive point of view.

OVERVIEW OF THE DAMAGE IN ISHINOMAKI CITY

Ishinomaki is a city facing the Pacific Ocean with a population of over 160,000 people; it is second only to Sendai City（仙台市）in Miyagi Prefecture. According to the damage statistics of June, 2011, nationally, more than 15,000 people were listed as

Photo 1 Extent of damage (Old Kitakamigawa Nakase area)

Photo 2 Extent of damage (area behind lindustrial port)

Photo 3 Extent of damage (area behind fishing port)

Photo 4 Comvenience store used as goods distribution point

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dead and 7,000 are still missing. In Ishinomaki, there were 3,000 dead and nearly 2,800 missing. The city has the largest number of dead and missing people of any quake-hit municipality.

Since the Meiji period (1868-1912), the Sanriku region has been repeatedly hit by tsunamis. But no major tsunami had hit Ishinomaki, I understand. But this time, a three- to five-meter-high tsunami came. The central area of Ishinomaki was all swallowed up. This area was badly drained in the first place, and then the drainage pump did not work properly, so the water did not recede for a long time.

Driving into the affected area by car, the first thing you noticed was that a convenience store not in business was being used as a supply stations for goods; it was functioning as a public facility, so to speak. Also, the rubble, including automobiles, had been swept into farmland, and there was no way the land could be used for any purpose in the immediate future.

In the case of Ishinomaki, there were several routes for the tsunami to reach inland. By the first route, the tsunami went directly over the tide embankment on the coast; on the second route, it rose through the Kitakami Canal that ran across the city and then inundated the inland area; and by the third route, it crept through the areas along the Kitakami River where no embankment had been constructed. The actual damage was not done by the flooding of the tsunami itself. Rather, the damage was done by the debris — all those things that had been swept and pushed up by the tsunami. They hit houses and the houses in turn ricocheted against other houses; those floating objects worsened the damage. The key measure to reduce damage from a tornado or tsunami is to stop or minimize the damage caused by broken or floating things. For example, observe the way bridges were broken. While there was little damage on the upstream side of a bridge, it was totally destroyed on the downstream side. In other words, objects that were carried from the ocean side caused major damage to such structures as boats and buildings.

Photo 5 Extent of damage (Senkarida area)

Photo 6 Extent of damage (O-magari area)

Photo 7 Drifting objects causing damages 1

Photo 8 Drifting objects causing damages 2

EXTENT OF DAMAGE TO THE COASTAL AREA

The damage to the tide embankment was staggering; in some cases, it was moved so far away that one had difficulty finding the original location. The tide embankment does not function if there is an opening of any sort; water will seep in even if the structure itself does not break. Apparently, the designer of the tide embankment did not sufficiently take into account the possibility that the seawater might go over it. Unfortunately, the embankment could not withstand such a massive tsunami.

Photo 9 Damages to fishing port facilities1

Photo 10 Damages to fishing port facilities2

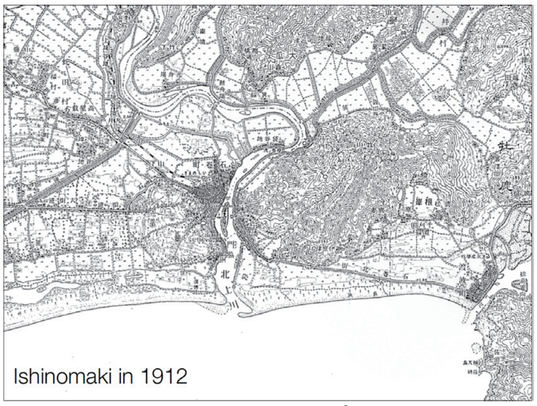
Looking at the facilities of the fishing port, overall, they experienced land subsidence of about 70cm. Under these conditions, no fishing boat can dock to land its catch. I didn't know this, but in the Japanese fishing industry, a fishing boat can land its catch of fish at any port, homeport or not. However, business-wise, it is extremely important for a port to maintain its characteristic catches. For example, at the Kesennuma Port（気仙沼港）, they land the bonito catch in May, and once they have lost that catch, other ports will take that "brand" away. That's why it is crucial to restore fishing ports as soon as possible. The construction of a fishing port requires not just a landing place and a market; it also requires ice-making, refrigerating and seafood processing facilities. They are all integrated and must function in coordination to bring in a catch.

THE RELATIONSHIP BETWEEN TSUNAMI DAMAGE AND THE TERRAIN

What I would like to particularly emphasize in this talk are the relationship between tsunami damage and the terrain, and evacuation behavior.

First, let's begin with the terrain of Ishinomaki. What topographic features did the most affected area have? The answer can be verified from old maps. The area most devastated was the area where before modern times (such as during the Meiji period) there were originally no inhabitants. Simply put, it was wetland/lowland along the coast, a boundary area between the sea and the land. Over the years, they encircled such an area with embankments utilizing civil engineering technologies, sometimes reclaiming or inflating it. And so, it is no exaggeration to say that after this earthquake and tsunami, the area was changed back into the original terrain. I went to the actual area as you can see from the photograph. Behind the breakwater lay ordinary residential land. The original sand beach had been used as dry land thanks to the construction of embankments. In any case, there were no residents in the first place.

Old maps show that old settlements were located on beach ridges or micro high land along the coast. This Watanoha（渡波）settlement, too, used to be located only on micro high land; there were no residents on the beach. Of course, that was probably because there were tidal waves or storm surges as well as tsunami disasters. Yet, we can also say that in those days, people were more sensitive to delicate topographic conditions than we are now. In modern times, civil engineers became increasingly overconfident that man could be protected from the natural elements — a belief shared by citizens. As a result of advancing into such terrain, a great many things that we had built were lost due to this tsunami devastation.



Fugure 1 Old coast line of Ishinomaki[2]
Note: The map aquired from Geospatial Information Authority of Japan.

Photo 11 Damaged houses behind seawall 1

Photo 12 Damaged houses behind seawall 2

The lesson we learned is that considering the tremendous force of natural disasters, there need to be areas that are not be for human use. Not even modern civil engineering can totally overcome nature. It's very obvious, but we must avoid utilizing high-risk areas.

EVACUATION BEHAVIOR AFTER THE EARTHQUAKE: SUCCESSFUL AND UNSUCCESSFUL CASES OF EVACUATION

Next, let us talk about evacuation behavior. Let me share with you a successful case and an unsuccessful one. The successful case was the evacuation at the Nippon Paper Industries plant, which is very close to the Ishinomaki Industrial Port. There were 1,500 employees there at the time of the earthquake and tsunami, yet no one lost their life. One possible reason was that they had frequently conducted tsunami evacuation drills. But there was one other important lesson.

Located next to the premises of this plant is a company housing building, which is constructed on higher ground on the inland side. When the earthquake hit, the employees began to evacuate toward higher ground (where the company housing is), just as they had been trained to do. There are two key points here. One is that they evacuated toward the familiar housing facility. The other is that they evacuated toward higher ground. It is logical and practical that those two key conditions were both met, which are suited to human intuition and sentiment. What if the company housing had been located on low-lying plains? If it were only a drill, everybody would go toward higher ground. But when actually faced with a quake and incoming tsunami, wouldn't they try to go check on their family?

Now, the case of an unsuccessful evacuation. This happened in the residential district facing that paper mill. This district has limited exits for evacuation facing inland. Particularly, when trying to evacuate by car, there are really only two exits that are available. Yet, everybody tried to flee by car. Naturally, they were stuck in traffic jams. They still could have run on foot. But most didn't. If they had walked, they could have directly run up to a hill, but they didn't. Consequently, many people lost their lives.

It is necessary that a safety evacuation plan be instinctively understood by people. The fundamental rules are: escape to the side opposite the sea, flee to higher ground, and evacuate to a place that you are familiar with on a daily basis. And there is one more issue. How do we behave when we are not in a disciplined and organized setting such as a school or company where we are used to being told what to do? Factory workers would flee in accordance with the drill, but once they are off the premises and have to think for themselves as individuals, how would they behave? Sadly, we were not sufficiently prepared for that. And that was reflected in this terrible disaster.

Q & A SESSION

Infrastructure Design Accounting for Earthquake Disasters

Mori: You said that no major tsunami had hit Ishinomaki. What kind of historic range are we talking about?

Fukui: The three major tsunamis that hit this region in relatively recent times were the Meiji Sanriku Tsunami（明治三陸津波）(1896), the Showa Sanriku Tsunami（昭和三陸津波）(1933) and the Chilean Tsunami (1960). As far as urban areas in the Ishinomaki plains are concerned, there are no records of damage from either the Meiji or the Showa tsunami. Perhaps this is because few people lived in the affected coastal areas at that time. But even from the Chilean Tsunami, the level of damage was very small with two people dead or missing. So, record-wise, we can say at least that since the Meiji period, the old Ishinomaki plains had incurred no major tsunami damage. Before that, there were disasters from the Keicho Tsunami（慶長津波）(1611) and the Jogan Tsunami（貞観津波）(869). That's why some told me that they used to believe that, "Even if a tsunami comes, Ishinomaki will be safe."

Terada: From a civil-engineering perspective, how much destruction can we absorb and still be able to repair the infrastructure? In terms of duration and financing, how much do we need to restore it to the original condition? And how do we estimate the long-term cost of the restoration of infrastructure?

Fukui: After the quake, the Tohoku Shinkansen resumed operation extremely quickly. To the layperson's eye, things may look so utterly destroyed that it seems impossible to fix infrastructure. But, for example, those broken poles or posts can be reused without problem after jacking up the floor and reinforcing them. At the time of the Great Hanshin Earthquake (1995), structures such as the Hanshin Expressway routes and Sanyo Shinkansen were destroyed and many lives were lost. Since then, in order to prevent such damage, new design ideas have been adopted, some of which helped mitigate the effects of this earthquake. Nevertheless, some time was, of course, required to resume Shinkansen service. The biggest reason was that many overhead wire poles had been damaged. In fact, with earthquakes in mind, the base of those poles was designed to be loose so that they could fall, yet not break. The trouble was that there were just too many fallen poles to deal with.

In contrast, this level of tsunami damage was unprecedented for coastal defense structures such as embankments and storm surge barriers. Basically, no one took into account the possibility that the seawater might go over the walls nor plan for its aftermath. So, when the tsunami waves surpassed the walls after the quake, they were completely destroyed. JSCE is keenly aware that design must be changed to avoid destructive consequences if an external force (tsunami, this time) greater than the predetermined force could pressure a structure, and they have been discussing how to deal with it.

Terada: One more question. You said, “people began living where no one should have lived in the first place.” Then, would it be possible to put a limit on the population? Would you say as a proposal, “No population greater than this should live in this area?”

Fukui: For a hundred years and several decades, technology has advanced tremendously, and resistance to disasters has improved greatly. So, I’m not saying that we have to live as people used to do in those old maps. I heard that one local person had commented before the tsunami-devastated area, “When I was a little child, the landscape looked like this.” I think his comment suggests that when considering a long history of this region, the picture of the area just before the disaster, which had been the consequence of the development in the last few decades, should be considered as only a temporary one that appeared between disasters. Historically, people did live in dangerous areas, but they were also aware of the associated risks. In more recent years, however, we were under the illusion that there exists no risk. Population control is a difficult issue, but at least we must realize that it is important to use land with proper knowledge of possible risks. Considering the history of disasters in this region, no matter how we look at it, it is not appropriate to build a residential complex on lowland in an estuary area, which may be hit by a tsunami once every fifty years. I think that we must carefully take facts like this into consideration when we think about a new direction of land use.

Will the View of Risks Change?

Mori: There is no doubt that people’s views on risk will change after this disaster. But in actuality, how much do you think will change? And the lessons we learned from placing too much faith in technology and the necessity of coming to terms with nature — to what extent are they shared? Lastly, how much would those changes be reflected in policy? As researchers who study civil engineering, what are your impressions?

Osaki: Sometimes I feel as if there would not be so much change after all. Of course, that’s not good. For instance, Otsuchi Town’s population was predicted to drop below 10,000 in 2030. This means that we must discard the conventional approaches to development based on the assumption of expanding urban areas. The reconstruction plans should be based on the projection of low birthrate and aging population. But the tsunami hit the town when no such alternative approach had been established yet. Thus, it is a race against time, and we must act quickly to protect the lives of disaster victims.

Fukui: Ishinomaki’s central district is actually located on the old river channel of the Kitakami River. So the risk of being flooded was already high, and indeed the water did not recede easily after the tsunami came. The residents there knew that risk, yet chose to continue living there. The city had not necessarily been developed with safety as the number-one priority. The city exists in an uneasy balance between convenience and the risk of disaster.

I hope that after this disaster, local residents became deeply aware that their life exists in such a precarious balance.

Osaki: The logic of fishermen is simple. Every day, fishermen face danger at work, and they are more conscious of the risks they take. That's why their reward is great. So, even if tsunami hit them and their boats were washed away, they would think, "It happens." By contrast, those on land blindly believed that the tide embankment walls would protect them.

Fukui: After the tsunami damage, I think there are many who feel deceived. They believed it was safe to build a house due to the presence of embankments.

Terada: Is it possible to put restrictions on private ownership in this area?

Fukui: Yes, it's possible. Several municipalities are making reconstruction plans under the policy that they will not allow people to reside in high-risk areas along the coastline. First, they will put building restrictions so that residents will not restore their place on their own. In the future, for example, high-risk areas will be turned into parks, green spaces and public facilities. However, the issue of how to provide compensation still remains. Since the revenue benefits are not yet determined, there is no conclusion in sight.

Terada: From what level will that decision come down?

Fukui: Ultimately, it's the municipality. Of course, the central government will be in the position of backing it up, but the basic stance is that the municipality is the decider.

Yamamoto: When the municipality makes decisions as to whether certain areas are unlivable, they would probably approach it from the physical side first, saying, "This area is physically too dangerous to live in." But there will be some gray areas in this, which should be a matter of social decision-making. I would imagine it is an issue where to draw the line. Where do you think lies the threshold, beyond which you cannot approach from the physical side and leave it to social decision-making?

Fukui: There have been always risks. But we tended to have the idea it is either zero or 100%. From now on, we must present all the risks in advance, and let people make choices as to whether or not accept the risks. In terms of the gray areas, we will need to respectfully discuss such matters as whether a residential complex or business office should be allowed to be built, and whether public facilities are suitable or not. All those things should be discussed based on various conditions such as the scale of flat land, industrial location, and the population of residents who will continue to live there. From physical aspects, we would calculate the extent of possible flooding according to the estimated scale of the potential tsunami and the possible specifications of the embankment. Then, it is a matter of social decision-making what choice will actually be taken. However, since every tsunami differs depending on the earthquake, we should also bear in mind that those estimations of physical aspects are merely one set of configurations.

The Perspective From Civil Engineering and Its Characteristics

Yamamoto: For this research, experts from various fields have got together. What did it mean to you?

Fukui: For instance, we realized that we knew nothing about agriculture even though we had been involved with regional development. After the research, we learned that the farming industry, including irrigation and drainage, had existed in this area in one broad system — a system much broader than we had expected. The subjects we need to examine are not only the physical environment but also the activities of people and industries in the whole region. It was significant that we became aware of this particular fact.

Machimura: What temporal scale do you normally use in civil engineering?

Fukui: For example, in the case of a river, it corresponds to flooding once every several years to several decades. As for an earthquake, because there hasn't been much accumulated data on the cyclical occurrence of earthquakes, we understand it as an external force to assume seismic motions that have occurred in the past. In the case of a tsunami, since there are very few cases to record as a disaster in the first place, we have yet to place physical phenomena on a temporal axis. In the meantime, what we often point out is the fact that our memories fade over several decades and we have this complacency that disaster will not strike us. That is one characteristic of the temporal scale of human cognition.

Iwadate: Was there any infrastructure that was not damaged or was damaged but was quickly restored? Also, how do you prioritize the types of infrastructure to be restored?

Fukui: When I first arrived at the affected area, I got the impression that electrical cables and poles amid the rubble had been restored rather quickly. The re-opening of the roads was also fast. In some places, the entire roadbed was swept away. I believe they restored it using heavy machinery. Considering the changing priorities in regard to quality of life from the onset of the disaster, the order of restoring infrastructure was, in time sequence, life-saving evacuation facilities, water/food, restrooms, hospitals, and temporary housing. But before undertaking all of this, the first priority was restoring the roads to evacuate and transport supplies. The information network is also very important, followed by electricity, waterworks, and transportation network.

Notes

1 All photos were taken by the author unless otherwise stated.
2 This map is a reproduction of the 1:50.000 Scale Topographic Map "Ishinomaki(1912)" published by Geospatial Information Authority of Japan with its approval under the article 29 of The Survey Act. (Approval Number JYOU-FUKU No.189 2012)