GIS BASED FOR DEVELOPING SUPPORT APPLICATION OF CONCRETE CONSTRUCTION UNDER THE VARIOUS ENVIRONMENT

Hiroki ISHIDA[1] and Sumiko ANNO[1] and Takeshi IYODA[1]
[1]Shibuara Institute of Technology, 3-7-5, Toyosu, Koto-ku, Tokyo 135-8548, Japan,
Email: me14007@shibaura-it.ac.jp

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ABSTRACT: In Japan, several concrete structures were built in era of high economic growth. Recently, those structures has suffered damages by time and need to be maintained. As a factor of the damages, climate conditions and physiographic factors have an effect on damages. In concrete construction, we should consider a climate conditions to build the concrete structure that gave an appropriate response. Therefore, we should build concrete structures that enable minor maintenance in the future. In general, designer and constructor should share to build concrete structure that was done measure construction about climate conditions in Japan. However, large-scale civil engineering project are dividing by specialization, measures of share are not enough among designer and constructor. Therefore, designer and constructor need the tool that enable to realize climate condition in Japan. In this paper, we used Geographic Information Systems (GIS) that enable to integrate different types of data on the map to create climate map. Then, we show these maps to the public by cloud GIS among designer and constructor currently. Finally, we developed support application that support to understand climate condition to share by cloud GIS for designer and constructor in Japan. Designer and constructor enable to build concrete structure that was done consistent measures by our application.

1. INTRODUCTION

In Japan, several concrete structures were built in era of high economic growth. Recently, those structures has suffered damages by time and need to be maintained. As a factor of the damages, recent studies showed that climate conditions and physiographic factors have an effect on concrete damages. For example, salt damage is caused distance from coast line, direction of the wind, salinity of concrete structure. Japanese geographical is wide in all direction under the different information of climate conditions, these climate condition have an effect on concrete damages. In concrete construction, we should consider a climate conditions to build the concrete structure that gave an appropriate response. Therefore, we should build concrete structures that enable minor maintenance in the future.

In general, when designer design concrete structure, the structure was done measure to minor many damages in regard to climate conditions of long term. When constructor construct concrete structure, they should care to climate condition of the day to construct concrete structure. If construct concrete structure that minor maintenance, designer and constructor should share about climate conditions of Japan. Then, they should does effective measure to many damages of concrete structure. However, large-scale civil engineering project are dividing specialization, measures of share are not enough among designer and constructor. Therefore, need the tool that enable to realize climate condition in Japan.

Recently, Automated Meteorological Data Acquisition System (AMeDAS) of Japan Meteorological Agency was used to consult climate conditions by designer and constructor in Japan. These data are opening to the public on the web site of Japan Meteorological Agency. There are a large number of AMeDAS every 17~21 km in Japan. Recent studies showed that AMeDAS enable to realize in regard to effectiveness of concrete structure. However, there aren't AMeDAS at between observation point, we should use nearest point of data. Such data isn't suitable data of climate. In this paper, we used Geographic Information Systems (GIS) to enable to integrate different types of data on the map. We create raster data based climate information of AMeDAS by interpolation processing of GIS in Japan. Then, we estimate damage level of salt damage and frost damage by such raster data of climates. These damages were caused by climate conditions. HASEGAWA (1975) proposed a method to estimate frost damage level based on climate conditions, NARITA (2008) improved the method used by inspecting data of concrete structures and created more detailed map. They created map of frost damage in Japan. We use about such damages caused by which climate conditions from precedence research. The purpose of this paper is to realize climate condition of Japan, we share such climate conditions to build concrete structure that enable minor maintenance by cloud GIS for designer and constructor easily.

2. MATERIALS AND METHODS

2.1 Japanese climate condition/AMeDAS

Figure 1 shows detail of Japanese climate conditions. Japanese geographical is wide in all direction under the different information of climate conditions. Northern Japan has warm summers and very cold winters with heavy snow on the Sea of Japan side and in mountainous areas. Eastern Japan has hot and humid summers and cold winters with very heavy snow on the Sea of Japan side and in mountainous areas. Western Japan has very hot and humid summers (with temperatures sometimes reaching 35 ºC or above) and moderate cold winters. Okinawa and Amami has a subtropical oceanic climate. These areas has hot and humid summers (with temperatures rarely reaching 35 ºC or above) and mild winters. The concrete structures has a noticeable effect under such various environment. Thus, we enable to visualize these difference definitely by making a climate map of our method.

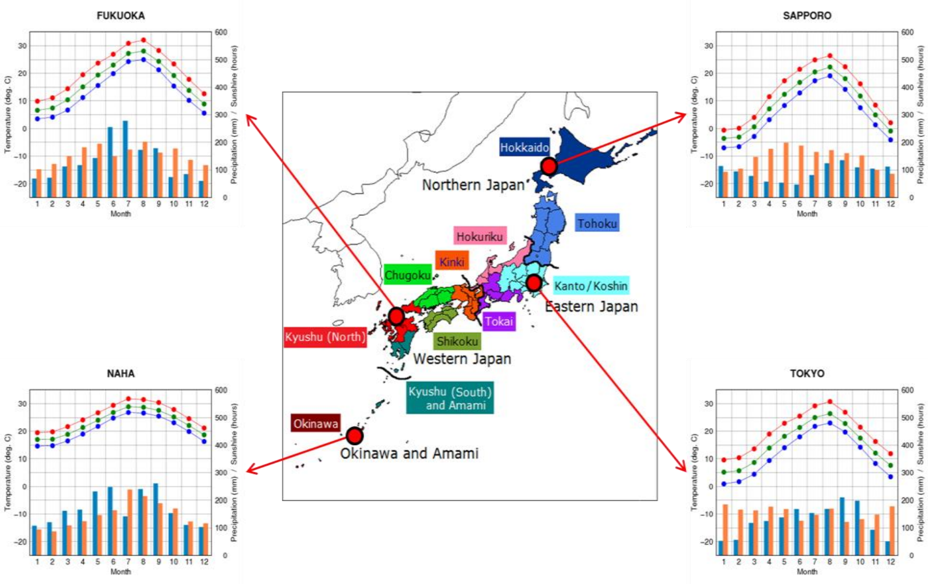

Figure1. Overview of Japan's climate
(Reference by Japanese Meteorological Agency)

In general, AMeDAS is used to consult these complicate climate condition. There are approximately 1,300 AMeDAS to measure, these AMeDAS has been used for measuring 6 kind of climate data every 10 minutes since 1974 in Japan. These data were gathered by Japan Meteorological Agency, then the data are opened to the public. In this paper, we focused to long-term deterioration of concrete structures by climate conditions, we use monthly AMeDAS data that has an effect to frost damage and salt damage. Frost damage is caused by temperature, amount of the precipitation, amount of maximum snow fall, amount of solar radiation. Salt damage is caused by wind speed, wind direction. We used 803 spots of AMeDAS that are gathering these climate conditions data. Then, we create climate conditions map to realize feature of Japanese climate conditions.

2.2 Climate conditions map

Figure2 show the method of this research. In this paper, we create climate conditions map by ArcGIS of ESRI Ink. At first, we integrate AMeDAS to GIS by longitude and latitude with climate data. We also integrate a significant wave data of National Maritime Research Institute as external factor of salt damage. There are these climate data as point, we create raster data to realize detail of climate conditions by using Spline interpolation processing in GIS. Spline interpolation processing is enable to create a raster surface from points using a two-dimensional minimum curvature spline technique.

In general, temperature falls 0.6 degrees Celsius every 100 meters. Then, we calculate suitable temperature by using computation expression of precedence research with Digital Elevation Model (DEM) of National Land Numerical Information download service (NLNI). NLNI is opening to public such DEM data as polygon data for GIS. As a reason for calculation, temperature data of AMeDAS is including elevation from the first. Figure3 show method to calculate suitable temperature. We change to point data from polygon data, we create raster data of DEM by using Inverse Distance Weighted (IDW) interpolation processing. The IDW interpolation is suitable to create raster surface from point data of elevation. Thus, we calculate 0 meter temperature by using equation (1). Using by value of calculated temperature, we create raster data of 0 meter temperature by using spline interpolation processing. Then, we calculate suitable temperature by using equation (2) with DEM.

$$T_0 = \mathrm{T} + (\alpha \times H_G) \quad (1)$$
$$T_{HG} = T_0 - (\alpha \times H_G) \quad (2)$$

where T_0 is 0 meter temperature, T is temperature, and α is the unit temperature amount of change; 0.006 ℃/m, and H_G is elevation, and T_{HG} is suitable temperature.

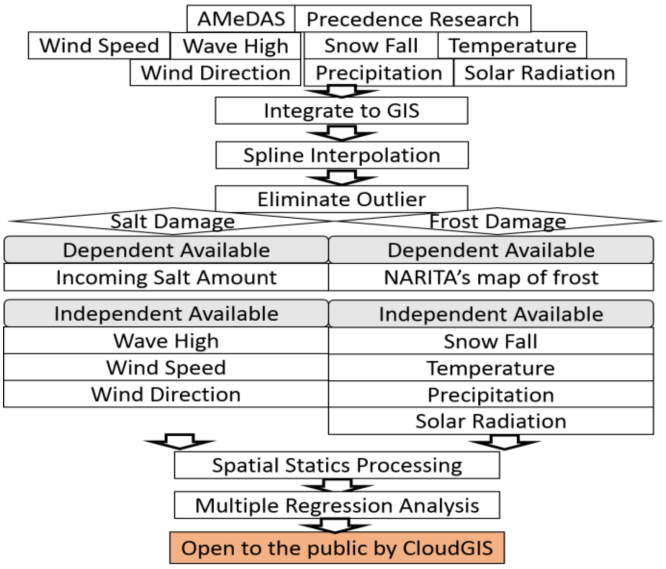

Figure2. Our method

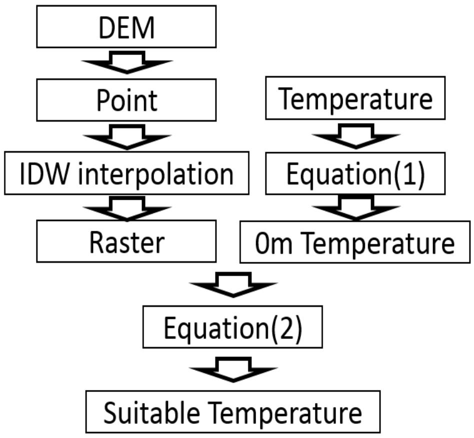

Figure3. Suitable temperture calculation method

2.3 Method for making damage level map

Frost damage and salt damage resulted from climate conditions applied on concrete construction. Accordingly, we realize about such damages caused by which climate conditions from precedence research. We decide damage level by evaluating these data. Firstly, we decide dependent variable by predicted value of precedence research, and decide independent value by raster data of climate condition. Secondly, we make formula by multiple regression analysis of SPSS. Finally, we calculate damage level by the formula of calculated multiple regression analysis.

2.4 Frost damage level map

Frost damage happen by frost and thawing in including water of concrete. If there is no space for this volume expansion, water containing material like concrete, frost may cause distress in the concrete. Then, frost and thawing destroy from inside of concrete, quality of concrete deteriorate.

We apply map of frost damage level map that created by NARITA as dependent variable. However, the map has seen by only paper material, there is not digital data. Therefore, we create raster data of frost damage level map by using Geo-referencing processing that enable to integrate. Then, apply pixel value of the raster data, we categorize frost damage level to agree with result of NARITA by using unsupervised classification processing. For the reason that apply unsupervised classification processing, such map was divided by object-based classification every damage level. Frost damage of risk calculation by HASEGAWA is apply climate data, we apply similar data. We use as an independent variable; temperature, amount of the precipitation, amount of maximum snow fall, amount of solar radiation. Finally, we perform a multiple regression analysis by using spatial statics processing.

2.5 Salt damage level map

Salt damage happen by wind including chloride ion in coastal place. When the wind blow concrete structure, chloride ion penetrates to a reinforcing rod, the reinforcing rod corrodes for long term. In general, large number of concrete structure are built with reinforced. Then, destroy from inside of concrete, quality of concrete deteriorate. Japanese Standard Specification for Concrete Structure showed result by experience of Independent Administrative Institution

Public Works Research Institute, flying salinity from the less than 1km coastline influence to salt damage. And measures design of the damage from salt damage was applied these experience data of flying salinity. Thus, in this research, we use such frying salinity data as dependent variable. However, the map has seen by only paper material, there is not digital data. Therefore, we integrate to GIS with AMeDAS by using data of flying salinity and performs spline interpolation processing. Flying salinity is carried by wind from sea. For the reason, salt damage is caused by wind and wave height. According to precedence research; when big waves come to coastline, it was demonstrated that flying salinity increased. Thus, we use as an independent variable; wind direction, wind speed, wave height. We use raster data of climate condition as wind direction and wind speed. The Port and Airport Research Institute is opening to the public wave height data. Then, we use such data and integrate these data to GIS by longitude and latitude. Salt damage of concrete structure deteriorate in long term, we use monthly climate data. Finally, we perform a multiple regression analysis to gathered data by using spatial statics processing from the less than 1km coastline.

2.6 Application by using cloud GIS

Recently, cloud computing is used various field by development of the Information and Communication Technology. We upload climate maps and damage level maps to cloud GIS enabling the usage on internet. Then, we open to the public these map on internet.

3. RESLUT AND DISCUSSION

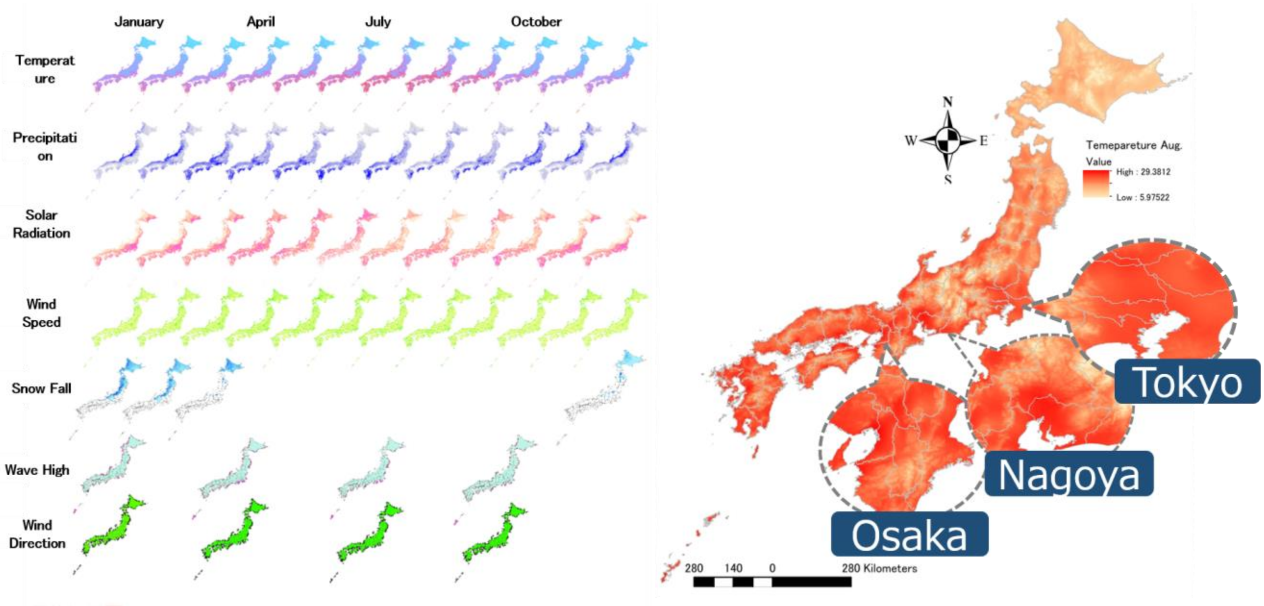

Figure4. Climate condition maps and temperature feature of metropolis in August

Figure4 show climate condition maps that created 1km resolution by using AMeDAS on GIS. However, we had seen outlier on climate condition maps. As the reason, such maps were estimated by using interpolation processing. Therefore, we eliminated the outlier of these value by using the mean and standard deviation, and the value were normalized. As a result, part of remote islands were eliminated by the normalization. In this method of research, those remote islands aren't cover by interpolation processing. These map show a special feature of climate. For example, we enable to find change of the temperature by every month. Furthermore, we also enable to find special feature that the temperature of metropolis is high in summer. In a case of structure design, designer should consider measure about detail design of concrete structure under the various climate condition. Figture4 show detail of climate maps in August. Example of these climate map include enable to find special feature of climate for designer who design detail of concrete structure. Constructor also should consider measure about detail of concrete structure under the various climate condition. If designer and constructor share our climate maps, they are enable to share climate conditions. Then, they are enable to build concrete structure that was done measure construction about climate conditions in Japan. Finally, we created tool that be enable to share climate condition among designer and constructor.

Table1 and Table2 shows the result of multiple regression analysis of frost damage. We extracted date every area and collected 1003 samples. Thus, we performed a multiple regression analysis by using stepwise method. The each coefficient of correlation exceeds 0.7, some P-value (tem, pre, snow) drop below 0.001. Therefore, estimate value of frost damage indicated a significant correlation between other climate conditions. However, P-value of "sun" over

0.01, we didn't select "sun" to make formula. Then, we propose formula (3) to estimate frost damage level of concrete.

$$Y' = 0.365 + (-0.05)\ X_1 + (-0.372)\ X_2 + (0.04)\ X_3 \quad (3)$$

where X_1 is precipitation, X_2 is temperature and X_3 is snow fall

The equation strongly caused by temperature. Thus, we created frost damage map using by formula (3). Figure5 show result of frost damage map using by formula (3). It has seen high level frost damage in Hokkai-do (Northern Japan). For the reason, climate of Hokkai-do is very cold winters with heavy snow on the Sea of Japan side and in mountainous areas. It also has seen frost damage level in center of Japan. For the reason, there are a lot of high elevation mountains at there, temperature was lowered by elevation.

Table1 Model Summary of frost damage level

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.874[a]	.764	.764	.830

a. Predictors: (Constant), snow, pre, tem, sun

Table2 Coefficients of frost damage level

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.365	.180		2.023	.043
	pre	-.005	.001	-.135	-6.726	.000
	sun	-.001	.001	-.012	-.532	.595
	tem	-.372	.009	-.767	-43.321	.000
	snow	.004	.001	.187	8.817	.000

a. Dependent Variable: Estimated frost value by Narita

Table3 Model Summary of salt damage level

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.425[a]	.180	.176	1.576434

a. Predictors: (Constant), w_speed, wave, w_dirction

Table4 Coefficients of salt damage level

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-2.273	.305		-7.462	.000
	w_speed	.276	.042	.254	6.545	.000
	wave	.020	.003	.240	6.285	.000
	w_direction	.004	.002	.077	2.108	.035

a. Dependent Variable: Incoming Salt Amount of

Table3 and Table4 shows the result of multiple regression analysis of salt damage. We extracted date every area and collected 642 samples. Thus, we performed a multiple regression analysis by using stepwise method. The each coefficient of correlation is really low and the other P-value drop below 0.001. Therefore, estimate value of salt damage doesn't indicate a significant correlation between other climate conditions. For the reason, that doesn't indicate a significant correlation, estimate value strongly caused by season. However, experience of Independent Administrative Institution Public Works Research Institute has only the result of annual statistics. Also, there is problem at independent variable. We applied value of wind direction as equivalent value. It is reasonable to think that consider measure about another dependent variable and independent variable.

Figure6 shows the result that open to the public by cloud GIS. We uploaded climate conditions map and frost damage level map to cloud GIS. These maps enable to consult 1km resolution. Thus, we are using cloud GIS to open the public on web, enable to confirm it anywhere if there is it under the environment where the Internet leads.

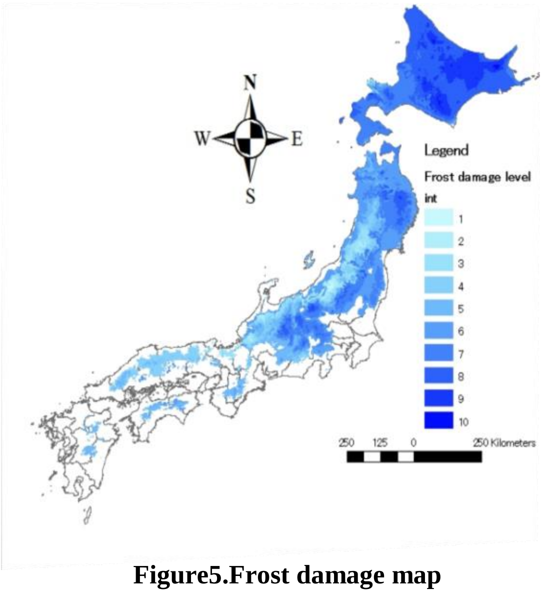

Figure5.Frost damage map

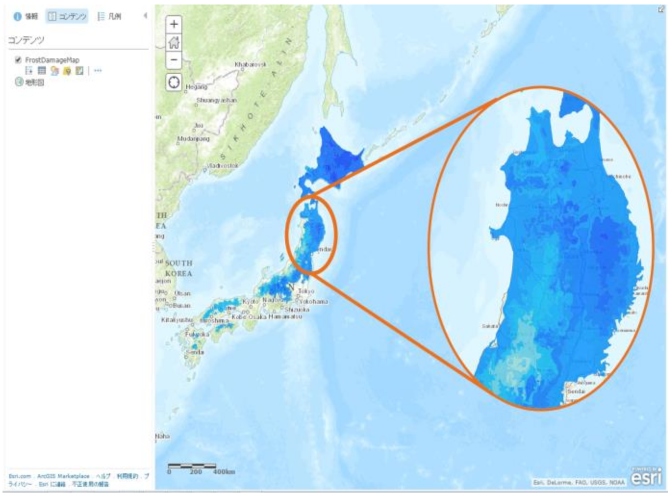

Figure6.Opened to public by cloud GIS

4. CONCLUSION

In conclusion, we created climate condition maps of 1km resolution and damage level map. These map show a special feature of climate and enable to consult details of Japan climate for designers and constructors. Thus, equation of frost damage level was proposed by using multiple regression analysis. These equation enable to calculate by data of AMeDAS for designer and constructor easily. However, equation of salt damage weren't achieved by any method on this paper. We should consider measure about another dependent variable or independent variable. Then, these map were opened to public by cloud GIS. Finally, we developed support application that support to understand climate condition to share by cloud GIS for designer and constructor in Japan.

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