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CURRENT DEVELOPMENT STATUS OF HYDROMETRIC SYSTEMS,SEDIMENT MONITORING SYSTEMS AND INFORMATION TRANSMISSION TECHNIQUE FOR THE PURPOSE OF PREVENTING SEDIMENT DISASTERS

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ABSTRACT

Averagely speaking, about 1,000 sediment disasters occur every year in Japan. Various hardware and software systems are being developed in order to mitigate the damage caused by such disasters. Coming up with proper measures definitely requires development and disposition of equipment and systems that can accurately observe the phenomena causing the sediment disasters and that can transmit the related information. We will present the latest development situation of hydrological and sediment observation systems as well as information transmission systems in Japan.

Key words: Sediment Disasters, Hydrological Observation, Sediment Observation, Information Transmission Systems

DEVELOPMENT HISTORY AND RECENT TREND

We will divide our presentation into two categories, i.e., the data gathering systems and the data transmission systems.

Data Gathering Systems

1)Hydrological Observation Systems

a)Water Level Gauge

The method of measuring a water level used to be reading the calibrations of a water level measuring board by eyes. Later, the measurement equipment was automated and water level gauges of different working principles were developed such as a float type, air bubble type, reed switch type and a water pressure type.

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They are all contact type gauges and directly measure a water level by installing the sensor units in the water, by means of buoyancy, water pressure, etc., which entails some weak points like debris and dirt sticking to the sensors and possible damage caused by a debris flow.
To solve such problems, non-contact type sensors have been introduced which include an ultrasonic water level gauge that allows indirect measurement and a radio wave water level gauge that avoids the influence of temperature and other environmental conditions.

Water Level Measuring Board → Float Type → Air Bubble Type → Reed Switch Type → Water Pressure Type → Ultrasonic Type → Radio Wave Type

b)Current Meter
The traditional method of measuring current velocity was to visually determine the traveling time of a floating cylinder thrown into the water between the two points. There was a possibility of errors because the starting time and arrival time were determined by human eyes. For that reason a rotary current meter, electromagnetic current meter, ultrasonic current meter, etc. were developed for the improved measurements.
Those current meters had their sensor units installed under water and consequently they had problems of debris and dirt clinging to themselves and a debris flow damaging the sensors.
For the purpose of solving the above problems, non-contact type current meters have been developed including a radio wave current meter and a completely new system that determines the velocity by analyzing the video data taken by a monitoring camera.

Floating Cylinder →Rotary Type →Electromagnetic Type → Ultrasonic Type → Radio Wave Type →Video Data Analysis

2)Observation Systems for Sediment and Crustal Deformation
a)Debris Flow Detective Sensor
The debris flow detection in the past was made by a contact method, or by stretching a wire across the anticipated area where a debris flow might flow down and the detection was accomplished when the wire was cut off.
The contact type system, once it detects the occurrence of a debris flow, cannot repeat the detection any more. To solve the disadvantage and to make repeated measurement possible, various non-contact type sensors have come into existence. They include a non-contact vibration sensor, acoustic sensor and a photo sensor. Revolutionary systems were recently developed, i.e., a sensor based on the analysis of video data available from a monitoring camera and a radar sensor that is capable not only of detecting a debris flow but also of measuring a water level and a current velocity.

Contact Type (Wire) → Non-contact Type (Vibration, Acoustic, Photo) → Non-contact Type (Video Data Analysis, Radar)

b)Observation Systems for Landslide and Other Crustal Deformation
A ground surface extensometer, ground tilt angle gauge and land surveying instrument used to

be employed for conventional landslide observation (ground surface displacement observation). However, the ground surface extensometer and ground tilt angle gauge have a common disadvantage that only a limited area can be measured with a single unit and usually multiple installations are necessary. In addition, it is quite difficult to select the right spot for the extensometer to be installed in case the landslide is anticipated in a large area and its head and side ends are not clear. On the other hand, a survey of the land requires a clear view between the two points, depending largely on weather condition.
Efforts were made to overcome these demerits and a new observation system using GPS was developed that could measure three dimensional displacement even at a location where the accumulated displacement was quite large. Naturally this system requires no visual clarity between the observation points. But the measurement accuracy was only as good as plus or minus several centimeters. A hybrid system has lately been introduced which combines GPS and a precision gyroscopic sensor, providing a high accuracy of millimeters.

Ground Extensometer, Ground Tilt Angle Gauge, Land Surveying Instrument →
Observation by GPS (accuracy: cm) → Observation by Hybrid GPS (accuracy: mm)

3)Monitoring Camera

The recent trend shows that a high definition three CCD monitoring camera has become a mainstream replacing a single CCD camera. We now have a three CCD monitoring camerawith as much as 33 telescoping power (optical and digital telescoping power all together). It has become more compact due to integration of various components to make its installation easier. The image data is now transmitted more often via optical fiber, instead of via metal cable, that provides transmission for a longer distance without being affected by lightning. Furthermore, radio communication using mobile phones or wireless LAN has been developed to replace the conventional telecommunications method via cable.

4)Information Gathering and Transmission Systems

High speed and large capacity transmission of data from the above sensors has become possible owing to the optical fiber and broad-band wireless transmission that provides the real-time, rather than intermittent, transmission of image data and the waveform of a seismograph.

5)Power Supply

The power saving feature of observation systems together with the advent of solar cells and wind power generators have made the observation possible even in the area where commercial power is not available. In addition, a fuel cell and hybrid power generator have been added to the newly developed items. The latter combines the features of a solar cell and a wind power generator.

Data Transmission Systems

Thanks to the rapidly improved infrastructure in the field of information technology, varied means of transmitting information have been established such as Internet, optical fiber, satellite communications, multiplex technology, radio communication, cellular phones, CATV, wireless LAN, etc. As a result, it has become possible for many people to share the multi-addressed information at high speed, in real time and extensively. Especially the following points are noteworthy:

1) Provision of image data, rainfall, observation data and alert/evacuation information via Internet
2) Building a wireless network system like wireless LAN
3) Provision of information via network like CATV
4) Provision of information for individuals utilizing, for instance, the cellular phone on-line service

In the area of erosion control activities, an interactive information system has started to be used, which consists of low cost information terminals to be placed at private homes and acentral information processing unit installed at a village office, for the purpose of exchanging information on sediment disasters between the village office and residents.

EXAMPLES

Video Monitoring System for Sediment Observation

1)Background of Development

In general at present, many contact type wire sensors are installed for detection of debris flows. However, the wire sensor has a definite disadvantage that, once the wire is cut by a debris flow, it does not work until the wire is replaced. It is not usable for repeated occurrence of debris flows. This is why non-contact type sensors have been developed. With the optical fiber network spreading rapidly of late, an increasing number of monitoring cameras are installed. A video monitoring system has recently been attracting wide attention, which is based on the video analysis technology applied to the video data available from the monitoring camera.

2)Present Situation of Technology Development

The video analysis technology is to determine the transfer direction and speed of pixels in the motion video taken by a monitoring camera, judging from the temporal and spatial change of the pixels. Actual procedure is that each pixel of the video shot at the time ‘t’ is converted into one of black-and-white 256 gradations, and then the following step is to detect where the respective pixel moved in the next picture at the time ‘t + Δt’, thus arriving at the direction and speed of the movement. The speed of a debris flow will be measured based on the information covering direction and speed of the moving pixels. If it exceeds the preset speed, the system judges that an actual

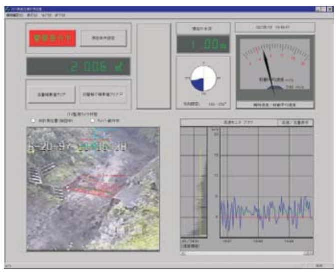


Fig. 1 Screen for video analysis

debris flow has occurred and raises the alarm.

The video monitoring system draws attention because of the fact that real-time image processing is now made possible by the advanced PC performance including much improved processing speed, that a highly accurate monitoring camera is readily available with high powered telescoping capability, and that it has become possible to record digitized images continuously for many hours and distribute or take a look at such image data via Internet.

3)Application Example

a)Place

Within the district of Fuji Sediment Control Office of Ministry of Land, Infrastructure and Transport located in Fujinomiya, Shizuoka Prefecture, Japan

b)Description

The Oosawa River is a rapid and devastated stream located in the north slope of Mt. Fuji. The river basin has the largest erosion scar in our country called "Oosawa-kuzure" that has produced a huge amount of sediment to flow down in the past, causing repeated sediment disasters in the lower reach.

Fig.2 Oosawa-kuzure of Mt. Fuji

An observation system was established to cover the whole river basin to prevent and mitigate the damage caused by debris flows originating from Oosawa-kuzure. Iwadoi Observatory located at the upstream end of the Oosawa river alluvial fan is equipped with different kinds of sensors including a water level gauge,rain gauge, current meter and monitoring cameras.

Fig. 3 Iwadoi observatory

The monitoring cameras are used as part of the debris flow monitoring system based on the video analysis technology.

When a debris flow occurred on June 20, 1997, the following data were procured by the video analysis system.

- Maximum water level: 2.6m
- Maximum flood discharge: 198.62cu.m/s
- Gross discharge: Approx. 450,000m^3
- Maximum velocity: 9.6m/s

4)Issues to be Examined and Improvement Effort Under Way

The accuracy of the monitoring system based on video analysis technology varies depending on the quality of the video data delivered from a monitoring camera. Especially weather conditions such as fog or rain and luminous intensity of a light, when the observation is made at night, affect the accuracy of the analysis. Compensation software is under development to stabilize the accuracy irrespective of varied conditions.

Landslide Monitoring System

1)Background of Development

We have about 10,000 dangerous spots throughout Japan where landslides could occur, each involving more than 5 houses that might suffer damages. Such landslide disasters happened mostly in snowmelt season every year. Monitoring and observation of landslides are necessary first of all to establish the appropriate measures to mitigate such disasters.

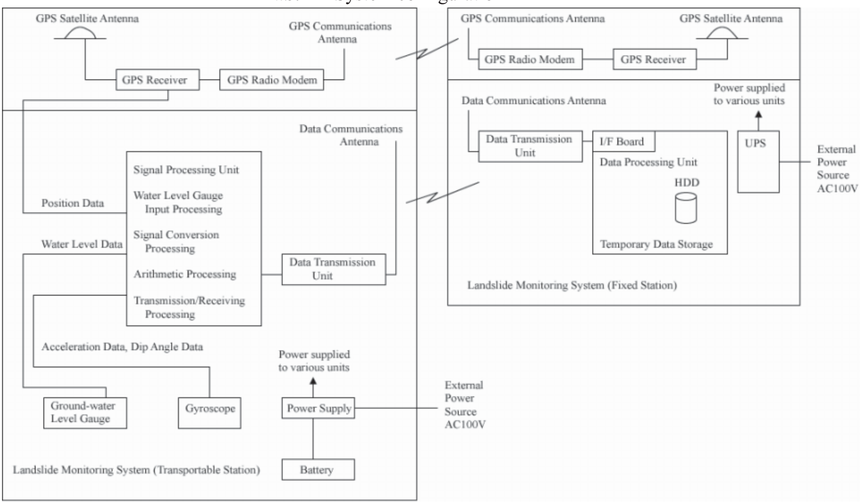
2)Technology Development Situation

The latest landslide monitoring system integrates GPS and a high-performance gyroscope developed for ground surface displacement observation, both of which respectively check the other's measurement data and make necessary correction to accomplish stable measurement of the displacement with the accuracy of millimeters, which was not possible with the traditional single unit instrument.

The gyroscope in general is an instrument to accurately detect the rotary motion of an object in space. It is combined with an accelerometer to compute and form a "fixed horizontal plane coordinates in space". When a landslide monitoring system complete with the gyroscope moves according to ground surface displacement, the system detects it comparing its own position with the fixed horizontal plane coordinates. By adding the feature of distance measurement to the basic function, the system can measure the quantity of movement including the direction, speed and position with the accuracy of millimeters.

Fig. 4 Full view of landslide Monitoring system

Tab. 1 System configuration



GPS is a system for determining the observation position on the earth by receiving signals from 24 Navigation Satellites (NAVSAT) on the orbit. Especially the GPS used for the landslide monitoring system employs what they call the Real-time Kinematics that determines the relative positions between two points by interference measurement method. It allows efficient measurement of the displacement of the landslide monitoring system with extremely high accuracy, namely plus or minus several centimeters per second. In addition, we have an expanded system configuration where a ground-water level gauge is added to the landslide monitoring system for detection of the ground-water level with the accuracy of plus or minus approximately 10cm. In other words, we can detect as a by-product the change of ground water level which is closely related with a landslide.

The specific low power radio communication equipment is used as a means of data transmission, which does not require a license and can transmit the data as far as 300m maximum (the distance can be extended by setting up a relay station).

3)Application Example

a)Place

Iwasaki Area Landslide Prevention Zone in Iwasaki Village, Nishi-Tsugaru-gun, Aomori Prefecture (The zone was specified by Aomori Prefectural Office)

b)Description

There are in Iwasaki area the village office, Mutsu Iwasaki Station of Japan Railway's Gonou Line, a rest home for the aged and many private houses located close to the possible landslide zone. The record shows that an earthquake swarm hit the west coast of Aomori Prefecture (the neighborhood of Iwasaki Village) in 1978. The earthquake recently occurred in the central part of Japan Sea caused various damages due to the ground upheavals or collapses.

Fig. 5 Panorama view of Iwasaki area

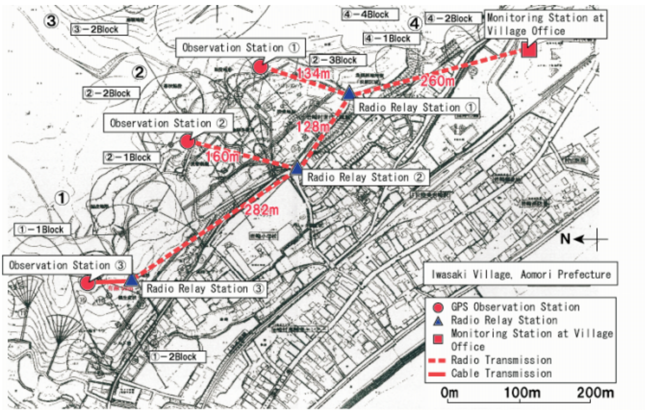


Fig. 6 Disposition of monitoring system

Three GPS observation stations and the same number of radio relay stations have been set up in Iwasaki area with one monitoring station in the village office. The specified low power radio communication is used between the monitoring station and GPS observation stations. The data is transmitted for more than 300m via radio relay station (transmission via cable is used just between the No. 3 observation station and its relay station). The data transmitted to the monitoring station is processed by a PC in the village office to watch the displacement value all the time.
The PC in the village office is connected with a leased circuit for cable transmission of data to the PC in Ajigasawa Civil Engineering Office so that the monitored information is readily available there. The automatic reporting system dispatches necessary information to each individual in charge via network.

4)Issues to be Examined and Improvement Effort Under Way

A ground displacement measuring system consisting of GPS and a gyroscope is currently used for monitoring possible landslides in Iwasaki area. By adding a ground-water level gauge the system is expected to provide, in addition to monitoring a landslide, information on the fluctuation of ground-water level that has a close relationship with the landslide itself, resulting in more effective observation.

Mutual Reporting System of Sediment Disasters

1)Background of Development

Information on disasters in general is sent to residents by the administration. On the other hand, the information those residents have regarding the sign of sediment disasters or damage incurred in the neighborhood is very important for the administration to make a decision of whether or not a warning/evacuation order be issued. In other words, there is a need for a system that allows exchanging information on sediment disasters between the administration and residents.

2)Technology Development Situation

The means of telecommunications for providing information on sediment disasters include a public telephone network, facsimile transmission, mobile phone communication, disaster prevention radio network, Internet, etc. But when a disaster occurs, the communication network for public telephones and mobile phones may collapse and will be useless owing to a power failure, traffic congestion, etc.
A new system has been developed that uses the data communications network for mobile phones (DoPa network), which is not affected at all by traffic congestion of other networks.
Wide area telecommunications are possible with the DoPa network as far as they are within the mobile phone service area. But it is completely independent from the public subscribers' telephone network and highly reliable in case a disaster occurs. The terminal for the system is designed to operate from a built-in battery, making it possible to work even when the power fails.
The Mutual Reporting System of Sediment Disasters comprises the central information

processing unit to be installed in an administrative office and information terminals for installation in the public facilities and private houses of residents in the dangerous area where sediment disasters are expected. The central information processing unit and terminals provide two-way communications between them exchanging disaster information. Each information terminal incorporates a mobile phone terminal and can be used anywhere in the mobile phone service area.

Fig. 7 Information terminal

3)Application Example

a)Place

Yokkaichi City, Mie Prefecture

b)Description

Mie Prefecture is known as one of the heaviest annual rainfall areas in Japan. Especially the southern part of the prefecture has an annual precipitation amounting to 3,000 to 4,000mm and is characterized by the extreme rainfall intensity. Many typhoons go through the area with heavy rains that tend to cause sediment disasters. Consequently, Yokkaichi City of Mie Prefecture decided to be the first among other local governments to introduce the above system for the purpose of sharing disaster information with the local residents.

The outline of the system configuration is as follows:

- A telemetry monitoring system that gathers data from rainfall observation stations and processes them to determine the level of danger and necessity of evacuation (installed at Disaster Division of Yokkaichi Municipal Office)
- The central information processing unit to provide residents with the information covering sediment disasters and the level of danger and necessity of evacuation determined by the telemetry monitoring system (installed at Disaster Division of Yokkaichi Municipal Office)
- Information terminals used by residents for reporting to the central information processing unit about sediment disasters (installed at Civic Center of Yokkaichi City, too)
- A sediment web server that monitors the information exchanged between the information terminals and the central information processing unit (installed at Software Center of Mie Prefectural Office)

Communication circuits used are:

- The data communications network for mobile phones (DoPa network) between the information terminals and the central information processing unit
- A leased line (DA 128 channels) between the central information processing unit and the sediment web server

The central information processing unit also has a function of automatically transmitting information to the information terminals according to the degree of danger or necessity of evacuation determined by the telemetry monitoring system.

4)Issues to be Examined and Improvement Effort Under Way

The current Mutual Reporting System of Sediment Disasters transmits information via data communications network for mobile phones in order to avoid disorder due to power failures or traffic congestion. Possibility is being studied to provide options of other communications means, such as existing public subscribers' telephone network, Internet or disaster prevention radio communication network in consideration of the cost involved, and also options of other information to be transmitted, such as welfare information and/or ordinary disaster information in addition to that of sediment disasters, to suit the specific local needs.

CONCLUSION

We believe it essential to try to keep up with the rapidly developing information and telecommunications technology, obtain such information on the new technology as quickly as possible, examine it to see if it is reliable enough to be applicable to data transmission of sediment disasters and positively use it once it proves to be satisfactory.

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