

Overview of Research Activities

Infrastructure Field

1 R & D of a more economical and safety structural system for long-span suspension bridges

Kunie NOGAMI and Yusuke KISHI

As the construction of long-span suspension bridges pushed forward into new territory, the emphasis of development was historically on financial integrity and safety. However, recent changes in the societal environment mean that more rational designs that provide better economy and durability are now required. Efforts to develop new structural forms and design methods that meet these new requirements are urgently needed. The aim of this research program is to pursue the long-span suspension bridges which have a more safety and cost-performance. During the current year, research focused on the themes outlined below.

a) Clarification of elasto-plastic behavior and ultimate strength characteristics of 3 and multi super long-span suspension bridges

We carried out to do the detailed design for the three-span, four-span and five-span structures which varied in the sag ratio(1/8, 1/10, 1/12), as an example of an super long-span suspension bridge. Parametric analysis was carried out to clarify the effects of adopting two boxes + a grating section form for the stiffening girder and of using high-strength main cables on the elasto-plastic behavior and ultimate strength characteristics of a whole structural system.

b) Clarification of elasto-plastic behavior and load-carrying capacity of the composite tower in long-span suspension bridge

The ultimate in-plane behavior in the longitudinal directions of the main towers for a 1,500 m suspension bridge had been clarified, considering steel, RC and composite structures. In this year, the ultimate in-plane behavior in the bridge-axis directions of the composite main tower was calculated. In addition, we clarified the possibility of the applicability of the composite tower.

c) Clarification of the seismic response characteristics of the multi super long-span suspension bridges by 3 earthquakes

Super long-span suspension bridge with 3000 m of center span length was taken up and the seismic response characteristics of the suspension bridge whole system by the typical 3 earthquake waves of our country were considered.

2 Research on durability (remaining ultimate strength) evaluation method for existing structural members in steel and composite structures

Kunieie NOGAMI and Yusuke KISHI

Typical causes of deterioration and damage in structural members and in steel structures are corrosion and deformation. As deterioration and damage progress in a structure, the cross-sectional area of structural members falls and the structure loses load-carrying capacity. This means that it is extremely important to accurately evaluate the remaining ultimate strength of structural members and structures after corrosion and deformation have progressed so as to determine future durability and study maintenance and/or replacement. For the purpose of establishing a method for evaluating the remaining ultimate strength of deteriorated or damaged structural members, this research program aims to clarify experimentally and analytically the ultimate strength characteristics and the corrosion parameters that lead to decreases the load-carrying capacity. It also includes a basic study aimed at proposing a method of evaluating remaining ultimate strength. The research focused on the themes outlined below during the current year.

a) The remaining load-carrying capacity of corroded compressive diagonal and chord members of steel truss bridges

Focusing on the compressive diagonal and chord members of steel truss bridges in 1955 's, we carried out the measurement of the corrosion shape and the experiment of the load-carrying capacity and reproduced the experimental result of the corroded columns by using the FEM. Parameters affecting load-carrying capacity were identified. An equation for evaluating remaining load-carrying capacity was proposed.

b) Ultimate strength analysis of overall systems of corroded steel truss bridge

After the corrosion shapes based on the measured corrosion data is introduced into gusset plate connections, we analyzed the ultimate strength of the whole system of steel truss bridge. A relationship between the corrosion forms and collapse behavior of the whole system and the evaluation of the ultimate strength were considered.

c) Corrosion distribution and ultimate strength of a plate girder bridge' s support area

This research focuses on a specimen of plate girder bridge' s support area where corrosion tends to develop typically, and seeks to elucidate the relationship between corrosion and the ultimate strength of the end part of the girder bridge experimentally. The bridge was removed after approximately 80 years in service due to change in train route.

3 Research on effective use of the advanced analysis technique towards rationalization of the steel bridge

Kunie NOGAMI and Yusuke KISHI

Specifications for the highway bridges is revised the allowable stress design method version 2012, and the revised work to performance based design method is done successfully. In such a situation, although the framed construction analysis based on beam theory is adopted as the structural analysis in a design, more advanced FEM etc. are applied to stress calculation in details structure or a complicated structure. Realization of a competitive steel bridge is attained by improving the environment where the details structure of a steel bridge can be designed flexibly and rationally. Furthermore, in order to secure the quality of a necessary level using the diagnostic of the steel bridge which is thin-walled structure, it is required to introduce on the code of the advanced analysis technique.

In this year, this research takes up the beam-to-column connections of steel bridge piers with complicated stress quality. We evaluated the stress distribution and ultimate strength of corner part of steel bridge piers with T type and compared about this stress quality evaluation and ultimate strength by the 3 analysis method of framed structural analysis which used the beam element, FEM analysis and fixed shear flow panel analysis. The ultimate strength characteristic of beam-to-column connections was made clear by FEM analysis.

4 Research on Coupled Buckling Strength of Steel Compression Members with Box Section

Kunie NOGAMI and Yusuke KISHI

Present design method for steel highway bridges is used for many years based on simplified theory and improved usability. However, these design calculations of mechanical bridge behaviors are simplified drastically comparing with actual bridge performance. Therefore, divergence between the design calculation results and structural performance in real bridges is focused in recent years.

On the other hand, advanced numerical calculation methods represented by FEM are widely used in various fields. These methods are able to calculate easily and accurately the structure's mechanical performance, therefore it is possible to investigate the irrational parts in current design method based on the real structural behaviors. Thus, this research verifies rational suggestion to improve the structural design method, and evaluation method of coupled buckling for box-section compression members was verified as an example.

Stiffened box-section based on actual steel arch rib were selected for numerical model of target member. In addition, width-thickness ratio and slenderness ratio were varied to calculate the distribution of coupled buckling strength. New evaluation method was proposed based on the distribution of coupled buckling strength for steel box-section compression members.

5 Elucidate of reduction mechanism of load carrying capacity for steel bridge piers under cyclic loading of long-duration earthquake motion

Yusuke KISHI

Recently, the occurrence of long duration time seismic motion is predicted during huge trench-type earthquakes around Japan, and dozens of cyclic behaviors are focused as the external force to cause serious damage to structures. However, the seismic performance of steel bridge piers subjected to such a wave has not been investigated sufficiently. Furthermore, local buckling affects the load carrying capacity of steel bridge piers under the dozens of cyclic motions. Hence, in this study, the load capacity of steel bridge piers was evaluated in the elastic range after maximum yield displacement with cyclic loading. Finite element analysis conducted to confirm the effect of widththickness ratio on buckling parameter. The numerical analysis results suggest that the load-carrying capacity during cyclic loading decreases with decreasing widththickness ratio parameter.

6 Application of innovative new material "FRP" for the infrastructures

Hitoshi NAKAMURA

a) Study on material and structural properties of GFRP members

The progress of the development of fiber reinforced plastics (FRPs) in recent years is remarkable, and they are spotlighted as new materials for bridges because of the ultra light weight and the high durability for the salt damage. However, the evaluation method of the material and structural properties were not established. In this study, the material and structural properties were experimentally studied for the pultruded and hand lay-up GFRP channel members.

b) Development of trussed inspection path for bridges using pultruded GFRP members

In order to develop the trussed inspection path for the bridges using pultruded GFRP members, the investigation of the connections between the lower chord and the diagonal members using the real-size models were conducted and the real-size prototypes were fabricated. The bending flexural tests and vibration tests were conducted. using the real-size prototypes. As the results, it was found that the proposed structures have the height rigidity and the serviceability is sufficiently satisfied.

7 Repair and strengthening for steel structures using externally-bonded FRP

Hitoshi Nakamura

a) Repair of fatigue cracks using externally-bonded CFRP strips

The fatigue damage has been generated in many members of steel bridges by the heavy traffic loads. The number of the steel bridge which requires repair and reinforcement increases. Fiber reinforced

plastics, which are the light weight and are excellent in workability and weather resistance, have been applied for materials of repair and reinforcement in civil engineering structures. The purpose of this study is to clarify the feasibility of carbon fiber reinforced plastic stripes for the fatigue crack repair of existing steel bridges, and to obtain basic data for establishing design and construction method.

b) Repair method of steel members with a partial loss of cross-sectional area using CFRP strips

The loss of cross-sectional area caused by the corrosion has been often reported in the existing steel structures. In such situations, the higher stresses occur in the loss of cross-sectional area under the dead load. However, the influence of the dead load on the repair effect and the ultimate strength does not have been investigated. In this study, the steel plates with the loss of cross-sectional area were repaired by the externally-bonded CFRP strips and the tensile tests were conducted in considering the dead load. As the results, the repair effects were discussed.

c) Evaluation of bending load carrying capacity for steel girders bonded by CFRP strips and epoxy resin adhesives

It is often required for the existing bridges to increase the load carrying capacity of the main girders or slab because of the change of design loads. The construction method of the bolted joint with steel patch plates and high strength bolts are selected. However the drilling and the bolt fastening are conducted in situ, so that it is not excellent for the workability. On the other hand, the construction method of bonded joint using CFRP strips has been proposed and pilot tested for practical use. However the comparison of both construction methods are not investigated in repair effects and the bending load carrying capacity under the initial load as the dead load. The purpose of this study is to clarify the repair effect of the steel girders repaired with the steel plates and CFRP strips under initial load.

d) Evaluation of fatigue strength and debonding progress of adhesively bonded joints between steel plates and CFRP strips

In this study, the fatigue durability of the adhesively bonded joints between CFRP strips and steel plates were investigated experimentally and analytically aiming at the debonding in the end of CFRP strips. Fatigue tests were conducted using the coupon specimens composed of the steel flat bar adhesively bonded by multi-layered CFRP strips varying the stress range and the number of layers of the CFRP strip. The stress intensity factor of the debonding tip were calculated by FE analysis and the propagation life of the debonding was predicted based on the linear fracture mechanics.

e) Development of repair method of steel members by externally bonded carbon fiber sheets using VaRTM technology

The objective in this study is to develop a repair and strengthening method of existing steel members by Vacuum assisted Resin Transfer Molding (VaRTM) technology. First, coupon specimens of hybrid FRP plates were fabricated using VaRTM and were tested in order to investigate fundamental material properties. Next, in order to study repair effect and bonding strength, the steel plates bonded the hybrid FRP plates using VaRTM were tested under bending load. The results show the quality of material

properties of hybrid FRP plates are high and equivalent to a pultruded material. Although the bonding strength varied widely, the bonding strength was high in general. Therefore, the significant repair effect by the VaRTM technology was confirmed.

8 Investigation research on history of material, structure and design for bridges, and evaluation as modern cultural heritages in civil engineering

Hitoshi NAKAMURA

Recently, civil engineering structures, which were constructed between the age of civilization in the pre-Meiji era and the end of war in the Showa era, have been evaluated as the modern cultural heritage. Bridges are among the most important civil engineering structures. In order to prevent loss of valuable bridge records and to stimulate repair or preservation works, immediate results of evaluation are desired. The purpose of this study is to investigate the development of Japanese bridge technology, the character of bridge distribution in each river, and the change of material, structure and design for each bridge type, focusing on bridges in the Tokyo metropolitan area. Then, results of this study are used for the evaluation as modern cultural heritages and for the reflection in designing, repair and strengthening of today.

9 Estimation Method for Vehicle Emissions Considering Dynamic Traffic Condition

Hiroyuki ONEYAMA

The air pollutants produced by road traffic, such as nitrogen oxides (NO_x), particulate matter (PM), and carbon dioxide (CO₂), which is a cause of global warming, are especially severe in the vicinity of intersections and congested areas. In order to effectively evaluate their effect, the dynamic changes in traffic flow should be described and the emission levels under these traffic conditions should be estimated using an emission model that can take into account the effect of variations in the speeds of vehicles on the emissions. This year, fuel consumption models, developed last year based on actual probe data obtained from the large amount of vehicle probe data, were improved and investigated further. As a result, the more precise model was developed.

10 Analysis of the Behavioral Changes of the Entrance and Exit Ramp in Case of Accident Using ETC Data

Hiroyuki ONEYAMA and Masami YANAGIHARA

Huge traffic is flowing on the Metropolitan Expressway (MEX) with its dense network structure, and even more arterial road network are substantial. Therefore, once accident occurs, there are drivers' behavior such as giving up to use MEX and changing the entering ramp and these phenomena have been identified in previous studies. However, the model to estimate entering ramp changing behavior has not

been constructed considering frequency of use and entering time. In the study, we analyzed the change of the main entrance rate in case of accidents using ETC data. Specifically, the daily user behaviors are classified into six categories by the usage of MEX, entering ramp and time. And then, the behavior change of each user was represented by the differences of the rate between normal cases and accident case. Furthermore, these users are classified applying the cluster analysis. As a result, the different characteristic can be seen by the entrance of the area such as the inner city and suburban areas.

11 Open Economy Spatial Computable General Equilibrium Model Featuring International Transport Gateway

Tomoki ISHIKURA

This paper builds a spatial computable general equilibrium model featuring international transport gateway region. The model explicitly handles export industry and import industry as the required transport service industries for international trade. Domestic interregional transport system is also explicitly modeled by introducing iceberg transport cost concept. Furthermore we illustrate the methodology for converting from standard Input-Output table to benchmark data for our model and apply the methodology to Tokyo Metropolitan Input-Output Table.

12 Analysis of car-following behaviors considering multiple drivers' latent intentions

Masami Yanagihara

A classification for car-following behaviors is provided, that is varied and affected by surrounding environments, individual attributes, and the drivers' intentions. Several car-following models are used in general microscopic traffic simulations and car-following behavior analysis. In order to support these studies, the provided method uses several values of likelihood of sub-car-following models used in some complex vehicle behavior models. EM algorithm is used for calculation of classification with some definitions of the number of groups and function forms for likelihoods of sub-models corresponding to each group. In an empirical study with real car-trajectory data, vehicles' behaviors are well classified into four groups of approximately the same size. One of the four groups is not well matches to the car-following model because of external factors. Additionally, a reasonable formulation for car-following behaviors is revealed.

13 Effect of Moving Light Guide System to smooth traffic flow

Hiroyuki Oneyama, Masami Yanagihara

It should be possible to achieve a smoother traffic flow if the desired speed of drivers could be levelled to a more uniform speed by an external factor. The relationship between the degree of levelling and the improvement in flow rate is analyzed using the microscopic traffic simulation. Moving Light Guide

System, whereby light emitters installed in the shoulder of the road light up as if light is flowing along them, is focused on as a measure to level the desired speed. The relationship between the proportion of vehicles that responded to this system and traffic flow is analyzed. When the proportion of vehicles responding to the system was low, we did not find any significant difference in the results. When it increased to around 50

14 Traffic state interpolation of unobserved road links

Hiroyuki Oneyama, Masami Yanagihara

It is hoped to estimate the traffic volumes on whole road network using more accurate method, in order assessment and management of road network. Wide area information for this is inexpensively collectible from probe car data. However in present status of spread of a few probe cars, information on all of road sections or time spans is rarely available without lack of data. In this study, a method to interpolate traffic volumes on road network using Gaussian Graphical Model is provided. In the estimation step of this method, traffic volumes on not all of roads are needed. In particular, computing load in the estimation step based on EM algorithm is reduced by calculation technique with closed-form formulation deformed by eigenvalue decomposition. In accuracy verification with dataset generated by traffic simulation, the relationship between the rate of lacking data and the accuracy of the estimated result are analyzed.

Environmental System Field

1 Systems Analysis for Environmental Engineering

Akira KOIZUMI, Toyono INAKAZU, Yasuhiro ARAI, Kimiko YAMAZAKI, Takaharu KUNIZANE and Minako KOMINE

In our laboratory of sanitary engineering, the computer applications to water-works, sewage-works and studying with the methods of systems analysis and applied mathematics, and also the experiments in a laboratory and the field surveys are assisted. Our subject is a practical study for an ideal future of the urban environment.

Nowadays, a lots of environmental problems in the cities are very complicated, and such problems are difficult to solve only on a viewpoint of civil engineering, therefore we must consider them on the economical and sociological viewpoints and etc. The purpose of our study is to find the compromised better solution for the problems in the fields of water and wastewater engineering and also municipal solid wastes engineering. In this year, we solved some problems and published the papers which are listed in the following pages.

2 Study on Short-term Water Demand Prediction and Water Distribution Control Planning

Akira KOIZUMI, Toyono INAKAZU and Yasuhiro ARAI

Water supply system serves as a lifeline for our urban life, and the active maintenance planning is needed to preserve its security. In this paper, we propose a time series model for hourly fluctuation of supplied water consumption. First, after analysis of the fluctuations, we find the two components that are the cyclic component (typical fluctuated pattern with a 1-day cycle) and the deviational component (complex and random pattern). Second, we make the cyclic and deviational component models by applying the finite Fourier series and multiple ARIMA models respectively. Third, we show a case study and we can obtain an effective model to describe the supplied water consumption. Our proposed model is useful for water distribution control planning.

3 Optimal Water Supply Control and Management Planning for Improvements in Energy Efficiency

Akira KOIZUMI, Yasuhiro ARAI and Takaharu KUNIZANE

In this research we considered the optimal water supply control and management plan for minimizing power usage by water distribution pumps. We first looked at water distribution systems in urban areas from the standpoint of energy conservation and determined what kind of water supply control and management is necessary for saving energy. We devised an optimal model of the “route/flow decision problem” for minimizing power use in the water distribution system while meeting demand in the distribution areas, and formularized the model by means of Mixed Integer Linear Programming (MILP). Then to validate the MILP model we attempted a case study in an actual water distribution system. This study was supported by joint research fund of Waterworks Bureau, Tokyo Metropolitan Government.

4 Study on Control and Management Planning for Water and Wastewater Systems in Urban Area

Akira KOIZUMI, Toyono INAKAZU

In order to maintain the stable activity of water and wastewater system, we need an economical and effective plan which has adaptability for the kinds of fluctuation arisen from urban factors. We may also consider the effective use of resources in the evaluation of control and management plan for urban systems. In one of our research, we apply time series analysis to the control planning for wastewater treatment system, and we can clear the structural relationship between factors which help us to keep stability of the treated water quality. In another research for water distribution network management we deal with the lower water quality problem, which makes great damage to many residents. We propose a method to estimate the amount of suspended iron rust which advects or sediments in water pipelines.

By using this method, we show how to decide the priority sequence minimizing water drain volume for pipeline cleaning.

5 Study on Optimization of Renewal Planning of Water and Wastewater Pipe Networks

Akira KOIZUMI, Toyono INAKAZU and Takaharu KUNIZANE

The damage caused by the aging of water distribution pipes or sewage pipes has become one of the major problems. The pipes renewal costs much money and time, so the renewal planning has to be made under evaluating its effects and costs sufficiently. In this research we quantify the effects of renewal in water distribution pipe system, and propose a new methodology applying Genetic Algorithm (GA) on the scheduling problem to maximize benefits of water supply performance in the planning period under the revenue constraints. Through the sensitivity analysis using our GA model, we can clarify the validity of investment under trade-off between water supply service level and renewal cost.

6 Statistical Analysis for Municipal Solid Wastes and Air Pollution

Akira KOIZUMI, Toyono INAKAZU, Kimiko YAMAZAKI and Yasuhiro ARAI

The increase of municipal solid wastes and air pollution are big problems in Tokyo, so it is very important how to control them. We have been studying the relationship between those actual conditions and regional characteristics depending on the statistics, and cleared the difference or similarity in each district of Tokyo metropolitan area. And we also explained the structures of those generations based on the statistical viewpoint by using the Multiple Regression analysis, Principal Component analysis and System Dynamics. Our results will be used for the municipal solid wastes treatment and disposal planning and also the air pollution control in the near future.

7 An Analysis of the Quantitative Relation of Recyclable Waste to Domestic Refuse

Akira KOIZUMI, Yasuhiro ARAI

This analysis shows the quantitative relation of the recyclable waste amount to domestic refuse generated from households, based on the continuous actual survey data collected from questionnaires and measurements. Firstly, we examined the change in the total waste amount generated between each survey period, and classified data samples into three groups by their amount. Secondly, we calculated the ratio R/D to be that of the recyclable waste amount to domestic refuse generated from a household, and showed the difference in the recoverable amount for every composition item. Thirdly, in order to show the variations in the recoverable amount of recyclable papers and plastics, we conducted a comparative analysis. Our proposed results are useful to estimate the reducible amount of domestic refuse.

8 Study on Optimization of Transportation Planning for Waste Treatment and Recycling

Akira KOIZUMI, Toyono INAKAZU and Yasuhiro ARAI

This study analyzes an optimal planning of facility arrangement and transportation problems for recycling and waste treatment. First, We proposed a fuzzy linear programming model for the area-wide hazardous waste transportation planning. This model selected the optimal route taking the planner's permissible level into fuzziness under multipurpose (to minimize the total transportation cost, to minimize the number of traffic accident). Secondly for the recycling of electric household appliance, we applied genetic algorithms (GA) to solve a combinational optimization problem. After estimating the annual number of electric appliances in Tokyo, we investigated the collection systems as network models using GA. Through a case study, it was revealed that the application of GA was useful for the optimization of these problems. Part of this study was supported by the joint research scheme of The Tokyo Metropolitan Research Institute for Environmental Protection.

9 Research on predictive models for determining nutrient levels on Ogochi reservoir eutrophication

Akira KOIZUMI and Kimiko YAMAZAKI

Accurately forecasting inflow water quality and its effect on eutrophication provides water management agencies valuable information on aquatic ecosystems. This study describes that was conducted on predicting nutrient levels from local watersheds, including runoff from rainfall, on Ogochi Reservoir in western Tokyo, and its impact on reservoir eutrophication by utilizing water temperature and turbidity measurements. Multi-regression analysis was used to extrapolate predictive models for phosphorus and other plant nutrients. The predictive models correlated well with actual data and demonstrated a high level of predictability. The predictive models, which include precipitation measurements from non-point sources, can forecast nutrient levels and provide management an important tool for controlling and reversing reservoir eutrophication.

10 An Experimental Study for Preservation of Water Quality in the Reservoir

Akira KOIZUMI, Kimiko YAMAZAKI and Minako KOMINE

Recently, the reservation of drinking water sources is an important problem because people's interest is focused on the taste and odor. This study examined the seasonal change of the water quality of a reservoir on the Bonin Island, Tokyo. We found that the water quality wouldn't become worse by stopping the water circulator for about 1 week even in summer. In addition, changing the position of intake was showed to be an appropriate way against stopping the water circulator for long time. Moreover, by the

consignment of research from the Tokyo public government office, we examined the water quality of the dam for agriculture in the Haha-Jima Island and showed the possibility of the water quality improvement by the aquatic plant.

11 PIV Measurements for Rear-end and Head-on Collisions of Two Solitary Waves

Motohiko UMEYAMA

In 1834, John Scott Russell first observed a wave in the form of a single hump with a symmetrical shape and propagating at uniform speed without change in form in the Union Canal, Scotland. Russell built a 30-ft wave tank in his back garden, and performed some experiments that generated solitary waves. Boussinesq (1871) gave the first mathematical treatment of Russell's work, and later Rayleigh (1876) supported Russell's experimental observations by calculating the form and speed of such a solitary wave. Finally, Korteweg and de Vries (1895) arrived at the final step of the theory by considering the balance between nonlinearity and dispersion. The subtle balance of these two effects in the Korteweg-de Vries (KdV) equation influences the stability of a solitary wave. The nonlinear interaction of two solitary waves was examined numerically by Zabusky and Kruskal (1965). They found that the solitary waves retained their original shapes and speeds with only a phase shift after the collision of a large wave overtaking a smaller one.

Numerous experiments have been devoted to the propagation, deformation, breaking, reflection, or collision of solitary waves generated by different types of wavemakers. However, these types of laboratory equipment can be used only for a limited range of kinetic problems because the obtained fluid velocities rely on point measurement techniques for the LDA data or on the precision of the camera and lens in the case of photographic visualization. During the past two decades, advances in several visualization techniques have played an important role in fluid flow research. The developments in particle image velocimetry (PIV) have led to the visualization of velocity fields and particle paths.

The flow visualization technique was applied to the collision of two solitary waves propagating in the same and opposite directions. Measurements of the velocity and trajectory of the solitary waves were conducted using a PIV system consisting of an 8-W ND:YAG laser and a high-speed CCD camera. In the solitary-wave interaction tests, we set up three kinds of velocity fields - smaller, taller, and compound waves in the rear-end collision tests, and right-running, left-running, and colliding waves in the head-on collision tests. Instantaneous and spatial surface profiles were measured using the image thresholding method in which the boundary plane between the air and water can be detected as the interface having the maximum luminance value. The measured run-up elevation of the colliding wave was compared with the theoretical elevation using a third-order perturbation solution. Based on a Eulerian-Lagrangian algorithm, the PIV result was applied to the particle tracking process that occurred in the two-dimensional plane.

The observed data shows that the compound wave amplitude becomes smaller than the taller wave amplitude during rear-end collisions, but the colliding-wave amplitude is more than twice as large as the

single-wave amplitude during head-on collisions. The experimental wave profiles suggest that there is a phase difference in each solitary wave before and after a head-on collision. We have not made a detailed inspection of the phase shift phenomenon because the horizontal distance of the test section was limited for some depth conditions. We presented instantaneous velocity vector maps to compare them with two single solitary wave results. We used a PIV algorithm to track water particle displacements. The high accuracy of the proposed approach could be applied to a Lagrangian description of the trajectory of a water particle for both rear-end and head-on collisions.

12 A Comprehensive Approach for Estimating Hydraulic Quantities in a Multi-Branched Estuarine System

Motohiko UMEYAMA

Despite many previous investigations, there is no theoretically justifiable equation to determine the freshwater discharge, tidal velocity, and salinity in a complex estuary that contains several branches. In this study, the longitudinal distributions of freshwater and salinity concentration in multi-branched estuaries are investigated using a mathematical model, considering the energy balance by frictional head loss and the salt balance by diffusion and advection in a one-dimensional steady-state condition. We attempt to obtain the time-mean freshwater discharge rate quantitatively at a junction where the main flow separates into two branches. The salinity distribution along each branch is calculated by following the dispersion coefficient equation previously proposed for a single estuary. The salinity field is divided into the near-coast region and the upstream region, because in each segment the inland velocity varies according to the tidal flux. For computing the tidal velocity, we propose the Burgers equation and the Hoph-Cole transformation. The objectives of this study are (i) to develop a new model for estimating the distribution of freshwater discharges in the branched channels of an estuary system, (ii) to derive a solution for estimating tidal velocity along a channel, and (iii) to develop a predictive salt intrusion model for a multi-branched estuarine system. A comprehensive methodology is examined for the Red River estuarine system in Vietnam. The area is located in the northern part of Vietnam, where the Red River and its distributaries spread out to form a large alluvial plain, the Red River Delta that has a surface area of approximately 16,600 km² and occupies 4.5 % of the total area of Vietnam. It is the most developed area in the nation, comprising numerous modern cities and important economic zones. The Red River estuarine system lies in the southeastern part of the delta and includes four estuary branches: the Tra Ly, Red River, Ninh Co, and Day.

The theoretical results obtained by these equations were found to be in good agreement with a set of observed data in the Red River estuary system. The newly developed models are appropriate for practical use. These models evaluate the large-scale mixing mechanism caused by the residual circulation and tidal flux in multi-branched estuarine systems, where hydraulic data are not always feasible to analyze from field observations.

13 A new concept for the safety of low-lying land areas from natural disasters

Motohiko UMEYAMA

In recent years, strenuous efforts have been made to restore damage to the global environment and create a more sustainable society. Yet, in spite of the widespread movement to diminish greenhouse gases, substantial rewards are yet to be reaped. It may be impossible to halt the acceleration of sea level rise under the influence of global warming. The situation is dire for the many cities located near a river or sea. Moreover, many such cities are located below the water level along the sea. Therefore, there is an urgent need to devise and implement effective solutions for minimizing damage caused by natural disasters. The construction of social infrastructures capable of withstanding the impact of any global climate change must begin immediately. Residents of coastal areas must be alerted to be prepared for future disasters. The authors propose that to deal with water-related disasters, as exemplified by floods, the answer lies not in massive structures like dams, dikes, and seawalls but rather in taking an indirect approach that tames the water's impact and minimizes the effect of water-related disasters more economically. Based on previous researches (Nakajima and Umeyama 2007; Nakajima et al. 2011, 2012; Nakajima and Umeyama 2013), we continued to work and refine the more detailed study on this subject.

The objective is to introduce a far-sighted project for waterfront development of a city area in low-lying ground. In addition to waterfront redevelopment in high-density urban areas, another application of our concept is introduced for the reconstruction of the coastal area, destroyed because of the tsunami caused by the Great East Japan Earthquake in northeast Japan. We believe that a similar coastal system works very well not only for this reconstruction scheme but is also applicable for isolated islands such as the Maldives and Tuvalu, which experience floods caused by global warming. The idea of constructing living spaces on floating foundations emanates from offshore technology. The application of them contributions for civil purposes, such as in very large floating structures, should be given very serious consideration. To realize a prosperous future, we strongly recommend that this offshore technology and knowledge about floating structures be applied to architecture and buildings on land.

At the same time, to protect the global environment, there must be a shift from conventional tenets by actively promoting the use of renewable energy and fully replacing our energy systems to meet the present demands. Concurrent with this Smart Grid thrust for energy, there is a need for a policy shift for low-lying urban areas away from conventional urban expansion and renewal efforts to enable the realization of a truly sustainable urban system for the future in an innovative and strategic manner.

14 Shore Protection against Global Warming and Sea Level Rise in Islands

Motohiko UMEYAMA

The Intergovernmental Panel on Climate Change (2014) estimates that average global temperatures will rise 2.6-4.8 by the year 2100, relative to 1990, and sea levels will rise 45-82 cm. Numerous investigations confirm that the indirect effects may be more significant than the direct effects from global

warming in this century: rising sea levels inundate low-lying land areas, erode beaches, and increases the salinity of rivers and estuaries. Climate change also affects the frequency and intensity of some extreme phenomena. Umeyama (2012) reported that the abrupt phase shift of the El Nino Southern Oscillation has resulted in severe cyclones in the Southern Pacific. Recently, a huge storm surge up to 5 m high surged inland and swept away coastal villages when Typhoon Haiyan tore through Leyte province in the Philippines in November 2013. Therefore, there is an urgent need to devise and implement effective solutions for minimizing damage caused by natural disasters. The construction of social infrastructures capable of withstanding the impact of any global climate change must begin immediately. Residents of coastal areas must be alerted to be prepared for future disasters.

The purpose of this study is to reduce such vulnerability by assessing the cyclone of the 100-year return period and to evaluate the allowable seawall height. Mathematical models are proposed to estimate the following components: (1) offshore wave of the 100-year return period; (2) wave attenuation and set-up on a coral reef; (3) wave runup on a foreshore slope; and (4) irregular wave overtopping of a seawall.

15 Changes in dynamic pressure under combined wave-current motions

Motohiko UMEYAMA

Stokes waves are periodic irrotational gravity water waves of permanent shape propagating at constant speed at the free surface of water over an impermeable at bottom. The aim of this investigation is to directly use elementary harmonic function theory to prove a number of new results on the flow beneath an exact Stokes wave. In particular, we prove experimentally the following facts: (1) The pressure in the fluid strictly decreases horizontally away from a crest line toward its neighboring trough lines; and (2) The pressure strictly increases with depth provided the maximum angle of inclination of the free surface is at most 45 degree. These results are new for exact nonlinear waves. As for (1) and (2), while they are not unexpected, they have never been proven before in the context of exact nonlinear gravity waves. The only such results of which we are aware concerning the pressure appear in the linear theory, for waves of small amplitude such as in KdV theory, in numerical studies, or in experimental studies. The research of changing in dynamic pressure for wave-current motions is yet under way.

16 Upwelling behavior of warm surface water released in the bottom of a reservoir by a pump system

Katsuhide YOKOYAMA, Kimiko YAMAZAKI and Akira KOIZUMI

To prevent algal blooms in the upper reaches of the Ogouchi reservoir, a pump system was deployed to transfer surface water containing phytoplankton and to release it in the bottom of the reservoir. Vertical temperature profiles were monitored for one month using thermistor chains in three stations: the pump outlet, 10 m upstream of the outlet, and 10 m downstream of the outlet. The difference in temperature between just above the outlet and the surrounding stations indicated that the released warm water was lifted up to the middle layer, and the radius of the water column was less than 10 m. Spatial distribution of temperature and suspended sediment concentration (SSC) were measured in a horizontal grid of width

2550 m. The difference between SSC distribution during operation and that during withdrawal suggested that the lifted water spread in the middle layer horizontally. A multiple regression model consisting of three variables—surface temperature, bottom temperature, and water depth—was proposed to predict the depth at which the surface water released from the pump system was lifted. This model facilitates efficient operation of the pump system.

17 Relationship between Expansion of the City to the Steep Slope and Sediment Disaster

Katsuhide YOKOYAMA, Hideo AMAGUCHI and Akira KAWAMURA

Geographic feature, temporal change in land use and its effect on the sediment disaster occur in urbanized area were investigated by using ArcGIS in the Yokohama City and Kawasaki City. The area of the building site increased by 1.5 times from 1974 to 2006, and the expansion of the city to the steep slope was found. It was appropriate to use 12.5 m grid in order to express slope angle accurately while investigating the relationship between sediment disaster and the slope angle. Furthermore, it was found suitable to give the slope angle of an adjacent grid to the point where disaster occurred. The number of sediment disaster became maximum at the slope where an angle ranges from 15 to 25 degrees. Sediment disaster occurred mainly at the border between hill and alluvial plane. The frequency of heavy rainfall that exceeding 15 mm/h increased year by year in the past 40 years. The combination of the spreading of urban area to the steep slope, sediment disaster and the increase in heavy rain suggests that the sediment disaster risk continuously increase in the nearby future.

18 Spatial distribution of dissolved organic matter concentration and characteristics in rivers of the Kesenuma Bay drainage basin

Keitaro FUKUSHIMA, Katsuhide YOKOYAMA

We examined the spatial distribution of dissolved organic matter (DOM) concentrations and characteristics and assessed its controlling factors in four rivers draining into the Kesenuma Bay. Ultraviolet absorbance of 254-nm light, which is an indicator of humification of DOM, and the relative fluorescence intensity of fulvic acid-like and protein-like substances determined by the excitation-emission matrix fluorescence spectra was used to characterize DOM.

Stepwise multiple regression analysis revealed that current land use strongly determined riverine DOM. DOM derived from humic substances increased with an increased proportion of broad-leaved deciduous forest and agricultural land area to the total watershed areas. A proportion of protein-like substances originating from aquatic microbes to riverine DOM increased with urban area, which may be attributed to mixing of treated water containing a high proportion of protein-like DOM, and the growth of phytoplankton in nutrient-enriched sewage water column. Newly-created salt marsh due to the Great East Japan Earthquake and following tsunami attack and ground subsidence in coastal area contained high DOM derived from fulvic-like and protein-like substances. This result suggests that the earthquake can

make a large impact on the concentration and quality of DOM outflux from the land to sea.

19 Physically Based Distributed Flood Runoff Model for Urban Catchments using the Urban Landscape GIS Delineation data

Akira KAWAMURA and Hideo AMAGUCHI

The urban environment is characterized by its abundance of impervious surfaces (roofs, roads, parking lots etc.), from which runoff is rapidly generated as overland flow. Under normal conditions, this flow enters the sewage system to finally be drained to a receiving watercourse, typically a river or an open channel. If the generated runoff exceeds the storage capacity of the sewage system, surface flooding is caused by excess water outflowing from manholes and inlets. The flooding may be exacerbated by a simultaneous overflow of the receiving watercourse.

A storm runoff model considering rain water collection system of a house is developed for urban runoff analysis. The set-up of the model is based on so-called urban landscape GIS delineation that faithfully describes the complicated urban land use features in detail. The flow between single spatial elements is based on established hydraulic and hydrological models with equations that describes all aspects of storm runoff generation in an urban environment. The model was set up and evaluated for the Palmviken catchment in city of Arvika, Sweden. The runoff response to a high-intensity storm event in 2006 which caused 30-40 buildings flooding was simulated. It was demonstrated how the model can be used to evaluate the basement flooding in the urban hydrological system.

20 Simulation for Assessment of Mitigation Measures for Individual Land-Surface Features against in Urban Watershed

Akira KAWAMURA and Hideo AMAGUCHI

The promotion of heat island mitigation measures is an urgent need in Tokyo. This study simulated evapotranspiration, land surface temperature, and watershed averaged land surface temperature for each individual land-surface feature in the Upper Kanda River Watershed, implementing a water-permeable pavement for roads and green roofs as heat island mitigation measures. The simulation took an advantage of TET model that can express the amount of evapotranspiration, accounting for changes in soil moisture and permeable characteristics of individual land-surface features. As a result, it was found that the state of the soil moisture had a significant effect in the impact assessment of urban heat island mitigation measures.

21 A New Groundwater Recharge Model for an Urban Catchment Using the Geographical Feature Based GIS data

Akira KAWAMURA and Hideo AMAGUCHI

In urbanized area such as Tokyo, it is difficult to construct new surface flood ways. Though construc-

tions of underground flood ways and underground regulating reservoir are an effective means of solving the problem of urban flooding, these kinds of facilities take a large amount of cost. Hence, there is an urgent need for a comprehensive approach such as river basin measures and damage mitigation measures.

A new groundwater recharge model for an urban catchment, an important process in the hydrological cycle, was developed. The model was developed using GIS geographical feature data, which can describe the infiltration area more accurately than the grid-type model, where artificial development of impermeable surfaces such as buildings, roads and parking spaces has formed complex land covers. In this research, the model was applied to the upper area of Kanda river basin using the actual GIS geographical feature data. The Infiltration process in the upper soil layer was modeled using SMPT model and the groundwater flow was modeled using a two dimensional model.

22 Inundation Risk Assessment under the Damage Situation by Earthquake of Storm Water Drainage System

Akira KAWAMURA and Hideo AMAGUCHI

The sewer system is one of the most important systems in urban infrastructure. The earthquake damage of sewer systems makes drainage by sewage difficult, and it affects runoff and inundation process system. The storm impact on earthquake damage of storm water drainage systems was assessed on the supposition that a large-scale earthquake and heavy rain occurred in the upper catchment.

The Tokyo Storm Runoff (TSR) model is applied for urban runoff analysis. The set-up of this model is based on so-called “urban landscape GIS delineation” that faithfully describes the complicated urban land use features in detail. The effects of earthquake damage of sewer system was examined based on the numerical model results

23 Flood Rainfall-Runoff Analysis for Urban Area by Storage Function Model

Akira KAWAMURA and Hideo AMAGUCHI

The progress of urbanization in the form of high-density housing land development increased the outflow into rivers, shortened the flood reach hours, and reduced the safety of rivers from flooding. With increased property values of buildings and other structures, potential damage from prolonged flooding can easily extend to millions of dollars. Development of a practical flood forecasting model for urban area is desired, in which discharge/water level of a certain point of a river should be predicted real-time with high accuracy.

New storage function model considering urban runoff process such as the outflow from combined sewer system is proposed. In this model, total runoff components are conceptually included, which enable to disuse an estimate of the effective rainfall as an input and to eliminate the runoff-component separations by taking into account of urban runoff process. The proposed model is applied to the upper river catchment of the Kanda River in Tokyo, the typical urbanized area, against 9 storm rainfall events

using 3 different objective functions. The results show that the proposed model is able to reproduce the observed hydrograph much more accurately with accurate peak discharge and the total amount of discharge compared with the conventional storage function model.

24 Characteristics of Annual Groundwater Level Fluctuation in Tokyo Before and After the 2011 Off the Pacific Coast of Tohoku Earthquake Using Self-Organizing Maps

Akira KAWAMURA and Hideo AMAGUCHI

Groundwater observation wells have been bored in 42 sites in Tokyo Metropolis. Large fluctuations of groundwater levels were observed after the 2011 off the Pacific coast of Tohoku earthquake at 102 observation wells in Tokyo. In this study, the fluctuation patterns of monthly groundwater levels caused by the earthquake were investigated using Self-Organizing Map (SOM). The SOM application classified the groundwater level fluctuation pattern into four clusters showing exclusively distinguishable patterns.

Consequently, the results show that the monthly fluctuation pattern of more than half observation wells changed after the earthquake. Additionally, an increase can be seen in the confined groundwater level in Musashino Plateau following a lower amount of groundwater being pumped due to the earthquake. Furthermore, all unconfined observation wells, and most of the observation wells at depths above 70m and those south of Tama River showed no significant changes following the earthquake.

25 Analysis of Long-Term Groundwater Level Fluctuation in Tokyo

Akira KAWAMURA and Hideo AMAGUCHI

In this study, the fluctuation patterns of the long-term groundwater levels at 87 confined and 13 unconfined water observation wells in 42 sites in Tokyo Metropolis were investigated using Self-Organizing Maps (SOM). The SOM application classified the yearly groundwater level fluctuation patterns into eight clusters showing clearly distinguishable patterns which were then divided into 3 large groups. Consequently, the results show that the fluctuation patterns of natural groundwater levels were classified into Group-1. Most of the wells in the Tama region which showed regular fluctuation patterns caused by pumping were classified into Group-3. However, the majority of the wells were moved to Group-2 due to the pumping of drinking water being suspended or decreased. These results show that the SOM analysis was successful in extracting the unique long-term fluctuations of groundwater levels.

26 Investigation on Surface Scum in Urban River Using Fixed Point Camera Image

Akira KAWAMURA and Hideo AMAGUCHI

For appropriate river management, continuous monitoring scum causing bad smell and aggravation of the scene and cleaning the water surface if appeared are necessary. In this study, the method of

monitoring scum at tidal area of urban river was proposed. With pictures of the fixed point camera for monitoring water level by Ryukei Bridge over Kanda River, scum were automatically distinguished from the surface of the water. For distinction of scum, pictures were split into lattice-like and each lattice having scum or not were distinguished by pattern analysis of color using artificial neural network. The results showed that the number of lattices having scum which the neural network detect follow volume of scum with visual observation. For monitoring scum, fixed point camera is useful.

27 Spatio-Temporal Analysis of Recent Groundwater-Level Trends in the Red River Delta, Vietnam

Akira KAWAMURA, Hideo AMAGUCHI

A groundwater monitoring network has been in operation in the Red River Delta, Vietnam, since 1995. Trends in groundwater level (1995-2009) in 57 wells in the Holocene unconfined aquifer and 63 wells in the Pleistocene confined aquifer were determined by applying the non-parametric Mann-Kendall trend test and Sen's slope estimator. At each well, 17 time series (e.g. annual, seasonal, monthly), computed from the original data, were analyzed.

Analysis of the annual groundwater-level means revealed that 35% of the wells in the unconfined aquifer showed downward trends, while about 21% showed upward trends. On the other hand, confined-aquifer groundwater levels experienced downward trends in almost all locations. Spatial distributions of trends indicated that the strongly declining trends (>0.3 m/year) were mainly found in urban areas around Hanoi where there is intensive abstraction of groundwater. Although the trend results for most of the 17 time series at a given well were quite similar, different trend patterns were detected in several. The findings reflect unsustainable groundwater development and the importance of maintaining groundwater monitoring and a database in the Delta, particularly in urban areas.

28 Hydrogeochemical Characteristics of Groundwater from the Two Main Aquifers in the Red River Delta, Vietnam

Akira KAWAMURA and Hideo AMAGUCHI

In the Red River Delta, situated in the northern part of Vietnam, nearly its entire population depends solely on groundwater for daily water consumptions. For this reason, groundwater quality assessments must be carefully carried out using hydro geochemical properties, to ensure effective groundwater resource planning for the Delta's present and future groundwater use.

In this study, the spatial and seasonal changes in the hydro geochemical characteristics of groundwater in the two main aquifers of the RRD were investigated by analyzing the physicochemical data obtained in 2011 from 31 conjunctive wells in the Delta's Holocene unconfined aquifer (HUA) and Pleistocene confined aquifer (PCA) using the Piper diagram and the Gibbs diagrams. Results of the data analysis show that the groundwater in both aquifers in the upstream area of the delta is dominated by the $[Ca^{2+}-HCO_3^-]$ water-type, while the $[Na^+-Cl^-]$ dominates along the middle-stream and downstream

areas. Seasonal changes in the hydro geochemical facies in both aquifers, comparing the results for the dry and the rainy seasons, were detected in about one third of the sampling wells, which were mainly located at the upstream portion of the Delta. The hydro geochemical facies of HUA were different from that of PCA by about 45% of the sampling wells in both the dry and the rainy seasons, which were found mostly in the upstream and middle-stream areas.

29 Study on an Automated Construction Method of Minute Road Segments

Akira KAWAMURA and Hideo AMAGUCHI

In recent years, the use of advanced delineation GIS data (ADGD) has become invaluable in studies that require accurate spatial distribution of land use. However, the preparation of ADGD, especially for urban catchment areas, is often tedious, time consuming and prone to errors, since these are mostly constructed manually using a digitized map.

In this study, a new automated construction method of minute road segments is developed. Numerical simulation models for rainfall-runoff and flood inundation model considering process on roads were based on so-called “Minute road segments” that are formed as simple shape polygons to calculate the flow on roads. In the developed method, firstly crossroads are demarcated from road sections of uninterrupted flow in order to simplify a polygon of road. Secondly road sections and crossroads are divided into minute road segments. The developed method was applied for Kanda catchment and the shapes of minute road segments were validated. It was demonstrated that minute road segments can be created by using the method of this study.

Safety and Disaster Prevention Field

1 Influence Factor and Evaluation Method for Performance of Filling of Grouting Materials

Kimitaka UJI, Atsushi UENO and Kentaro OHNO

Recently, mortar - filling method has been adopted for the strengthening of existing structures using jacket plate around the structure. It is most important to fill up adequately the space between structure and jacket plate with mortar or cement past. It is required to make clear the components of materials in consideration of the space and the area for filling. It is known that the filling performance can be estimated by flow in grouting material. A grouting material having larger than 250 mm flow can fill for narrow space. But, there is a fear of insufficient filling for narrow space due to the segregation and blocking of aggregate. In this study, the influence factors for filling in grouting materials uniformed at 250 mm flow and the segregation of mortar were investigated by several tests. As a result, it is suggested that the boundary of filling for narrow space is determined by plastic viscosity.

2 Effect of Reinforcing Bar Array on Compactibility of Fresh Concrete

Kimitaka UJI, Atsushi UENO and Kentaro OHNO

Compaction by using vibration is important to obtain high quality concrete. Faulty construction usually occurs when compaction of fresh concrete is not appropriate. However, it is difficult to control compaction by using vibration because compaction time and insert interval time of vibration depend on judge of workers. Also, working environment affects compactibility of fresh concrete. In this study, three types of concrete having the slump of 80 mm considering s/a were conducted. Concrete was cast in inside of fabricated reinforcing bars, the behavior of flowability to the space between fabricated reinforcing bars and formwork. Also, the compactibility of fresh concrete is investigated to understand effect of reinforcing bar array in consideration of distribution of acceleration.

3 Influence on Durability of Pre-cast Concrete Products under Curing Conditions

Kimitaka UJI, Atsushi UENO and Kentaro OHNO

Most of small pre-cast concrete products are usually cured in steaming chamber, and curing of them are not needed at construction site. So, the advantage of pre-cast concrete is able to shorten the work period. Therefore, it is expected promotion of utilization of pre-cast concrete products. The microstructure of the surface of concrete is different from inside. Study on relation between the microstructure of concrete and water supply is not enough. Therefore, mechanical properties and durability are investigated focusing on the relation between the microstructure of surface of concrete and water supply. Recently, Blast furnace slug and Fly ash are used for a part of binder such as Portland cement for the pre-cast concrete. These mineral admixtures are affected by the condition of steam curing. In this study, the microstructures of pre-cast concrete with mineral admixture are investigated considering the steam curing condition.

4 Investigation of Shear Bonding Behavior on Interface between Base Concrete and Repairing Material containing of Sprayed Mortar and CFRP Grid

Kimitaka UJI, Kentaro OHNO and Atsushi UENO

There is an increasing demand on restore or strengthen method for existing concrete structures. As for the repairing technique, retrofitting method by using sprayed polymer mortar and Carbon Fiber Reinforced Plastic (CFRP) grids have been adopted because CFRP have such good characteristics as high tensile strength and high corrosion resistance. In this study, pull-out test was carried out in a laboratory in order to investigate the shear bonding behavior between base concrete and polymer-modified mortar including CFRP grids. Assuming the fracture energy of interface between existing concrete and repairing material, the shear bonding behavior is analytically estimated. And, the properties of the node of CFRP

for the tensile load and the bond behavior of CFRP in the longitudinal direction are investigated in consideration of the type and space of CFRP.

5 Estimation of Deterioration Factors and Mechanisms of Concrete at Advanced Water Treatment System

Kimitaka UJI, Atsushi UENO and Kentaro OHNO

In advanced water treatment system, which consists of ozone contact and biological activated carbon adsorption basin, concrete were deteriorated by some factors based on chemical attack and abrasion by activated carbon. However, deterioration mechanisms of concrete in the advanced water treatment system have been not clarified yet. In this study, visual inspections at all water treatment plants were conducted to obtain much information on deterioration of concrete. In addition, water quality survey was also carried out at water treatment plants. As a result, it is estimated that concrete in biological activated carbon adsorption basin has been deteriorated by chemical and physical actions. The chemical actions consist of two factors, 1) elution of the cementitious material by fresh water, 2) chemical attack by carbonic acid which comes from breathing of microorganism in activated carbon. Focusing on the chemical actions, accelerated deterioration tests of mortar specimens were conducted in a laboratory. Then, the prediction curves on concrete deterioration due to chemical actions were estimated based on laboratory tests.

6 Reduction of Environmental Impact by Construction of Concrete Structures

Atsushi UENO, Kimitaka UJI and Kentaro OHNO

a) Applicability of Extremely Dry Concrete made with Eco-Cement to Pavement

An incinerated city waste is main raw material of the Eco-cement. We should use the cement for long-term use of the landfilling area for the ash and for the conservation of natural resources, since the landfilling area for the ash cannot be prepared around the large city especially in our country. The eco-cement has a tendency to include relatively high amount of alkali metals and chloride ion compared with ordinary portland cement by the higher content of them in the main raw material. Therefore, the unit eco-cement content is should be controlled from the prevention of ASR. Also, the plain concrete, with no steel reinforcement, is suitable for the use of the cement if possible. The extremely dry concrete is the most suitable for the cement because it contains lower cement paste volume and lower unit cement content. We investigate freezing and thawing durability, especially on scaling under deicing agent condition, of extremely dry concrete made with eco-cement and replaced with blast-furnace slag powder. As a result, the replacement is very effective to reduce scaling under deicing agent condition.

b) Temperature Controlling of Sidewalk Pavement during Summer

It is serious problem for highly developed city that it is very high temperature in the daytime and the temperature is kept at night during summer. One of the reasons of the phenomenon is the higher pavement area by asphalt concrete or cement concrete. In order to improve the temperature properties at the city area, it may be essential to reduce of energy input to the pavement material and to release rapidly the stored energy to environment at night. We investigate the influence of surface geometry on retro reflection properties of pavement block for sidewalk.

7 Influence of Formation of Structure of Hydrates in Early Age on Structure of Hardened Mortar under Thermal History Condition

Atsushi UENO, Kimitaka UJI and Kentaro OHNO

The thermal history is often given for concrete for quick demolding especially in precast concrete production. It is significant that structure of cement-based material before the thermal action can resist stress caused by the thermal history. The standard thermal histories recommended in specifications are not always reasonable because the formation of early age structure is different by type of cementitious material and water binder ratio. In this study, we investigate the influence of cementitious material type and temperature rising rate on the mechanical properties of hardened mortar after thermal history.

8 Size Effect on Concrete Fracture Energy Test

Kentaro OHNO, Kimitaka UJI and Atsushi UENO

Fracture energy test conducts by three-point bending of notched concrete beam. It is well known that the fracture energy varies with specimen size and geometry. The fracture energy can be obtained that total energy of the works of the applied load and specimen weight is divided by ligament area. However, even if specimens were made by same fresh concrete, same fracture energy cannot be obtained from different sizes of the specimens. In this study, fracture energy test was conducted to specimens with different heights of notch to evaluate the work of the applied load during the test. In addition, acoustic emission (AE) method was applied to the test to monitor fracture process zone. As a result, amount of the work of the applied load changed only at after the maximum load. Therefore, it is suggested that the work of the applied load at maximum load affects to the size effect of the concrete on fracture energy test.

9 Health Monitoring of the RC Deck Slab reinforced with Steel Plate Bonding Method by Elastic Wave

Kentaro OHNO, Kimitaka UJI and Atsushi UENO

Numerous RC deck slabs have been subjected to a variety of environmental conditions such as traffic loads, temperature and humidity. Especially, fatigue durability on RC deck slab decreases as time

passage. In order to maintain and/or repair these aged RC deck slabs with a limited budget, deteriorated RC deck slabs have been reinforced by steel plate bonding method. This method was applied to a large number of aged RC deck slabs in bridges. Recently, delamination between concrete and steel plate detected in reinforced RC deck slabs. In this study, wheel load running test was conducted to RC deck slab specimen. The specimen was made by complied with old guideline in Japan. The experimental procedure consists of 3 steps, 1) non-reinforced RC deck slab was damaged by wheel load running test until crack density became 15 m/m², 2) steel plate bonding method was applied to damaged RC deck slab, 3) reinforced RC deck slab was tested under wheel load running test. In the experiment, AE method was applied to the specimen in order to estimate failure process. In addition, impact elastic wave method was also conducted to detect delamination between concrete and steel plate. As a result, the delamination could be quantitatively estimated by centroid frequency in impact elastic wave method.

10 Detection of Un-grouted Tendon Duct in Prestressed Concrete by First Motion of Elastic Wave

Kentaro OHNO, Kimitaka UJI and Atsushi UENO

Prestressed Concrete (PC) has been widely used to log span concrete bridges. PC member consists of concrete and tendon ducts including tendon and cementitious grout. In case that tendon duct is not fully filled by cementitious grout, corrosion of the tendon occurs and then crack generates in PC member. The corrosion of tendon induces readily loss of cross-section area in tendon and leads to breaking of the member. It is important to detect improper grouting condition in tendon duct by using nondestructive evaluation techniques (NDT) in order to prevent collapse of PC member. Impact-echo method and elastic wave velocity tomography (EVT) method are widely studied for detecting un-grouted tendon duct. In this study, a fundamental study was carried out to evaluate un-grouted tendon duct in PC model specimens by using impact elastic wave method in a laboratory. 4 type specimens were prepared by changing the filling ratio of the cementitious grout in tendon duct. Prior to experiment in a laboratory, numerical experiment of the EVT was conducted for all cases. As a result, it is found that the EVT is not suitable method for small cross-section area in specimen, because resolution capability of equipment for detection of elastic wave is not enough to evaluate grouting condition. On the other hand, it is realized that the amplitude of the first motion in elastic wave is good index to evaluate grouting condition in the specimens.

11 Behavior of sands during shear deformation with particle crushing

Mitsutoshi YOSHIMINE

Increase of fines in various sands due to particle crushing during shear deformation was experimentally examined. The concept of inter granular void ratio for evaluating liquefaction strength of sands was then introduced into a plasticity model to propose a method for predicting the behavior of sands during shear deformation with particle crushing.

12 Method of estimating precise volume of triaxial specimen

Mitsutoshi YOSHIMINE

It is difficult to estimate precise volume of triaxial specimens of saturated soils because the accurate and handy measurement of the sample volume change during saturation. To obtain more reliable measure, several methods of estimating volume change of specimens during saturation, the method of measuring the dimensions of the specimen after saturation, and the method of calculating the density of specimen using dry density, water content and particle density after the test were examined and compared.

13 The seismic characteristics of surface ground of Zushi-site

Yoshiya ODA

To clarify the surface ground motion characteristics at Zushi-site which has irregular ground condition, the horizontal and vertical array earthquake observations were performed at the five stations on the ground surface and one base rock (-26m depth) in Zushi-site. From these data, seismic characteristics of the surface ground in Zushi-site were clarified. Moreover, we carried out ultra high density seismic observation in Zushi City for 6 months this year.

14 Seismic refraction data processing using neural networks

Yoshiya ODA

We have developed a new seismic refraction data processing method by use of neural network technology. Discretization of subsurface structure and consideration of initial model are not needed on the new method. This year, we have applied the pattern coding to detect very complex subsurface structure. As the results, we can achieve the subsurface velocity structure with better accuracy compare with the conventional method.

15 Development of Low-cost seismograph using single board computer

Yoshiya ODA

To figure out real behavior of seismic wave, we are planning to install super high-density seismic network. In this study, we have developed a low-cost seismograph using single board computer named Raspberry Pi. The seismograph has four MEMS type acceleration sensors and 3G communication module on it. We have also modified the control program to save waveform data during earthquakes this year.

16 Numerical study on the effects of property change of focal area on seismic wave

Yoshiya ODA

To detect the effect of property change of focal area on seismic wave, we have conducted numerical simulations using finite-difference method. Seismic waveforms are computed changing V_p and V_s velocities of focal area and we compute spectrum ratio between stations across the focal area. As the result, spectrum ratios between stations across the focal area changed according to property changes.

17 Seismic performance evaluation using microtremor measurements

Yoshiya ODA

Evaluation of seismic performance of buildings is very important to reduce earthquake disaster. Generally I_w value is used as the seismic performance index in Japan. However it is not easy to compute I_w value from drawing. So we are thinking of developing a new simple evaluation method using microtremor. As the first step, we have observed microtremor at more the 10 houses and compared with I_w value of each houses. As the results, resonant frequency of house computed from microtremor observation correlate closely with I_w value.

18 Study on stability of microtremor H/V

Yoshiya ODA

Generally microtremor H/V is handled as stable value in earthquake engineering field. However sources are various and must change depending on time, season, weather and so on. Therefore, we have observed microtremor for 6 months to confirm the stability of microtremor H/V. As the results, it is revealed that the resonant frequency of H/V is stable and H/V ratio of resonant frequency slightly changes depending on time.

19 Ground investigation in Hakuba Village in Nagano

Yoshiya ODA

A main earthquake caused by Kamishiro Fault on November 22, 2014 hit Hakuba Village in Nagano Prefecture. We have conducted damage investigation and microtremor measurements at more than 50 points in Horinouchi area where was severely damaged by the earthquake. As the results, the resonant frequency of H/V spectrum ratio observed at Horinouchi area is approximately 1Hz that is different from other area in Hakuba Village.

20 Application and Effect of New Technology in Lining Concrete Construction for Extending the Working Lives of Mountain Tunnels

Kazuo NISHIMURA and Tsuyoshi DOMON

Securing the quality of lining concrete has become an issue of great public concern as lining concrete spalled in railway tunnels in 1999. It is required that lining concrete is durable over a long period of time. Tunnels are maintained to secure their durability and extend their lives. However, as a result of

recent measurements of tunnel environment, it has been revealed that it was not necessarily humid in the tunnel. Cracking is therefore likely to occur due to dry shrinkage. In this research, various measures have been taken to enhance the quality of lining concrete in such terms as materials, placement and curing in the laboratory tests and test construction in situ. Further technology development is required. More research on new technologies in relation to materials, placement and curing are pursued.

21 Numerical Analysis on Seismic Isolation Method for Existing Tunnels

Kazuo NISHIMURA and Tsuyoshi DOMON

Seismic isolation methods of existing cut and cover tunnels are investigated mainly on soft seismic isolation layer as a wall. But there are less construction results because there're some problems of this seismic isolation layer method of construction. This study is aimed at understanding the isolating effect of seismic isolation walls and pile method. This research derived the results of the transfer mechanism of dynamic action from ground to tunnel, by dynamic analysis on the model in which one rectangular tunnel is set through a section where ground conditions vary suddenly.

22 Verification of Validity of Static Analysis Methods to Evaluate Seismic Behavior of Underground Structures

Kazuo NISHIMURA and Tsuyoshi DOMON

The static analysis methods are often used to evaluate the seismic behavior of underground structures, because these methods can be conveniently used. But the limitation of the applicability of static analysis methods for seismic behavior is not well-known. Therefore, comparing the results obtained from the some static analyses and dynamic analysis. As a result, there are few differences in the distributions of sectional forces, especially at the corners of walls of cut and cover tunnel. Furthermore, the validity of the distributions of dynamic earth pressure on cut and cover tunnel as the nodal forces of FEM model is examined. This distribution profile of dynamic earth pressure is different from ordinary design pressures.

23 Seismic Response on Tunnel in the ground with Irregularity

Kazuo NISHIMURA and Tsuyoshi DOMON

The previous earthquake damage data indicate that these deformation modes of the lining can't occur in the ordinary seismic ground shear motion of stratified ground. In this research, numerical analyses of ground with irregularity of stratum boundary face between diluvium and alluvium were performed using intersecting angles between the axis of the tunnel and the stratum boundary face as parameter. It became obvious that the maximum axial force of tunnel lining in the ground with topographic irregularity is larger than that in horizontally stratified ground, and the position of the maximum cross-sectional force of tunnel lining was rotated toward to the crown of lining from shoulder, at which the maximum force was induced in horizontally layered ground.

24 Evaluation of Earth Pressure Acting on Deep Underground Tunnels

Kazuo NISHIMURA

Deep underground tunnels should be designed with some surcharge in consideration of the building load of overlying structures such as skyscrapers. However, there are some problems to be solved. Tunnel linings need to be designed such that they have high rigidity and bearing force. To overcome this problem, in this study, model tests were performed to clarify the load share mechanism in consideration of tunnel flexibility, ground elasticity, and boundary conditions between the tunnel and the ground. As a result, the cross-sectional forces of the flexible tunnel were smaller than those of the rigid tunnel. These analysis results confirmed its applicability to elastic ground such as soft rock, but not too soft ground lacking tension strength.

25 Tunnel Face Stabilization of Various Excavation Methods under Base Frictional Field

Tsuyoshi DOMON and Kazuo NISHIMURA

Various auxiliary methods have been carried out in tunneling sites due to increasing in the size of the tunneling machines and developing their technology. Thus, full-face tunnel excavation has been increasingly employed for sequential excavated method tunneling as well as the ground control effect of early ring closure. As the stability of the tunnel face is essential to full-face tunnel excavation, the tunnel stabilizing method utilizing curved tunnel faces, which would naturally form as part of the tunnel excavation sequences, can be considered effectively.

This paper addresses an investigation into the stability of various shapes of tunnel face considering full face and bench cut methods. In order to clarify the stability, we carried out the model tests using base friction apparatus and numerical simulations with discrete element method (DEM). As a result, it was confirmed that curved tunnel faces were advantageous and the stability of the tunnel face could be improved by a simple reinforcing method such as shotcrete on tunnel face. In addition, we concluded that there was a difference in the reinforcing effect by the shape of the tunnel face or excavation method.

26 Numerical Study on the Effects of Curved Tunnel Face depending on Various Ground Conditions

Tsuyoshi DOMON and Kazuo NISHIMURA

Curved tunnel face is applied in tunnelling sites in recent years as a rational excavation methods utilizing arch action of the ground. As the stability of the tunnel face is essential to full-face tunnel excavation, the tunnel stabilizing method utilizing curved tunnel faces, which would naturally form as part of the tunnel excavation sequences, can be considered effective.

We carried out numerical study by FDM (finite-difference methods) analysis considering the elastic

modulus, initial in-situ stress and competency factor etc. to clarify the effects of tunnel stability and ground behavior with curved tunnel face. As a result it is confirmed that curved tunnel faces are advantageous and the stability of the tunnel face can be improved by a simple reinforcing method such as shotcrete on tunnel face at some specific ground conditions.

27 Prediction of Ground Behavior due to Shallow Tunnelling and Ground Surface Excavating by Numerical Analysis Considering Unloading Stress Path

Tsuyoshi DOMON and Kazuo NISHIMURA

Surface settlement or ground behavior due to shallow tunnelling may cause damage to existing structures and environmental hazards especially in urban areas. In these cases, surface settlement or ground behavior are predicted using 2D FEM generally, but the simulated value of the ground behavior strongly depends on the constitutive laws.

This study is to clarify the constitutive law of ground material for shallow tunnelling. We paid attention of Hardening Soil model which can consider confining pressure-dependency and unloading stress path. Comparison between numerical solutions and field measurements are also made. The following conclusions can be drawn from these comparisons; i) Hardening Soil model can simulate the field measurements compared with other nonlinear elastic model and elasto-plastic model; ii) The parameter expressing confining pressure-dependency is highly dependent on numerical simulation. We also propose the beam-spring model that is applicable to unloading conditions (ex. surface ground excavating above existing tunnel). The proposal model is based on superposing of unloading step considering unloading reaction modulus delivered from the FEM analysis.

28 Numerical Study and In-situ Measurement of Lining Shape in order to Investigate Cracks in Tunnel Lining Constructed by Timbering Support Method

Tsuyoshi DOMON

It is important to determine the cause of cracks in tunnel lining in order to establish a reasonable repair scheme. The main purpose of this study is that we classify whether surface cracks in the lining is cause of external force or/and curing process of concrete.

This study addresses the use of the lining shape obtained by laser scanning for the investigation of the cause of the cracks. Profiles of tunnel lining constructed by timbering support method were measured by a mobile laser scanner with improved accuracy. The tunnel was assumed no to be affected by the external force. Curvature radii of the upper section of the tunnel lining were determined by the original method using the 3-D point cloud obtained from the laser scanning.

The results showed the characteristic curvature radii that were consistent throughout each installation interval of tunnel lining form. It was concluded that the lining shape was attributed to the deformation

during the curing process of the lining concrete or the shape of the arch concrete form on the basis of the curvature radii obtained from the 3-D point cloud.

29 Simple Measuring System of Tunnel Deformation by a New Mobile Inspection Method Using a Vehicle with Laser Scanners

Tsuyoshi DOMON

The MMS (Mobil mapping system) measurement method is the technique that can grasp a tunnel deformation and road-surface condition by a run of about 80km/hr. without stopping the traffic using a vehicle with laser scanner devices.

The main purpose of this study are; i) simple measuring system is developed permitting the both of cost reduction and simplified measurement, ii) the evaluation technique of the measurement result is established in order to contribute to tunnel maintenance. To realize these purposes we measured many expressway tunnels in last fiscal year.

The results shows that the evaluation technique made it possible to obtain bottom heaving of road, cracks and joint openings in tunnel lining with some precision. Especially in the bottom heaving of road, we succeeded in visualizing a rumble of road surface by displaying contour lines obtained from the 3-D point cloud by MMS. After this year, we will present the importance of the simple measuring system by utilizing the MMS method and data handling technique to make maintenance work more efficient, more accurate and safer.