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### **Publications of the Disaster Prevention Research Institute of Kyoto University**

The Disaster Prevention Research Institute publishes the results of its research activities in annuals (in Japanese) and bulletins. The annual is published at the end of an academic year, April to March. One volume of the bulletin, corresponding to an academic year, is divided into five parts. Each of the first four parts includes several papers, and the fifth part comprises the abstracts of papers published by staff members of the Institute in the academic year.

Discussions and the request for a copy of a paper should be addressed to the authors at the Disaster Prevention Research Institute, Kyoto University, Gokasho, Uji, Kyoto, Japan.

## CONTENTS

	Page
An Analysis of Strong Motion Accelerograms near the Epicenter ..... Kojiro IRIKURA, Kazuko MATSUO and Soji YOSHIKAWA	1
Local Crustal Effects on Seismic Waves ..... Tamotsu FURUZAWA, Syuzo TAKEMOTO, Kojiro IRIKURA and Junpei AKAMATSU	2
The Underground Structure of the Southern Part of the Kyoto Basin obtained from Seismic Exploration and Some Related Problems of Earthquake Engineering..... Choro KITSUNEZAKI, Noritoshi GOTO, Yoshinori TOMOZAWA IWASAKI	3
The Characteristics of Vibrations of a Layered Viscoelastic Ground near a Source..... Michiyasu SHIMA	4
The Characteristics of Vibrations Produced by a Horizontal Point Force in a Multilayered Viscoelastic Ground..... Michiyasu SHIMA	5
Application of Seismic Prospecting for Engineering Purposes with Some Ex- amples ..... Soji YOSHIKAWA and Ken ZAKO	6
Seismological Study on the Sakurajima Volcano (1) — Classification of Ex- plosions and Some Characteristics of These Explosions— ..... Kiyoshi NISHI	7
Volcanic Crustal Deformations (V) —On the Observations of Crustal Defor- mations at Volcano Sakura-jima— ..... Tsuneo ETO	8
Preliminary Report on the Shimo-ishiki Observation Station, Sakura-jima Volcanological Observatory ..... Tsuneo ETO	9
An Investigation on the Volcanic Micro-Earthquake and Volcanic Explosion of Sakura-jima Volcano (2) —On the Hypocentral Distribution of the Volcanic Earthquakes— ..... Kiyoshi NISHI	10
Seismic activity at Amami-Oshima ..... Keizo YOSHIKAWA	11
On the Seismicity in the Eastern Area of the Volcano Aso ..... Kōsuke KAMO, Hiroyasu ONO and Yasuaki SUDO	12
The Structure of the Volcano Aso Deduced from the Azimuthal Deviation of P-wave ..... Tatsuhiko WADA and Keiichi NISHIMURA	13
The Nature of Non-Volcanic Micro-tremors Observed on the Aso Caldera ..... Akira KUBOTERA and Michio OTSUKA	14
Seismic Studies during the JARE South Pole Traverse 1968-1969..... Tsuneo ETO	15
Measurement of Kinetic Energy of Volcanic Micro-Tremors ..... Tatsuhiko WADA, Kosuke KAMO and Yasuaki SUDO	16
Aftershock Activity in the Vicinity of Kyoto..... Kennosuke OKANO	17
On the Nature of the Occurrence of Intermediate and Deep Earthquakes 1. The World Wide Distribution of the Earthquake Generating Stress ..... Kazuo OIKE	18
Crustal Movements Related to the Seismic Activity in a Restricted Area (5A) — Relation between the Seismic Activity in the Northwestern Part of the Kinki District and the Crustal Movements Observed at the Ikuno Station— ..... Yutaka TANAKA, Makoto KOIZUMI and Masaaki KATO	19

Crustal Movements Related to the Seismic Activity in a Restricted Area (5B) — Relation between the Seismic Activity in the Northwestern Part of the Kinki District and the Crustal Movements Observed at the Ikuno Station — .....	Yutaka TANAKA, Makoto KOIZUMI and Masaaki KATO	20
Crustal Movements Related to the Seismic Activity in a Restricted Area (6) — Relation between the Seismic Activity in the Northwestern Part of the Chubu District and the Crustal Movements Observed at the Kami- oka Station .....	Yutaka TANAKA, Masaaki KATO and Makoto KOIZUMI	21
Ground Tremors caused by Rock Bursts in the Ikuno Mine .....	Yutaka TANAKA and Ryohei NISHIDA	22
On Temporary Observation of Microearthquakes near Tottori City (1) .....	Kazuo MINO, Ryohei NISHIDA and Junichiro MIYAKOSHI	23
Source Process of Deep and Intermediate Earthquakes as Inferred from Long-Period P and S Waveforms 1. Intermediate-depth Earth- quakes in the Southwest Pacific Region .....	Takeshi MIKUMO	24
Some Investigations in Ebino Earthquake Swarm .....	Kunihiko WATANABE	25
Focal Mechanism of Microearthquakes in Wakayama Region in Relation to the Upper Crustal Structure .....	Takeshi MIKUMO, Michio OTSUKA and Kazuo OIKE	26
On the Accuracy of the Distance Measurements by Electro-Optical Means. .....	Fumio OHYA and Torao TANAKA	27
Observations of Crustal Strains by Electro-Optical Measurement (Part 1) .....	Michio TAKADA, Torao TANAKA, Kensuke ONOUE, Masaru YAMADA, Yasuyoshi FUJITA and Fumio OHYA	28
Ocean Tides and Tidal Tiltings of the Ground Observed at the Oura and Akibasan Stations, Wakayama .....	Torao TANAKA	29
Observations of Ground Strains Caused by Periodic Water Drawings. .....	Izuo OZAWA	30
Investigation Methods of Underground Water in Landslide Areas — New Investigation Methods and their Application — .....	Atsuo TAKEUCHI	31
Landslides in Hyogo Prefecture (I) — Topographical and Geological Cha- racteristics — .....	Atsuo TAKEUCHI	32
Some Problems of Electric Prospecting in Shattered Zone Type of Landslide Areas.....	Takahiko FURUYA, Hidemi TSUMOTO and Toshifumi KONISHI	33
Fractured Zone Type Landslides in Kochi Prefecture by an Electrical Resis- tivity Survey .....	Atsuo TAKEUCHI	34
Some Consideration on Geomorphic Processes deduced from Land-Slide Studies of Shikoku Island .....	Takahiko FURUYA	35
A Study on the Ground of Mountainous Regions (I) — On the Weathered Granite Zone at Tanakami Mountain Range Due to Seismic Pro- specting .....	Akira NAKAGAWA	36
Halogens of Ground Water in the Matsushiro Landslip Area .....	Ryuma YOSHIOKA, Setsuo OKUDA and Yasushi KITANO	37
Investigation of Ground Water Flow in the Kamenose Landslide Area .....	Kazuo OKUNISHI	38

Synthetic Observation on Rocky Mudflow Part 1. The Planning of a New Observation System for Mudflow and Field Test at the Eastern Slope of Mt. Yake in 1970 .....	Mudflow Research Group	39
Slope Failure Caused by Ground Water Flow Due to Infiltration.....	Yoshiaki FUKUO	40
Paleolimnological Study on Lacustrine Sediments in Lake Biwa-ko .....	Shoji HORIE, Osamu MITAMURA, Seiichi KANARI, Hideo MIYAKE, Atsuyuki YAMAMOTO and Norio FUJI	42
The Historical Development of Lake Yogo-ko Inferred from Granulometric Analyses .....	Shoji HORIE and Hideo MIYAKE	43
Calcium Chloride Type Water Discharged from the Matsushiro Area in Con- nection with Swarm Earthquakes .....	Ryuma YOSHIOKA, Setsuo OKUDA and Yasushi KITANO	45
Studies on Bed Load Transportation for Non Uniform Sediment and River Bed Variation .....	Kazuo ASHIDA and Masanori MICHIEU	46
Studies on Fluvial Processes of Stream Channels (2) — Self-Formed Stable Channel Profile and Process — .....	Kazuo ASHIDA, Yoshio MURAMOTO and Shūji NARAI	47
A Study on Friction Factors for Flow in Movable Bed Channels (1) .....	Kazuo ASHIDA and Yuichiro TANAKA	48
Probability of Levee Breaks Due to Heavy Rainfalls in a River. .....	Yasuo ISHIHARA and Kunio SENO	49
A Study on Statistical Laws of Time Distribution of a Rainfall .....	Yasuo ISHIHARA and Kunio TOMOSUGI	50
On the Rainfall around the Suzuka Mountains .....	Yukio GOCHO and Chotaro NAKAJIMA	51
On the Water Balance in the Ara Experimental Basin .....	Yasuo ISHIHARA and Shigeki KOBATAKE	52
Transformation System in Flood Runoff Phenomena .....	Tojiro ISHIHARA and Takuma TAKASAO	53
A Study of Long Range Runoff System Response Based on Information Theory .....	Tojiro ISHIHARA and Shuichi IKEBUCHI	54
Turbulence Characteristics in a Free Surface Shear Flow in Terms of Universal Function .....	Hirotake IMAMOTO	55
On the Spatial Structure of Turbulence in Open Channel Flows .....	Hirotake IMAMOTO and Tetsuo UENO	57
Experimental Study of Local Flow Around a Bridge Pier .....	Tadashi UTAMI	58
Dispersive Characteristics of Free Surface Flow in Terms of Lagrangian Descriptions.....	Yoshiaki IWASA and Hirotake IMAMOTO	59
Some Topics discussed at the Twelfth International Conference on Coastal Engineering —A brief Consideration of the Recent Status of Coastal Processes— .....	Yoshito TSUCHIYA	60
Mechanism of Motion of Sand Grains by Wind (2) —On the Characteristics of Saltation of Sand Grains— .....	Yoshito TSUCHIYA and Yoshiaki KAWATA	61
Studies on Cnoidal Waves (Ninth Report) —Applicability of Cnoidal Wave Theory to Near Breaking Waves—.....	Yuichi IWAGAKI and Tetsuo SAKAI	62
Characteristics of Beach Process by Wind Waves (1) —Laboratory Study of Equilibrium Beach Profile— .....	Yoshito TSUCHIYA and Shigeru YOSHIOKA	63

Some Problems on the Prevention of Wave Overtopping by Seawalls and Seadikes .....	Masao INOUE, Yuichi IWAGAKI and Yoshito TSUCHIYA	64
Studies on Wave Forces Exerted on Large Cylindrical Piles (1) —Characteristics on the Distribution of Wave Pressure and the Variation of Water Level— .....	Yoshito TSUCHIYA and Masataka YAMAGUCHI	65
Recirculating Random Wave Generator (Shallow Water Ocean Wave Simulator) Using a Wind Wave Tank and Its Characteristics .....	Yoshito TSUCHIYA and Masataka YAMAGUCHI	66
Tsunami Model Experiment of Kochi Harbour (2) —Effects of Tsunami Breakwaters and of River Discharges— .....	Shigehisa NAKAMURA, Yuichi IWAGAKI and Yoshito TSUCHIYA	67
A Numerical Experiment of Water Motion in Lake Biwa —On the Two-Dimensional One-Layer Model— .....	Norihisa IMASATO, Seiichi KANARI and Hideaki KUNISHI	68
Basic Observations on Coastal Processes at Ogata Coast (1) —On the Results of Observation in a Monsoon in 1970— .....	Yoshito TSUCHIYA, Toru SHIRAI, Shigehisa NAKAMURA, Masataka YAMAGUCHI, Teruo SHIBANO, Yoshiaki KAWATA and Shigeru YOSHIOKA	69
On the Beach Processes at Ogata Coast (1) —On the Seasonal Change of Beach Profiles— .....	Toru SHIRAI and Yoshito TSUCHIYA	70
On the Oceanic Processes at Kii-Suido .....	Hideaki KUNISHI, Hiroshi YOSHIOKA and Toru SUZUKI	71
A Study of the Air-Sea Boundary Processes at the Shirahama Oceanographic Tower Station .....	Yoshiaki TOBA, Hideaki KUNISHI, Katsuya NISHI, Sanshiro KAWAI, Yoshie SHIMADA and Nakao SHIBATA	72
Some Observations on Coastal Processes in Tanabe Bay (III) .....	Katsuya NISHI, Toru SUZUKI and Hideaki KUNISHI	73
Successive Saltation of a Sand Grain by Wind .....	Yoshito TSUCHIYA	74
Limiting Condition for Standing Wave Theories by Perturbation Method. ....	Yoshito TSUCHIYA and Masataka YAMAGUCHI	75
Model Study of the Transformation of 'Tsunamis' in Urado Bay .....	Shigehisa NAKAMURA, Yuichi IWAGAKI and Yoshito TSUCHIYA	76
Experiments on Water Particle Velocity at the Water Surface of near Breaking Waves .....	Yuichi IWAGAKI, Tetsuo SAKAI, Junichi KAINUMA, and Takeshi KAWASHIMA	77
On the Characteristics of Standing Waves in the Case where Wave Overtopping Exists .....	Yoshito TSUCHIYA and Masataka YAMAGUCHI	78
On the Irregular Wave Generator of the Electro-Hydraulic Type .....	Yuichi IWAGAKI, Hitoshi MURAKAMI, Tetsuo SAKAI and Akira KIMURA	79
Model Experiments on 'Tsunami' and Its Response in Kochi Harbour .....	Shigehisa NAKAMURA	80
Breaking of Wind Waves and the Sea Surface Wind Stress .....	Yoshiaki TOBA and Hideaki KUNISHI	81
A Constitutive Equation of Soils .....	Sakuro MURAYAMA	82
The Mechanism of Shearing and its Similarity for Sands and Clays .....	Sakuro MURAYAMA and Hajime MATSUOKA	83

Consideration on the Stress Wave Attenuation in Soils ..... Koichi AKAI and Masayuki HORI	84
Model Experiment on the Propagation of Water Pressure in Sandy Aquifer .....Norio YAGI	85
Model Studies on the Stress Distribution in Layered Soil Systems ..... Koichi AKAI, Satoshi SHIOMI and Tsutomu KIUCHI	86
A Viscoelastic Approach to the Problem of Stress Wave Propagation in Cohesive Soils .....Koichi AKAI and Masayuki HORI	87
Earth Pressure on Tunnels in Sandy Ground ..... Sakuro MURAYAMA and Hajime MATSUOKA	88
Two-variate Exponential Distribution and its Numerical Table for En- gineering Application.....Masashi NAGAO and Mutsumi KADOYA	89
Study on Two-Variate Gamma Distribution and its Engineering Applica- tion (2) —Estimation of Population Parameters— ..... Masashi NAGAO and Mutsumi KADOYA	90
Study on Two-Variate Gamma Distribution and its Engineering Applica- tion (3) —Numerical Table of Two-Variate Exponential Distribution— ..... Masashi NAGAO and Mutsumi KADOYA	91
Study on Two-Variate Gamma Distribution and its Engineering Applica- tion (4) —Synthesis of Short-Time Intense Rainfall Data Applying Two-Variate Exponential Distribution Theory— ..... Masashi NAGAO and Mutsumi KADOYA	92
A Simple Method of Generation of Simulated Rainstrom Data for Drainage Planning in the Matsue District. ....Reijiro TANAKA and Mutsumi KADOYA	93
Runoff Characteristics in an Urban Area. .... Mutsumi KADOYA and Taro OKA	94
Runoff Characters in Yoko-oji Low Land —Present and Future— .....Mutsumi KADOYA, Taro OKA, Eiji TOYOKUNI and Akira FUKUSHIMA	95
Effects of the Urbanization of a Drainage Basin on Flood Runoff .....Mutsumi KADOYA	96
Method of Numerical Analysis for Three Dimensional Unconfined Seepage —Seepage Problem for River Structure (3)— Applied Examples of Numerical Analysis for Three Dimensional Unconfined Seepage —Seepage Problem for River Structure (4)— ..... Taro OKA	97
Flood Flow in an Irregular Channel (2) ..... Tamotsu TAKAHASHI	98
Studies on the Equipment for Bed Load Discharge Measurement .....The Study Group of Sediment Measurement Techniques	99
Study on the Suspended Sediment (1) —An Optical Method for Measure- ment of Suspended Sediment Concentration— ..... Masanori MICHIE and Kiyoshi SHIRAKAWA	100
Landslides and the Weathering of Rock (2) —Rock Characters as a primary factor in landslides— ..... Toyoaki SAWADA	101
Distribution of Ground Waters in the Gamata River Basin (2) —Characters of Ground Waters and Weathering of Rocks— ..... Katsumasa YANO and Toyoaki SAWADA	103
On Air-sea Interaction in the Kii Channel ..... Chotaro NAKAJIMA and Hiroshi YOSHIOKA	104

Studies on Heavy Rainfall (III) On the Heavy Rainfall in the Central Kinki District .....	Hisashi EDAGAWA	105
Experimental Studies on the Tidal Mixing in the Seto Inland Sea .....	Takashige SUGIMOTO and Haruo HIGUCHI	106
Hydraulic Model Experiment on the Tidal Current in Matsukawa-Ura .....	Haruo HIGUCHI and Masaaki TSUJI	107
Basic Study on Salt Damage (V) Distribution of Sea-Salt Particles Near the Coast in Strong Wind Conditions. ....	Masaaki TANAKA	108
On the Microstructure of Tidal Current and the Horizontal Diffusion due to it .....	Haruo HIGUCHI and Takashige SUGIMOTO	109
Dynamical Behaviour of a Non-linear Porous Elastic Layer .....	Hisao GOTO, Kenzo TOKI and Tadanobu SATO	110
On the Vibrational Characteristics of Foundation Structure in the Ground .....	Hisao GOTO, Kenzo TOKI and Shiro TAKADA	111
Experimental Study on the Horizontal Restoring Force Acting on Substructures. ....	Hisao GOTO, Susumu YOSHIHARA, Masaru KITAURA and Akihiro OTA	112
On the Three Dimensional Consolidation Theory of Clay .....	Seiki OMAKI	113
Effect of the Stress-Anisotropy on the Shear Velocity in Soils .....	Yoshio ISHIGURO	114
Liquefaction of Saturated Sand due to Cyclic Loading (II) .....	Toru SHIBATA and Manabu MIYOSHI	115
Seismic Response of Structures in Heterogeneous Ground .....	Kenzo TOKI	116
On a Model for Vibration Analysis of Ground Soil and Rigid Foundation Structure .....	Hisao GOTO	117
Seismic Response Characteristics of Foundation Structures in Elastic Ground —Rigid Foundation Structures with Elliptic Cross Section— .....	Hisao GOTO and Takashi AKIYOSHI	118
Liquefaction of Saturated Sand due to Cyclic Loading (I) .....	Toru SHIBATA and Hiroshi YUKITOMO	119
A Study on the Plastic Deformation of Elasto-plastic Structures in Strong Earthquakes.....	Hisao GOTO and Hirokazu IEMURA	120
Experimental Studies on the Large Plastic Deformation of Frames Due to Horizontal Impact —Measurements of Impact Loading and Vertical Load Effect— .....	Minoru WAKABAYASHI, Taijiro NONAKA, Koichi MINAMI and Michio SHIBATA	121
The Elasto-Plastic Stability of Space Frames .....	Minoru WAKABAYASHI and Haruhito OKAMOTO	122
An Experimental Study on Centrifugally-Cast Steel Pipe to H-Beam Connections .....	Minoru WAKABAYASHI, Ryoichi SASAKI and Yoshio KISHIMA	123
An Experiment on the Behavior of a Steel Bar under Repeated Axial Loading .....	Minoru WAKABAYASHI, Taijiro NONAKA, Osamu KOSHIRO and Noboru YAMAMOTO	124
A Model Test of Reinforced Concrete Frames with Emphasis on the Shear Failure of Columns .....	Minoru WAKABAYASHI, Koichi MINAMI, Kunihiro ADACHI and Masami NAKAGAWA	125
An Experimental Study on Shear Failure of Reinforced Concrete Columns Under Cyclic Loading		



..... Minoru WAKABAYASHI, Koichi MINAMI and Takeshi YAMAGUCHI	126
An Experimental Study on the Elastro-Plastic Characteristics of Composite Members Using an Encased H-Section Subjected to Combined Bending and Axial Force .....	Minoru WAKABAYASHI, Koichi MINAMI and Katsuhiro KOMURA
127	
Studeis on Leteral Buckling of Wide Flange Beams, Report No. 2 —Elastic Lateral Buckling Tests Using Plastics Models— .....	Minoru WAKABAYASHI, Takeshi NAKAMURA, Hiroyoshi KOYANAGI and Hiroshi SAWADA
128	
Linear Response Analysis for a Slender Body Subjected to Gust pressure .....	Taijiro NONAKA
129	
Rainfall Deposit on a Wall of a Building in a Storm .....	Hatsuo ISHIZAKI, Yasushi MITSUTA and Yuji SANO
130	
Disasters Caused by Severe Local Storms in Japan.....	Hatsuo ISHIZAKI, Yasushi MITSUTA, Tatsuo MUROTA, Yuzo YOSHIKAWA and In Whan SUNG
131	
A Wind Tunnel Test of Pressure Distributions on Box-Shaped Models .....	Hatsuo ISHIZAKI and Junji KATSURA
132	
The Influence of Adjacent Buildings on Wind .....	Hatsuo ISHIZAKI and In Whan SUNG
133	
On the Severe Storm and Damage at Hikone on September 15th, 1970 .....	Hatsuo ISHIZAKI, Yasushi MITSUTA, Tatsuo MUROTA, In Whan SUNG and Yuzo YOSHIKAWA
134	
Studies of a Tatsumaki at Toyohashi, Dec. 7th, 1969. ....	Hatsuo ISHIZAKI, Yasushi MITSUTA, Sumio KAWAMURA, Tatsuo MUROTA, Eiji KIMOTO and Makoço TAHIRA
135	
Turbulent Diffusion in a Road Tunnel .....	Yasushi MITSUTA
136	
On the Real Time Analysis of the Characteristics of Atmospheric Turbulence .....	Yasushi MITSUTA, Tatsuo HANAFUSA and Tokunosuke FUJITANI
137	
Fluctuation of the Atmospheric General Circulation and Abnormal Weather (I) .....	Ryozaburo YAMAMOTO
138	
Wind Damage and Wind Load Problems in Japan .....	Hatsuo ISHIZAKI
139	
Vibration of a Trussed TV-tower due to Wind .....	Tatsuo MUROTA and Hatsuo ISHIZAKI
140	
Contributions of Rain Drops to Wind Effects in the Storm .....	Yasushi MITSUTA
141	
On the Earthquake Response of Structural Systems Considering Interaction Effects of Ground .....	Takuji KOBORI, Ryoichiro MINAI and Yutaka INOUE
142	
The Dynamical Ground Compliance of a Rectangular Foundation on a Visco-elastic Stratum .....	Takuji KOBORI, Ryoichiro MINAI and Tamotsu SUZUKI
143	
Vibrational Charzcteristics of Semi-Infinite Visco-Elastic Medium to Surface Excitations on a Rectangular Area (Part 3) .....	Takuji KOBORI, Ryoichiro MINAI and Kaoru KUSAKABE
144	
Response Analysis of Elasto-Plastic Frame Structures with Ramberg-Osgood Characteristics .....	Takuji KOBORI, Ryoichiro MINAI and Teizo FUJIWARA
145	
On the Statistical Aseismic Determing the Optimum Dynamic Characteristics of Structures (Continuned) .....	Takuji KOBORI, Ryoichiro MINAI and Masahiro KAWANO
146	
On Earthquake Response of Elasto-Plastic Structures Considering Ground Characteristics .....	Takuji KOBORI, Ryoichiro MINAI and Yutaka INOUE
147	

On the Optimum Aseismic Design Data of Multistory Structures Based on Earthquake Elasto-Plastic Responses.....	Binji HISATOKU and Takuji KOBORI	148
On Earthquake Response of Ground-Structure Systems .....	Ryoichiro MINAI and Yutaka INOUE	149
Foundation Vibrations on a Viscoelastic Multi-Layered Medium .....	Takuji KOBORI and Tamotsu SUZUKI	150
Numerical Analysis on Foundation Vibration by Finite Element Technique .....	Takuji KOBORI and Shigeru SETOGAWA	151
Reliability Analysis of Aseismic Safety of Elasto-Plastic Structures Considering Random Fatigue.....	Ryoichiro MINAI and Yoshiyuki SUZUKI	152
A Statistical Method of Detecting the Damping Characteristics of Structures by Measuring Their Microtremors .....	Takuji KOBORI, Ryoichiro MINAI and Yoshihiro TAKEUCHI	153
On a Model of Non-Linear Soil-Ground Supporting a Building Structure .....	Ryoichiro MINAI	154
On Experimental Determination of the Dynamic Properties of a Structure .....	Takuji KOBORI, Ryoichiro MINAI, Yutaka INOUE and Teruo KAMADA	155

## An Analysis of Strong Motion Accelerograms near the Epicenter

By Kojiro IRIKURA, Kazuko MATSUO and Soji YOSHIKAWA

Bulletin of the Disaster Prevention Research Institute, Kyoto University,  
Vol. 20, Part 4, No. 182, March 1971, pp. 267-288 (in English)

### Abstract

The strong motion accelerograms of the Matsushiro earthquakes were analyzed by various methods. When the velocity and the displacement in the time domain and in the frequency domain are calculated from the accelerogram, various errors, such as small random reading errors, centerline adjustment, setting of initial values, chart paper distortion and etc., may be introduced. Therefore, it is necessary to check and select the methods of data processing according to the aims of the analyses. In this paper, it was shown that the comparison of observed values with theoretical ones in the form of velocity amplitude spectral density might be most preferable.

The main factors affecting ground vibration during disastrous earthquakes are generally conceived to be: source, path and local geology. The relations between the observed seismogram and the theoretical one were compared when a moving dislocation model was assumed. It was found that the direction of the S wave's particle motions at several stations surrounding the epicenter were qualitatively compatible with the theoretical.

In relation to the source parameters many quantities have not as yet been clarified, hence the model was simplified as a unilateral moving dislocation. And the rough estimation of the surface layer was considered as an amplification factor only. Fairly good coincidence was then found between the observed values and the theoretical ones as far as the velocity amplitude spectral density were concerned.

However, the synthesized seismograms and the observed ones in the time domain are not precisely consistent because the phase spectra are difficult to consider in both the theoretical and the observed data. That is, the above inconsistency might be caused by the fact that the source model was over-simplified and strict estimation of the effect of the surface layer was very difficult.

It is shown that the source time function of a ramp (duration time  $T=0.26$  sec, slip velocity  $D/T=100\sim 200$  cm/sec) is preferable when a moving dislocation is assumed. The strong earthquake motion incident to the base will be strongly affected by the source time function.

## Local Crustal Effects on Seismic Waves

By Tamotsu FURUZAWA, Syuzo TAKEMOTO, Kojiro IRIKURA  
and Junpei AKAMATSU.

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 189-202 (in Japanese)

### Abstract

Micro earthquakes were observed with linear array at four observation points including one three-components point, at the Amagase Crustal Movement Observatory, from Aug. 20th to Sept. 1st, 1970. Using analog filters and a high speed A-D converter, particle motions, displacement spectra and coda parts were studied on about 25 events.

(1) There were systematic differences between the directions of the particle motions of the initial P waves and those of the epicenters determined from the seismograms at the five microearthquake observation stations belong to the Abuyama Seismological Observatory. These differences depended on the azimuth of epicenters and suggest the existence of an east dipping layer.

(2) P wave velocities were determined with apparent velocities in linear array and the directions and the emergent angle of initial P wave particle motions. They were  $4.6 \pm 0.3$  km/sec and were well coincident with the value obtained from the travel time curve of rock-mining explosions around the Observatory. The layer with the velocity value was therefore shown to extend over several kilometers.

(3) In order to investigate the focal mechanism, the distribution of the push and pull of P waves were examined. Also the initial motions of SH phases were determined from particle motions in the horizontal plane. Almost all of the 25 events were examined by four-quadrant double couple source systems, and were consistent with the tectonic forces reported by K. Okano and I. Hirano.

(4) In the displacement spectra of P waves obtained at three-component observation point, there were notable trough around 8 Hz in vertical components on all events, and in 1-5 Hz in radial ones varying at different events. In the vertical component spectra of the other observation points, troughs appeared in slightly higher frequencies, but almost similar frequencies for different events at the same observation points.

In the calculated responses of the half-space and parallel layered media to plane P waves, the effects of the depth of observation points appeared as seriously strong troughs in both vertical and radial components and producing the observed spectra.

(5) Seismic coda parts were analyzed in regard to the backscattering waves through Aki's processing. The extent of the period with the lapse in time was very small and the coda spectra was not obtained.

Seismic waves from microearthquakes are of very high frequency ranges (1-20 Hz) and are seriously affected by local conditions such as dipping layers, topographical conditions. In order to approach the source mechanisms of microearthquakes, stational calibration and its limits must be determined precisely for deterministic data processing, and statistical methods such as coda analysis must be combined in future.

## The Underground Structure of the Southern Part of the Kyoto Basin Obtained from Seismic Exploration and Some Related Problems of Earthquake Engineering

By Choro KITSUNEZAKI, Noritoshi GOTO and Yoshinori Tomozawa IWASAKI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 203-216 (in Japanese)

### Abstract

A seismic exploration (refraction method) in the southern part of the Kyoto Basin (Fig. 1) was planned by the U.M.P. committee and carried out by a private company. Because of technical and economical reasons, the eastern part of the area, which the authors had been particularly interested in, was not covered by this exploration. It was decided to have sub-observation lines in the eastern part extending the main line. Observation for the sub-lines was carried out at the same time for the main line.

The structure obtained (Fig. 2) shows that the surface layer (Quaternary) with P-wave velocity of 2.1 km/s is about 700 m deep around the center of the basin. The base rock (Paleozoic strata) is found to have a P-wave velocity of 5.2 km/s.

Exploration was conducted from an engineering point of view, full use being made of existing well log data on the underground geological setting and to earthquake wave modification due to the basin structure.

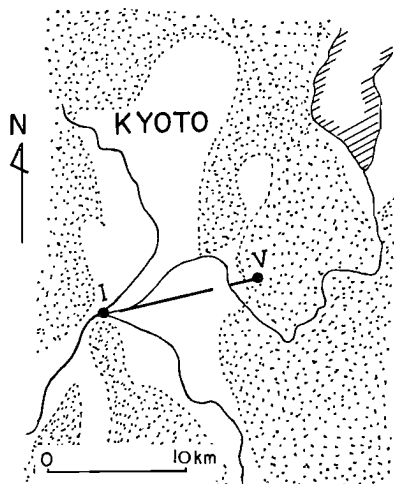


Fig. 1

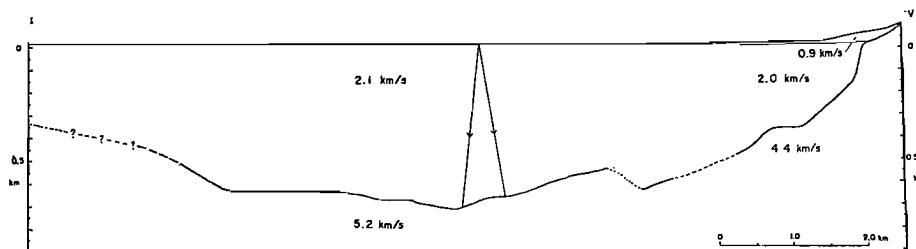


Fig. 2

## The Characteristics of Vibrations of a Layered Viscoelastic Ground near a Source

By Michiyasu SHIMA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 217-232 (in Japanese)

### Abstract

The vibrational characteristics of layered viscoelastic ground are investigated theoretically in the case of the harmonic vibration of the surface of such ground. The sources considered are as follows: (1) a vertical point force, (2) a horizontal point force.

Integral expressions for the displacement fields are derived by using a technique applied first by N.A. Haskell to seismological problems. The integrals are calculated along the real axis.

The numerical results are plotted for the frequency characteristics of the amplitudes of displacement and for the variations of the amplitudes with the increase of the distance from the source. When the layered medium is composed of alluvial soils, the peak of the second mode in the curves of the frequency characteristics at the points more than one wave length remote from the source are negligibly lower than that of the fundamental mode. In the latter case, the amplitudes decrease with the increase of the distance in a similar manner as the surface waves, when the points are more than one wave length from the source. The displacement in that range may be expressed in the product.

## The Characteristics of Vibrations Produced by a Horizontal Point Force in a Multilayered Viscoelastic Ground

By Michiyasu SHIMA

Proc. of the Third Japan Earthquake Engineering Symposium,  
Nov., 1970, pp. 247-253 (in Japanese)

### Abstract

The vibrational characteristics of multilayered viscoelastic ground are investigated theoretically in the case of the stationary harmonic vibration of the surface of such ground. In this paper, we shall consider the vibration generated by a horizontal point force on the surface, and clarify the relation between the vibrational characteristics of the ground surface caused by upward incident plane waves and those caused by the incidence of spherical waves generated from a point source.

Integral expressions for the displacement fields are derived by using a technique applied first by N.A. Haskell to seismological problem. That is, the integrand is composed of the product of Haskell's layer matrix for each layer and the factor expressing the characteristics of the source. The integrals are calculated along the real axis.

The numerical results are compared with the spectra in a case where an infinite train of harmonic plane waves is vertically transmitted to the surface layers. In every case, the horizontal point source whose frequency characteristic is constant with respect to the displacement is on the surface and the amplitudes of displacement are calculated from the surface to a depth equal to three times the thickness of the surface layer under the source. For the range shown in Fig. 2 of the frequency, the curves at the points of the bottom medium have two peaks. The first peak of the curve at the points of the bottom medium and the intermediate layer corresponds to the fundamental mode of the surface layer consisting of the two layers, and the peak of the higher frequency to the second mode. The first peak at the points of the upper layer corresponds to the fundamental mode of the upper layer. With the increase of the attenuation constant, however, the second peak becomes ambiguous or disappears. The peaks and dips of the amplitude spectra at each point become clearer with the increase in depth, and the shape of the spectral curve approximates to that in the case in which the harmonic plane waves are normally incident upwards to the surface layer.

It is clear from these results that when the observation points in the vibration test are in the bottom stratum and the intermediate layer, the characteristic frequency of the ground in earthquakes can be inferred from the amplitude spectrum of the vibration test.

## Application of Seismic Prospecting for Engineering Purposes with Some Examples

By Soji YOSHIKAWA and Ken ZAKO.

Text Book of J. S. C. E., Western Section  
April, 1970 pp. 27-50 (in Japanese).

### Abstract

In Japan, seismic prospecting has been conducted in many engineering projects and its applicability has proved to be very effective when due caution was paid for construction purposes. In this paper, methods are developed in various cases of construction projects, i. e., tunnels, measurement of rock property, ripperbility, land slide, foundations and so on. Results show that seismic prospecting should be planned in accordance with other surveys, for instance, layout of bore holes, boring data, and general aspects of geology. In the past applicability of seismic prospecting was restricted because the geological structure and physical property were only given in relation to the velocity contrast of P wave. However, the S wave velocity and consequent evaluation of Poisson's ratio have been shown to be closely connected with the rock property. In particular, the values of Poisson's ratio of rock corresponded to the shear zones in actual tunnel construction.

When geological structure is complicated the velocity log of both P and S wave should be conducted to achieve a more accurate geological section. Besides refraction methods, fan shooting methods have also been carried out for tunnels and foundations where the surface geology was very complicated. Methods of seismic prospecting in combination with other methods of surveying have been planned according to construction objectives and their actual uses on the land are shown in this paper. The analysis of data and its dependence on engineering projects are also described at various construction sites.



**Seismological Study on the Sakurajima Volcano (1)**  
**—Classification of Explosions and Some Characteristics of These Explosions—**

By Kiyoshi NISHI

Bulletin of the Disaster Prevention Research Institute, Kyoto, University,  
vol. 20, part 1, No. 170, Oct., 1970, pp. 23-35 (in English).

**Abstract**

Volcanic explosions of the Sakurajima volcano are classified into six types according to the mode of occurrence of the volcanic microearthquakes before and after each explosion. In terms of this classification, some characteristics of the recent activity of the Sakurajima volcano are discussed. The main results are as follows:

1) The rate of occurrence of D I type explosions have increased since 1965, whereas those of D III' and D IV' types have decreased.

2) Explosions of the same type occur in succession; and when one type shifts into another type, explosions of a form intermediate to both types are sometimes observed. From these facts it is considered that the conditions of the volcanic vent and the energy supply from the reservoir are reflected in the explosion types.

3) Large explosions are only observed in the D IV or the D IV' types.

4) After the lava-pool has formed in the crater, D I type explosions occur frequently at the first stage, then D II type explosions begin to occur at the later.

5) Judging from the arrival time difference of the air shock wave and the initial P wave of the explosion earthquakes, the origin of D I type explosions seems to be shallower than those of other types of explosion. This is confirmed by separate observation of the incident angle of the initial motion of the explosion earthquakes.

Volcanic Crustal Deformations (V)  
—On the Observations of Crustal Deformations at Volcano Sakura-jima—

By Tsuneo ETO

Annuals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp, 97-106 (in Japanese)

Abstract

Crustal deformations accompanying recent volcanic activity in the vicinity of Volcano Sakura-jima were studied from the results of continuous instrumental registrations of crustal deformations and the repeated precise geodetic levellings.

The analyses of horizontal pendulum type tiltmeters during the period from 1964 to 1970 showed the mean tilting rate of  $27''$ /year dip to the NNW direction at Kitadake station and  $3''$ /year dip to the SE direction at Harutayama station. Secular variation of tiltgrams at Hakamagoshi station showed a mean tilting rate of  $7''$ /year dip to the SSE direction during the period from 1962 to 1965, but  $2''$ /year dip to the west during the period from 1965 to 1970.

As a parameter of volcanic activity, a total of three monthly volcanic explosions at Minamidake crater were compared with the elevation change of B.M. 29 and B.M. 111. There were fairly close relations between the elevation change of B.M. 111 and the recent volcanic activity at Volcano Sakura-jima.

**Preliminary Report on the Shimo-ishiki Observation Station,  
Sakura-jima Volcanological Observatory**

By Tsuneo ETO

Annuals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 107-111 (in Japanese).

**Abstract**

A preliminary report is given on the Shimo-ishiki observation station, Sakura-jima volcanological observatory which was established in Kagoshima city in 1970. This paper contains introductory data made at this observation station and the instruments used during volcanic crustal deformations.

The list of instruments installed at the Shimo-ishiki station are as follows.

Instrument	Observational direction	Span (cm)	Period (sec)	Optical length (cm)	Sensitivity
H-59 type Extensometer	N 37° W	1000	10.0	200	$3.30 \times 10^{-9}$ /mm (1)
	N 53° E	1000	10.0	200	$3.30 \times 10^{-9}$ /mm (1)
V-59 type Extensometer	Vertical	500	10.0	200	$6.60 \times 10^{-9}$ /mm (1)
Sassa type Extensometer	N 31° W	2500	—	200	$1.20 \times 10^{-8}$ /mm (2)
	N 58° E	2540	—	200	$1.22 \times 10^{-8}$ /mm (2)
Horizontal pendulum type Tiltmeter	N 35° W	—	30.3	200	0.0113"/mm (3)
	N 55° E	—	30.3	200	0.0113"/mm (3)
	N 38° W	—	30.0	200	0.0115"/mm (3)
	N 52° E	—	30.0	200	0.0115"/mm (3)
Recording water tube Tiltmeter	N 36° W	5000	—	200	0.010"/mm
	N 57° E	4210	—	200	0.012"/mm
Aneroid Barometer	—	—	—	200	0.15 mb/mm
Bimetal Thermometer	—	—	—	200	0.01°C/mm

- Remarks: (1) Super invar bar with horizontal pendulum.  
(2) Super invar slack wire and bifilar suspension.  
(3) Super invar with oil damper.

An Investigation on the Volcanic Micro-Earthquake and Volcanic  
Explosion of Sakurajima Volcano (2)  
—On the Hypocentral Distribution of the Volcanic Earthquakes—

By Kiyoshi NISHI

Annals, Disaster Prevention Reserch Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 113-121 (in Japanese)

**Abstract**

In order to clarify the location of hypocenters of volcanic microearthquakes originating in the Sakurajima volcano, temporal seismometric observation was performed. Eleven observation points were distributed around the crater. Analyzing the data of March and April, 1970, the following results were obtained.

- 1) The large majority of hypocenters of A type volcanic earthquakes were deep. The large majority of hypocenters of not A type volcanic earthquakes were shallow, but there were some deep.
- 2) The seismicity at the crater rim was heigher than that within the crater.
- 3) There is a possibility of locating the new volcanic active place from the hypocentral distribution of shallow earthquakes in the volcanic region.
- 4) Hypocenter distribution suggesting the existance of a magma resovoir, was obtained.

## Seismic Activity at Amami-Oshima

By Keizo YOSHIKAWA

Annals, Disaster Prevention Research Institute Kyoto University,  
No. 14 A, April, 1971, pp. 123-130 (in Japanese).

### Abstract

In studying the seismic activity at Amami-Oshima and its vicinity, 3 components electro-magnetic type seismographs were established at Naze city during Feb., 1969. On the 1st of Jan., 1970, a severe earthquake hit the region causing considerable damage.

In this paper, the modes of the seismic activity before and after the earthquake are discussed using data taken by the seismograms. The main results are as follows.

1) The number of fore-running earthquakes in this region was a few, but a great many after-shocks would follow the main-shock.

2) The decreament of the after-shocks was slow untill 20 days after the main-shock, but after that it was normal. That is, the value of  $p$  in the reformed formula for Omori's, proposed by Utsu,  $n(t) = A/(t+c)^p$ , was 1.15.

3) The epicenter of most of the after-shocks were distributed 10-15 km apart NW from Naze.

4) The value of  $m$  in Ishimoto-Iida's emperical formula was 2.06 before the earthquake, and 1.81 for the after-shocks.

## On the Seismicity in the Eastern Area of the Volcano Aso

By Kōsuke KAMO, Hiroyasu ONO and Yasuaki SUDŌ

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 131-138 (in Japanese)

### Abstract

A seismic observation was carried out from late January to the beginning of March, 1970, in order to investigate the seismic activity in the eastern area of the Volcano Aso. In this period two temporal stations established at the eastern and the southeastern plateau of the Aso caldera. In analyses, the data obtained from the seismic stations of the Volcanological Laboratory of Kyoto University were also used. The results are as follows: (1) the seismic activity of the eastern plateau appears to be very low compared with that of the northwestern plateau, (2) the small earthquakes of which the focal depth is 120 km were detected and their foci distribute in the zone of deep earthquakes in Kyūshū District.

**The Structure of the Volcano Aso Deduced from  
the Azimuthal Deviation of P-wave**

By Tatsuhiko WADA and Keiichi NISHIMURA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 139-148 (in Japanese).

**Abstract**

The differences between the epicentral azimuths and the direction of arrivals of the initial phases are determined from the horizontal seismograms at the Volcanological Laboratory of Kyoto University situated inside the Aso caldera. Recent data in addition to the previous data given by Sassa (1936) exhibit a systematic deviation. We can interpret the deviation by advancing the following structural model under the Aso caldera. A tectonic line or zone runs across the center of the caldera from east to west and the northern part inclines nearly eastwards with a dip of about  $15^\circ$ , and the southern part inclines toward NNE with a dip of  $25^\circ$ . The chain of the central volcanoes, one of which, the Nakadake, is now active, stands on a tectonic line or zone. Moreover the skyline of the caldera rim exhibits a similar inclination as noted above.

## The Nature of Non-Volcanic Micro-tremors Observed on the Aso Caldera

By Akira KUBOTERA and Micho OTSUKA

Journal of Physics of the Earth, Vol. 18, 1970. pp. 115-124 (in English).

### Abstract

Seismic measurements at over seventy points on the Aso caldera have revealed the nature of stationary ground tremors on the atrio area, which cannot be attributed to traffic passage nor to volcanic activity.

The tremor is sinusoidal and stationary, the wave characteristics suffering little temporal change at any fixed point. However, it does change remarkably when observed from different points.

The spatial trend of observed wave forms have a definite correlation with topography suggesting possible structural interpretations of the Aso caldera.

The particle motion at the ground surface is observed to be confined in a horizontal plane. The spatial phase relation of the tremor shows that it is not a simple standing wave phenomenon but has a complicated propagating nature and that the particle motion is transversal to the direction of wave propagation.



## Seismic Studies during the JARE South Pole Traverse 1968-1969

By Tsuneo ETO

Reports of the Japanese Traverse, Syowa-South Pole 1968-1969, JARE Scientific Reports,  
Special Issue No. 2, Polar Research Center, National Science Museum,  
March 1971, pp. 115-124 (in English).

### Abstract

During the 1968-1969 austral summer, the JARE (Japanese Antarctic Research Expedition) South Pole Traverse party undertook a program of seismic investigation of the ice cap in the East Antarctic plateau area.

Refraction profiles were shot at five stations to determine variation in the velocity of seismic waves with depth in the upper transition zone from snow to ice. The seismic measurements consisted of short refraction profiles to ascertain near-surface velocity structure and long refraction shots (up to about 1.2 km) to measure the velocity of propagations of compressional  $P$  waves in the snow. Travel time curves were prepared for five long refraction stations from which velocity variations with distance were measured. Assuming a continuous increase of velocity with depth, velocity-distance curves were reduced to velocity-depth curves by the standard Weichert-Herglotz-Bateman formula. Seismic compressional waves in the snow over the area were shown to reach a maximum velocity of 3891-3937 meters/second at a depth of 210-230 meters.

Velocity variations over the area are also of interest in the study of snow density. From the compressional seismic wave velocity with depth values calculated for five refraction stations, snow density with depth profiles was calculated using the empirical expression which G. de Q. Robin (1958) showed to be valid below a depth of 15 meters.

## Measurement of Kinetic Energy of Volcanic Micro-Tremors

By Tatsuhiko WADA, Kōsuke KAMO and Yasuaki SUDŌ

Special Contributions, Geophysical Institute, Kyoto University.

No. 10, 1970, 149-158. (in English)

### Abstract

An apparatus has been devised for measuring automatically the kinetic energy of volcanic micro-tremors. This digital energy accumulator, called DEA-1, enables us to obtain precise results more easily than before. DAE-1 counts the number of pulses which are proportional to the integrated value of kinetic energy of volcanic micro-tremors and prints out automatically the total number of pulses in a certain interval with an electro-magnetic counter.

From its application to the measurement of volcanic micro-tremors at the Volcano Aso, it may be concluded that the release of energy in the form of volcanic micro-tremors is about  $10^{12}$  ergs per day in the quiescent state. In addition, the variation of the period of volcanic micro-tremors against the changes in the volcanic activity may be detected by the use of DAE-1.

## Aftershock Activity in the Vicinity of Kyoto

By Kennosuke OKANO

Bulletin of the Disaster Prevention Research Institute, Kyoto University,  
Vol. 20, Part 1, No. 169, October, 1970, pp. 17-22 (in English).

### Abstract

During the period 1964 to 1968 about 50 earthquakes with a magnitude of 3.0 or greater occurred in the vicinity of Kyoto. These earthquakes were studied on their aftershock activity. Earthquakes of more than about 4.0 magnitude were accompanied almost entirely by aftershocks. Most of the earthquakes studied here did not have enough aftershocks for customary statistical analyses; time and spatial distributions, energy release, magnitude-frequency relation etc. In this paper the aftershock activity of each earthquake is examined in relation to the regional variation in two ways; one to the magnitude relation between the main shock and its largest aftershock; the other to the number of aftershocks. No significant features can be obtained from the former examination, but the latter leads to an interesting observation in the regional variation of aftershock activity: i.e. earthquakes occurring in the southern part of the region concerned are followed by more aftershocks than those in the northern part. See Fig. 1.

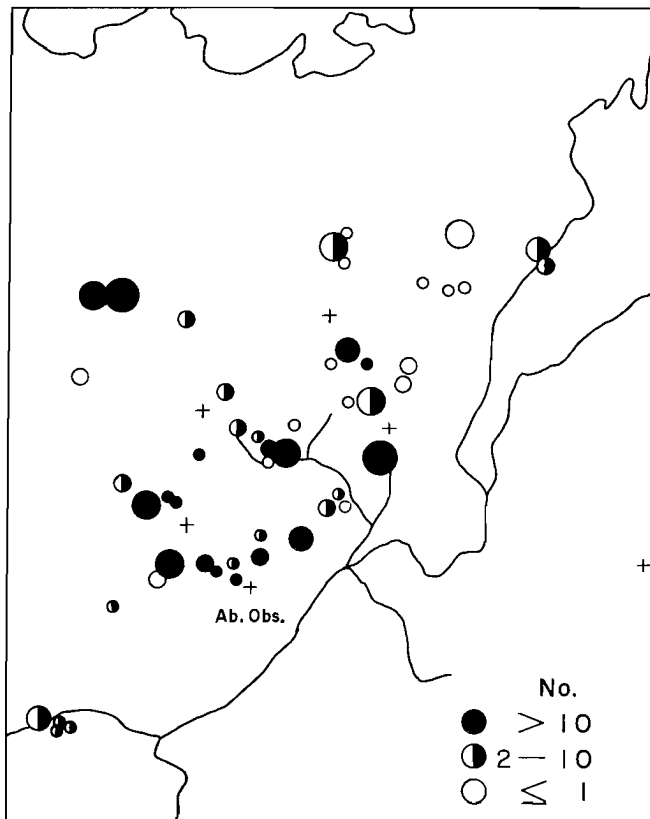


Fig. 1 Regional variation of aftershock activity indicated by the number of aftershocks observed.

## On the Nature of the Occurrence of Intermediate and Deep Earthquakes

### 1. The World Wide Distribution of the Earthquake Generating Stress

By Kazuo OIKE

Bulletin of the Disaster Prevention Research Institute, Kyoto University,  
Vol. 20, Part 3, No. 177, March, 1971, pp. 145-182 (in English).

#### Abstract

The world wide distribution of the earthquake generating stresses of intermediate and deep earthquakes has been mainly obtained from the smoothed radiation patterns of P waves of groups of earthquakes in fifty-one seismically active regions. These results were compared with the fault plane solutions of individual earthquakes in the same regions.

Data used in this study were taken from the Bulletins of the International Seismological Center, 1964 and 1965 for very active regions; and for regions where a few intermediate and deep earthquakes occurred, data from the Earthquake Data Reports of the U. S. Coast and Geodetic Survey, 1966-1969, were added.

The smoothed radiation patterns of Kuril-Japan, the Izu-Marianas and the Tonga-Kermadec regions determined from only two years' data showed satisfactory agreement with the patterns obtained for larger earthquakes by other seismologists.

In almost all regions the axes of maximum pressure align themselves with the dip of the seismic plane. The direction of the horizontal component of the axis of maximum pressure in each region was compared with the direction of differential movement between two blocks computed by Le Pichon where they agreed well with each other except in the following regions. In the South America region, the axes of maximum pressure lie in the NW-SE direction, while the vectors of the differential movement lie in the east-west direction. The patterns of intermediate earthquakes of the Chile-Peru border region, the Honshu of Japan and the New Hebrides region show that the axes of maximum tension align themselves with the dip of the seismic plane.

Crustal Movements Related to the Seismic Activity in a Restricted Area (5A)  
—Relation between the Seismic Activity in the Northwestern Part  
of the Kinki District and the Crustal Movements  
Observed at the Ikuno Station—

By Yutaka TANAKA, Makoto KOIZUMI and Masaaki KATO

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 13A, March, 1970, pp. 91-108 (in Japanese).

Abstract

The vector of secular ground tilts observed at Ikuno station changed direction twice between 1951 and the present. The first turning occurred from 1955 to 1957 and the second reverse one began in 1964 or 1965. The directional turnings of tilting movements were also more distinctly observed at Kamigamo in 1956 and 1964.

On the other hand, time variation of distribution of epicenters and rate of energy release show that the shift of seismically active region in the northwestern part of the Kinki district coincided with these turnings.

Further, it is conceivable from a construction of the results of geodetic surveys and the state of seismic activities that a similar phenomenon occurred in the district around 1925 on a larger scale.

From these findings, a close relationship between the mode of gradual crustal movements and the transition of seismic activities may be deduced.

Crustal movements Related to the Seismic Activity in a Restricted Area (5B)  
—Relation between the Seismic Activity in the Northwestern Part  
of the Kinki District and the Crustal Movements  
Observed at the Ikuno Station—

By Yutaka TANAKA, Makoto KOIZUMI and Masaaki KATO

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 71-84 (in Japanese).

Abstract

In the previous paper (5A), the peculiar mode of secular ground tilts observed at Ikuno was noted. Namely, the directional turnings of tilting movements appearing twice, in 1956 and 1964, and the shift of seismically active regions in the northwestern part of the Kinki district coinciding with those turnings.

Earthquakes then began to occur in 1969 in the zone passing east of Ikuno and extending from the northeast to the southwest. This zone is parallel to the seismic zone of Yodogawa which has been in action since 1964 and it seems that both zones from the view point of geotectonics, belong to the same system. It is possible therefore, that directional turnings in gradual tilting movements have not occurred since 1964.

However, as epicenters of this series of earthquakes were very near to Ikuno, anomalous ground tilt toward the northeast appeared from June, 1969 to April, 1970 and there remained a permanent set of ground tilting.

Crustal Movements Related to the Seismic Activity in a Restricted Area (6)  
—Relation between the Seismic Activity in the Northwestern Part  
of the Chubu District and the Crustal Movements  
Observed at the Kamioka Station

By Yutaka TANAKA, Masaaki KATO and Makoto KOIZUMI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 85-95 (in Japanese).

Abstract

A sequence of shallow earthquakes alternated through 1959 in the Chubu district. Coincidentally, at the Ogoya observation station, the rate of ground tilts changed in the direction of the tectonic forces and the mode of anomalous variation of ground tilts accompanied by the individual earthquakes also changed.

A similar phenomenon was found in the mode of tilt variations at the Kamioka observation station. It was confirmed that the change in the rate of gradual ground tilts appeared in the direction of  $N45^{\circ}W-S45^{\circ}E$  from the fact that the acceleration of gradual tilting movements accumulate in this direction. It is a remarkable fact that this direction closely coincides with that of Ogoya ( $N25^{\circ}W-S25^{\circ}E$ ).

On the contrary, it has been ascertained that the tilt variation as a see-saw motion corresponding to three active stages in the Kitamino earthquake series appears in the direction parallel to the Atotsugawa fault ( $N60^{\circ}E-S60^{\circ}W$ ). In other words, it may be imagined that a see-saw motion with the shorter period superposes itself on the gradual movements in the direction of  $N45^{\circ}W-S45^{\circ}E$ .

## Ground Tremors caused by Rock Bursts in the Ikuno Mine

By Yutaka TANAKA and Ryohei NISHIDA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 149-164 (in Japanese).

### Abstract

Rock bursts occurred at the Ikuno mine in the central part of Hyogo prefecture twice in January 1970. Coincidentally, ground tremors were also observed by the network for micro-earthquake observation stations in the prefecture and it is evident that the origin of tremors on Jan 26th coincided with the rock burst area.

Magnitudes and wave-energies ( $E_t$ ) of rock bursts estimated from the analysis of microseismograms, and strain energies ( $E_s$ ) estimated from the situation of the broken domains and the strength of rocks are shown in the following table.

	M(V. amp.)	M(F-Ptime)	$E_t$ (G-R)	$E_t$ ( $\tau$ , max. amp.)	$E_s$ ( $W_e$ , Vol.)
Jan. 10	-0.93	-0.95	$1.0 \times 10^{11}$ erg.	$1.7 \times 10^{11}$ erg.	$1.7 \times 10^{11}$ erg.
Jan. 26	0.2	0.3	$1.2 \sim 1.8 \times 10^{11}$	$6.2 \times 10^{11}$	$3.0 \times 10^{11}$

An exact source-mechanism for the tremors could not be obtained however, it seems that the direction of the principal stress inferred from the seismic data was perpendicular to the vein-plane near the scene and a null vector of focal sphere was within the plane.

Moreover, the E-W direction was the same as that of the tectonic forces in the prefecture. It is interesting to note that the frequency of the rock burst and the active epoch of the seismic belt near Ikuno coincided with each other.



## On Temporary Observation of Microearthquakes near Tottori City (1)

By Kazuo MINO, Ryohei NISHIDA and Junichiro MIYAKOSHI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 177-188 (in Japanese).

### Abstract

Studying seismicity near Tottori city, a temporary station at Shimosunami-cho and a tripartite seismometer net with a span of about 1 Km along the Yoshioka fault, produced by the Tottori earthquake of 1943, were established.

The distribution pattern of microearthquakes hypocenters is almost the same as the aftershock area of the Tottori earthquake in 1943, no hypocenter being found in the sea.

Along the Yoshioka and Shikano faults, there are few microearthquakes but at both ends and below the bottom of the faults, they are numerous.

Crustal structure agrees with the assumed one. But locally there is some difference, especially top surface layer with lower velocity, derived from tripartite observation results.

Source Process of Deep and Intermediate Earthquakes as Inferred  
from Long-period P and S Waveforms

1. Intermediate-depth Earthquakes in the Southwest Pacific Region

By Takeshi MIKUMO

Journal of Physics of the Earth, Vol. 19, No. 1, 1971, pp. 1-19 (in English).

Abstract

The source process of four intermediate earthquakes with magnitudes of 6.0-6.8 and focal depths between 100 and 200 km has been reinvestigated from the analysis of long-period P and S waveforms.

The source process times recovered from the times of the first half cycle of recorded P waves or the group delay times derived from the slopes of equalized phase spectrum show an azimuthal dependence with respect to the orientation of a nodal plane and of the null vector. If we assume shear dislocation models for these earthquakes, the dependence yields a solution to the problem of which of two nodal planes corresponds to the slip plane. Various source parameters have also been estimated from the azimuthal dependence by least squares technique.

The dimension of the slip plane or the fault length and width range in 25-40 km and 8-18 km, respectively, and the rise time of dislocation is found to be about 1 sec. The rupture velocity might be as low as 3.2 km/sec, if bidirectional propagation is assumed.

The theoretical seismograms of both direct P and S waves appropriate to each recording station have been synthesized on the basis of the estimated source parameters, taking into account the combined effects of wave propagation in the mantle and crust and of the seismograph response. A good agreement of general features between the observed and synthesized waveforms on the three component seismograms gives support to the above slip dislocation model. Comparison of the amplitudes on the both kinds of seismograms yields seismic moment of the order of  $1.6-3.0 \times 10^{26}$  dyne·cm and the amount of dislocation of 80-140 cm. The stress drop at these earthquakes ranges from 50 to 90 bars but might exceed 170 bars for one shock. The effective initial stress to produce shear dislocations is also estimated in relation to the frictional stress on the slip plane.

## Some Investigations in Ebino Earthquake Swarm

By Kunihiko WATANABE

ZISIN II, Vol 23, 1970, pp. 32-40 (in Japanese)

### Abstract

On February 21, 1968, a large earthquake occurred at Ebino plateau in the southwest part of Miyazaki Pref. in Kyushu. The Ebino earthquake swarm was active for approximately one year. Abuyama Seis. Obs., Sakurajima Volcano. Obs. and Disast. Prev. Res. Inst. of Kyoto Univ. made temporary observations at 5 stations. The main conclusions on the nature of the Ebino earthquake swarm are as follows:

- 1) The epicentral region characteristically changed its shape with time.
- 2) The aspects of the push-pull distribution of the initial  $p$  motions appeared to be nearly the same both in large shocks and microearthquakes, showing the same focal mechanism in both cases. This phenomenon did not seem to vary throughout the whole period of the study.
- 3) According to the wave-period analysis, we recognized an interesting relation between the location of the epicenter and the frequency of shocks. It may be considered that this was caused by the difference in the properties of the crustal rocks in the hypocentral region compared with those outside the focal area.

**Focal Mechanism of Microearthquakes in Wakayama Region  
in Relation to the Upper Crustal Structure**

By Takeshi MIKUMO, Michio OTSUKA and Kazuo OIKE

ZISIN, Vol. 23, No. 3, September, 1970, pp. 213-225 (in Japanese)

**Abstract**

The focal mechanism of 20 microearthquakes in the Wakayama region have been determined from the seismograms recorded at ten temporary stations and eight routine network stations covering the region.

The hypocenters of the earthquakes have been determined for five different crustal models (with a continuously varied velocity profile), to estimate the accuracy of their location and the emergent angle of seismic rays at the focus. The radiation pattern of *P* wave first motions for the 15 shocks, which was corrected for an appropriate crustal structure, can be interpreted by the double-couple type mechanism with dipping nodal planes.

The average of the maximum pressure axes is oriented nearly horizontally along the N70°W-S70°E direction, while the axes of the maximum tension show a steep dip in many cases. If a slip dislocation is assumed to be a likely model of the earthquakes, the source would be thrust faulting with a predominant component of dip slip. The other five earthquakes show, however, the radiation pattern inconsistent with the double-couple type mechanism.

## On the Accuracy of the Distance Measurements by Electro-Optical Means

By Fumio OHYA and Torao TANAKA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 15-31 (in Japanese).

### Abstract

The accuracy of the electro-optical distance measurements by an AGA Geodimeter for the purpose of the observation of crustal deformation is statistically estimated from the measured values over 3 years. The standard error of final result  $Lm'$  is 5.62 mm. If the modulation frequencies have maintained nominal values, it can be considered that the error consists of a random error of 2.20 mm and a systematic delay line error of 5.17 mm. But by the revision of the calibration tables the delay line error can be reduced to 3.41 mm. This means that repeated revision of the calibration tables will ensure the accuracy of  $\pm(3-4)$  mm.

An approach to estimate the temperature distributions on some topographic profiles for the appropriate meteorological correction is tried. The temperature is calculated along the light path from the measured values on the ground at several stations assuming the lapse rate and the decreasing rate of the amplitude of daily variation with altitude. These parameters are varied within reasonable ranges. On each model, meteorological correction is carried out by the mean temperature on the path. It is suggested that correction to the accuracy comparable to the machine error will be possible by the temperature measured on the ground.

Measurements with high accuracy in a crustal deformation observatory are also reported.

## Observations of Crustal Strains by Electro-Optical Measurement (Part 1)

By Michio TAKADA, Torao TANAKA, Kensuke ONOUE, Masaru YAMADA,  
Yasuyoshi FUJITA and Fumio OHYA.

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 33-40 (in Japanese).

### Abstract

Results from repetitional measurements of six base-line networks founded in western Japan by a geodimeter (AGA Geodimeter Model 6) are here introduced. In the Tottori district, two seismic faults, the Yoshioka and Shikano faults, appeared during the Tottori Earthquake of Sep. 10, 1943. The Shikano and Yoshioka networks have base-lines which intersect these faults, and we may observe the relative movements of the two faults by these networks. Using base-lines in a tunnel at the Amagase Crustal Deformation Observatory, comparison of the results from the electro-optical measurement with those from continuous observations by extensometers in the same tunnel is possible. At the same time the shortest base-line in the tunnel can be used as a standard length for instrumental calibration. At the base-lines in Shimoda we may also compare the results with the ground strain observed at the Donzurubo Crustal Movement Observatory. Characteristic vertical movements of the ground are observed in the southern part of Shikoku and the Kii peninsula relating to the seismic activity in the southern offing of this district. For detection purposes of the crustal strain accompanied by these characteristic movements, a network has been established in Kochi City. Significant changes of measured lengths of these base-lines are hardly noticeable in the results from three observations from 1968 to 1971.

Ocean Tides and Tidal Tiltings of the Ground Observed at the Oura  
and Akibasan Stations, Wakayama

By Torao TANAKA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 55-69 (in Japanese).

Abstract

Amplitudes and phases of eight principal tidal constituents and the meteorological constituent  $S_1$  of the ground tilts observed at Oura and Akibasan in Wakayama City have been determined from one year's data by the method of least squares. Marked discrepancy can be seen between the tilting diagrams obtained at the two stations even for the  $M_2$  constituent. It is shown that the discrepancy can not be explained by the difference of the loading effect of the ocean tides in the neighbouring sea calculated according to the theory of Boussinesq. Although there are many points which are uncertain, the discrepancy might be attributable to the existence of confined water.

Observations of Ground Strains Caused by Periodic Water Drawings

By Izuo OZAWA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 13 A, March, 1970, pp. 79-90. (in Japanese).

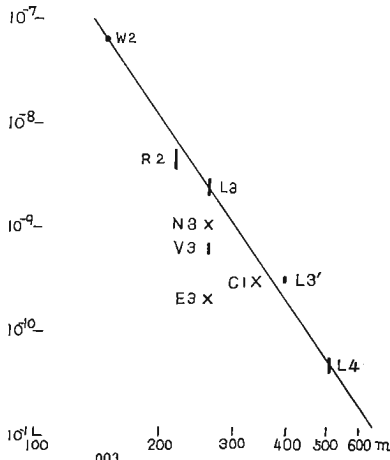
Abstract

Observations of ground strains caused by periodic water-drawings have been performed by means of the horizontal and vertical components of extensometers, rotation-meter, water-tube tiltmeter and pendulum type tiltmeters at Osakayama Observatory since July 1964. One ton of ground-water has been drawn from 40 meters under ground in about 7 minutes every 30 or 40 minutes.

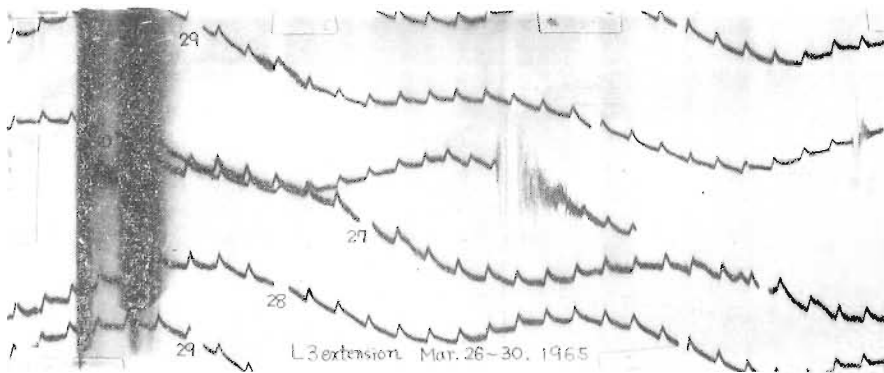
According to these observations, the radial components of the strain ( $\gamma$ ) attenuates for the distance ( $r$  meters) from the well as follows

$$\log_{10} \gamma = 5.60 - 5.89 \log_{10} r.$$

These strain curves have a simple shape and little phase lags refer to water-drawing. The effects are negligible in the secular change of ground strains.



Relations between affected linear strains by water-drawing and their distance from the well.



Record of the extensometer  $L_3$  in the direction  $S38^\circ W$ . This records the after shock of the Aleutian Earthquake whose magnitude is 7.0.



Investigation Methods of Underground Water in Landslide Areas  
—New Investigation Methods and their Application—

By Atsuo TAKEUCHI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 533-542 (in Japanese).

Abstract

The results of an examination on conditions of underground water in and around a landslide area, showed it to be natural vein-stream water rather than a product of stratiform underground water. Any investigation, therefore, by tracer methods would not give sufficient results. And it was decided that the existence of an underground water vein-stream should be assumed in advance and investigation methods be conducted accordingly.

An attempted underground temperature survey such as those used at hot springs was employed in order to locate the position of the underground water vein-stream. Results proved that this type of survey could obtain excellent data on underground water vein-streams in and around landslide areas.

It is hoped that further theoretical tests may be made in future in an attempt to define the size and depth of underground water vein-streams.

**Landslides in Hyogo Prefecture (I)**  
**—Topographical and Geological Characteristics—**

By Atsuo TAKEUCHI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 543-561 (in Japanese).

**Abstract**

Landslides in Japan are of three main types. The Tertiary type, the Fractured zone type, and the Hot-spring-Volcanic type. Each type has different characteristics in landslide topography and landslide movement. Furthermore, the topographical factors and the geological factors of landslide areas belonging to the same landslide type will have a different landslide topography and landslide movement mechanism due to different characteristics of the rocktype or the stratum existing in the landslide area.

Consequently, it may be possible to discover different points from the results of numerous landslide investigations. i. e. taking landslides occurring at different points in the rock-strata or rock-types and working out the different topographical results along with landslide results it should provide valuable data for future investigation and particularly for preventive work.

It was stated above that the topographical and geological character of Tertiary type landslide areas in Hyogo Prefecture were examined.

The following results were obtained :

- (1) Geology and geological tectonics have a considerable effect on each factor of the landslide topography.
- (2) In Tertiary period strata, both stable and unstable stratum were present along with stratum of an unstable type when exposed to faults, cap-rocks etc.

## Some Problems of Electric Prospecting in Shattered Zone Type Landslide Areas

By Takahiko FURUYA, Hidemi TSUMOTO and Toshifumi KONISHI

Annals, Disaster Prevention Research Institute, Kyoto University  
No. 14 A, April, 1971, pp. 563-587 (in Japanese)

### Abstract

The writers think that shattered zone type landslides caused by geological conditions are of three types, (1) the detrital material layer of base rock, (2) crush of the inner parts of base rock, (3) the deep weathering of base rock. Accordingly topographical and geological conditions at shattered zone type landslides at Zentoku, Oto, Kuraishi, Goto-kudanigawa, Wada, and Nyutai, in Shikoku have been thus classified.

A survey was conducted by the electric resistivity method in order to observe how such topographical and geological conditions are electrically reflected. Electric prospecting was applied to the lateral sounding based on the electric resistivity method, and the pole-dipole method arranged in CPPC and depending on the disposition of an electrode. Measuring apparatus used were a specific earth resistance of the 3244 type produced at the Yokogawa Electric Works Ltd, and for the Wada landslide area alone, a specific earth resistance tester of L-10 type produced by the same company were employed.

The results of the topographical, geological survey and the electric prospecting are summarized as follows.

1) The topographical and geological phenomena of the surveyed landslide areas do not always fit into the distribution of the apparent resistivity value but the landslide areas of Zentoku, Kuraishi and Nyutai are found to be rather more equally distributed. The detrital material layer of these landslide areas shows an apparently low resistivity value and the base rock is likely to indicate an apparently high resistivity value.

2) The reasons why topographical and geological phenomena of the shattered zone type of landslide area not always compatible with the distribution of the apparent resistivity value are explained by the condition of the grounding electrode, rugged layers of unhomogeneity, low reliefs on the ground, etc.

**Fractured Zone Type Landslides in Kochi Prefecture  
by an Electrical Resistivity Survey**

By Atsuo TAKEUCHI

Jisuberi, The Japan Society of Landslides, December, 1970 pp. 19-30 (in Japanese).

**Abstract**

The usefulness of the electrical resistivity survey in Fractured zone type landslides were examined at the Choja landslide area and the Wada landslide area in Kochi Prefecture. Results shows that electrical resistivity surveys could be satisfactoraly applied in Fractured zone type landslide areas as well as in Tertiary types, and that much information could be obtained by electrical resistivity surveys.

A thorough survey was therefore conducted to determine its positive efficiency at many other Fractured zone type landslide areas in Kochi Prefecture.

The following results were obtained.

1. From the assumed diagram of the underground structure.
  - a. An outline of the underground structure of the investigated landslide area.
  - b. Fairly exact information on the form and existing depth of bedrock surface and slide surface.
  - c. The landslide area can be divided into blocks due to the area's topographical map plotted by the discontinuity belts of the resistivity values seen from the assumed diagrams of the underground profile.
  - d. Even if the bedrock exists so deeply and can not assumed the existing depth of bedrock by an electrical resistivity survey, the shallow slide layer which caused damaged to land and property was sufficiently detected.
2. From the analyzed results of the horizontal electric profiling.
  - a. It is assumed that the distributed areas of the apparent low resistivity values belong to one of the adjacent areas; the existence of abundant underground water, present active landslide areas, weather exposed areas of soil mass, and areas where possible landslide movement may occure in future.
  - b. Contained in the distributed area of apparent low resistivity values and discontinuity belts of resistivity values of underground structures, the landslide area can be divided into blocks, these blocks having an important relation to landslide movement.

Some Considerations on Geomorphic Processes deduced from Land-Slide  
Studies of Shikoku Island

By Takahiko FURUYA

Annals of the Tohoku Geographical Association Vol. 22, No. 4, October, 1970, pp. 211-217.  
(in Japanese)

Abstract

Several samples of the land-slide in Shikoku Island show the significance of groundwater as a morphogenesis. The role of groundwater, however, is thought to be universal in the geomorphic processes of other kinds of landforms.

The author proposes a tentative principle to be applied to studies in such fields of study:

(1) Action of groundwater on the material which constitute the present landform rules of present morphogenesis.

(2) Action of groundwater at present is controlled by the nature of the terrain inherited from previous landform development.

The author stresses that the groundwater is a morphogenesis rather than surface water, though the latter is sometimes assumed to be the chief agency for fluvial process.

**A Study on the Ground of Mountainous Regions (I)**  
**—On the Weathered Granite Zone at Tanakami Mountain**  
**Range Due to Seismic Prospecting—**

By Akira NAKAGAWA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 589-597 (in Japanese)

**Abstract**

The methods of seismic prospecting using P-waves were investigated at weathered granite zones in the Tanakami mountain range. The objective was to determine the weathering mechanism of ground at a mountainous region.

The experimental ground was composed of three structural types classified  $V_I$ ,  $V_{II}$  and  $V_{III}$  as the velocity of seismic waves.

The  $V_I$  upper layer was rock weathered sand along with new weathering and erosion. The  $V_{II}$  middle layer was of pressed sand weathered from granite rocks. The  $V_{III}$  was non weathered granite rock.

The velocity of each layer are as follows.

$$V_I = 0.37 \sim 0.55 \text{ km/sec}$$

$$V_{II} = 0.74 \sim 0.83 \text{ km/sec}$$

$$V_{III} = 4.0 \sim 6.0 \text{ km/sec}$$

The  $V_{II}$  layer showed special weathering and an exponential curve from the velocity of seismic waves.

## Halogens of Ground Water in the Matsushiro Landslip Area

By Ryuma YOSHIOKA, Setsuo OKUDA and Yasushi KITANO

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 667-675 (in Japanese)

### Abstract

The following is an analysis of the chemical composition of ground water which appeared in connection with swarm earthquakes in the Matsushiro area (Nagano Pref., Central Japan), from September 1966 to December 1968. Calcium chloride type water with a large amount of carbon dioxide gas unusual in thermal and mineral spring waters in Japan is found.

In order to clarify the source of calcium chloride type water in this area, the authors carried out chemical analysis on the traces of bromide, iodide and borate-boron in the ground water samples taken during November 1966 to September 1968.

The following results were obtained: (1) clear positive relationships are observed between bromide, borate-boron contents and chloride content, but the iodide content varies in comparison with the contents of the other constituents, (2) the ratios of weight of bromide, iodide and borate-boron contents to chloride contents are  $0.6-5.0 \times 10^{-3}$ ,  $0.5-6.8 \times 10^{-4}$  and  $1.1-3.5 \times 10^{-2}$ , respectively, (3) the ratio of weight of bromide content to iodide content is 2-50.

The origin of calcium chloride type water in the ground water of this area is discussed as follows:

(1) judging from the similarity in the ratio of bromide content to chloride content in the calcium chloride type water of this area and in hot spring water in the Tertiary volcanic or hypabyssal rock and granite areas in Japan, and from the fact that the ratio of bromide content to iodide content is more than that in oilfield brine and less than that in sea water, the origin of calcium chloride type water observed in this area is assumed to be the remains of past volcanic activity,

(2) on the other hand, judging from the similarity in the ratios of bromide, iodide and borate-boron contents to chloride content in the interstitial and fossil waters, its origin is thought to be the remnants of sea water entrapped with sediments during long periods of time and without contact with the atmosphere.

At present, therefore, there appear to be no significant compositional trends as a conclusive factor on the origin of calcium chloride type water discharged from the Matsushiro area.

## Investigation of Ground Water Flow in the Kamenose Landslide Area

By Kazuo OKUNISHI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 677-689 (in Japanese).

### Abstract

Ground water flow regime of the Kamenose landslide area in Osaka Prefecture was investigated from 1964 to 1969 as a part of a synthetic research of the Kamenose landslide. The results of the investigations of the ground water level and the geological structure suggest that the ground water in this area can be treated as phreatic water. It was also confirmed by the result of the logging of the ground water flow in the boreholes. The distribution of ground water storage can be shown from a contour map of the water table and the geological map showing the thickness of the permeable layer (mainly weathered andesite). The path of significant ground water flow was estimated through the ground water tracing and the geochemical investigation of land waters. It was found that the main ground water vein exists in the zone where the landslide motion was significant. The result of the investigation of water balance in the watershed of a brook in the landslide area showed that the net recharge of the ground water accounts for about 60% of the annual precipitation. The discharge of the springs and the artificial drainage works, and the base flow of the brook in the watershed are summed up and compared with the ground water recharge. It is shown that about 60% of ground water recharge flows away without appearing on the ground surface of this area.

It is generally said that the ground water flow in landslide areas usually exists as ground water veins in underground channels. It was demonstrated that, in such a case, distribution of the potential of ground water, direction of the significant flow, and water balance of each part of the watershed must firstly be investigated to determine the fundamental network of the ground water flow, and to determine then, its more detailed structure through further investigations.



## Synthetic Observation on Rocky Mudflow

### Part 1. The Planning of a New Observation System for Mudflow and Fields Test at the Eastern Slope of Mt. Yake in 1970

By Mudflow Research Group\*

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 691-705. (in Japanese)

#### Abstract

In Japan, rocky mudflow is a terrible natural disaster often occurring at the foot of mountainous regions after heavy rainfall. Consequently the scientific study of mudflow is of great importance in this country. In order to investigate the physical process of mudflow, field observation, model experiments, numerical simulation and theoretical analysis should be made side by side. As a first step, the Mudflow Research Group planned to establish a synthetic observation method capable of recording the dynamic behaviour of mudflow through its life cycle i.e. the various stages of occurrence, growth, decline, and standstill.

A new observation system was designed to satisfy severe natural conditions and for the safety of observation members. The system consists of the detector of mudflow arrival, automatic switching circuits to operate a video camera (with a recorder), 35 mm camera (motor-driven for constant interval shots) and illumination flare tubes (for night shots). This system acts automatically recording the moving state of rocky mudflow. In addition to this system, rain gauges and water level gauges must be set in order to investigate hydrological characteristics in small mountainous basins under heavy rainfall conditions.

During the summer of 1970, the observation system and hydrological survey instruments were established along Kamikamihori valley on the eastern slope of Mt. Yake in the North Japan Alps, where volcanic detritus flows down in the form of rocky mudflow after heavy rainfalls several times a year. In the object region along the valley, poles with constant length markings were fixed to show a scale of standard length, and large rocks were painted with fluorescent paints in order to observe the scouring force and transport distance.

There were very few opportunities to test the observation system during the summer of 1970 because heavy rainfall and mudflow did not occur so often as in normal years. However we succeeded in measuring the frontal velocity of mudflow (5 m/sec in a slope of 12°) from the video tape record and 8 mm photos of the moving top of the rocky mudflow.

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\* group members in 1970

S. ORUDA, K. OKUNISHI, K. YOKOYAMA, H. SUWA, K. YANO, A. DAIDO, T. OKUMURA,  
C. NAKAJIMA, H. EDAGAWA.

## Slope Failure Caused by Ground Water Flow Due to Infiltration

By Yoshiaki FUKUO

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 707-715 (in Japanese)

## Abstract

Ground water flow may be generated in sloping soil layer over semi-pervious rock surface when the infiltration of rain water exceeds the downward leakage of water from a rock surface. This flow brings about an increase of shearing stress and a decrease of compressional stress between soil particles through the drag force in the direction of the flow and pressure gradient of pore water, respectively, and may result in slope failure. This paper is a theoretical report on this type of failure. Taking account of the distribution of effective stress, the sloping layer is divided into two regions, an upper layer (I) in wet conditions due to infiltration and a lower layer (II) influenced by ground water flow.

According to the Mohr's theory of failure, the occurrence of slip surface may be initiated in layer (II) if it is formed. At first, the necessary condition of occurrence is considered and is obtained as follows,

$$\gamma_w \frac{(u \cos \rho - v \sin \rho)}{k \sin(\rho - \beta)} - (1 - \sigma)(\gamma_s - \gamma_w) > \frac{H \sin \rho}{D \cos \beta \sin(\rho - \beta)} \quad (\rho > \beta)$$

where,  $\gamma_s$  and  $\gamma_w$  are the specific weights of soil particles and water,  $\sigma$  and  $k$  are the porosity and permeability of soil layer,  $\beta$  and  $D$  are the inclination and plumb thickness,  $\rho$  and  $\kappa \equiv H \tan \rho$  are the internal frictional angle and cohesive stress in Mohr's theory and  $u$  and  $v$  are the components of Darcy's velocities of flow in the  $x$  and  $y$  axes which are taken along slope surface and perpendicular to it, respectively.

Secondly, the drawing method of slip line is derived in active and passive failure based on the conception of a limiting state of static equilibrium. Mathematical representation of this line is as follows,

layer (I);  $0 \leq y \leq \zeta_{2b}$

$$Y_1 = \frac{H}{\gamma_s'} \frac{\sin 2\varphi}{\sin \lambda - \sin(2\varphi + \beta)} \quad \left( \sin \lambda \equiv \frac{\sin \beta}{\sin \rho} \right)$$

$$X_1 = \frac{H \sin \beta}{\gamma_s' \sin(\rho - \beta)} \left[ \frac{\cos(\rho - \beta) \sin 2\varphi - \sin \lambda \{ \cos \rho + \cos(2\varphi + \rho) \}}{(\sin \lambda + \sin \beta) \{ \sin \lambda - \sin(2\varphi + \beta) \}} - \frac{1}{\cos \lambda} \log \left| \frac{\{1 - \cos(\lambda + \beta)\} \{1 - \cos(2\varphi - \lambda + \beta)\}}{(\sin \lambda + \sin \beta) \{ \sin \lambda - \sin(2\varphi + \beta) \}} \right| \right]$$

layer (II);  $\zeta_{2b} \leq y \leq y_b$

$$Y_2 = \zeta_{2b} - \frac{a - b \sin 2\varphi - c \cos 2\varphi}{A - B \sin 2\varphi - C \cos 2\varphi}, \quad a - b \sin 2\varphi_1 - c \cos 2\varphi_1 = 0$$

$$X_2 = \frac{(Ab - Ba)}{(A \cos \rho - B)} \left[ \frac{(B \cos \rho + C \sin \rho) \sin(2\varphi - 2\varphi_1) + A \{ \cos(2\varphi + \rho) - \cos(2\varphi_1 + \rho) \}}{(A - B \sin 2\varphi_1 - C \cos 2\varphi_1)(A - B \sin 2\varphi - C \cos 2\varphi)} \right]$$

$$-\frac{2}{\sqrt{A^2 - B^2 - C^2}} \tan^{-1} \left\{ \frac{\sqrt{A^2 - B^2 - C^2} \sin(\varphi - \varphi_1)}{A \cos(\varphi - \varphi_1) - B \sin(\varphi + \varphi_1) - C \cos(\varphi + \varphi_1)} \right\} \Bigg]$$

$$\left\{ \begin{array}{l} A = \left\{ (1 - \sigma)(\gamma_s - \gamma_w) \sin \beta + \gamma_w \frac{u}{R} \right\} \quad a = \gamma_s' \zeta_{2b} \sin \beta \\ B = \sin \rho \left\{ (1 - \sigma)(\gamma_s - \gamma_w) \cos \beta + \gamma_w \frac{v}{k} \right\} \quad b = \sin \rho (\gamma_s' \zeta_{2b} \cos \beta + H) \\ C = A \sin \rho \quad c = a \sin \rho \end{array} \right.$$

where  $\gamma_s'$  is the specific weight of wet soil in layer (I),  $\zeta_{2b}$  is the depth of free surface of ground water flow,  $\varphi$  is the angle between  $x$ -axis and maximum principal stress and  $y_b$  is the depth of slip line at  $\varphi = \varepsilon \equiv \frac{\pi}{4} - \frac{\rho}{2}$ .

The interval of the angle  $\varphi$  in an active state is  $\frac{\pi}{2} \geq \varphi \geq \varphi_1$  at layer (I),  $\varphi_1 \geq \varphi \geq \varepsilon$  at layer (II) and that in a passive state is  $\varepsilon \geq \varphi \geq \varphi_2$  at layer (II),  $\varphi_2 \geq \varphi \geq 0$  at layer (I), where

$$\cos(\varphi_1 + \varphi_2) = \sqrt{\frac{1}{1 + (\cot \beta - H/a)^2}}, \quad \frac{\pi}{2} > \varphi_1 > \varphi_2 > 0.$$

Paleolimnological Study of Lacustrine Sediments in Lake Biwa-ko

By Shoji HORIE, Osamu MITAMURA, Seiichi KANARI, Hideo MIYAKE,  
Atsuyuki YAMAMOTO and Norio FUJI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 745-762 (in Japanese)

Abstract

In this paper, the historical development is considered of Lake Biwa-ko during late-glacial and the postglacial times. The main purpose being to clarify paleohydrology, paleoclimate, and to establish the late-pleistocene chronology which is comparable to the European and American chronological time table. Discussion was made from a chemical, mathematical, physical, and palynological point of view concerning the various features of core samples nearly 12 m in length.

On the basis of pollen analytical data, former temperatures during the lateglacial time is thought to have been several degrees centigrade lower than the present one. Although the correlation between the amount of calcium carbonate as an indication of former temperature, nutrient salt and organic matter is indistinct, temperature rise since the lateglacial time is clear. The reason might be a complicated combination of water environments, organic production and decomposition, turn over rate, source of organic material, and density current found in such a large lake as Biwa.

Because of the existence of thick lacustrine sediments in Lake Biwa-ko, they afford unique information on the fluctuation of the Pleistocene climate in Japan.

## The Historical Development of Lake Yogo-ko Inferred from Granulometric Analyses

By Shoji HORIE and Hideo MIYAKE

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 763-769 (in Japanese).

### Abstract

In order to clarify the historical development of Lake Yogo-ko from a paleohydrological viewpoint, examination of the granulometric analyses on a core sample 6.5 m long was made.

Although the sediment is of Gytjtja, the result of the analyses shows the existence of an alternation of two kinds of strata with 1-1.5 m interval. One is a coarse stratum composed of fine sand and silt, the other is a clay dominant stratum. The content of the former seems to be about 50% and the latter approximately 70-80% respectively.

The coarser stratum contains much organic carbon and therefore more humic material. Accordingly, the specific weight of that stratum is relatively light.

Discussion on the past limnetic environment under which the coarser, black colored, and high organic material was deposited, has revealed that such an environment might be caused by the following conditions.

(1) In accordance with the increase of precipitation, surface runoff from the drainage area must have carried much terrestrial organic material forming the considerable part of the lake sediments.

(2) When the level dropped, the surface area of the lake must have shrunk and aquatic vegetation would be dense in the newly formed littoral region. In addition, the balance between the trophogenic layer and the tropholytic layer must have changed. For that reason the undecomposed organic matter should be regarded as an increase in the sediment itself.

(3) Lake productivity might increase as a result of the above mentioned mechanism of eutrophication; consequently more organic remains derived from high productivity must produce further higher productivity. Such interaction might promote mutual conditions in each other and the organic content in the sediments would be increased.

Although the true cause is still unknown, continuous study of the granulometric analyses together with chemical and ecological investigation may clarify the question of the lake's development i.e. the transition of the environment.

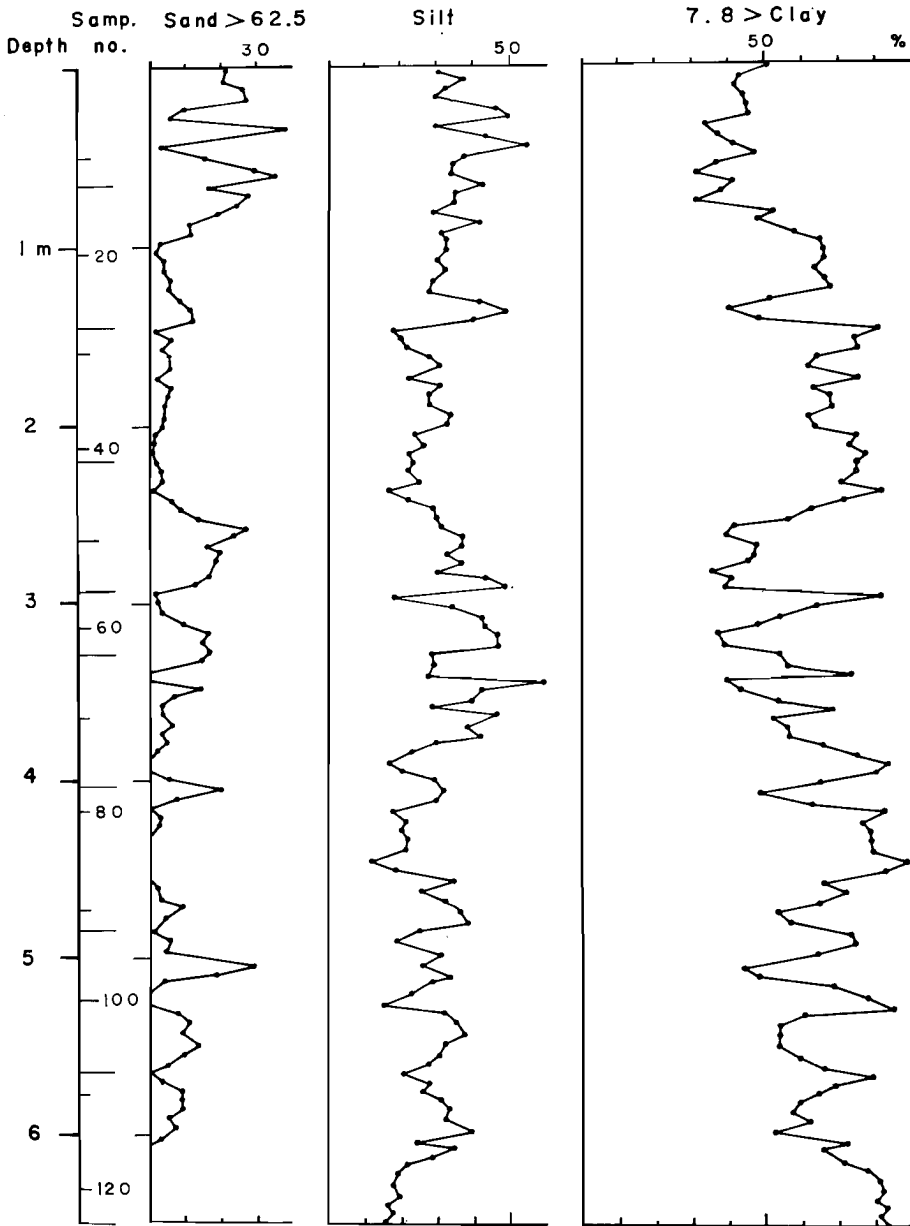


Fig. 1 Granulometric analyses on the core sample of Lake Yogo-ko

Calcium Chloride Type Water Discharged from the Matsushiro Area  
in Connection with Swarm Earthquakes

By Ryuma YOSHIOKA, Setsuo OKUDA and Yasushi KITANO

Geochemical Journal, Vol. 4, No. 2, November, 1970, pp. 61-73 (in English).

Abstract

Swarm earthquakes in and around the Matsushiro area in Nagano Prefecture began in August 1965. The total number of earthquakes was counted at 62,396 between August 1965 and December 1968.

A positive relationship has been observed in the activity of the swarm earthquakes and the amount of salt content in the ground waters of the area. A considerable change in the conditions under the ground is expected through a change in the chemical composition of the ground water.

For the investigation of hydrochemical features in this area, from September 1966 to December 1968, ground water samples were taken monthly and chemical constituents such as  $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{HCO}_3^-$ , borate-B, and soluble  $\text{SiO}_2$ , were determined in the laboratory. The following results were obtained:

(1) clear positive relationships are observed between calcium, magnesium, sodium, borate-B, bicarbonate, carbon dioxide and chloride contents,

(2) soluble silica and sulfate contents do not vary in comparison with the contents of the other constituents,

(3) calcium, chloride and carbon dioxide contents increased remarkably with the increasing activity of the swarm earthquakes.

The following hypothesis on the origin of calcium chloride type water observed in the Matsushiro area is advanced: Saline water in the area might have been confined in deep sedimentary layers containing clay minerals during long periods without contact with the atmosphere, and might have gradually changed to calcium chloride type water containing a large amount of carbon dioxide, increasing salt concentration, by various processes such as ion exchange, semipermeable membranes of clays, dissolution of calcium carbonate in sediments, and removal of various ions from solutions by adsorption, precipitation and reduction.

**Studies on Bed Load Transportation for Non Uniform Sediment  
and River Bed Variation**

By Kazuo ASHIDA and Masanori MICHIEU.

Annuals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 259-273 (in Japanese).

**Abstract**

This paper describes the results of investigations concerning the bed load transportation for nonuniform sediments, armouring phenomena and the degradation of a river bed composed of graded material in the case of no upstream sediment supply.

The effect of non uniformity of material on the bed load transportation can be expressed by the difference of the threshold condition of movement of sediment for various size classes. The process of river bed degradation can be treated by using a representative diameter for the sediment mixture when the material of various grain size classes is in a moving state. However, when some parts of the bed material are under the threshold condition of movement, river bed degradation scarcely occurs for the effect of an armour coat.

The process of river bed degradation is therefore classified into three regions, and a method to predict the grain size frequency distribution of the armour coat on each region and to compute the amount of river bed degradation, is proposed.



Studies on Fluvial Processes of Stream Channels (2)  
—Self-Formed Stable Channel Profile and Process—

By Kazuo ASHIDA, Yoshio MURAMOTO and Shūji NARAI.

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14B, April, 1971, pp. 275-297 (in Japanese).

**Abstract**

As described in the previous paper, a stable or a zero-bed state is established in the upstream reach of an alluvial channel under conditions of the absence of sediment feeding and a given discharge. This paper deals with the stable channel profile and process on the basis of several results obtained from experiments conducted in a large alluvial channel and theoretical consideration based on the fluvial hydraulics.

As a degradation of a channel bed and a flow stage in the upstream reach, the channel shape is stabilized from the upper part of the side bank to the central part of the bed in a cross section, and different self-armoring states by the coarser sediment are observed along the flow perimeter. The stable cross sectional shape observed at the final stage is appreciably flatter than Lane's expression for a stable channel in the threshold condition, and relations of a cross sectional area and bed slope to channel width according to Lane differ from those observed here and by other investigators in alluvial channels with uniform sand. From this fact, it may be concluded that the self-formed stable channel profiles are affected by the channel process with bank erosion and a stabilized condition.

In connection with the channel process, one-dimensional analysis based on the fluvial hydraulic model was developed for longitudinally uniform and nonuniform channel processes and compared with several experimental results. In addition to usual fundamental equations of fluvial hydraulics, an expression of sediment supply due to bank erosion were assumed on the basis of the phenomenological consideration and experimental results in several kinds of laboratory flumes. The analytical results are in good agreement with the observed ones at the initial stage of channel process.

Further study on the effects of sediment mixture and stream meandering on the channel process will be needed in order to predict the criteria of stable profile in the upstream and the prominent bank erosion in the downstream reach.

## A Study on Friction Factors for Flow in Movable Bed Channels (I)

By Kazuo ASHIDA and Yuichirō TANAKA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 299-310 (in Japanese)

### Abstract

This paper describes the results of a study on the friction factors for flow in movable bed channels. The authors investigate the flow pattern on sand waves by measuring the velocity distribution on artificially fixed sand wave beds in order to obtain an analytical model for friction factor. The result shows that the analytical model by dividing the energy slope into components due to form resistance and friction resistance can be accepted. The flow on a bed with sand waves is similar to one over a negative step. Therefore, by using an equation of momentum, form resistance can be expressed by a function of  $Fr$ ,  $H/h_m$  and  $L/h_m$ , where  $Fr$ : Froude number,  $h_m$ : mean depth and  $H$ ,  $L$  are representative height and length of sand waves respectively. In a movable bed the values of  $H/h_m$  and  $L/h_m$  change with varying flow conditions and sediment characteristics. Using the present knowledge on the relation between the geometries of sand waves and flow conditions, the friction factor due to form resistance is expressed by a function of  $\tau_* (= u_*^2 / \text{sdg})$  with parameters  $I$  and  $d$ , which is discussed by the various experimental data.

## Probability of Levee Breaks Due to Heavy Rainfalls in a River

By Yasuo ISHIHARA and Kunio SENO

Bulletin of the Disaster Prevention Research Institute, Kyoto University,  
Vol. 20, Part 1 No. 171, October 1970, pp. 37-50 (in English).

### Abstract

Since Japan is small in area and has a large population, there are many intensively developed areas. To protect these areas against floods, levees are constructed to restrain flood flows caused by heavy rainfalls. The results are often catastrophic when they are breached or overtopped. However, a levee break upstream in a river system results in reduction of the flow downstream, because flooding due to the levee break has a similar effect to diverting flood waters into a reservoir and impounding them.

This paper describes how to evaluate the probability of a levee break in the levee system of a river. After critically examining the causes of flood losses, we shall show that this probability can be evaluated by applying the probability theory of multidimensions. A computational example, the case of two areas of protection by levees against floods is presented; and it is concluded that a levee break in the upstream area reduces the flood risk in the downstream area, and that the larger the correlation coefficient between the peak discharges of two flood hydrographs from the upper and lower sub-basins is, the less the reduction effect becomes.

## A Study on Statistical Laws of Time Distribution of a Rainfall

By Yasuo ISHIHARA and Kunio TOMOSUGI.

Annals of Disaster Prevention Research Institute, Kyoto University,  
Vol. 14B, April, 1971, pp. 87-102 (in Japanese).

### Abstract

Under the present condition that a fine prediction of hyetograph is impossible, the statistical time distribution characteristics of a heavy rainfall can be an available basis for judgement on short range water problems such as flood control or flood forecasting.

This paper will deal mainly therefore with the statistical characters of some factors on the normalized shape of hyetograph over a short term (one day or under), firstly through mathematical analysis of a model of occupancy problem, treating rainfall units as balls, and divided parts of rainfall time as cells, under the assumption that the process of the distribution of a rainfall is random, and secondly, with those of the same factors in order to verify the mathematical analysis and of the other factors, through a statistical analysis of actual data of hyetographs.

The probability distributions of some factors of hyetograph are obtained by the mathematical analysis and it is concluded that the process of the distribution of a rainfall is nearly random though not quite so by data analysis.

This approach will play an important role in the design of water works and flood prevention.

## On the Rainfall around the Suzuka Mountains

By Yukio GOCHO and Chotaro NAKAJIMA.

Annals, Disaster, Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 103-117 (in Japanese).

### Abstract

Analyzing detailed data on rainfall during the warm season over three years (1967-1969) which include the data of our own observations around the Suzuka Mountains with other meteorological elements, a few characteristic features of heavy rainfall were clarified and some problems concerning them revealed.

In the case of heavy rainfall in which 24-hour precipitation was around 200 mm or over, strong easterly winds prevailed in the lower troposphere, the middle and lower troposphere was nearly saturated with water vapour, and the stability was nearly neutral. The heavy rainfall area around the mountains shifted more or less westward according to the easterly component of wind in the upper troposphere. Such contributions of upper wind to orographic rainfall was theoretically considered after the dynamical model proposed by Sarker (1966). Comparing that results with the observation, it appeared that our evaluation was on the whole realistic.

## On the Water Balance in the Ara Experimental Basin

By Yasuo ISHIHARA and Shigeki KOBATAKE

Annals of Disaster Prevention Research Institute, Kyoto University,  
Vol. 14 B, April, 1971, pp. 131-141 (in Japanese).

### Abstract

In order to elucidate the runoff process, detailed observations of the phenomena has been carried out in the Ara experimental basin. Soil moisture and groundwater runoff were observed and the basis of this observation, the relation between soil moisture and groundwater runoff was established. i. e., the observed groundwater runoff rate increases when soil moisture of 50~100 cm below the ground surface comes up to the maximum capillary water content. Finally, a water balance equation for this basin was constructed from the results mentioned above. From the water balance equation, the amount of interception and the relation between evapotranspiration rate and the time lapse after the rain had ceased were clarified. That is, (1) the amount of interception by forest is about 3 mm, (2) the maximum and constant evapotranspiration rate of 7 mm/day continues for about 1.5 days after the rain has ceased, (3) evapotranspiration rate decreases exponentially during 1.5~13 days after the rain has ceased, (4) the steady evapotranspiration rate of 1.2 mm/day appears from 13 days after the rain has ceased.

## Transformation System in Flood Runoff Phenomena

By Tojiro ISHIHARA and Takuma TAKASAO

United States-Japan Bi-Lateral Seminar in Hydrology, Honolulu, January 1971.  
(in English)

### Abstract

The purpose of this study is to generalize the flood runoff process in a river basin as a dynamic transformation system. On the basis of the hydraulic study on rainwater behavior, the runoff process in a relatively small basin is classified and analyzed with a quasi-deterministic approach. As a result, three equivalent transformation systems are found to exist in the flood runoff process for various conditions of rainfall and basin surface. These systems are nonlinear time invariant (NTI) in which the effective rainfall is equal to the rainfall excess; nonlinear time invariant (NTIc) varies spatially as well as timely; and nonlinear time variant (NTV) in which the area of runoff occurrence varies with time and the effective rainfall is the rainfall excess plus the maximum intensity of subsurface runoff over the area. For these three transformation systems, three fundamental patterns can be identified in actual runoff processes namely; NTI, NTIc and NTIc-NTV involving the system transformation. The characteristics of each pattern are analyzed, and the transformation operator from rainfall to runoff is presented, and the significance of the nonlinearity of runoff is disclosed in the light of system dynamics. The results obtained in this research play an important role in runoff analysis of a river basin as small as several hundred square kilometers in size. In a larger basin, the effect of the stream flow in the channels distributed over a river basin on the flood runoff process should be considered additionally. We add that the flood hydrograph near the peak at a gaging station can be estimated through both the network structure of the channel distribution and the confluent process of peak flows.

## A Study of Long Range Runoff System Response Based on Information Theory

By Tojiro ISHIHARA and Shuichi IKEBUCHI

United States-Japan Bi-Lateral Seminar in Hydrology, Honolulu, January 1971.  
(in English)

### Abstract

Long-range runoff phenomena are essentially stochastic processes. To understand them, we must know not only their deterministic characteristics but also the statistical laws involved in the system of transition between precipitation and river discharge. This paper proposes methods for the analysis and synthesis of a long-range runoff response based on the ideas and techniques of information theory.

Firstly, statistical properties of daily precipitation and river discharge series are discussed through their correlation analysis; then, after time invariant linearization of the runoff system according to the physical mechanisms in the runoff phenomena, the unit-impulse response function is derived from the Wiener-Hopf equation. We have designated this as the "statistical unit hydrograph". Next, the statistical unit hydrographs for the rainy season and the snowmelt season are derived in consideration of the soil moisture content in the subsurface stratum and the daily snowmelt water as the input to the system, respectively. Furthermore, in order to improve the accuracy of prediction in the lower stages of river discharge, we separate the groundwater runoff from the subsurface runoff and estimate the statistical unit hydrographs for each runoff system. Finally, the results of these procedures were applied to the Yura River basin with good agreement among the natural stream records.



## Turbulence Characteristics in a Free Surface Shear Flow in Terms of Universal Function

By Hirotake IMAMOTO

Annuals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 189-203 (in Japanese).

### Abstract

The Eulerian and Lagrangian properties of turbulence in a free surface shear flow are described in a form of a universal function expressed with flow depth, shear velocity and local mean velocity, using the flow similarity which is known as the Reynolds numbers similarity. Descriptions of three cases by universal function are obtained from the two properties of turbulence among turbulence intensity, Eulerian mean scale and rate of turbulent energy dissipation per unit mass and time. The differences between these three cases are characterized by the factor of the friction coefficient of the flow.

Theoretical relationships obtained in each case were examined by the Eulerian properties of turbulence in free surface shear flows. For example, experimental results of

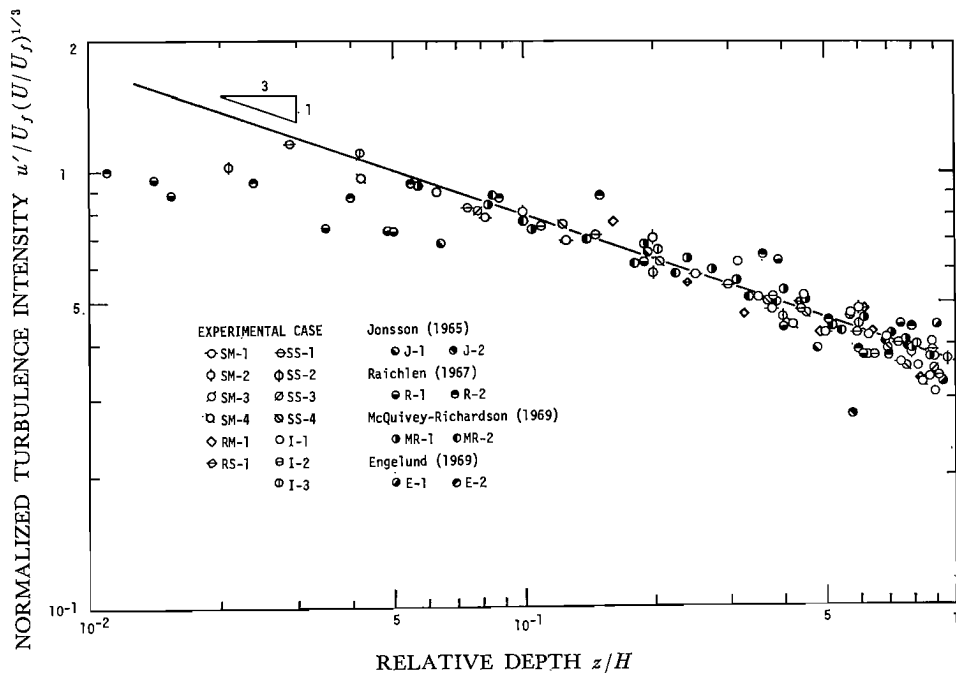


Figure 1 Turbulence intensity in free surface shear flows.

turbulence intensity distribution are shown in figure 1. It is concluded that the following relationships obtained theoretically for the Eulerian properties of turbulence are probable.

$$\phi_{u'}\left(\frac{z}{H}\right) = \frac{u'}{U_f(U/U_f)^{1/3}} \sim \left(\frac{z}{H}\right)^{-1/3}, \quad \phi_{LE}\left(\frac{z}{H}\right) = \frac{L_E}{H(U/U_f)} \sim \text{const.}$$

$$\phi_\varepsilon\left(\frac{z}{H}\right) = \frac{\varepsilon}{U_f^3/H} \sim \left(\frac{z}{H}\right)^{-1}$$

$\phi$ : universal function,  $z$ : height from bottom,  $H$ : flow depth,  $U_f$ : shear velocity at bottom,  $U$ : local mean velocity,  $u'$ : turbulence intensity (RMS) in flow direction,  $L_E$ : Eulerian mean scale,  $\varepsilon$ : energy dissipation rate.

## On the Spatial Structure of Turbulence in Open Channel Flows

By Hirotake IMAMOTO and Tetsuo UENO

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14B, April, 1971, pp. 205-217 (in Japanese).

### Abstract

This paper deals with the spatial structure of turbulence in free surface shear flows. The field measurements of turbulence were carried out in the Nobi agricultural canal constructed at Inuyama along the left side levee of the river Kiso, using 4 current meters of a propeller-dynamo type.

The intensity, the skewness factor and the flatness factor of velocity fluctuations, the auto- and cross-correlation and spectra, the coherence and the phase-lag were analyzed from the record of velocity fluctuations in the flow direction. From these experimental data, some qualitative properties of spatial structure of turbulence were revealed, that is, the turbulence element was wider spread in the free surface region, and the scale of turbulence estimated from space correlation coefficient was more than 10 times as large as the water depth longitudinally, equivalent to the water depth transversely and vertically. The phase of turbulence near the free surface was in progress compared with that near the bed. Furthermore, the hypothesis of frozen turbulence by G.I. Taylor was good applied for the turbulence in the flow direction.

## Experimental Study of Local Flow Around a Bridge Pier

By Tadashi UTAMI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 231-238 (in Japanese)

### Abstract

It has been suggested that local scour around a bridge pier may be due to horseshoe vortices with horizontal axes. On this vortex, fluid composing it is supplied from the main flow, which is one of the characteristics distinguishing the horse-shoe vortex from two-dimensional one. However, the vortex being three-dimensional, an analytical method to predict its behavior has not yet been established. In this paper, the author has tried to analyse the flow pattern in the central section of a channel by means of a model that supposes a vortex filament and a point sink at the point of the vortex axe. The experimental study shows that the strength  $k$  of the vortex filament and the position of the vortex are determined by the approaching velocity profile and the ratio between the radius of the pier and the water depth respectively. From these results, the position of the separation, the flow pattern in the central section, and the velocity distribution along the water surface, channel bed and the surface of the pier may be calculated. Comparison between the analytical results and the experimental ones shows a fairly good agreement by the appropriate choice of the  $k$  value.

## Dispersive Characteristics of Free Surface Flow in Terms of Lagrangian Descriptions

By Yoshiaki IWASA, and Hirotake IMAMOTO

Proc. 14th Congress, IAHR, Paris, 1971 (in English).

### Abstract

This paper deals with the Lagrangian properties of turbulence in a free surface shear flow. Using the Reynolds number similarity, described by A. A. Townsend, the Eulerian properties of turbulence are first concerned in terms of a universal function expressed with the flow depth, the shear velocity and the local mean velocity. Through the empirical relationship of Hay and Pasquill, the Eulerian description is transformed into the Lagrangian description.

Theoretical relationships obtained were examined by Lagrangian observations made in two experimental flumes. Because of the narrowness of the experimental flumes used in this research program, the condition of two-dimensionality of free surface shear flow induced a small flow depth with the result of a small Reynolds numbers. The range warranting flow similarity also became limited.

Experimental results show that the Lagrangian properties may be expressed in any form obtained theoretically, for larger aspects ratio  $B/H$  than 10 ( $B$ : width of flume,  $H$ : flow depth). The differences between the three forms of universal function are small because of the small range of friction coefficient in the flows.

Lagrangian measurements for turbulence properties are still few, and further experimental observations are required.

Some Topics Discussed at the Twelfth International Conference  
on Coastal Engineering  
—A Brief Consideration of the Recent Status of Coastal Processes—

By Yoshito TSUCHIYA

Annuals, Disaster Prevention Research Institute, Kyoto University,  
No. 14B, April, 1971, pp. 31-42 (in Japanese).

**Abstract**

The Twelfth International Conference on Coastal Engineering was held in Washington, D. C., U. S. A. from the 13th to the 18th of September, 1970. At the conference, about 179 papers were presented over four days although some of them were not represented. Based on the results of the papers presented and some further recent papers, a consideration of the coastal processes, especially the characteristics of beach profiles, the criterion for the generation of longshore bars, the longshore currents and littoral drift, beach erosion and its protective works in the States is briefly made along with an outline of the conference and tour.

Mechanism of Motion of Sand Grains by Wind (2)  
—On the Characteristics of Saltation of Sand Grains—

By Yoshito TSUCHIYA and Yoshiaki KAWATA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 311-325 (in Japanese).

Abstract

In studying sand transport by wind, the mechanics of motion of sand grains should be established. It is necessary to clarify the characteristics of the trajectory of sand grains in sand transport. Therefore the trajectory was photographed with a high speed camera and the films were analyzed with a film motion analyzer. The motion of sand grains is considered as a saltation which includes sliding, rolling and jumping motion, and various other characteristics, i.e. saltation height, distance, vertical density distribution of saltating sand grains in a saltation layer etc, are clarified with the aid of results taken from wind tunnel experiments. Comparison is also made with experiments conducted by the authors in a turbulent stream. They are furthermore discussed in comparison with the theory of first and successive saltation of sand movement in a turbulent stream already established by the authors. The following conclusions can be summarized as follows.

(1) It appears that sand grains begin a saltation motion without rolling for the distance of a few sand grains after collision with bed sand when sand grains on the bed are moved by aerodynamical forces.

(2) The assumption that the fluid velocity in a saltation layer is proportional to the shear velocity in the case of the sand transported in a turbulent stream is not valid in sand transported by wind due to the saltation height of sand transport by wind becoming very high in comparison with the size of sand grains.

(3) The stationary velocity defined in the theory of successive saltation is provided with the flow intensity and the parameters expressing bed conditions, although very few sand grains in a saltation layer are in stationary saltation.

(5) To an extent, theory of successive saltation can be applied to the saltation of sand grains by wind. In further investigations the mechanics of the exchange of sand grains on the bed and the effect of wind velocity distribution on the motion of sand grains will be considered in detail.

Studies on Cnoidal Waves ( Ninth Report )  
 —Applicability of Cnoidal Wave Theory to Near Breaking Waves—

By Yuichi IWAGAKI and Tetsuo SAKAI

Annuals, Disaster Prevention Research Institute, Kyoto University,  
 No. 14 B, April, 1971, pp. 327-345 (in Japanese).

**Abstract**

The previous eight papers dealt with discussions on the applicability to practical problems of the cnoidal wave theory from various points of view. It was concluded that the cnoidal wave theory should be used rather than Stokes wave theory when the wave period becomes long. However, these papers do not consider waves with large wave height near breaking.

As a breaking limit of progressive waves, several conditions have been proposed, one of which is that the horizontal water particle velocity at the wave crest is equal to the wave celerity. Recently, in order to confirm the validity of this condition, the wave profile and the horizontal water particle velocity at water surface near the crest of breaking waves on a gentle sloping beach (1/200) were measured. Photographs of the wave profile and the motion of small floats used as tracers were taken with a 16 mm high speed camera following waves (128 frames/sec). This paper presents the distribution and change of the horizontal water particle velocity at the water surface near the breaking propagation of waves, and compares these experimental results with theoretical ones.

Especially, the paper discusses the values of the ratio of the horizontal water particle velocity at the wave crest to the wave celerity based on Skjelbreia's Stokes wave theory of the 3rd order and Laitone's cnoidal wave theory of the 2nd approximation for several breaking criteria. Further, it presents the relation of  $T\sqrt{g/h}$  and  $H/h$  giving the water particle velocity at the wave crest equal to the wave celerity based on the cnoidal wave theory, and compares it with previous wave breaking criteria.

Conclusions obtained are as follows:

(1) The horizontal water particle velocity at the wave crest becomes equal to the wave celerity near the breaking point, and the assumption which has been used as the breaking condition of progressive waves is roughly confirmed.

(2) The wave profile and the distribution of horizontal water particle velocity at the water surface near the breaking point have sharper crests than theoretical ones under the same condition, and it is found that the influence of a very gentle slope (1/200) is considerable.

(3) In several breaking criteria, values of water particle velocity at the wave crest based on two theories are generally not equal to the wave celerity, and especially the value of Laitone's cnoidal wave theory is considerably larger than the wave celerity.

(4) The value of  $H/h$  giving the water particle velocity at the wave crest based on Laitone's cnoidal wave theory equal to the wave celerity is considerably smaller than Laitone's breaking criterion of solitary wave 0.727.



Characteristics of Beach Process by Wind Waves (1)  
—Laboratory Study of Equilibrium Beach Profile—

By Yoshito TSUCHIYA and Shigeru YOSHIOKA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 347-360 (in Japanese).

Abstract

As a first step in clarifying the effect of irregularity of waves on beach processes, experiments were performed using wind waves in a high wind-wave tank 40 m long, 0.8 m wide and 2.3 m deep. Three kinds of wind velocity were produced by a 100 HP blower 11.9 m/sec, 12.7 m/sec and 14.3 m/sec at the center of wind-wave tank. Waves generated and developed by wind action were 5.57 cm to 10.3 cm in significantly deep water wave height and 0.705 sec to 0.846 sec in significant wave periods. Median sand sizes of beach materials used were 0.21 mm and 0.73 mm. Also, in order to compare the results of beach process by wind waves directly with those by regular waves, a few experiments using regular waves were conducted under approximately similar conditions of wave height and period as the wind waves used.

In this paper, with the aid of the results of experiments by the authors and other authorities, the characteristics of beach process by wind waves are considered comparing equilibrium beach profiles by wind waves and regular waves, Consideration of the time sequence of beach profile, criterion for the generation of bars, foreshore slope, elevation of berm crest above the still water level, depth at bar crest and depth of configuration limit of equilibrium beach profile are discussed.

The main results are briefly summarized as follows.

(1) Wind waves used were so steep that they produced a storm beach with long-shore bars in each of experiment. Consequently a criterion for the generation of bars under wind wave action cannot be advanced.

(2) When comparison is made between the equilibrium beach profiles by wind waves and those by regular waves, it is shown that there is a wide difference between them, especially with respect to the generation location and scale of longshore bar.

## Some Problems on the Prevention of Wave Overtopping by Seawalls and Seadikes

By Masao INOUE, Yuichi IWAGAKI and Yoshito TSUCHIYA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14B, April, 1971, pp. 361-372 (in Japanese).

### Abstract

In this paper, results of model tests on wave overtopping for the seawalls at Port Island in Kobe Harbor, Sakai Harbor in Osaka Prefecture, Yui Coast in Shizuoka Prefecture, Sennan Coast and Nishikinohama Coast facing Osaka Bay are presented. Based on the above results, the effect of seawalls and seadikes on the prevention of wave overtopping is discussed.

The main results are summarized as follows:

(1) When incident waves do not break in front of the seawall, water depth at the toe of the wall is greater compared with the wave height. Wave absorber works in front of the seawall are not sufficient to prevent wave overtopping; on the contrary they tend to increase the quantity of wave overtopping in some cases. Consequently, the scale of wave absorber works should be carefully predetermined.

(2) When waves break just in front of the seawall, the water depth is not large compared with the wave height shallowing the water depth at the toe of the seawall to decrease the quantity of wave overtopping would be more effective than increasing the wall height from water level. Artificial beach nourishment therefore is preferable not only from the view point of beach enlargement but also for disaster prevention.

Studies on Wave Forces Exerted on Large Cylindrical Piles (1)  
 —Characteristics on the Distribution of Wave Pressure and  
 the Variation of Water Level—

By Yoshito TSUCHIYA and Masataka YAMAGUCHI

Annals, Disaster Prevention Research Institute, Kyoto University,  
 No. 14B, April, 1971, pp. 373-390 (in Japanese).

Abstract

As a first step to clarify the wave forces on large cylindrical piles, some experiments on the characteristics of vertical and horizontal distribution of wave pressure and variation of water level along the pile were carried out.

Compared between the theoretical curves computed from the diffraction wave theory and experimental results including the results of other researchers, it was concluded that this theory predicts relatively well the experimental results at phase of wave crest for wave pressure in the case of a large value of  $h/H_0$  except for small deviations where  $h$  is the water depth and  $H_0$  is the incident wave height, but that the correspondence for wave pressure at phase of wave trough and variation of water level is poor.

Some examples are shown in Fig. 1 and Fig. 2.

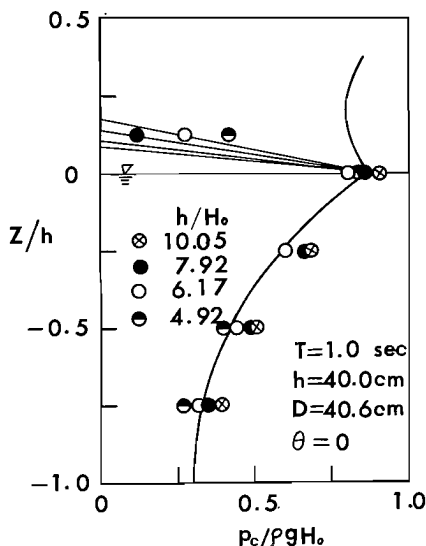


Fig. 1 Comparison between theoretical curves of vertical wave pressure distribution on a vertical cylinder at phase of wave crest and experimental values.

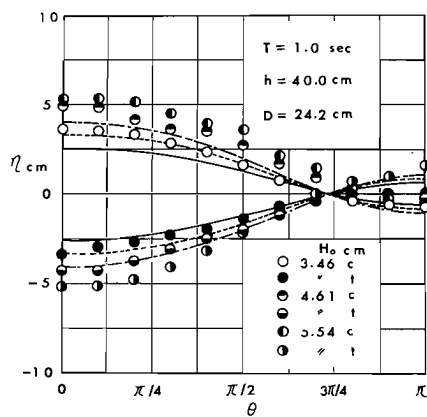


Fig. 2 Comparison between theoretical curves of spacial variation in water level along a vertical cylinder at phase of wave crest and wave trough at  $\theta=0$  and experimental values.

Recirculating Random Wave Generator (Shallow Water Ocean Wave Simulator)  
Using a Wind Wave Tank and Its Characteristics

By Yoshito TSUCHIYA and Masataka YAMAGUCHI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 391-406 (in Japanese).

Abstract

There are various types of random wave generators in operation to reproduce waves simulating shallow water ocean waves. A random wave generator using a recirculating wind wave tank called a shallow water ocean wave simulator was established. This consists of a doughnut shaped wind wave tank, a blower, a wave direction controller, a wave generator of submerged piston type and an experimental straight tank. Some characters of this apparatus are examined. With respect to the generation of wind waves, spectral characteristics of wind waves generated in a non-steady condition are compared with those of fully developed wind waves in a steady condition. It was found that the characteristics of wind waves are good for investigations in the development of wind waves of considerable height. An influence from the curved part of the tank on the development of wind waves was examined with the aid of analysis of the coherence between wave records at the straight and curved parts of the tank. Records of generated waves by this apparatus were analyzed both by the significant wave method and the spectral method. It was found that the generated waves can be used well in experiments of random waves except in the case of high winds when there occurs a wind drift current. Long-crested random waves superposing uniform regular waves generated by a wave generator of submerged piston type and wind waves can be reproduced in order to investigate the non-linear interaction and mass transport. A damping characteristic of wind waves generated in the wave tank is considered with some experimental data.

Further problems in the production of random waves by a simulator were briefly considered and it was decided that a controller examinations should be established. It was concluded from the above considerations that this apparatus is well to reproduce random waves in conducting experimental investigations in coastal engineering.

Tsunami Model Experiment of Kochi Harbour ( 2 )  
—Effects of Tsunami Breakwaters and of River Discharges—

By Shigehisa NAKAMURA, Yuichi IWAGAKI and Yoshito TSUCHIYA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 407-413 (in Japanese).

**Abstract**

The tsunami experiment in Kochi Harbour was conducted by the use of a hydraulic model, which has a topography modelled on the latest harbour plans, i.e., dredging of the navigation course and reclamations in the harbour. The reproductivity of the tsunami model has been formerly proved, and this paper gives the results of the tsunami model experiment in regard to the river discharges in Kochi Harbour.

Firstly the influence of the tsunami breakwaters the backwater was studied experimentally and theoretically for conditions on the given river discharges and of the given water level at the entrance of the harbour. The construction of 'tsunami' breakwaters caused an increase in the water level in the harbour. A theoretical study by an application of Escoffier's method for one dimensional open channel flow, gives a similar result to that of the model experiment. Secondly, transformations of the 'tsunami' design in the harbour were studied under the condition of the given river discharges. For the 'tsunami' height, it was proved that the distribution is comparable with two conditions: ( 1 ) With the 'tsunami' breakwaters and without river discharges, ( 2 ) Without the 'tsunami' breakwaters and with river discharges. The experiment showed that the distribution for the two conditions are similar to each other. For the 'tsunami' crest height, the experimental result was also studied. Linearity was not found for the co-existence system of the 'tsunami' wave and river discharges in the harbour model. Generally, it should be remarked that areal consideration is necessary for a model harbour study of 'tsunami'.

A Numerical Experiment of Water Motion in Lake Biwa  
—On the Two-Dimensional One-Layer Model—

By Norihisa IMASATO, Seiichi KANARI and Hideaki KUNISHI.

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 451-464 (in Japanese).

Abstract

In order to understand the water motion in Lake Biwa, numerical experiments have been conducted. Lake Biwa has been divided into  $25 \times 65$  square meshes of 1 km intervals. Nonlinear hydrodynamic equations for this two-dimensional one-layer model are numerically integrated by giving the wind stress as the external force, the effects of the bottom stress and the Coriolis' force also being taken into account.

A south-west wind blowing uniformly over the whole lake with a speed of 5 m/sec has been given, and the elevations of water surface and velocities at 30 points in the lake have been punched at every 5 minutes. The frequency spectra of amplitude and velocity obtained by Fourier analysis on these 296 digital data at each point gives the characters of longitudinal seiches in Lake Biwa. The periods of these seiches thus obtained are of 255.5, 79.8 and 69.1 minutes, and these oscillations correspond uni-, bi- and tri-nodal seiches in Lake Biwa respectively. On the other hand, it has been shown that the cyclonic lake currents appear in the northern basin when a southerly wind prevails. Some results on the distribution of the elevation of water surface and the effects of the nonlinear terms and the Coriolis' term are also mentioned.

Basic Observations on Coastal Processes at Ogata Coast (1)  
—On the Results of Observation in a Monsoon in 1970—

By Yoshito TSUCHIYA, Toru SHIRAI, Shigehisa NAKAMURA, Masataka YAMAGUCHI,  
Teruo SHIBANO, Yoshiaki KAWATA and Shigeru YOSHIOKA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 465-485 (in Japanese).

Abstract

In order to discover the coastal processes at Ogata coast facing the Japan Sea, some basic observations have been conducted. This paper is the first report to deal with some of the characteristics in the shore process during monsoons especially sand drifts by wind waves, changes in beach profiles and bottom sediments, wave run-up on beach slopes and longshore currents. Changes in the rate of sand drift by waves, beach profiles and characteristics of bottom sediments with incoming waves are considered and some results of wave run-up and longshore currents contributive to beach processes are presented.

The main results are summarized as follows:

(1) Distributions of the rate of sand drift along the 250 m long observation pier, measured with bamboo samplers, correspond to the characteristics of breakers and beach profiles very well. Sand size distributions have the same characteristics as mentioned above. Total sand drift seems to have a certain relationship with the energy flux of incoming waves. Sand drift measurements using bamboo samplers are not very reliable and the development of a water-pump sampler is expected.

(2) During this observation, longshore bars were found at the end of the pier and at the middle where the water depth is nearly 5 m to 6 m. It was found that the latter bar was smaller than the former and that it was changing widely with incoming waves.

(3) Variation of  $M_d$  of bottom sediments corresponds to beach profiles but further characteristics of bottom sediments will be discussed in detail in the following.

(4) With respect to the relation between 1/10 or 1/3 maximum wave run-up height and mean wave run-up height, the results of the observation agree well with those by Kubo.

On the Beach Processes at Ogata Coast ( 1 )  
—On the Seasonal Change of Beach Profiles—

By Toru SHIRAI and Yoshito TSUCHIYA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 487-497 (in Japanese).

Abstract

The Ogata coast facing the Japan Sea is a sandy beach and it is here that the Ogata Wave Observatory, Disaster Prevention Research Institute of Kyoto University is situated. Beach profiles along a 250 m observation pier extending from the shoreline have been measured once a week from October, 1969 to the present. This paper deals with the seasonal change of beach profile and the characteristics of bottom sediments. The main conclusions can be summarized as follows:

(1) During the observation there were longshore bars at the ends of the pier and at the middle where the water depth is nearly 5 m to 6 m. It was found from the observation that the configuration of the latter bar and the ratio of water depth at the bar crest to the bar length were changing seasonally, although the change of the former bar was not observed in detail. It was also found that the location of the latter bar moved offshore during the summer and moved nearshore during the winter.

(2) Although it was found that characteristics of bottom sediments correspond to the change in beach profile, further detailed consideration should be made in future investigations.

(3) It appears that seasonal change in the elevation of the beach was also found during the observation.



## On the Oceanic Processes at Kii-Suido

By Hideaki KUNISHI, Hiroshi YOSHIOKA and Toru SUZUKI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14B, April, 1971, pp. 511-518 (in Japanese).

### Abstract

This is an introductory paper concerning the atmospheric and oceanic processes in the Seto Inland-Sea and the related seas which are under investigation.

There appear to be marked discontinuities in water temperature and chlorinity at the mouth of the Kii-Suido in the winter which extend to the bottom. They are thought to be a front between the water mass of the Kii-Suido inside sea and that of the Kii-Suido sea approach. The interesting feature of this front is that there seems to be no discontinuity in water density there. The problems of generation, maintenance and degeneration will be left to future investigations.

The process of yearly change in oceanic situation of the Kii-Suido sea is here described. The distribution of the yearly mean chlorinity averaged over 0 to 50 m depth also shows a discontinuity near the mouth of Kii-Suido. The horizontal diffusion coefficient is calculated at  $10^7$  cm<sup>2</sup>/sec in the inside sea of Kii-Suido, the eastward transport of sea water at the east part of Harima-Nada where the chlorinity is minimum, and the fresh water supply between the east part of Harima-Nada and the section of this calculation in the inside sea of Kii-Suido being assumed after Hayami and Unoki (1970). On the other hand, the horizontal diffusion coefficient is estimated to be  $2 \times 10^6$  cm<sup>2</sup>/sec near the mouth of Kii-Suido, where the discontinuity in chlorinity exist, by a similar calculation procedure as above.

The possibility that the former value of  $10^7$  cm<sup>2</sup>/sec is explained as the dispersion coefficient due to the shear effect of a horizontal circulation in the sea of Kii-Suido and the latter value of  $2 \times 10^6$  cm<sup>2</sup>/sec as the diffusion coefficient due to the so-called tidal mixing and the dispersion coefficient due to the shear effect of a vertical circulation through Kii-Suido is discussed.

**A Study of the Air-Sea Boundary Processes at the Shirahama  
Oceanographic Tower Station**

By Yoshiaki TOBA, Hideaki KUNISHI, Katsuya NISHI, Sanshiro KAWAI,  
Yoshie SHIMADA and Nakao SHIBATA

Annuals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 519-531 (in Japanese).

**Abstract**

A study was carried out on the air-sea boundary processes at the Shirahama Oceanographic Tower Station, Kyoto University, laying stress on the field of strong interaction between air and sea: in a situation where the wind is strong, wind waves are breaking, air bubbles are being entrained in waves, many sea-water droplets are produced at the sea surface. This is part of a series of studies using wind flume and theoretical treatment on R. V. Hakuho Maru and at the Oceanographic Tower Station.

Two special observations were carried out at the Tower Station: in August 1968 (the 1st Special Observation) and in November 1969 (the 2nd Special Observation). Especially in the 2nd Observation, a wind of 12 m/sec or over from the direction of a long fetch was encountered, and a continuous record of over 7 hours of wind profiles, growing wind waves, and the breaking of wind waves, was obtained. Other data, including the vertical distributions of the number concentration and size distribution of sea-water droplets, were also obtained.

It was found that the overall degree in the breaking of the field of wind waves, plotted against the Reynolds number describing the degree of turbulence of the sea surface itself, shows a similar trend with that found by the wind-flume experiments by Toba and Kunishi (1970). The Reynolds number is defined by  $u_*H/\nu$ , where  $u_*$  is the friction velocity of air,  $H$  the characteristic wave height, and  $\nu$  the kinematic viscosity of air.

It was also found that the vertical distribution of sea-water droplets approximately agrees with Toba's 1965 theory, and the rate of the production of sea-water droplets of various sizes was estimated as a function of the Reynolds number  $u_*H/\nu$ .

### Some Observations on Coastal Processes in Tanabe Bay ( III )

By Katsuya NISHI, Toru SUZUKI and Hideaki KUNISHI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14B, April, 1971, pp. 533-550 (in Japanese).

#### Abstract

In the second report of the same title, we discussed a series of oceanographic survey carried out in Tanabe Bay in August 1966, and the intrusion of a water mass of lower salinity and higher temperature was considered to be a density flow due to the density difference between the inside and the outside of the bay.

In this report, the postulation that the pressure gradient would balance with the Corioli's force is firstly applied. Using the concept of the geostrophic current, we calculated the velocity profiles from the observed water temperature and chlorinity data, and examined the relation between the chlorinity flux and the time change of the mean chlorinity in Tanabe Bay. The calculated magnitude of the velocity, however, appears ten times larger than the expected one in Tanabe Bay, and the chlorinity flux is also ten times larger than that estimated from the time change of the mean chlorinity. Hence, this postulation is considered unreasonable.

We postulate in secondly that the pressure gradient would balance the stress terms. The result shows that the magnitude of the velocity is resonable and that the chlorinity flux calculated from the velocity profiles explains the time change of the mean chlorinity observed inside Tanabe Bay. Thus, we have reached the stage where the abrupt shift of water level temperature shown on the record of water temperature observed at Shirahama Oceanographic Tower Station is due to a water mass outside Tanabe Bay intruding into the bay in a form of a density current where the stree terms balance with the baroclinic pressure gradient. The latter method mentioned in this report will be effective in understanding the coastal processes in a bay like Tanabe Bay or in a coastal area. In this type of study, it is thought that the most useful results are obtained by the use of the STD instrument which has made rapid progress in recent years. We shall continue investigations therefore, by designing the STD to suitable requirment for the survey of coastal areas.

## Successive Saltation of a Sand Grain by Wind

By Yoshito TSUCHIYA

Proceedings of the 12 th Conference on Coastal Engineering,  
September, 1970, pp. 1417-1427 (in English).

### Abstract

In order to establish the mechanics of sand transport by wind, the mechanics of the saltation of sand grains should be first considered. In sand storms, most of the saltating sand grains on a granular bed successively continued the saltation motion. In this paper, such a saltation motion is defined as successive saltation. As an application of the theory of saltation of a sand grain in a turbulent stream, a theoretical approach to the saltation of a single sand grain on a fixed granular bed is proposed on the basis of the equations of motion for the saltation and the dynamic characteristics of collision between a saltating sand grain and bed sand grains. Some experiments on the first and successive saltation of a single sand grain on a fixed granular bed were carried out to compare with the theoretical relationships. Fig. 1 shows the comparison between the theoretical relationship for the first saltation and the experimental values in which  $\bar{H}_1$  is the ratio of the saltation height to the grain size and  $u_*^2/(\sigma/\rho-1)gd$  the flow intensity. It was verified from further comparison that the theoretical relationships of the height and distance of saltation of a sand grain are in fairly good agreement with the results of the experiments.

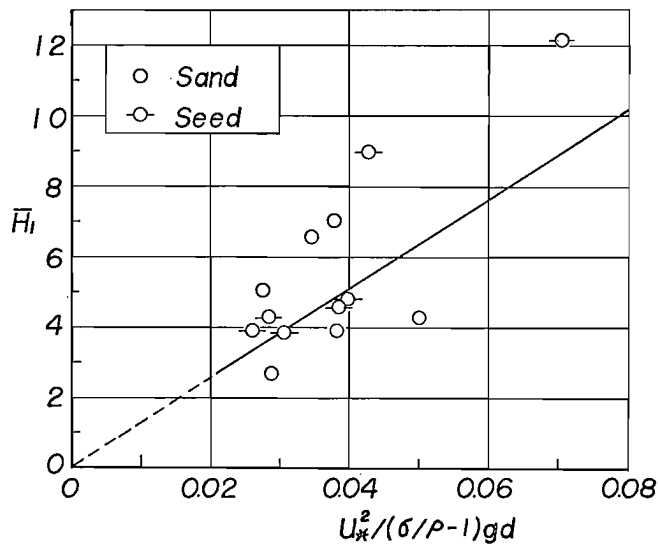


Fig. 1 Comparison between theoretical relationship for the first saltation of a sand grain and experimental values.

## Limiting Condition for Standing Wave Theories by Perturbation Method

By Yoshito TSUCHIYA and Masataka YAMAGUCHI

Proceedings of the 12th Conference on Coastal Engineering,  
September, 1970, pp. 523-542 (in English).

### Abstract

The purpose of this paper is to clarify the validity and limiting condition for the application of finite amplitude standing wave theories by the perturbation method. In a numerical example, the errors of each order solution of these theories for two non-linear free surface conditions are computed for various kinds of wave characteristics and compared with each other.

Some experiments on the wave pressure on a vertical wall by standing waves were carried out and a plot of the limiting condition for the application of these theories as shown in Fig. 1 is proposed based on the comparison with theoretical curves.

As an additional example of the application of these theories, the change of characteristics of wave pressure for standing waves accompanying the overtopping wave on a vertical wall is discussed.

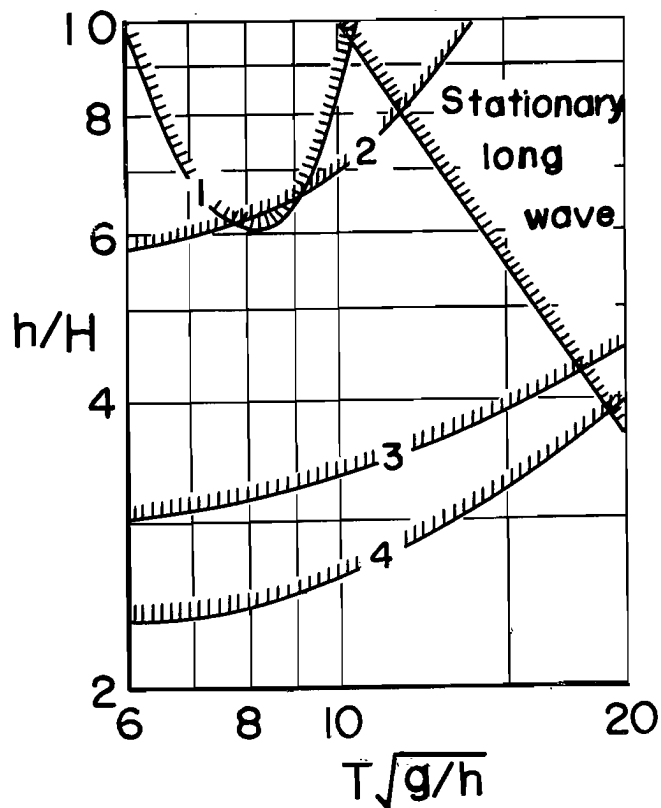


Fig. 1 Limiting conditions for the application of finite amplitude standing wave theories.

## Model Study of the Transformation of 'Tsunamis' in Urado Bay

By Shigehisa NAKAMURA, Yuichi IWAGAKI and Yoshito TSUCHIYA

Proceedings of 12th Conference on Coastal Engineering,  
September, 1970, pp. 2089-2102 (in English).

### Abstract

For the city and harbour of Kochi, including Urado Bay, facing the Pacific Ocean, an experimental study has been carried out on the problem of protection from tsunami disasters, and future harbour planning; that is, dredging, reclamations and the construction of 'tsunami' breakwaters. A hydraulic model of horizontal scale 1/250 and vertical 1/100 was used according to Froude's similitude. The transformation of the designed 'tsunami' in the bay was studied to discover the effect of 'tsunami' breakwaters, dredging and reclamation by the use of a model able to reproduce the Chilean 'Tsunami'.

The crest height distributions of the designed 'tsunami' were considered for a model on the present topography, a model without the 'tsunami' breakwaters for after dredging and reclamation, and a model with the 'tsunami' breakwaters for after dredging and reclamation. The distributions were obtained as two dimensional or areal distributions which will hold in understanding the complexity of wave characteristics in the bay. In this paper, the distributions are shown only along the navigation course from the entrance to the head of the bay and along the Kagami River and the Kokubu River or Kuma River.

These studies were made in order to find the negative effect of dredging the navigation course and to find the active effect of 'tsunami' breakwaters in protecting the harbour from 'tsunami' inundation. It was proved that reclamations had a little influence on the crest height distribution and on the wave height distribution of 'tsunami'.

Kochi was directly hit by typhoon 7010 on 21 August, 1970, and suffered heavy damage due to the storm surge which accompanied the typhoon. This means that further study should be made not only on 'tsunamis' but also investigating storm surges in Urado Bay. Future harbour construction should refer to the above mentioned studies in order to avoid coastal disasters.

## Experiments on Water Particle Velocity at the Water Surface of Near Breaking Waves

By Yuichi IWAGAKI, Tetsuo SAKAI, Junichi KAINUMA, and Takeshi KAWASHIMA

Proceedings of the 17th Conferenc on Coastal Engineering in Japan,  
November, 1970, pp. 67-72 (in Japanese).

### Abstract

Progressive waves in shallow water are affected by a decrease in the water depth, and consequently the wave height, wave celerity, wave length and wave profile change. At the final stage of this process, the phenomenon of wave breaking takes place. Many conditions have been proposed as a limit of wave breaking. However, these conditions have not been fully discussed. It is necessary therefore to examine the validity of these conditions.

In the present study, to investigate the problem experimentally, the wave profile and the water particle velocity at the water surface near the crest of breaking waves are measured. These waves progress and break on a very gently sloping beach (1/200), which can be regarded as having a horizontal bottom. Small floats are used as tracers to measure the water particle velocity. Photographs of the wave profile and motion of floats are taken with a 16 mm high speed camera following the waves (128 frames/sec). Experimental results of the wave profile and the water particle velocity of near breaking waves are compared with theoretical values.

The following facts are observed on progressive near breaking waves:

- (1) As waves progress on a gentle slope and approach breaking point, the maximum value of the horizontal water particle velocity at the water surface approaches the wave celerity and becomes almost equal to it near the breaking point. The validity of the breaking criterion of progressive waves, that is, the horizontal water particle velocity at wave crest is equal to the celerity, confirmed experimentally.
- (2) The wave profile and distribution of horizontal water particle velocity at the water surface near the breaking point have sharper crests than theoretical ones under the same conditions. The reason is not clear and further study is necessary.

On the Characteristics of Standing Waves in the Case  
Where Wave Overtopping Exists

By Yoshito TSUCHIYA and Masataka YAMAGUCHI

Proceedings of the 17th Conference on Coastal Engineering in Japan,  
November, 1970, pp. 79-84 (in Japanese).

Abstract

With respect to the wave pressure of finite amplitude standing waves in the case where wave overtopping exists, a series of basic experiments was conducted.

When the theoretical findings by finite amplitude standing wave theories were compared with experimental measurements of wave pressure distribution on a wall at wave crest, wave crest heights above the still water level, and time variations of water level and wave pressure on the wall, the following results were obtained.

(1) If the reduction of wave height at the wall by wave overtopping can be estimated, the experimental measurements of the wave crest heights above the still water level agree with the theoretical ones.

(2) While the absolute values for the wave pressure accompanying the wave overtopping decrease compared with the pressures not accompanying wave overtopping, each theory is applicable in this case within the range of the limiting condition for validity, if the reduction of wave height at the wall by the wave overtopping can be estimated. But, when the value of  $H/H_c$  is relatively large in which  $h$  is the depth of water,  $H$  the amplitude in water level variation at the wall and  $H_c$  the crest height of wall, the phenomena of the wave pressure are not made sufficiently clear by these theories, even though the reduction of wave height at the wall by wave overtopping can be estimated, because of the change of the characteristics of the wave motion field near the wall.

(3) The rate of wave height reduction at the wall by wave overtopping can be estimated by the relation of  $H/H_c$  regardless of the wave period within the range of these experiments except for relatively large values of  $H/H_c$ .

In additions, the data for the rate of wave overtopping obtained by the authors were compared with the curve of the rate of wave overtopping proposed by Goda. It was found that the correspondence in the comparison is relatively good except for  $T\sqrt{g/h} \leq 14$  and  $H_0/L_0 < 0.015$  in which  $T$  is the wave period,  $g$  the acceleration of gravity,  $H_0$  the wave height of deep water and  $L_0$  the wave length of deep water.



## On the Irregular Wave Generator of the Electro-Hydraulic Type

By Yuichi IWAGAKI, Hitoshi MURAKAMI, Tetsuo SAKAI and Akira KIMURA

Proceedings of the 17th Conference on Coastal Engineering in Japan,  
November, 1970, pp. 409-414 (in Japanese).

### Abstract

Many problems of coastal engineering have been studied using the concept of monochromatic waves. However, coastal waves are irregular, and the irregularity of waves is usually expressed by energy spectra. The influence of this irregularity on coastal engineering problems remains unclear.

In order to investigate irregular waves and the influence of their irregularity in a laboratory wave tank, an irregular wave generator is required. In a laboratory, irregular waves can be generated by several methods. This paper presents the design of an irregular wave generator for generating random electric signals and the analysis of the various characteristics of generated waves.

This irregular wave generator drives a plate by servo pulsers corresponding to generated electric signals. Input electric signals consist of three kinds. The first is filtered noise produced by an ultra low frequency random noise generator, the second is regular waves of sine, triangle and rectangle by an ultra low frequency wave generator, and the third is external signals from a data recorder. Further, this generator is capable of generating a solitary wave. The band pass filter consists of 15 units ranged from 0.2 to 5.0 Hz, and therefore the spectrum of white noise can be arbitrarily modified. The higher frequency part ( $\geq 1.0$  Hz) of the filtered noise, controls one of two actuators on the flatter type motion of the plate. The lower frequency part ( $\leq 1.0$  Hz) controls the other one to cause a piston type motion.

In experiments, regular waves and filtered random waves were used as input signals. Power spectral densities of the input signal, the displacement of the plate and the displacement of the water surface were calculated. Using these calculated power spectral densities, the linearity of response characteristics of waves produced by the generator was discussed. The following conclusion was reached.

The wave height of the longer period component ( $\geq 1.0$  sec) of irregular waves agrees with the wave height of regular waves caused by the motion of piston type, and the wave height of the shorter period ( $\leq 1.0$  sec) agrees with that of regular waves produced by the motion of the flatter type. However, component waves with the wave period shorter than 0.5 sec break at the front of the plate, and linearity can not be expected in this region.

## Model Experiments on 'Tsunami' and Its Response in Kochi Harbour

By Shigehisa NAKAMURA

Proceedings of 17th Conference on Coastal Engineering in Japan,  
November, 1970, pp. 435-439 (in Japanese).

### Abstract

'Tsunami' studies have been carried out for Kochi Harbour in relation to future harbour plans and to the protection project against tsunami disasters. Reports on the model study have been presented concerning the 'tsunami' protection of Kochi Harbour. In this paper, the effects of 'tsunami' breakwaters, dredging and reclamations are studied by the use of a hydraulic model (vertical scale 1/100 and horizontal scale 1/250). Firstly, crest height distributions of a designed tsunami were compared to the three different model conditions.

Current velocity in the model was studied at the same time as studying water level changes caused by the 'tsunami' in relation to the response of Kochi Harbour. Effects of the 'tsunami' breakwaters were studied referring to the data of wave height and of current velocity obtained from the model experiment.

It were proved that the effect of the symmetry of the 'tsunami' breakwaters was remarkable near to the breakwaters, and that wave height and current velocity did not produce a remarkable effect from the asymmetry of breakwaters near to the head of the harbour.

A theoretical consideration of the wave height response gave a good correspondence with the result of the model experiment for the long period waves (1 min to 3 min) including the equivalent 'tsunami' period, when the reflections of the 'tsunami' were considered to be negligible.

To find the response curve from the observed 'tsunami' records, the records at Katsurahama and Urado were analyzed into power spectra, and the power spectra of the 'tsunami' were reduced into the wave height response curve with the assumption of the possibility of linear data processing and of proportional wave height to the root of the spectra. The response curves from the observation of the Chilean 'Tsunami' showed a similar trend to that from the reproduced 'tsunami' in the model experiment.

## Breaking of Wind Waves and the Sea Surface Wind Stress

By Yoshiaki TOBA and Hideaki KUNISHI

Journal of the Oceanographical Society of Japan,  
Vol. 26, No. 2, April, 1970, pp. 71-80. (in English).

### Abstract

In the conventional treatment of the coefficient of sea surface wind stress by plotting it against 10-m wind speed, there are inevitable discrepancies among the results of various investigators. The reason is thought to lie primarily in the fact that the state of the sea surface or of the waves is disregarded, and consequence may have great influence on the sea surface wind stress.

Former concepts concerning the conditions which control the sea surface wind stress are discussed, and it is shown that a more universal expression may be obtained by plotting the coefficient against a kind of rough Reynolds number:  $Re_2^* = u_* H / \nu$ , where  $u_*$  is the friction velocity of air,  $\nu$  the kinematic viscosity of air, and  $H$  the characteristic wave height.  $H$  is used here in treating some data in wind-wave tunnels, as a tentative variable, one step towards a more rigorous approach to the problem.

This variable  $Re_2^*$ , or  $Re_4^* = u_{*w} L / \nu_w = 2\pi g u_{*w} / \nu_w n_1$ , where the subscript  $w$  represents values for water,  $L$  and  $n_1$  the characteristic wave length and frequency, respectively, is also the condition describing the air entrainment of the breaking of wind waves. In this case, these Reynolds numbers are interpreted as the quantity describing the intensity of the turbulence of the water surface itself. It is shown, using data from our wind-wave tunnel experiments, that the breaking commences as  $Re_2^*$  reaches  $1 \times 10^3$ , or as  $Re_4^*$  reaches  $3 \times 10^3$ . Simultaneously, the stress-coefficient begins to increase sharply at this value of  $Re_2^*$ . This phenomenon is understood as an increased momentum transfer from the air to the water through "boundary penetration of turbulence" caused by the breaking of wind waves. Further, it is suggested that there is a possibility that this excess momentum transfer does not increase wave momentum, but reinforces drift current.

## A Constitutive Equation of Soils

By Sakuro MURAYAMA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 17-29 (in Japanese).

### Abstract

This is a brief summary in which theoretical studies on the constitutive relations of soils performed by the author are presented. In this study, general stress-strain-time relations, a failure criterion and some thermal effects on the behavior of soils are deduced by assuming soil as a random assembly and applying to it statistical considerations. To ascertain these considerations and assumptions, the relations obtained are verified with some experimental results, and they showed close agreement.

With regard to the stress-strain-time relation, the maximum shearing strain caused by a deviatoric stress under a constant mean principal effective stress in a triaxial compression apparatus can be expressed by the product of newly designated factors  $A$ ,  $W$  and  $z$ . In this relation,  $A$  is the "displacement factor", which is mainly determined by the mobilizing distance of soil particles,  $W$  the "structural factor" which relates to the structure of random assembly and  $z$  the "stress ratio" of the deviatoric stress and the effective mean principal stress. The former two are the dependent factors on stress ratio and time. By applying this relation to cohesionless soil, the stress-strain relation for dense sand and loose sand, and that under repetitious loading are obtained. Similarly, the stress-strain relation of cohesive soil under drained conditions is also obtained. Moreover, adding time dependent characters and thermal effects to these considerations, the flowing behavior of cohesive soils are investigated.

Such flowing behavior of cohesive soil is influenced by the structure of the soil as well as the relative relation of the applied stress and two critical values. If the applied stress is less than the lower critical value, flowing is only due to the retarded elasticity and the flowing behavior is characterized by the retardation spectrum of the generalized Voigt model simulated. If the applied stress is between these two critical values, flowing with disintegration of structure continues during a finite period, and if the applied stress exceeds the upper critical value flowing leads to failure.

As for the criterion of failure of soil, two kinds of failure are introduced. One is failure caused under condition where the whole of the external input energy is consumed only by the continuation of internal work for the mobilization of particles. Another is failure caused by condition where the number of mobilizing particles becomes less than that of non-mobilizing stationary ones.

## The Mechanism of Shearing and its Similarity for Sands and Clays

By Sakuro MURAYAMA and Hajime MATSUOKA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 551-563 (in Japanese).

### Abstract

Sand is an assembly of particles, therefore its mechanical properties should reflect the microscopic behavior of the individual particles. It is also seen that clays, which consist of very fine particles, show a granular property such as dilatancy. The granular nature of soil is considered to be one of its most essential properties. Therefore, in this investigation, the shearing mechanism of granular soils such as sand and gravel have been studied from a microscopic point of view in order to understand better its macroscopic behavior.

For this purpose, shearing tests were carried out using not only real soils but also horizontal piles of aluminium rods and rods made of a photoelastic material with various diameters in order to simulate a two-dimensional granular mass. From these experiments, the slope angle of particle contact surface  $\theta$ , the interparticle force  $f$  and the frictional angle between the particles  $\delta$  were chosen as the fundamental factors that control the shearing resistance of soils. The concept of "the frequency distribution of  $\theta$ " was introduced in order to represent the macroscopic shearing resistance and dilatancy.

In this paper, the stress ratio ( $\tau/\sigma_N$ ) and strain-increment ratio ( $d\varepsilon_N/d\gamma$ ) relation is derived from these microscopic considerations as follows;

$$\frac{\tau}{\sigma_N} = (1.4 \sim 1.5) \cdot \frac{d\varepsilon_N}{d\gamma} + \tan\delta$$

and it is found that this relation is applicable not only to sands but also to clays. It is interesting to note that, in the above equation, the stress ratio ( $\tau/\sigma_N$ ) happens to be made up of two parts: the first being the shearing resistance due to the particle structure (or dilatancy) and the second due to the friction between particles.

From these experimental results the similarity of the shearing mechanism between sands and clays is shown. Furthermore, it is clear that this stress ratio and strain-increment ratio relation is related to the stress~dilatancy theory of P. W. Rowe.

## Consideration on the Stress Wave Attenuation in Soils

By Koichi AKAI and Masayuki HORI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 611-630 (in Japanese).

### Abstract

This investigation is mainly concerned with the propagation problem of stress waves through confined soils from a viewpoint of attenuation by viscous damping. Firstly an analytical solution is obtained for semi-infinite one-dimensional rods of some linear viscoelastic models, here, in the case of boundary stress forming a spike pulse with exponential decay. A three-parameter viscoelastic model is introduced to simulate characteristics so that there occurs a discontinuous jump of stress in the neighbourhood of the surface of the medium subjected to an impulsive loading and also indicates the collapse of wave form behind the wave front.

The results are confirmed by a shock tube test originally performed in the authors' laboratory. The shock tube utilized in this study is appropriate as a shock loading apparatus on confined soil. It has the following merits.

- a) The magnitude of a shock pressure is easily controlled.
- b) The wave form of shock pressure obtained has a sharp wave front and an exponentially decaying part for which one can obtain analytical solutions.
- c) It can give a reproducible load that is essentially independent of the specimen response.

Comparing experimental data with analytical, it is shown that the use of a Voigt-spring model in soil gives a better prediction of one-dimensional stress wave propagation. It follows from the fact that there exists little variation of rise time in both experimental and theoretical results, namely the wave form at the boundary surface almost never collapses as the wave goes down, and the theoretical attenuation expresses very well the experimental one.

## Model Experiment on the Propagation of Water Pressure in Sandy Aquifer

By Norio YAGI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14B, April, 1971, pp. 643-653 (in Japanese).

### Abstract

In this paper, the following two contents are included.

1) An experiment on the propagation of water pressure in sandy aquifer was carried out using a ground model shown in the figure. The water pressure in the tank on the right side was periodically changed i.e. to a sine wave. The water pressure in confined sandy aquifer at any place and at any time may be expressed by the differential equation

$$\frac{\partial \zeta}{\partial t} = c_v \frac{\partial^2 \zeta}{\partial x^2},$$

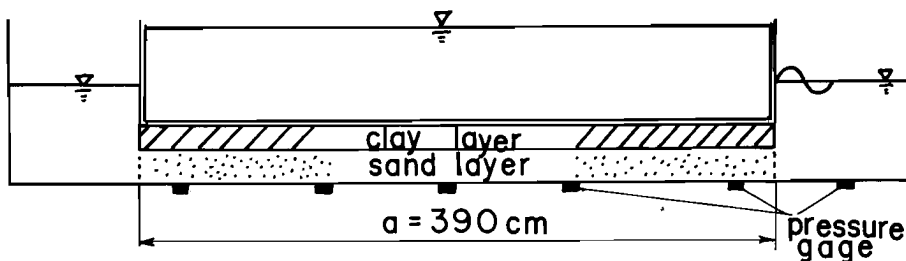
where  $\zeta$ ; water pressure,  $t$ ; time,  $x$ ; distance,  $c_v = k/\gamma_w m_v$ ,  $k$ ; permeability of sandy aquifer,  $\gamma_w$ ; density of water ( $\doteq 1 \text{ g/cm}^3$ ),  $m_v$ ; compressibility of sand aquifer. Results of the experiment show that  $c_v$  calculated from damping of water pressure with distance using the solution of the above equation when  $a = \infty$  is nearly equal to one calculated from  $k$  and  $m_v$  obtained from laboratory tests when the period of water change in the tank is smaller than 5 sec.

On the other hand, the equation expressing the relation between  $c_v$  and effective pressure  $\sigma'$  in sandy aquifer was derived from the fact that the permeability of sand increases by 13% for 1% change in porosity and relation between effective stress  $\sigma'$  and strain  $\varepsilon$  of sand in one dimensional compression is given by the equation  $\varepsilon = a\sigma^b$  where  $a$  and  $b$  are constants.

2) When the repetitious effective stress is applied to sandy aquifer, for example, due to repetition of the pump up of ground water and the stop, it may be clear from repetitious one dimensional compression that the settlement of sandy aquifer is expressed by the following equation

$$\rho_R = \frac{N}{\alpha + \beta N}$$

where  $\rho_R$ ; residual settlement,  $N$ ; numbers of repetition,  $\alpha$  and  $\beta$ ; constants.



## Model Studies on the Stress Distribution in Layered Soil Systems

By Koichi AKAI, Satoshi SHIOMI and Tsutomu KIUCHI

Proc. JSCE, No. 185, Jan. 1971, pp. 83-94 (in English).

### Abstract

A series of model tests on ground stress distribution have been performed with respect to a single or two-layered soil system. Three kinds of soil were used in the experiment, termed sandy loam, sand and gravel, respectively. The test pit used in this work was 2 m square in plan and 1.2 m depth. A loading system has been developed to apply both static and dynamic load on the soil medium. The apparatus is operated by oil pressure with electronic servomechanism. From loading tests with the loading plate (radius 15 cm), the following results are noted.

- (1) Both sand and gravel, compared with sandy loam, have tendencies of stress concentration toward the axis of the load.
- (2) Variation in stress distribution with load is larger in the range of small load intensity, this is obvious at shallow depths and also on the axis of the load.
- (3) In a two-layered system, the mechanical properties of the soil material in the upper layer have a marked increase in thickness of the upper layer.
- (4) The effect of dynamic loading on the stress distribution is remarkable in all loading tests. That is, the pattern of stress distribution becomes flatter under dynamic loading compared with static.
- (5) The influence of load frequency is not recognized at all within the range used during the loading test, i. e., 0.5-5 cps. The effect of sustained load on the stress distribution is seen only at shallow depth.
- (6) Reaching the depth  $z=2a$  ( $a$ : radius of loading plate), the stress distribution under dynamic loading agrees with that under a static one. The depth to which the stress distribution is affected by dynamic loading, however, may vary with the intensity of the dynamic load.



A Viscoelastic Approach to the Problem of Stress Wave  
Propagation in Cohesive Soils

By Koichi AKAI and Masayuki HORI

Proc. JSCE, No. 185, Jan. 1971, pp. 95-103 (in English).

**Abstract**

In the propagating process of stress waves in soil, energy is absorbed by compaction (i.e., intergranular friction) and the viscosity of soil materials. The damping effect of energy differs in the kind of soil.

In this study, theoretical solutions for one-dimensional stress propagation problems in boundary stress, forming a spike pulse with exponential decay are advanced. Theoretical models considered here are the Voigt model, Maxwell model and the standard linear viscoelastic model with three parameters.

For the later there have been no analytical solutions other than a step-pulse type boundary stress by Morrison et al. The authors propose a solution in the present study, using the principle of superposition. In this method the surface stress of exponentially decaying type is uniformly divided into ten step-pulse type stresses, and the solution for each step is finally superposed with each other.

As a result, it is known that the standard linear viscoelastic model explains fairly well wave propagation behavior in saturated clay. The characteristics are that there exist discontinuous stress jumps in the neighbourhood of the surface of the medium and, at the same time, there is no wave collapse at these positions. At a deeper level, some roundness appears at the wave front, and at greater depths, the peak stress does not occur at the wave front, the collapse of wave form being remarkable. Cohesive soils therefore have characteristics of both Voigt and Maxwell bodies, and the standard linear viscoelastic model is valid for expressing a finite wave velocity through the soil medium.

## Earth Pressure on Tunnels in Sandy Ground

By Sakuro MURAYMA and Hajime MATSUOKA

Proceedings of the Japan Society of Civil Engineers,  
No. 187, March, 1971, pp. 95-108 (in Japanese).

### Abstract

In order to investigate the mechanism of generating earth pressures on tunnels or underground structures in a sandy ground, a series of model tests of the "trap door" type (the lowering panel) was performed using not only real sands but also horizontal piles of aluminium rods and rods of various diameters made of a photoelastic material simulating two-dimensional granular media. In these tests, the settlement or the local yielding of the ground in the tunnels caused by tunnel excavation was simulated by gradually lowering a panel which formed a part of the horizontal base under the pile of rods.

The following experimental results were obtained;

(1) The load on the lowering panel decreases suddenly to reach its minimum value after a very small amount of lowering of the panel, and maintains an approximately constant value in spite of further lowering provided that the weight of the medium in the hollow just above the lowering panel is subtracted from the load on the panel.

(2) "The primary zone", where the medium settles in the same way as the lowering panel, is very similar in the case of piles of aluminium rods and real sands, and it shows approximately the same shape in spite of the increase in the amount of panel lowering.

(3) The load on the lowering panel is changed significantly by the width of the panel and is not effected very much by the depth of the medium. It is nearly equal to the weight of the medium in the primary zone.

(4) The normal stress at the top of the arch-shaped primary zone decreases suddenly to about zero, after a small amount of lowering.

(5) From the results of photoelastic experiments using photoelastic piles of rods, it is seen that the fringe pattern of the photoelastic photograph changes suddenly after a small amount of lowering and the arch-shaped lines of the interparticle force are clearly formed above the lowering panel. Furthermore the part below the arch lines, where the interparticle force is scarcely transmitted, is nearly equal to the primary zone.

From the above experimental results, the mechanism of the arch action (arching) is clarified and the equation for the calculation of the load on the lowering panel derived. The calculated values agree well with the experimental values of the load on the lowering panel under various experimental conditions. Furthermore the effect of the sectional shape of tunnels and the settlement due to the stress concentration around tunnels on the earth pressure is demonstrated by these model tests of the "trap door" type. The validity of the empirical saying "Don't loosen ground round tunnels" is theoretically verified as a result of these experiments.

## Two-Variate Exponential Distribution and its Numerical Table for Engineering Application

By Masashi NAGAO and Mutsumi KADOYA

Bulletin of the Disaster Prevention Research Institute, Kyoto University,  
Vol. 20, Part 3, No. 178, March, 1971, pp. 183-215 (in English).

### Abstract

This study aims to develop the fundamental theory of a two-variate gamma distribution, especially of a two-variate exponential distribution for engineering application. In outline, the study is as follows:

(1) Methods of estimating the parameters included in the probability density function of the distribution, the shape parameter in the marginal distribution of which is the same in each, are developed by using the techniques of maximum likelihood and moments. The results show that the estimator for the correlation parameter by the latter is coincident with the ordinary Pearsonian definition of correlation coefficient, but that by the former is not.

(2) The characteristics of the two-variate exponential distribution, which is a special type of gamma distribution, especially the characteristics of a correlation surface and locus of the mode of the conditional probability density function are clarified theoretically and numerically in relation to the correlation parameters.

(3) For convenience of engineering application of two-variate exponential distribution, numerical values of the conditional probability function are provided in a table. That is, for the fixed values of one variate, the computational values of the other variate are prepared under various conditional probabilities and correlation parameters.

Study on Two-Variate Gamma Distribution and its Engineering Application ( 2 )  
— Estimation of Population Parameters —

By Masashi NAGAO and Mutsumi KADOYA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 43-56 (in Japanese).

**Abstract**

In the first report, the fundamental characteristics on two-variate gamma distribution, especially two-variate exponential distribution were discussed. In this report, as the second step, the estimation of population parameters of two-variate gamma distribution were developed for cases when a sample from a total population is given and a sample from a sub-population. In outline, the study is as follows :

1) The estimating method based on a sample from a total population, every marginal distribution of which has two parameters, was developed using the technique of the moments method. As the results, it was clarified that the estimator for the correlation coefficient is expressed as a simple function of shape parameters and sample correlation coefficient.

2) The estimating method based on a sample from a sub-population, in which the domain of independent variable was defined as upper tail over a given value, was developed by using the technique of the maximum likelihood method. This method is composed of two steps i. e.

i) The shape and scale parameters of an independent variable are estimated by applying the censored sampling theory. The calculation diagrams prepared may be utilized for this estimation.

ii) The scale parameter of dependent variable and the correlation parameter are estimated by applying the method of the least squares. In this step, the shape parameter of the variable is assumed to be equal to the one of an independent variable.

3) The applicability of the theory of two-variate gamma distribution was examined by applying it to the data of river flows in the Yoshino River.

Study on Two-Variate Gamma Distribution and its Engineering Application ( 3 )  
 —Numerical Table of Two-Variate Exponential Distribution—

By Masashi NAGAO and Mutsumi KADOYA

Annals, Disaster Prevention Research Institute, Kyoto University,  
 No. 14 B, April, pp. 57-75 1971, (in Japanese).

Abstract

By using the theory of two-variate exponential distribution, the conditional probability density function,  $f(x_2|x_1)$ , of  $x_2$  for a fixed value,  $x_1$ , is given as follows :

$$f(x_2|x_1) = \frac{1}{\sigma_2(1-\rho)} \exp\left\{-\frac{\rho x_1}{\sigma_1(1-\rho)} - \frac{x_2}{\sigma_2(1-\rho)}\right\} \cdot I_0\left(\frac{2\sqrt{\rho}}{1-\rho} \sqrt{\frac{x_1 x_2}{\sigma_1 \sigma_2}}\right)$$

in which  $\sigma_1$  and  $\sigma_2$  are scale parameters;  $\rho$  is correlation parameter; and  $I_0(z)$  means the modified Bessel function of the 0 degree. Using the standardized variables  $\xi = x_1/\sigma_1$ , and  $\eta = x_2/\sigma_2$ , the conditional cumulative distribution function,  $F(\eta|\xi)$ , for a fixed value of  $\xi$  is defined by the following.

$$F(\eta|\xi) = \int_0^\eta f(\eta|\xi) d\eta = \frac{1}{1-\rho} \exp\left(-\frac{\rho\xi}{1-\rho}\right) \int_0^\eta \exp\left(-\frac{\eta}{1-\rho}\right) I_0\left(\frac{2\sqrt{\rho}}{1-\rho} \sqrt{\xi\eta}\right) d\eta$$

This depends on the values  $\xi$ ,  $\eta$  and  $\rho$ .

The numerical computation was conducted by the following procedure. First,  $f(\eta|\xi)$  was computed for the given value of  $\rho, \xi$  and  $\eta$ . Next, the integration was done by using the Newton-Cotes formula. Finally, the obtained results were compiled in a table, for the convenience of engineering practice such as data generation. For this compilation, considerable interpolation of numerical values were carried out. In this table, the value of  $\eta$  has been shown for  $F(\eta|\xi) = 0.001(0.001)0.01(0.01)0.20(0.05)0.80(0.01)0.99(0.001)0.999$ ,  $\xi = 0(0.25)3.00(0.5)5(1)10(2)18$  and  $\rho = 0.1(0.1)0.9$ .

**Study on Two-Variate Gamma Distribution and its Engineering Application (4)**  
**—Synthesis of Short-Time Intense Rainfall Data Applying Two-Variate**  
**Exponential Distribution Theory—**

By Masashi NAGAO and Mutsumi KADOYA

Annals, Disaster Prevention Research Institute, Kyoto University,  
 No. 14 B, April, 1971, pp. 77-85 (in Japanese).

**Abstract**

In this paper, a statistical technique is developed to generate short-time intense rainfall data at a point for a long-term, when the record period is only few years, on the basis of long-term data observed at an adjacent observatory. The technique is based on the theory of two-variate exponential distribution which is a special type of two-variate gamma distribution. Outline of this study is as follows:

1) Characters of probability distributions are examined of 10 minutes rainfall depths,  $X_{10}$ , over 5 mm and 1 hour rainfall depths,  $X_{60}$ , over 10 mm, observed at Kyoto for 32 years. They show an extremely skewed distribution as  $\nu < 1$  in shape parameter of gamma distribution. It seems, however, both  $x_{10} = \sqrt{X_{10}}$  and  $x_{60} = \sqrt{X_{60}}$  follow exponential distributions. Similar examinations are made of the data,  $Y_{10}$  and  $Y_{60}$ , observed at Obata gauging station for 3 years, to obtain the same conclusion.

2) To simplify the treatment, the theory of two-variate exponential distribution is applied to a set of  $x$  and  $y = \sqrt{Y}$ . Population parameters are estimated applying the technique proposed for a sample from a sub-population defined as upper domain over a given value. As a result, the estimated values of correlation parameters become as  $\rho_{10} = 0.2$  for 10 minutes rainfall and  $\rho_{60} = 0.9$  for 1 hour rainfall.

3) The simulated short-time rainfall data,  $Y$ , are generated for the long-term corresponding to the record period for  $x$ , by using the regression model derived from the theory of two-variate exponential distribution. In this step, the numerical table of conditional probability prepared for the standardized two-variate exponential distribution is utilized.

4) The following is an applied example of the data generated. An extreme value distribution is fitted to annual maxima of short-time rainfall data obtained and the expected value for a given return period is estimated. The rainfall intensity curve for a given return period is estimated knowing the values of 10 minutes and 1 hour rainfall for the return period and assuming Sherman's formula. Moreover, the relation between peak discharge of flood flow and its concentration time is estimated from the observed data for flood flow. Therefore, combining the above results, the design flood discharge is estimated for an assigned return period.

## A Simple Method of Generation of Simulated Rainstorm Data for Drainage Planning in the Matsue District

By Reijiro TANAKA and Mutsumi KADOYA

Transactions of The Japanese Society of Irrigation, Drainage and Reclamation Engineers,  
No. 34, November, 1970, pp. 28-33 (in Japanese).

### Abstract

A simple statistical method for generating simulated rainstorm data was developed for the optimal design of drainage systems in farm lands. The rainfall data over 30 mm for one-day storms and 50 mm for two-day and three-day storms observed at the Matsue Meteorological Observatory for the period 1926 to 1967 were used as the fundamental data for this study.

Firstly, the probability distributions of rainfall depths, continuous rain and drought days of each month were examined and it was clear that all were regarded as exponential distribution, and that they could be classified into three patterns, the summer type for June to September, the winter type for November to March and the spring-autumn type for April, May and October. Secondly, the yearly variation of occurrence number,  $y$ , of rainstorms in summer (June-Sep.) was examined through the correlogram analysis for each rain-duration. It was clear that there exists a cycle of about four years, but it is so slight that it may be negligible to engineering practices. Moreover, the array patterns of one-day and two-day maxima rainfall depths in three-day rainstorms and of one-day maximum depths in two-day rainstorms during the summer, were investigated to utilize arranging generated original data.

After the examinations mentioned above, the following technique was adopted to generate simulated rainstorm data in summer over a long period. 1) The occurrence number,  $y$ , of rainstorms is determined using a random number,  $p_y$ , from a uniform distribution on the interval (0,1) and the probability distribution of  $y$  for each duration. 2) The rainfall data,  $x_1 \sim x_3$  in depth, are generated using a second uniform random number,  $Q_1 \sim Q_3$ , respectively, in which a suffixed figure shows the duration of the storm. 3) The generated data are distributed to each year according to the value of  $y$ . 4) The depths,  $x'_2$  and  $x'_1$ , corresponding to  $Q_3$  are found through the respective conditional probability distributions of maxima two-day and one-day depths contained in three-day storms. The depth,  $x_2$  and  $x_1$ , nearly equal to  $x'_2$  and  $x'_1$ , respectively, are searched through the generated data in a unit period (one or few years) and regarded as part of lumped depth,  $x_3$ , if the condition,  $x_3 - x_2 \leq x_1$ , is satisfied. The generated data might be changed slightly within the interval by which the historical data were arranged to obtain a histogram or the probability distribution if it were needed. Such a technique is also applied to the distribution of two-day storms. 5) The distributed data are arrayed by the help of a third uniform random number,  $P_d$ , in such a way that the statistical characters on the array pattern of one-day maximum depths in three-day rain storms and so forth of historical data, are preserved.

## Runoff Characteristics in an Urban Area

By Mutsumi KADOYA and Taro OKA

Annals, Disaster Prevention Research Institute, Kyoto University  
No. 14 B, April, 1971, pp. 143-155 (in Japanese)

### Abstract

In this paper, runoff characteristics in an urban area were discussed on the basis of observed data in the Tenjin Basin, north-western district of Kyoto City. The basin has an area of 2.65 km<sup>2</sup>, slope of 1/50-1/70 from north to south and fairly well consolidated road and drainage channel networks. Kyoto Meteorological Observatory is situated in the south-eastern corner of the basin. Water gauges have been installed at the upper and lower ends of the Tenjin River within the basin since January, 1969.

An outline of the results obtained in this study are as follows:

1) There exists a functional relation between peak discharge,  $Q_p$ , of flood runoff and its concentration time,  $t_{pc}$ , such as  $t_{pc} \propto Q_p^{-c} \propto r_e^{-c}$ , in which  $r_e$  means the effective peak rainfall intensity and  $c$  constant. This relation suggests that the kinematic wave method must be applicable for runoff analysis in an urban area. If the Manning formula is applicable to rain-water flow, the constant,  $c$ , must be near to, but smaller than 0.4.

2) Runoff percents for heavy rains in June and July, 1969, were almost 100%, and the peak runoff coefficients 0.7~1.0.

3) The value of equivalent roughness,  $N(m^{-1/3}\cdot\text{sec})$ , for slope surface in a basin model in the kinematic wave method seems to be almost near the value of the coefficient of roughness for concrete surface in Manning's definition, if the model is constructed carefully to express drainage channel systems. However the value of  $N$  changes in accordance with simplification of the model.

4) In flood runoff, the weight of river channel on concentration time defined at the outlet of a basin is generally regarded as 10-20% in a mountain basin. The one in the Tenjin Basin, however, seemed to be 50-60%.

5) A method to check the concentration time by hand was proposed, and its applicability was confirmed. Moreover, a runoff hydrograph for rainfall on June 4, 1969, applying the kinematic wave method and using a digital computer showed a good coincidence with the observed hydrograph.



## Runoff Characters in Yoko-oji Low Land

—Present and Future—

By Mutsumi KADOYA, Taro OKA, Eiji TOYOKUNI and Akira FUKUSHIMA

Annals, Disaster Prevention Research Institute, Kyoto University  
No. 14 B, April, 1971, pp. 157-166 (in Japanese)

### Abstract

The purpose of this study is to clarify the effects of urbanization on runoff characters and flood damage potential, in Yoko-oji low-lying drainage basin of 7.25 km<sup>2</sup>, south-western district of Kyoto City. The basin is surrounded by the Kamo, Katsura, Uji and Higashitakase Rivers, and has a gentle slope of 1/1200-1/2000. The lowest area, south-western part of the basin, sometimes suffers from inundation when heavy rain falls over 100 mm in depth. To cope with the situation, two pump stations have been constructed. The basin consists of paddy, farm and villages at present, but there is a probability of urbanization in the near future. Hydrological observations have been therefore conducted since May, 1969.

As a first step in this study, runoff characters at present and their presumed changes with future urbanization were discussed on the basis of observed data in June and July, 1969. The outlines are as follows:

1) Hydrographs of runoff discharge at the end of the main drainage channel were estimated from the records of water levels in the channel and rivers, and pump operation, by considering curves for depth-volume in inundated areas and for pump capacities. However, there were problems concerning the accuracy of the hydrographs due to the distance between water gauges installed near the end of the main drainage channel not being adequate to meet rapid changes of water level caused by pump operation. Further, the inflow discharge from rivers through and under embankments had to be estimated by a simple formula for seepage in order to cope with lack of data.

2) The kinematic wave method for runoff analysis was applied using a simple model of the basin and a moderate value for equivalent roughness to examine the runoff hydrographs mentioned above, although the use of this method might be questionable for a low-lying basin. However, the results were fairly good from an engineering view point.

3) A model of the basin was made assuming a future urbanized condition, and values of equivalent roughness were selected in accordance with urbanized steps. Runoff hydrographs for given rainfall conditions were then estimated applying the kinematic wave method to examine the effects of urbanization on runoff hydrographs. The results suggested that the peak discharge of flood runoff in future must be two and/or five times as large as the ones at present, and may be influenced by rainfall conditions.

## Effects of the Urbanization of a Drainage Basin on Flood Runoff

By Mutsumi KADOYA

Proceedings of the 7th Japan National Congress, for Natural Disaster Science,  
November, 1970, pp. 207-210 (in Japanese).

### Abstract

A study was made of the methodology for predicting changes in flood runoff characteristics according to the urbanization of a drainage basin. We have no observed data of runoff hydrographs for a long period at the outlet of the basin, most of which was converted from forest and agricultural areas into urban areas within the period. The study was carried out, therefore, on the basis of the hydrological data observed in some drainage basins, each of which is composed mainly of a forest, agricultural or urban area.

First, the relation between the effective peak rainfall intensity,  $r_e$ , obtained from value of peak runoff discharge,  $Q_p$ , at the outlet of the basin, and its concentration time,  $t_p$ , was examined using the data for rainstorms in June and July, 1969, and it was made clear that there exists a functional relation between them. For the rainstorms, the values of the coefficient of peak runoff,  $f_p$ , were 0.59-0.73 for a forest area of 1.37 km<sup>2</sup> in the basin of River Obata, and 0.73-1.0 for an urban area of 2.66 km<sup>2</sup> in the basin of River Tenjin, although they might be changeable in corresponding to intervals between rains. From the functional relation between  $r_e$  and  $t_p$ , the values of the equivalent roughness,  $N(m^{-1/3}\cdot\text{sec})$ , defined in the kinematic wave method for runoff analysis in a slope surface of a drainage basin, were estimated as 0.5-0.6 in the forest area and 0.01 in the urban area. In addition,  $N$  was 0.04-0.05 for an urbanized area of 0.17 km<sup>2</sup> on a hillside of the basin of River Yamashina. Of course, the value of  $N$  may differ slightly due to the simplified model employed for a drainage basin in general.

Next, a method for predicting changes of  $Q_p$  caused by urbanization of a hillside slope in a drainage basin was investigated in relation to presumable changes in  $f_p$  and  $N$  and in consideration of a type of rainfall intensity curve. An urbanizing limit, by which  $Q_p$  may not exceeded the one before urbanization, was discussed in area and situation within the basin. Moreover, the effect of urbanization on runoff characters in a low-lying agricultural basin was examined to show hydrographs in the present and the future conditions.

Method of Numerical Analysis for Three Dimensional Unconfined Seepage  
 —Seepage Problem for River Structure (3)—

Applied Examples of Numerical Analysis for Three Dimensional Unconfined Seepage  
 —Seepage Problem for River Structure (4)—

By Taro OKA

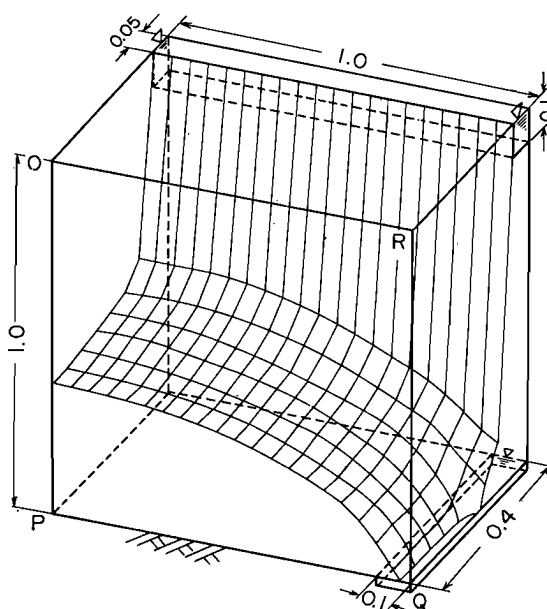
Annals, Disaster Prevention Research Institute, Kyoto University,  
 No. 14 B, April, 1971, pp. 167-178, pp. 179-187, (in Japanese)

Abstract

In the first paper, a method of numerical analysis for three dimensional flow in homogeneous porous media was investigated on the assumptions that the flow is steady and governed by Darcy's law. The usefulness of the method for analysis of the flow was clarified from the comparison between the author's solutions and the results already shown by Shaw et al. and Hervert et al. for two dimensional flows in some earth structures.

In the second paper, a few examples for engineering application of the author's method were shown. That is, the result calculated for the flow in a three dimensional earth dam was discussed in comparison with the result obtained as two dimensional flow. Moreover, three dimensional characters of ground water flow in a wide alluvial fan were examined using the results calculated by the method and data observed.

The following figure shows an example of the three dimensional flow obtained by the method.



## Flood Flow in an Irregular Channel (2)

By Tamotsu TAKAHASHI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 219-230 (in Japanese)

### Abstract

This paper describes the results of experiments of unsteady flow in two kinds of irregular open channels, of which one has no storage region and another has a storage region along the river abutting the main channel.

Considerations on the experimental results reveal that the theoretical routing method which was proposed in the last report is a good and simple approximation for the irregular channel flood in cases where the characteristics of resistance and widths of the main channel and storage region are known beforehand.

Resistance produced by the mixing of flow between the main channel and storage region is discussed and a method for determining the modified Manning's roughness coefficient is proposed.

Effects of the width of the storage region and large scale diffusion coefficient to the celerity and attenuation of peak were also discussed using numerical solutions of proposed fundamental equation for irregular channel floods.

## **Studies on the Equipment for Bed Load Discharge Measurement.**

**By the Study Group of Sediment Measurement Techniques.**

Annuals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 239-249 (in Japanese).

### **Abstract**

In this paper, we present the idea of several kinds of apparatus for measuring the bed load discharge in an alluvial channel and discussed their merits and demerits.

For the purpose of continual measurement of bed load which varies with time, we selected among many other types, the rotating bucket type and balance type measuring devices and manufactured them for trial.

This paper mainly discusses the former type of apparatus by experiments in our laboratory flume. This type of equipment has four rotating buckets round a wheel which rotates one-fourth par unit weight of bed load and emits a pulse to a recorder with each rotation. The sand dumped from the bucket is automaticaly excluded by a screw driven by a motor.

Satisfactory results were obtained after several modification. For actual river application, however, this apparatus still requires further improvement.

## Study on the Suspended Sediment ( 2 )

—An Optical Method for Measurement of Suspended Sediment Concentration—

By Masanori MICHIEUE and Kiyoshi SHIRAKAWA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14B, April, 1971, 251-258 (in Japanese).

### Abstract

In this paper a theoretical consideration for the measurement of suspended sediment concentration was conducted on the basis of the optical principle. It was clarified from this consideration that suspended sediment concentration can be measured with the optical method if we measure the average diameter and the standard deviation of the suspended sediment, and the rectilinear attenuation.

The probe of an instrument for the measurement of suspended sediment concentration, consists of the Gallium Arsenide Diode as the light source and the Phototransistor as the sensor. Concentration of the suspended matter consisted of a uniform and a nonuniform sediment was measured with this instrument. The result was compared with a theoretical equation derived by authors.

**Landslides and the Weathering of Rock (2)**  
**—Rock Characters as a Primary Factor in Landslides—**

By Toyoaki SAWADA

Annals, Disaster Prevention Research Institute, Kyoto University,  
 No. 14 B, April, 1971, pp. 717-726 (in Japanese).

**Abstract**

We extend our investigations of the character of rocks as a primary factor of landslides, mentioned in our previous paper.

In the investigation of landslide, it is the purpose of this paper to point out that the hardness of rocks as the factor in landslide, is expressed by weathering and alternation

In this type of investigation, choice of method is in itself a problem. Procedure for the survey of rock hardness and indication method of it is therefore described.

The rock hardness is expressed by the density of joint and the compressive strength (hammer rebound), as seen in Fig. 1.

Procedure for the survey is as follows:

(1) Joint density is expressed by the number of joint block in  $1 \text{ m}^2$ . it is expressed by  $10000/d$ , where  $d \text{ (cm}^2\text{)}$  is the mean area of joint block. The mean area of joint block can be obtained by cumulative area percentage, (see Fig. 2).

(2) Orientation of joint, opening of joint, test-hammer rebound and seismic survey.

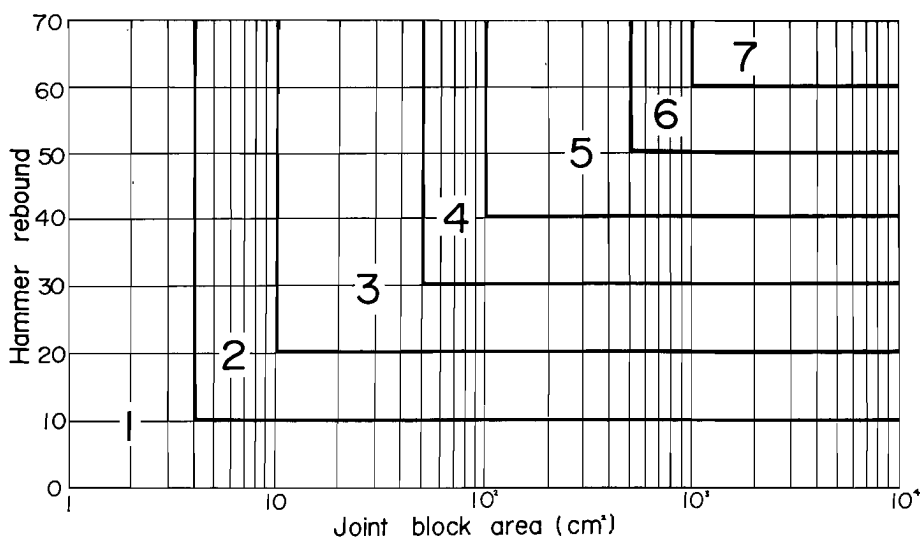


Fig. 1 Expression of rock hardness by the joint block area ( $d \text{ cm}^2$ ) and hammer rebound ( $P$ ).

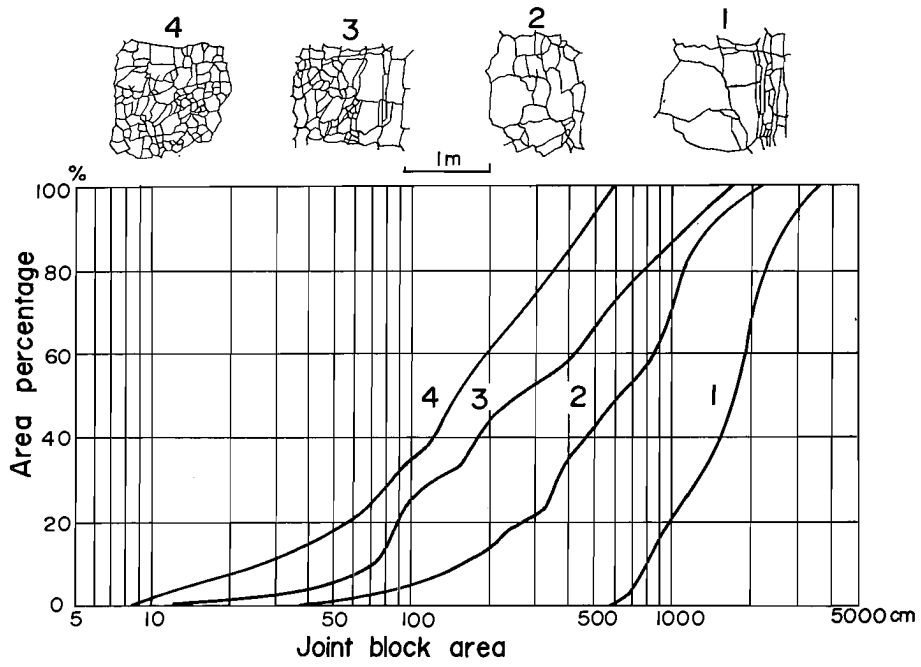


Fig. 2 Relation between state of crack and cumulative curves of joint block area.



Distribution of Ground Waters in the Gamata River Basin ( 2 )  
—Characters of Ground Waters and Weathering of Rocks—

By Katsumasa YANO and Toyoaki SAWADA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 727-743 (in Japanese).

**Abstract**

We extend our investigations of the relationship between the composition of ground water and the order of weathering of rocks mentioned in our previous paper.

In this paper, the relation between the character of ground waters and the weathering of rocks is described.

Our investigation was made from August 1969 to January 1970. Ground water samples were taken at intervals of two weeks.

A few experiments on the effect of the consistency of water composition on the weathered rocks were also made.

Temperature, pH and conductivity values were measured in the field. Chemical constituents such as  $\text{Ca}^{2+} + \text{Mg}^{2+}$ , soluble  $\text{SiO}_2$ ,  $\text{Na}^+$  and  $\text{K}^+$  were determined in the laboratory.

The main results are as follows:

- (1) The concentrations of  $\text{Ca}^{2+} + \text{Mg}^{2+}$  increased in the landslide areas for small rainfalls.
- (2) The grade of weathered rock is roughly proportional to ionic concentration in ground waters within the limits of this soluble experiment for rocks.

## On Air-sea Interaction in the Kii Channel

By Chotaro NAKAJIMA and Hiroshi YOSHIOKA

Bulletin of the Disaster Prevention Research Institute, Kyoto University,  
Vol. 20, Part 3, No. 179, March, 1971, pp. 217-226 (in English).

### Abstract

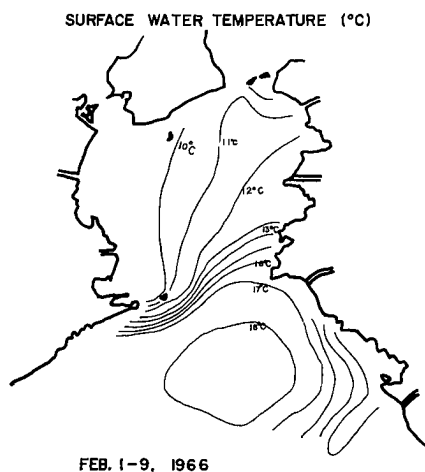
Taking the Kii Channel and Osaka Bay as our model region, we have studied the interrelation between small scale oceanic phenomena in a narrow ocean area and meso-scale atmospheric phenomena.

Between a line connecting Murotomisaki and Shionomisaki and a line connecting Hinomisaki and Gamatazaki, a countercurrent of the Kuroshio flows along the Pacific Coast of Western Japan. This same region is orographically open to the south, and favourable for southerly winds to blow into inland parts with horizontal convergence. Osaka Bay, located at the inmost part of this area, has a remarkable inland character both meteorologically and oceanographically and the middle region from the line connecting Hinomisaki and Gamatazaki to the Kitan Strait is the intermediate region between the inland and open sea regions where, in winter, a remarkable discontinuous zone of surface water temperature appears. In this paper, we have summarized the oceanic conditions in these seas and then considered what kind of atmospheric phenomena produced these oceanic conditions.

Examples are then shown of the effect of these oceanic conditions on medium scale atmospheric phenomena occurring in the neighbouring regions. The existence of a discontinuity of surface water temperature affects the stability of the lower layer of the atmosphere and makes for local distribution of dense fog and air pollution.

We have explained that the existence of this discontinuous zone of surface water temperature produces a suitable condition for the development of secondary small cyclones of low height. In summer, moist air currents in the lower layer flow into the central part of the Kinki District through the Kii Channel and make a narrow concentration band of heavy rainfall.

The region of the Kii Channel and Osaka Bay has only a small area, but the oceanographic conditions of this region and its meso-scale atmospheric phenomena are intimately related.



**Studies on Heavy Rainfall (III)**  
**—On the Heavy Rainfall in the Central Kinki District—**

By Hisashi EDAGAWA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14B, April, 1971, pp. 119-129 (in Japanese)

**Abstract**

For a case study of the mechanism of heavy rainfall, we analysed the heavy rainfall on 25th June, 1969. In the cross-section and the time-section of this disturbance, we found a distinct low level jet stream combined with the frontal system. The main rainfall occurred over the area where the surface warm front and the low level jet stream crossed each other. This area also corresponded to the center of the surface convergence. We discussed moreover the smaller scale disturbances superposing the main disturbance.

## Experimental Studies on the Tidal Mixing in the Seto Inland Sea

By Takashige SUGIMOTO and Haruo HIGUCHI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971. pp. 435-450 (in Japanese).

### Abstract

The mechanism of tidal mixing and its effect on the tidal flushing of matter discharged from rivers and coasts into the Seto Inland Sea are studied with the use of a small hydraulic model, of which the horizontal and vertical scales are 1/100,000 and 1/1000 respectively. The effect of density, wind and waves are not considered.

Seto Inland Sea is about 20,000 km<sup>2</sup> in area about 500 km in length, 30 m in mean water depth and connected by two straits, Kii Suido and Bungo Suido, with the Pacific Ocean, through which the tidal wave comes into the sea. The tidal range becomes maximum at both the central part and most westerly part, where it is about 3 m. The maximum velocity of tidal current is about 10 knots at some straits and less than 0.2 knots elsewhere.

The tide generated by a tide generator of plunger type was provided for the model through both straits. Both the amplitude and the phase of semi-diurnal tide was well reproduced in the model and the length of tidal excursion has a reasonable value.

The tidal locus does not close and some residue remains, forming a residual flow such as residual circulation. The residual circulation develops within the bay and at both sides of the straits playing an important role on the diffusion and control of the horizontal distribution of matter discharged from the land.

Since the model is too small and the frictional condition may not be sufficient, it is rather difficult to find out the similitude in a strict sense. It is expected however that the distribution of dyed water in the model, roughly represents that in the prototype. In fact, the distribution of the warm water area in summer in the prototype, which is supposed to show that the water is stagnant there, corresponds with the absence of such a circulation.

The matter discharged into the sea east of the western part of Bisan Seto is mainly flushed out through Kii Suido and that discharged west of this location through Bungo Suido.

## Hydraulic Model Experiment on the Tidal Current in Matsukawa-Ura

By Haruo HIGUCHI and Masaaki TSUJI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 415-434 (in Japanese).

### Abstract

The flow pattern and diffusion phenomena due to the tidal current in a very shallow estuary of present state and dredged state are studied through a hydraulic model experiment, for which Matsukawa-Ura Bay is used as the prototype. The effect of density, wind and waves are not considered.

The bay is 6.45 km<sup>2</sup> in area, which is connected with the Pacific Ocean by a narrow channel, of which the minimum cross-sectional area is 220 m<sup>2</sup>, and the length about 500 m. The mean water depth in the bay is 124 cm, which is almost the same as the tidal range. Therefore the non-linear effect is remarkable; the larger the amplitude at the bay mouth, or the smaller the mean water depth is, the smaller the amplitude ratio becomes and the larger the phase lag in the bay.

A distorted model with many wire nets as an artificial bottom roughness, of which the horizontal scale and vertical scales are 1/600 and 1/50 respectively, was constructed and a semidiurnal tide was provided for it. The water level is measured at six stations with the use of an electric resistance wave meter, the flow pattern by tracing many floats and the diffusion by dye concentration analysis with the use of a fluorometer.

The tide is well reproduced in the model including the nonlinear effect. The flow pattern is also well reproduced. The distribution of dyed water after a thirty tidal cycle, which is initially regarded as the water from the bay, is almost similar to the distribution of chlorinity in the prototype. The diffusivity reduced through the mixing theory of tidal flushing by Arons-Stommel is  $0.8 \sim 1.0 \times 10^5 \text{ cm}^2 \cdot \text{sec}^{-1}$  in the present state.

After several water ways are dredged to intensify the infiltration of sea water into the inner part of the bay, the distortion of the tidal curve becomes smaller, the amplitude ratio larger, and the phase lag smaller. The velocity of tidal current in the flood becomes smaller and that in the ebb larger by about 10% excepting in the water way, where the velocity is intensified to 150~170% of that out of the water way. The diffusivity becomes  $1.2 \sim 1.5 \times 10^5 \text{ cm}^2 \cdot \text{sec}^{-1}$  in the dredged state.

Basic Study on Salt Damage (V)  
—Distribution of Sea-Salt Particles Near the Coast in Strong Wind Conditions—

By Masaaki TANAKA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 499-510 (in Japanese).

Abstract

Observations of the horizontal distribution of the number concentration of giant sea-salt particles near the ground surface were carried out in strong wind conditions at several stations distributed from the coast to the inland near Ogata, Niigata Prefecture, on Jan. 24, Dec. 13 and Dec. 14, 1970.

The wind from the sea ranged from 10 to 18 m/sec in speed in the lowest several hundred meters layer. The observation showed that the particle number concentration near the ground decreased with the distance from the coast, as expected from our theoretical model.

The impaction-sedimentation ratio,  $\gamma$ , estimated from our observation, is about 10 for 10 m/sec, in wind speed and about 13 for 16 m/sec.

The impaction factor,  $\lambda$ , obtained from our present observation, however, is rather smaller than but nearly the same order with that estimated in the previous report from the observations of the horizontal and vertical distributions for weak wind.

The particle number concentration observed at the coast is compared with data observed by Toba et al. at the sea surface. The concentration at the coast for the variable wind speed is also discussed.

## On the Microstructure of Tidal Current and the Horizontal Diffusion due to it

By Haruo HIGUCHI and Takashige SUGIMOTO

Abstracts of Invited Papers, General and Special Symposia,  
Joint Oceanographic Assembly, Sept., 1970, p. 31

### Abstract

The microstructure of tidal current and the horizontal diffusion due to it in the coastal sea area, are here studied comparing the results of field surveys with those obtained in hydraulic models. It is considered that the so-called tidal current involves several kinds of currents in relatively shallow sea areas which have a complex topography, i.e., the original tidal current which is generated by the tide generating force, the compensating current and the eddy current due to configuration such as headlands and islands, and the eddy current due to bottom stresses.

In general, it is difficult to determine the tidal current which corresponds to the tide in a real sea area. Although an electronic computer is sometimes used for this purpose, it is still difficult to get a sufficient results mainly because of the small capacity of the computer. A hydraulic model is a useful tool to reproduce the tidal current in some detail, serving as an analog computer when the similitude holds well.

The tidal current in Mizushima Nada, in the central part of Seto Inland Sea, where the semidiurnal tide predominates, was studied. There the water depth is about 10 m, the spring tidal range is 2.7 m, the velocity of tidal current is 1 to 2 knots, and the tidal excursion is of the order of 10 km. Such a tidal range and velocity field are well reproduced in a hydraulic model with a horizontal scale of 1/2000 and a vertical scale of 1/160. The field data for other sea areas, such as Ariake Bay and Kashima Nada, are also compared with experimental results. The compensating current and eddy current due to the jagged coast line and island are well reproduced in the model. It is not yet confirmed whether the eddy current or turbulence due to bottom stress is reproduced or not because of difficulties in measuring.

River water just inside the river mouth and waste water discharged into the harbor are first carried by the local current, which is eddy-like due to the configuration, during which they are diffused continuously by eddies of smaller scale. Then they come offshore gradually, where they are diffused while carried by the tidal current. The diffusion phenomena in such processes are discussed. The  $4/3$  power law for diffusivity seems to hold well both in the actual sea area and in the hydraulic model.

## Dynamical Behaviour of a Non-linear Porous Elastic Layer

By Hisao GOTO, Kenzo TOKI and Tadanobu SATO

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 233-252 (in Japanese).

### Abstract

This paper is concerned with a conceptual model representing the dynamic behaviour of saturated soil. Generally soil-material is considered to be a homogeneous mechanical mixture of two phases, that is, one phase representing the structure of solid particles in the soil aggregate and the other phase representing the fluid water in the pores or voids of the aggregate. In this paper, we assumed that such a material is approximated by a fluid-saturated porous hyperelastic material, for which we tried to apply the theory of mixtures composed of several constituents in relative motion to each other.

Using the Lagrangean density on mixtures, the Lagrangean formulations of the equations of motion were deduced in the Cartesian reference coordinates for a mixture of a hyperelastic solid and a non-linear compressible fluid:-

$$\begin{aligned} \rho_{11} \frac{\partial^2 U_I^{(1)}}{\partial t^2} + \rho_{12} \frac{\partial^2 U_I^{(2)}}{\partial t^2} + b \left( \frac{\partial U_I^{(1)}}{\partial t} - \frac{\partial U_I^{(2)}}{\partial t} \right) + \rho_0^{(1)} \mathbf{G}^{(1)} &= \left( \frac{\partial \mathcal{W}}{\partial U_{I,J}^{(1)}} \right)_{,J} \\ \rho_{12} \frac{\partial^2 U_I^{(1)}}{\partial t^2} + \rho_{22} \frac{\partial^2 U_I^{(2)}}{\partial t^2} - b \left( \frac{\partial U_I^{(1)}}{\partial t} - \frac{\partial U_I^{(2)}}{\partial t} \right) + \rho_0^{(2)} \mathbf{G}^{(2)} &= \left( \frac{\partial \mathcal{W}}{\partial U_{I,J}^{(2)}} \right)_{,J} \end{aligned} \quad (1)$$

where  $\rho_{11}$ ,  $\rho_{12}$  and  $\rho_{22}$  are mass coefficients which take into account the fact that the relative flow through the pores is not uniform,  $U^{(\alpha)}$ ,  $\rho_0^{(\alpha)} \mathbf{G}^{(\alpha)}$  and  $\rho^{(\alpha)}$  indicate the displacement, body force, and mass of  $\alpha$  phase respectively ( $\alpha=1$ : elastic phase,  $\alpha=2$ : fluid phase),  $_{,J}$  denotes partial derivative with reference coordinate,  $(X_J)$ :  $\partial/\partial X_J$  and  $\mathcal{W}$  is the strain energy function of mixture.

$\mathcal{W}$  was expanded as a generalized Taylor's series in the strain invariant of two phases as

$$\begin{aligned} \mathcal{W} = & p_E^0 I^{(1)} + p_f^0 I^{(2)} + \frac{1}{2} (\lambda + 2\mu) I^{(1)2} - 2\mu II^{(1)} + R I^{(1)} I^{(2)} + \frac{1}{2} Q I^{(2)2} \\ & + P II^{(2)} + l I^{(1)3} + m I^{(1)} II^{(1)} + n III^{(1)} + L I^{(2)3} + M I^{(2)} II^{(2)} + N III^{(2)} \\ & + f_1 I^{(2)} II^{(1)} + f_2 I^{(2)} I^{(1)2} + f_3 I^{(1)} I^{(2)2} + f_4 I^{(1)} II^{(2)} \\ & + (\text{higher order term}) \end{aligned} \quad (2)$$

in which  $I^{(\alpha)}$ ,  $II^{(\alpha)}$  and  $III^{(\alpha)}$  are strain invariant of  $\alpha$  phase,  $p_E^0, \lambda, \mu, l, m$  and  $n$  are elastic constants of solid phase,  $p_f^0, Q, P, L, M$  and  $N$  are elastic constants of fluid phase and  $R, f_1, f_2, f_3$  and  $f_4$  are constants expressing the coupling between solid and fluid strain.

Differentiate equation (2) with respect to Green's strain tensor of  $\alpha$  phase, and the non-linear constitutive equations for a mixture of these two continua have been obtained. Based on equations (1) and (2), the dynamical behaviour of a non-linear elastic layer and a liquid-filled non-linear porous elastic layer have been examined, from which it has been found that vertical displacement occurs not only in the case of vertical input displacement but also for the horizontal input, and the pore pressure response in the layer would be seen to be an important phenomenon.



## On the Vibrational Characteristics of Foundation Structure in the Ground

By Hisao GOTO, Kenzo TOKI and Shiro TAKADA

Annals, Disaster Prevention Research Institute, Kyoto, University,  
No. 14 A, April, 1971, pp. 263-282, (in Japanese).

### Abstract

The paper is concerned with the interaction between structures and ground. The system treated herein consists of an elastic homogeneous surface layer with uniform depth to the base extending over the semi infinite elastic half space and the cylindrical structure which extends from the base through the layer. Emphasis is on the analysis of the vibrational characteristics of the structure influenced by the surrounding material.

The system has been investigated with consideration to the elasticity of the base layer, investigating the effects of radiation damping on the vibrational characteristics. Analysis have been made in the case where SH waves arrive at the boundary plane at a certain angle and some are reflected into the base layer and some refracted into the surface layer. The time that the SH wave arrive at the points on the boundary plane are not the same by virtue of the incident angle. In this case the surface layer vibrates with phase differences. Apparently, in the surface layer, the SH wave propagates in the horizontal direction and its directions of propagation and movement are quite the same as the Love wave. Under these conditions, the propagating wave is scattered by the structure. As the reaction of this scattered wave, the vibrational earth pressure is caused. We derived the theoretical expression for this pressure acting upon the rigid structure. Moreover, the analytical method has been proposed to treat the interaction between the superstructure in the air and the foundation structure in the ground.

The results indicate that the vibrational earth pressure is proportional to the ratio of the shear wave velocity of the base layer to that of the surface layer and the vibrational earth pressure due to the scattered wave has a considerably small effect. The vibrational characteristics of the foundation structure in the ground are greatly influenced by the surface layer and the effect of the property of the superstructure in the air is not evident. The deflection of the structure in the ground is remarkably restrained and apparently the rigidity and damping of the whole structural system are considerably increased by the ground. The amount of the radiating wave is estimated by way of equivalent viscous damping. This value is influenced by the shape of the structure. In the case of cylindrical structures, this value is inversely proportional to the ratio of the radius to the height of structure.

Finally, model experiments were carried out to verify the theoretical results, they showed good agreement.

## Experimental Study on the Horizontal Restoring Force Acting on Substructures

By Hisao GOTO, Susumu YOSHIHARA, Masaru KITaura and Akihiro OTA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 282-299 (in Japanese).

### Abstract

In this study, the horizontal restoring force acting on substructures surrounded by surface layers was investigated by means of laboratory experiments. In the previous experiments, the authors had used dry sand layers to represent the surface layers and had obtained some useful results. In the present case, the surface layers used in the experiments were a clay layer as well as a dense sand layer and the difference between the characteristics of the restoring force of a sand layer and those of a clay layer was investigated. Furthermore, it was examined whether the restoring force of a clay layer could be estimated from the vibrational earthpressure acting on the surface of the model, which had been already verified in a sand layer without cohesion.

The hysteresis loops of the restoring forces of a sand layer were of a slip type with friction and the curves connecting the maximum points of the hysteresis loop were of softening type with wide linear zones for small displacement but for large displacement they became of more softening type. In the clay layer, on the other hand, the hysteresis loops were of a frictional type and the curves connecting the maximum points were of a degrading spring type within a certain level of displacement but for higher displacement levels they are nearly straight lines.

The restoring force curves of a clay layer were hardly influenced by the excitation frequency but those by a sand layer were slightly influenced by the frequency. The reason seems to be that the gearing of the sand grains becomes loose as the frequency becomes high.

The restoring force was estimated directly from the reaction and the earthpressure. In a clay layer. It is so difficult to measure the restoring force that careful attention must be paid when this method is adapted. The hysteresis loop of the response acceleration of the model was very similar to the restoring force. Hence it would be an effective method to estimate the restoring force by the acceleration if the phase difference of the accelerometer is negligible.

Hysteresis damping in a clay layer is larger than that in a sand layer. And hysteresis damping seems to be almost in proportion to the excitation velocity.

In order to apply these experimental results to earthquake-resistant design, the restoring force characteristics have been represented by an empirical formula, and it was verified that this formula can be applied to the restoring force curves both for sand and clay layers if the only parameter was changed. Discussions have been made on the appropriateness of the idealization by means of the frequency response curve for this vibrational systems. The response curves obtained from experiments have been approximated by the curves calculated from this formula if the parameters take fit the values.

## On the Three Dimensional Consolidation Theory of Clay

By Seiki OMAKI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14B, April, 1971, pp. 585-601 (in Japanese).

### Abstract

In this paper, the author deals with a general theory, and one boundary value problem of a three dimensional deformation of porous material. The deformation of two-phase porous material such as clay is attributable to two causes; one is due to dehydration of pore water as is observed during the consolidation of clay, and the another is due to a viscoelastic behavior of the soil skeleton as observed in the process of the secondary compression of clay. Forming this theory, two-phase material is treated as a composition of a viscoelastic skeleton and incompressible water. The effective stress-strain relation of the viscoelastic skeleton of material is expressed by an application of a linear theory of viscoelasticity developed by Gurtin and Sternberg which is based on the Stieltjes convolution. In the process of obtaining a continuity equation, the change of porosity during consolidation is considered. This continuous equation has the same form as that obtained by Biot etc., although the form of the coefficient of consolidation is slightly different.

In the latter half of this paper, the results of solutions of a boundary value problem are represented by using this theory. This problem is considered to analyse a triaxial compression creep test in a drained condition. It is treated as a cylindrical sample with a radius  $a$  and a height  $h$  receiving a radial and axial compression stress under drained conditions at a radius  $a$  and undrained conditions at the base and a height  $h$  of the sample. Under these conditions, the solution in the Laplace transform is obtained, and in particular case, deformation, effective stress etc., in the sample are obtained by applying the inverse Laplace transform. In this case, the displacement of a sample is composed of two parts, one is as immediate change which is caused by deviatoric stress, the other is a time dependent change which is caused by a mean effective stress.

## Effect of the Stress-Anisotropy on the Shear Velocity in Soils

By Yoshio ISHIGURO

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971. pp. 631-641 (in Japanese).

### Abstract

It is known that there exists an obvious relation between the vibration characteristics of the ground and the shear wave velocities  $v_i$  in soils. In the case of sandy soil under isotropic stress, the dynamic shear modulus of specimens are proportional to approximately 1/2 power of the effective stress in no change in void ratio. In the ground however it is natural that anisotropic stress acts on the soil element. In this paper  $v_i$  in dry sand were measured by the ultra-sonic pulse method in the triaxial compression and extension cells. The ratio of axial and lateral stresses  $\sigma_a/\sigma_r$  in the cells was varied from 0.2 to 4.0.

By the experimental results, as seen in Fig. 1,  $v_i$  depends on the stress component parallel to the direction of wave propagation until the shear phenomenon does not progress very much.

Cohesive soil has anisotropy due to particle orientation differing from sand. Relationships were obtained between the consolidation pressure  $p$  and  $v_i$  in the reconsolidated clay, and between  $p$  and the margin occurred by the difference of the direction to the particle orientations.

By these results, the relationship mentioned above, gives both essentially straight lines on log scales and agrees approximately with the data using undisturbed clays. (see Fig. 2)

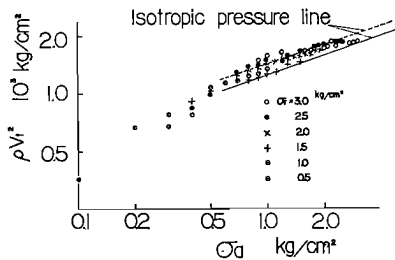


Fig. 1  $\log v_i \sim \log \sigma_a$  curves in extension tests.

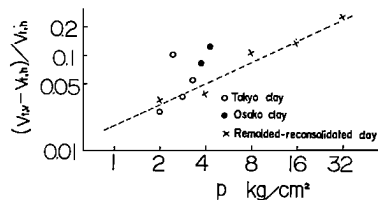


Fig. 2 Degree of velocity-anisotropy vs. consolidated pressure.

## Liquefaction of Saturated Sand due to Cyclic Loading (II)

By Toru SHIBATA and Manabu MIYOSHI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 B, April, 1971, pp. 655-665 (in Japanese).

### Abstract

It is universally known that saturated, loose sand induces the phenomenon of liquefaction when it is exposed to cyclic loading occurring at relatively short intervals. A logical explanation of this phenomenon postulates that the shear failure due to the decrease in internal friction resulting from the cyclic loading develops in concert with the failure due to the decrease in effective stress occurring in sand in consequence of the rise in pore water pressure in sand. This paper aims principally to treat both of these two factors.

In the first, the authors devoted a full discussion to the excess pore water pressure which develops and builds up in saturated sand when shear stress  $\tau$  of a fixed magnitude is exerted repeatedly on a simplified pattern designed to represent the condition in which the soil element in the ground is exposed to stress at the time of earthquake. The excess pore water pressure  $\Delta\bar{u}$  developing within one cycle was then obtained as follows.

$$\Delta\bar{u} = a \left\{ \left( \frac{\tau}{\sigma} \right) - \left( \frac{\tau}{\sigma} \right)_c \right\} \tau$$

Where  $a$  and  $(\tau/\sigma)_c$  are the coefficients to be determined by the density of soil. The value  $\Delta\bar{u}$  developing in each cycle could be regarded as remaining substantially constant excepting the liquefaction phase of cyclic loading.

In the second, the mobilized internal frictions of sand and glass beads at the time of initial liquefaction  $\varphi_i'$  were observed and compared with the true angle of friction  $\varphi_\mu$  between the mineral surfaces of the particles. As a result, it was tentatively concluded that  $\varphi_i'$  is nearly equal to  $\varphi_\mu$  for sand and glass beads respectively.

To date, numerous researches have been engaged on the liquefaction of sand in connection with the simplified stress conditions; viz. the normal stress  $\sigma$  exerted on the shear plane remains constant and the shear stress  $\tau$  is exerted in alternate directions. In actual earthquakes, however, irregular vibrations are conferred the ground, and the principle of analysis which is based on such simplified stress conditions can not be applied, in its unmodified form, to practical designs. In this respect, some tests were carried out to investigate the influence of irregular vibrations on the liquefaction of saturated sand.

## Seismic Response of Structures in Heterogeneous Ground

By Kenzo TOKI

Proc. 3rd Japan Earthquake Engineering Symposium, Nov., 1970, pp. 73-80 (in Japanese).

### Abstract

The elastic wave velocities in soil specimens depend on the confining pressure. The elastic constants which can be converted from the wave velocities in ground are, therefore, almost proportional to the depth from the ground surface. This paper is concerned with the vibrational characteristics of the heterogeneous ground and the interaction between structure and ground.

The elastic constants are assumed to be proportional to the half power of the depth from the ground surface. The differential equation which governs the behavior of the system considered herein, is analyzed throughout. In this analysis, two functions are proposed to express the vibrational characteristics of the ground. Using these two functions, the response of the heterogeneous surface layer can be represented whether the plane wave which is generated on the structural surface is transmitted or not.

The dynamic pressure which acts on a cylindrical structure is calculated by using the assumption that the structure and the base are excited together harmonically to the horizontal direction. The total amount of dynamic pressure which is parallel to the exciting force per unit length of the structure is expressed and its computed results are shown. As a result, the dynamic pressure on the structure in the heterogeneous surface layer differs from that of the homogeneous layer, especially in the vicinity of the ground surface and its inverse proportional to the radius ratio of the depth of the structure below the ground surface.

A system which is constructed between structure and ground is a feedback system because the lateral force acting on structure depends on the deflection of structure. In this study using the Green function which satisfies the boundary conditions of the structure, the interaction between the structure and ground are investigated. Consulting the results of numerical computation, it is pointed out that the ground surrounding a structure makes a structure harder than that in air.

## On a Model for Vibration Analysis of Ground Soil and Rigid Foundation Structure

By Hisao GOTO

Proceedings of the Third Japan Earthquake Engineering Symposium-1970,  
Nov., 1970, pp. 509-516 (in Japanese).

### Abstract

In the vibration analysis of the system of ground soil and foundation structure, there are two well known techniques; one of them deals with spring-dashpot systems, and the other is based on the application of the wave propagation theory. Aiming at the practical uses for the dynamic design of substructures, the author deals in this paper with a comparatively simple model so-called equivalent soil prism.

First, for the vertical vibration, an equivalent soil prism whose top's deformation equals statically the depression of ground surface was assumed, and by analyzing the longitudinal free vibration of this elastic soil prism whose top is loaded by the foundation structure body the equivalent spring constant containing the effect of the vibrating mass of ground soil was obtained from the frequency equation of this system. The same analysis was then expanded to the case where the viscosity of ground soil is taken into consideration, and thus the equivalent model was made up of the mass  $M$  of foundation structure, the spring constant  $k$  representing the elasticity of ground soil, and the damping coefficient  $c$  due to the viscosity of ground soil.

On the other hand, the dynamic energies dispersed from the vibrating structural body into the elastic and visco-elastic semi-infinite soil prism were analyzed respectively, and the dispersive effects of the ground soil was evaluated in appearance as a damping coefficient represented by a dashpot model analogous to viscous damping. From the results of some numerical computations it has been pointed out that the dispersive damping has considerably greater effect than the viscous damping, and that the compound effect tends to decrease the spring constant of ground soil and to increase, to some extent, the natural period of the present system.

There are some further problems to be investigated. The model for pure rocking vibration was directly obtained from the above-mentioned results for the vertical direction, and model for horizontal vibration supported horizontally by the side surface and base of a foundation structure was set up by applying the same idea as in the vertical direction. Finally, by combining these results the model of rocking vibration which was composed with the horizontal translation and the pure rocking has been set up and analyzed.

The results of a few numerical computations gave us some possibilities of application to the practical dynamic design of soil-structure system, but it is needless to say that the rough assumption in which the one dimensional model was set up statically should be reconsidered and discussed further.

Seismic Response Characteristics of Foundation Structures in Elastic Ground  
—Rigid Foundation Structures with Elliptic Cross Section—

By Hisao GOTO and Takashi AKIYOSHI

Proc. of JSCE, No. 177, pp. 21-32 (in Japanese).

Abstract

This paper deals with the seismic response characteristics of foundation structures in elastic ground, subjected not only to harmonic excitation but also to random excitation of a stationary random process. The structure is rested on a hard bed rock, horizontally supported by an elastic surface layer and is allowed to rotate about the axis which is the center line in the bottom surface of the structure. The seismic wave propagates vertically in the surface layer and excites the structure along the principal axes of the cross section. It is shown firstly that the frequency response of foundation structures is analitically obtained and is much affected both by the shape of the cross section and the dispersion of waves which gives the damping effect approximately proportional to the velocity. The unit impulse response function of this system is deduced by inverse transformation of the above frequency response function, and is used in the analitical expression of any kind of random excitation. Discussion is also made for the transient response of r.m.s. values of the displacement and velocity, correlation coefficients and the threshold crossing numbers for given levels, to Gaussian white process. It follows that the response r. m. s. values more rapidly fall into stationary states in the vibration along the major axis of the cross section than the minor axis.



## Liquefaction of Saturated Sand due to Cyclic Loading (I)

By Toru SHIBATA and Hiroshi YUKITOMO

Proc. J.S.C.E., No. 180, Aug., 1970, pp. 83-89 (in Japanese).

### Abstract

The phenomenon of the liquefaction of saturated sand in time of earthquake was analyzed by assuming simplified stress conditions. The results of this analysis were applied to the study of a cyclic triaxial shear test and the cyclic simple shear test conducted under fixed values of normal stress.

On the assumption that the occurrence of liquefaction in consequence of cyclic shear of saturated sand is a manifestation of the process in which the decline in effective stress due to the dilatancy of sand continues and approaches the state of failure, the number  $n$  of repetitions required for the occurrence of such liquefaction has been expressed in the form of function of the ratio of the cyclic shear stress  $\tau$  to the normal stress  $\sigma$ . The results of the calculation of this expression substantially agree quantitatively with the inclination of the test values representing the relation between  $\tau/\sigma$  and  $n$ . Thus, the postulate of this expression provides a logical explanation of the fact that the phenomenon of liquefaction is more likely to occur as the value of  $\tau$  increases and the value of  $\sigma$  decreases. One factor which governs the phenomenon of liquefaction is the density of sand. As to the effect of this factor, it has been concluded that variation of the two coefficients contained in the basic expression will suffice for the purpose. Since these coefficients are indices for expressing the volumetric change and dilatancy under isotropic pressure, they are to be determined by such factors as sand density, grain size and grain shape.

The data treated by this paper covers both triaxial and simple shear tests. The results of these two tests are noted to differ considerably from each other—for example, it is reported that, even for the same ratio of  $\tau/\sigma$ , the phenomenon of liquefaction was less likely to occur in the triaxial test than in the simple shear test. The authors believe this difference to be due to the fact that the region of shear is limited in the triaxial test, while the sand specimen is deformed throughout in the simple shear test. In consideration of the development of a soil testing method in connection with the aseismic design of building foundations, the cause for such difference in the two methods of test awaits early elucidation.

## A Study on the Plastic Deformation of Elasto-plastic Structures in Strong Earthquakes

By Hisao GOTO and Hirokazu IEMURA

Proceedings of the Japan Society of Civil Engineers,  
No. 184, Dec., 1970, pp. 57-67. ( in Japanese).

### Abstract

In this study, the plastic deformation of elasto-plastic structures in strong earthquakes has been investigated by means of numerical simulation on a digital computer, since it is considered to have direct connection with the process of structural collapse during earthquakes.

First, to ensure generality of the analysis, the dimensionless representation of the equation of motion of a single-degree-of-freedom system with arbitrary restoring characteristics has been derived.

Both bi-linear and modified Jennings' restoring forces have been taken into account for the hysteretic characteristics of structures, and a random process generated as an artificial earthquake was adopted for the excitation.

A technique to control the hysteresis loops during random response has been developed by using upper and lower boundary force curves and used for the modified Jennings' system.

The plastic deformation has been defined as a moving average on the time axis of the displacement response by which the elastic component has been eliminated.

Discussions have also been made as to what cases would make the plastic deformation grow large by reference to nondimensional parameters showing the intensity and duration of excitation, rate of nonlinearity of hysteresis loops and the natural frequency of structures.

In these discussions, it has been emphasized that the plastic deformation grows very large in cases where the rigid structures with strong rate of nonlinearity are subjected to earthquakes whose predominant period is longer than the natural period of the structure.

Through this study the authors have found that the moving average technique is a powerful method for analyzing the stability of hysteresis loops and the process of structural collapse during earthquakes.

**Experimental Studies on the Large Plastic Deformation of Frames  
Due to Horizontal Impact**

—Measurements of Impact Loading and Vertical Load Effect—

By Minoru WAKABAYASHI, Taijiro NONAKA, Koichi MINAMI  
and Michio SHIBATA

Bulletin of the Disaster Prevention Research Institute, Kyoto University,  
Vol. 20, Part 4, No. 181, March, 1971, pp. 245-266 (in English).

**Abstract**

An experimental study was made on the nature of the large permanent deformation of columns in a portal frame with a single bay and storey, under horizontal impact loading. The column specimens were made of mild steel, aluminum alloy or copper plates. The beam was made of a metal block to be rigid as compared with the columns, and was repeatedly used.

Preliminary tests were first carried out, and portal frame specimens were subjected to impact loads at their column tops, and the load-time relation was observed by using the piezoelectric effects of barium titanate ceramics. It has been found that the loading system adopted in this study can be considered to give a purely impulsive load, and that the overturning moment considerably affects the final plastic deflection of the frame tested.

Another series of experimental studies was then performed, in which portal frame specimens fixed to a bifilar pendulum were subjected to impact motion at the column base, and the acceleration-time record of the input was taken by an accelerometer. This impact could also be regarded as purely impulsive.

Static loading tests were also performed in order to investigate the restoring-force characteristics. The importance of the over-turning moment due to the beam weight was confirmed, though the axial forces of the columns were less than 2 per cent of the yield limit axial force.

The theoretical predictions based on an analysis which approximates the frame-restoring-force characteristics to be bi-linear with a negative second slope agreed well with the experimental values of the final plastic deflection for the aluminum alloy and the copper specimens. For the mild steel specimens the theory overestimated the deflection by about 20 per cent. The reason for this may be that strain-rate effects were ignored in the theory.

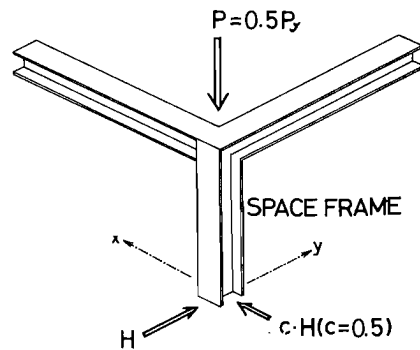
## The Elasto-Plastic Stability of Space Frames

By Minoru WAKABAYASHI and Haruhito OKAMOTO

Annals, Disaster Prevention Research Institute, Kyoto Univ.  
No. 14 A, April, 1971, pp. 333-341 (in Japanese).

### Abstract

As to the load-carrying capacity and the behavior of frames, even if they are constructed three-dimensionally, they are treated as if they are constituted of plane frames. In this paper, the load-carrying capacity and the behavior of a space frame are studied when it deforms three-dimensionally. The frame is a three-dimensional elbow-type, consisting of two beams and a column of wide flange section. One of the ends of each beam is simply supported, and the end of the column is free to move. The beam-column joint is rigid. The axial force, of the column



is assumed to remain constant while the horizontal force, acting at the end of the column by which the column is bent biaxially, is applied. (See Fig.) This paper is composed of two parts. In the one part, the moment-curvature relations about each principal axis of H-section under constant axial force are computed. In this case, the moment-curvature relation about one principal axis is calculated in the condition of several values of constant moments about the other principal axis under the following assumptions.

- 1) The stress-strain diagram of the material is ideally elastoplastic.
- 2) Strain reversal is considered.
- 3) Residual stress is ignored.
- 4) Plane sections remain plane, and warping is neglected.

In order to consider strain reversal, the cross section is divided into small elements of area. The moment-curvature relations are given under the consideration of axial force and bending moments about two principal axes. In the other part, the frame is analysed. It is so difficult to solve the differential equations of the column of this frame directly, that in this paper the following method is introduced. The column is divided into several parts along its longitudinal axis, the vertical deflections in two directions of the end of the column and the horizontal force acting at the end of the column are assumed. The bending moments and twisting moment are then calculated and rotations about three principal axes at the top of the column are calculated. From the moments of the first part of the column division and moment-curvature relations, the curvatures are calculated. The deflections are given from integrating the curvatures and these operations are repeated along the column, and the deflection of the end of the column are determined. If these deflections are not equal to the assumed deflections, assumed deflections are adjusted. For a larger load, these operations are repeated. Then load-deflection curves are calculated. In consequence, the influence of biaxial bending and axial force of the column clearly observed.

## An Experimental Study on Centrifugally-Cast Steel Pipe to H-Beam Connections

By Minoru WAKABAYASHI, Ryoichi SASAKI and Yoshio KISHIMA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14, April, 1971, pp. 343-369 (in Japanese).

### Abstract

This paper presents some experimental results of a study on the strength and behavior of pipe column to H-beam connections under vertical load and horizontal load.

Three types of experiment were carried out. One type was a full-size model test, there were two test specimens of this type; one was tested under vertical load and the other under horizontal load. Similar tests were done on the 1/3-scale models, which had the same proportion as that of the full-size specimens. The third type of experiment was on the same scale but with a more simplified model consisting of a pipe column and tension side flange plate. There were 11 test specimens of this type, with the dimensions of the connections as parameters. The parameters chosen for the investigation were,

- 1) The thickness and the length of the thick wall portion of the pipe column at the connection,
- 2) The size of the ring stiffener, and
- 3) The thickness of the flange plate, which was always the same as that of the ring stiffener.

These specimens were tested under tension.

Conclusions drawn from the study are as follows.

- 1) The "tension type" test results showed that the strength and the deformation characteristics were much better in the connections with ring stiffeners than those without and that the size of the ring stiffener did not contribute very much to improving the load carrying capacity of the connections. The most important factor was the existence of the ring stiffener.
- 2) The thickness of the pipe column at the connection panel zone had considerable effect on the characteristics of the pipe column to H-beam connections, and the maximum load that a connection could carry was increased with the increase of the wall thickness.
- 3) For the connections without the ring stiffener, failure occurred at the end of the intersection of H-beam to pipe column to attain the maximum load carrying capacity of the entire connection.
- 4) Comparison of the results of the scaled model tests with those of the full-size model tests showed that the scaled model tests were reliable enough to reproduce the behavior of the real structure, and so were the more simplified "tension type" tests.

## An Experiment on the Behavior of a Steel Bar under Repeated Axial Loading

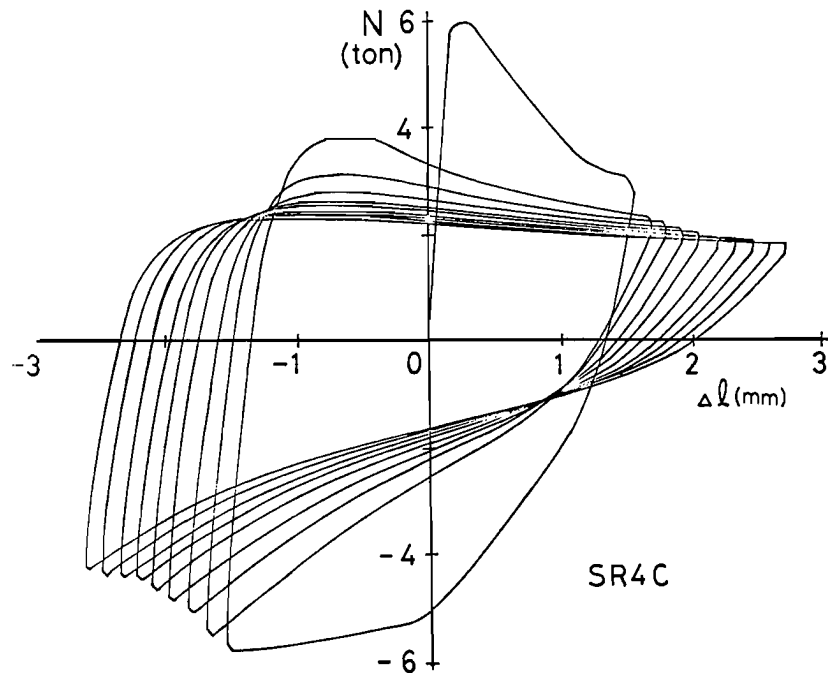
By Minoru WAKABAYASHI, Taijiro NONAKA, Osamu KOSHIRO  
and Noboru YAMAMOTO

Annals, Disaster Prevention Research Institute, Kyoto University,  
Vol. 14 A, April, 1971, pp. 371-381 (in Japanese).

### Abstract

The structural behavior of a braced frame greatly depends on the restoring-force characteristics of the bracings themselves. A bracing is primarily subjected to the axial force, tensile and/or compressive. This paper presents the results of an experimental study on the behavior of steel bars under alternate cyclic axial loading.

In the first series of tests, bars are monotonously compressed, the main attention being paid to their post-buckling strength. In the next series, bars are subjected to a number of cycles of compression and tension with gradual increase of the axial displacement amplitude. The axial load-displacement relations are recorded by an "Autograph" testing machine, and the hysteretic behavior that a buckled bar recovers its strength due to the subsequent tension is clearly observed, a typical behavior being illustrated in the figure.



**A Model Test of Reinforced Concrete Frames with Emphasis  
on the Shear Failure of Columns**

By Minoru WAKABAYASHI, Koichi MINAMI, Kunihiro ADACHI  
and Masami NAKAGAWA

Annals, Disaster Prevention Research Institute, Kyoto University  
No. 14 A, April, 1971, pp. 383-392 (in Japanese).

**Abstract**

In none earthquake regions, columns may not be subjected to large shear force. Consequently very little research has been done in Western countries. The 1923 Kanto Earthquake caused many shear failures in reinforced concrete columns. However there were very few studies even in Japan. In 1954, for the first time in Japan, M. Wakabayashi published a series of research articles on the shear strength of reinforced concrete and steel framed reinforced concrete columns. In 1968, considerable damage was observed in many reinforced concrete buildings due to the Tokachi-Oki Earthquake. From this experience, several recent investigators have started to study the behavior of columns under shear force. To prevent shear failure, the following methods are possible solutions.

- 1) Letting the shear capacity of the designing column larger than the maximum shear force determined from the plastic moments of the top and bottom of column sections.
  - 2) Designing columns for shear after knowing the elasto-plastic characteristics of shear failure and after knowing the ultimate situation of the frame.
- For such purposes, it is necessary to know the exact horizontal force-displacement relations of frames which fail in shear.

A preliminary test was performed for the study of the restoring-force characteristics of reinforced concrete frames consisting of columns which fail in shear. The tests included 6 single bay one-story frames subjected to a constant vertical load and a varying horizontal force, and 9 columns subjected to moment, shear and axial force. All specimens were of the same cross section (5 cm × 5 cm), and of the same column length (20 cm). The major variables were the percentage of web reinforcement and axial load. The experimental behavior was noted in detail.

## An Experimental Study on Shear Failure of Reinforced Concrete Columns Under Cyclic Loading

By Minoru WAKABAYASHI, Koichi MINAMI and Takeshi YAMAGUCHI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14A, April, 1971, pp. 393-416 (in Japanese)

### Abstract

The problem of shear behavior of reinforced concrete columns has been of particular interest in recent years, as a result of considerable damage observed in many reinforced concrete buildings due to an earthquake which took place in the offing of Tokachi on May 16, 1968. Most of the shear failure in reinforced concrete columns was the consequence of an underestimation of the values of the shear forces that were produced during the earthquake. That is by the use of crude methods of analysis for lateral loads. Although this fault is, at present, being corrected by certain requirements in the Building Code, it is felt that there is still a need for information regarding the effects on the strength and stiffness of reinforced concrete columns subjected to a low number of cycles of relatively high load. This is the purpose of the investigation presented here. It must be noted that the investigation was directed not only to determine the effect of cyclic loadings on the strength and stiffness of the members, but also to the restoring-force characteristics of members which failed in shear.

Forty specimens were tested with the following variables under cyclic and monotonous loading: (1) ratio of column length to column depth ( $h/D$ ); (2) percentage of web reinforcement ( $p_w$ ); (3) ratio of axial force to yield strength of column ( $N/N_y$ ). All specimens were of the same rectangular cross section (10 cm  $\times$  15 cm) and were designed so as to guarantee a failure in shear before flexural failure could develop. The loading apparatus was designed to meet the state of stress in actual columns. The experimental behavior was described in detail and was discussed with some qualitative conclusions obtained from the experiments.



An Experimental Study on the Elasto-Plastic Characteristics of Composite Members Using an Encased H-Section Subjected to Combined Bending and Axial Force

By Minoru WAKABAYASHI, Koichi MINAMI and Katsuhiro KOMURA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14A, April, 1971, pp. 417-437 (in Japanese).

Abstract

With the demand for super high buildings, the problems of stability and rigidity of such structures in the elastoplastic range of the material has increased in importance. Considering this situation in practice, a fundamental investigation was planned and conducted both experimentally and theoretically to obtain information on moment-curvature relationships of composite members under combined bending moment and constant axial force.

The experiments were carried out on four test specimens. The cross section (21 cm  $\times$  21 cm) adopted for the specimen was composed of an encased H-section with nominal reinforcement. The constant axial forces applied to these specimens were 0, 20, 40 and 60% of the yield load of the cross section. The bending moment was applied monotonously to the test specimen.

In the theoretical analysis, the moment-curvature-axial force ( $M-\phi-N$ ) curves were derived from the geometrical relationships of the member cross section and the stress-strain relationships of the materials, steel and concrete. Full composite action throughout the member was assumed. Also, a parabola was assumed for the elasto-plastic range of the concrete stress-strain curve, and a straight line for the plastic range. The tensile strength of concrete was neglected. For steel, a bilinear stress-strain relationship was used. By a numerical calculation,  $M-\phi-N$  curves were obtained.

Both experimental and theoretical results were presented in this paper and compared for values of ultimate strength and corresponding curvature. The comparison showed that the difference between the experimental and theoretical results was about 10% and 8%, respectively, for the values of the ultimate strength and the corresponding curvature. Thus,  $M-\phi-N$  curves obtained for the composite members studied turned out to be in good agreement with the results.

Studies on Lateral Buckling of Wide Flange Beams, Report No. 2  
 —Elastic Lateral Buckling Tests Using Plastics Models—

By Minoru WAKABAYASHI, Takeshi NAKAMURA, Hiroyoshi KOYANAGI  
 and Hiroshi SAWADA

Annals, Disaster Prevention Research Institute, Kyoto University,  
 No. 14 A, September, April, 1971, pp. 439-449 (in Japanese).

Abstract

In report No. 1, lateral buckling tests of SS41 steel wide flange beams in the inelastic range of material were presented. In this paper elastic lateral buckling tests were conducted using miniature plastics models. Test specimens were made of Acrylite sheet. All specimens consisted of three spans. The mid-span was to be observed and the side spans were to be loaded. Load was applied vertically at the ends of the side spans by weights. At the loading points and supporting points the specimens were laterally braced and were able to rotate in the vertical and horizontal planes without constraint. Eight specimens were tested. Test parameters were three testing spans (60, 75 and 89 cm) and three end-moment ratios (+1, 0 and -1). At the same time, numerical study was performed by means of finite difference methods in order to obtain the elastic lateral buckling load of beams. Many investigators have calculated the elastic lateral buckling load of simply supported beams under linear moment gradient by the energy method. Test results were plotted in Fig. 1 with the calculated values by the authors and other investigators.  $C$  in Fig. 1 was the coefficient estimating the lateral buckling load of beams under various moment-gradients. As a result,  $C$  in AISC specification would be practically applicable according to its simple representation and its reasonable agreement with experimental values. The lateral force exerted by the bracings in the tests was about 1~5% of the compression resultant force by the bending moment in the cross-section of beams.

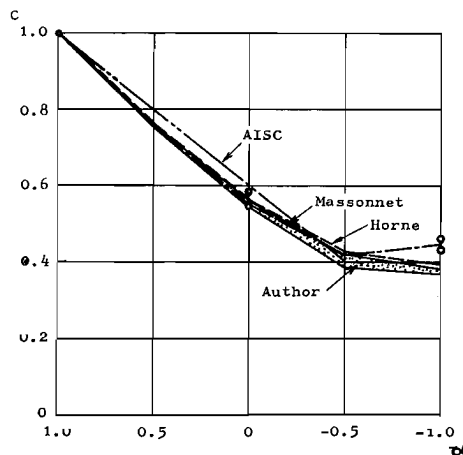


Fig. 1 Coefficient of lateral buckling stress ( $C$ ) vs End-moment ratio ( $\alpha$ )

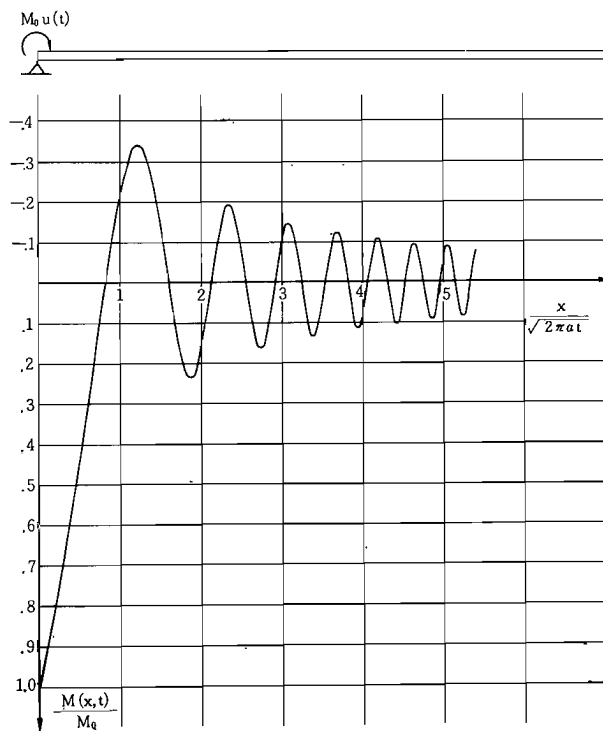
## Linear Response Analysis for a Slender Body Subjected to Gust Pressure

By Taijiro NONAKA

Proceedings of U. S. A.-Japan Research Seminar on WINDLOADS ON STRUCTURES  
held at University of Hawaii, Honolulu in October, 1970, pp. 219-231.

### Abstract

Frequent experience of local failures in buildings and structures due to wind action has motivated the author to investigate theoretically the transient response of a slender flexible body to locally applied dynamic loading. The beam is assumed to be semi-infinite with one end simply supported, and to have a linearly elastic property. A distributed load, a concentrated load or a couple, is taken to apply near the supported end. Closed-form solutions are obtained for the impulsive and step loading functions in terms of Fresnel integrals. An example of the results of the response analysis is illustrated in the figure.



## Rainfall Deposit on a Wall of a Building in a Storm

By Hatsuo ISHIZAKI, Yasushi MITSUTA and Yuji SANO

Bull. Disas. Prev. Res. Inrt., Kyoto Univ., Vol. 20, Part 2, No. 174,  
December, 1970, pp. 95-103 (in English).

### Abstract

Rainfall, driven by wind hitting the wall of a building, usually runs off rapidly. However, sometimes in a heavy rain storm, like a typhoon, the amount of rain water on a wall becomes too large to drain off and forced by wind pressure, it soaks through windows and walls to the inside of the building causing great damage.

Rainfall on the vertical wall of a building during a storm is studied. Raindrops in wind are carried horizontally at the speed of the wind; and they fall with a terminal speed determined by their size. The deposition efficiency of rain water on a building was estimated from analogy with the deposition of fog particles on an obstacle in wind, and was tested by field experiments. The field experiments show that the efficiency of deposition is about unity in the case of heavy rain and high wind and that the ratio of vertical and horizontal rainfall is proportional to the wind speed in heavy rain storms. The proportional constant is about 0.14, that is

$$Rw/Rh = 0,14 u$$

For practical purposes, design criteria for water protection of windows can be deduced from the relation obtained in such studies if we know the design values of rainfall and wind speed in critical conditions.

The extreme value in Japan for 10 min. rainfall is 56 mm; this was observed at Shionomisaki; maximum mean wind speed expected there is about 30 m/sec. Therefore, if we use the relation shown above, the maximum expected deposit of rain water on the wall will be about 23 liters  $m^{-2} min^{-1}$ . This value is much larger than the current Japanese design criteria for curtain walls, which is 4 liters  $m^{-2} min^{-1}$ .

## Disasters Caused by Severe Local Storms in Japan

By Hatsuo ISHIZAKI, Yasushi MITSUTA, Tatsuo MUROTA,  
Yuzo YOSHIKAWA and In Whan SUNG

Bulletin, Disaster Prevention Research Institute, Kyoto University,  
Vol. 20, Part 4, No. 180, March, 1971, pp. 227-243 (in English).

### Abstract

The occurrence probability of severe local storms in Japan is much smaller than that of typhoons. But such storms sometimes cause extremely severe damage to structures. The authors describe here the necessity of taking the wind effects of such severe local storms into consideration in the design of important structures such as atomic reactor plants.

Severe local storms, which cause damage in Japan, are Tatsumakis, thunderstorms and small whirlwinds. However, knowledge of the characteristics of these severe local storms is at present quite insufficient to be applied to the design of structures. The present authors therefore, propose a first approximation of the characteristics of such severe local storms from the survey of current knowledge and field studies of damage caused by a Tatsumaki and a thunderstorm which have occurred recently in the central part of Japan.

Tatsumakis in Japan are normally observed near ocean coasts (Pacific, Japan Sea or East China Sea). Even though their probability of occurrence at a given point is as small as  $10^{-6}$  per year and the area hit by them is very small, for example a hundred meter times a few kilometers, they sometimes cause severe damage in and around the area. An estimated wind speed of a Tatsumaki at Toyohashi described in this paper was more than 100 m/sec near the Tatsumaki center.

Small whirlwinds with about 10 m/sec of maximum rotating speed are reported to develop even in typhoon conditions on the coasts in the southern part of Japan, with a relatively higher occurrence probability than that of Tatsumakis.

Strong winds caused by thunderstorms may occur at any place in Japan. The probability of occurrence at a given point may also be as small as that of Tatsumakis. The characteristics of these plow winds are not well known, but the example given in this paper shows a maximum peak wind speed of 50 or 60 m/sec.

## A Wind Tunnel Test of Pressure Distributions on Box-Shaped Models

By Hatsuo ISHIZAKI and Junji KATSURA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 451-457 (in Japanese).

### Abstract

Wind pressure distributions on the surface of a rectangular cylinder model were measured in smooth and turbulent flow. Experiments were also made on box-shaped models with a square section. It was observed in the two dimensional model test that pressure distributions on the surfaces where reattachment of separating flow occurred, were affected by turbulence. In three dimensional test, suction on the roof surface became more uniform with an increase in the height of the model. In the case when the wind direction was not vertical to the windward surface, the pressure distributions were remarkably dependent on the wind directions. When the wind direction was  $45^\circ$  to the wall, vortices could not be seen on the side walls, while alternative pressure fluctuations were observed on the roof.

## The Influence of Adjacent Buildings on Wind

By Hatsuo ISHIZAKI and In Whan SUNG

Annals, Disaster Prevention Research Institute, Kyoto University.

No. 14 A, April, 1971, pp, 459-468 (in Japanese).

### Abstract

It is well known that wind speed is developed through channels and valleys. Suspension bridges, transmission lines and towers in such places have often been severely damaged. In recent years many tall buildings have been built. They cause funnel phenomenon similar to valleys and may produce strong wind between buildings.

A new problem other than wind loads on buildings, is the estimation of wind speed around buildings in relation to their dimensions. There are many problems to be solved on the wind distribution between buildings and in urban areas. The authors made a preliminary experiment on wind velocity distribution around several simple models by using a hot-wire anemometer in a wind tunnel. As a simple case, two solid models were placed parallel to the wind tunnel axis on the table in a wind tunnel. Changing the clearance of the two models, we made measurements of the increase and decrease of wind speed between them. Furthermore, the influence of the width and height of models on the velocity distribution were examined. The effects of the roughness of the ground surface has been left unsolved in this paper.

## On the Severe Storm and Damage at Hikone on September 15th, 1970

By Hatsuo ISHIZAKI, Yasushi MITSUTA, Tatsuo MUROTA  
In Whan SUNG and Yuzo YOSHIKAWA

Annals of the Disaster Prevention Research Institute, Kyoto University,  
Vol. 14A, April, 1971, pp. 469-480 (in Japanese)

### Abstract

Tatsumaki, thunderstorms and small whirl winds are known as severe local storms in Japan. They occur very rarely, their scale being smaller and the amount of damage caused by them less than that by typhoons. Sometimes however they do cause severe damage to structures, and their wind effects can not be ignored in the design of wind resistant structures. Especially in important structures such as atomic reactor plants, railways and electric power lines, much inconvenience may be caused, if they are damaged. Sufficient consideration must be given therefore to such severe local storms.

These phenomena are seldom caught by an observational network because of their scale and sudden occurrence. We do not have therefore sufficient knowledge concerning them. One way to understand them, however, is to examine the actual damage. We had such a chance after the storm at Hikone City on the 15th, September 1970.

This severe storm was a thunderstorm judging from the results of the field expedition. The duration time was as short as 5 minutes and the damage caused by wind extended in a small area of 2 km $\times$ 2.5 km. Several houses and other structures were severely damaged. Crops and trees were extensively defoliated or demolished. The analysis of wind effects on damaged structures led to the maximum wind speed estimate of more than 62 or 55 m/sec and less than 57 m/sec.

By summarizing the distribution and appearance of damage and estimating maximum wind speed, some useful data of thunderstorms in the design of wind resistant structures were given.



## Studies of a Tatsumaki at Toyohashi, Dec. 7th, 1969

By Hatsuo ISHIZAKI, Yasushi MITSUTA, Sumio KAWAMURA, Tatsuo MUROTA,  
Eiji KIMOTO and Makoto TAHIRA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 481-500 (in Japanese).

### Abstract

In the evening of Dec. 7th, 1969 a Tatsumaki caused severe damage in the city of Toyohashi, situated on the coast of Ise Bay in the central part of the Japanese main island. About 70 persons were killed or wounded and more than 100 houses were damaged. Moreover, the Tokaido and New Tokaido Lines of JNR and highway Route No. 1 connecting Tokyo and Osaka were effected producing indirect social disruption extending throughout the main part of Japan.

The authors have surveyed the characteristics of the Tatsumaki and damage to structures and have reported the results in this paper.

Buildings damaged appear along a strip about 50 to 200 m wide and about 4 km long. The Tatsumaki moved along the strip across the urban area of Toyohashi from SSW to NNE with an estimated speed of 30 to 40 km/hr.

The intensity of damage appears to change according to the difference of city features along the strip. It is worth noting especially, that in the city center of Toyohashi where high buildings are crowded, was very slight.

From the reports of many residents, the wind force of the Tatsumaki had a strong impact similar to explosions and the duration time was very short.

Wooden and steel structures were the most seriously damaged, reinforced-concrete buildings suffering damage mainly at openings. The general features of the damage were similar to those caused by the strong winds of typhoons, but severe local damage caused by heavy debris was also often observed.

Estimation of wind speed was made in several cases by analysis of wind-effects on damaged structures and a wind speed of more than 100 m/s was calculated near the Tatsumaki center. In comparison with the intensity of damage caused by past Tatsumakis, this one was not particularly strong but it had a comparable scale and intensity with past Tatsumakis. The characteristics of this Tatsumaki obtained by the survey may be considered to be a first approximation of Japanese Tatsumakis to be applied to the design of wind resistant structures.

## Turbulent Diffusion in a Road Tunnel

By Yasushi MITSUTA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 501-504 (in Japanese).

### Abstract

The diffusion process in a road tunnel of two way traffic is discussed. Even in calm conditions, the air in a road tunnel is quite turbulent owing to traffic. The traffic diffusion coefficient is estimated from the analogy of molecular motion. The diffusion coefficient is proportional to the product of the mean traffic speed and the mean path of a car passing by, e. i.

$$K_T = kS^2/N,$$

where  $K_T$  is traffic diffusion coefficient,  $k$  constant,  $S$  mean speed and  $N$  being traffic density.

The density distribution of pollutant contained in exhaust gass can be estimated by solving the diffusion equation,

$$E = \frac{eN^2}{2kS^3A}(L-X)X,$$

where  $E$  is the density,  $e$  the rate of pollutant production,  $A$  the area of the tunnel,  $L$  the length of the tunnel and  $X$  being the distance from the end of the tunnel. The maximum value of the density becomes,

$$E_{\max} = \frac{eL^2N^2}{8kS^3A}.$$

The constant  $k$  was estimated from the results of a pollution experiment in a road tunnel 600 m in length. The estimated value of  $k$  is about  $1.3 \times 10^{-4}$ . The traffic diffusion coefficient at the time of the experiment (the density of CO was 0.015%,  $S$ : 40 km/hr,  $N$ : 1400 cars/hr and  $L$ : 600 m) was about 300 cm<sup>2</sup>/sec and was about 3000 times as large as that of molecular diffusion.

## On the Real Time Analysis of the Characteristics of Atmospheric Turbulence

By Yasushi MITSUTA, Tatsuo HANAFUSA and Tokunosuke FUJITANI

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April 1971, pp. 505-511 (in Japanese).

### Abstract

In this paper, the outlines of the analog data analyser system to estimate mean value and standard deviation of wind speed and wind direction measured by a sonic anemometer are described.

This system consists of four main parts, they are, vector synthesizer converts the velocity component signal from a sonic anemometer into total wind speed and wind direction, a mean-meter unit to obtain mean value through a low pass active filter with cut off frequency of 0.0044 cps (which is nearly equivalent to 100 sec moving average), sigma-meter unit to measure *rms* value of fluctuations of signals between 10 cps and 0.0044 cps and a recorder to record these values from the analog data analyser system every 30 sec.

The method used to estimate the standard deviation of wind fluctuations by using this analog data analyser system is discussed.

The results obtained by this analog system agree well with those by the usual digital analyzing method for mean value and standard deviation of wind speed and mean value of wind direction within the relative error of 5%, and for standard deviation of wind direction within 20%.

## Fluctuation of the Atmospheric General Circulation and Abnormal Weather (I)

By Ryozauro YAMAMOTO

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 513-522 (in Japanese).

### Abstract

The monthly mean fields of the atmospheric motions which are reasonably represented by the pressure fields can, in good accuracy, be expressed by the ultra-long waves with wavelength comparable to the earth's radius. It is rather convenient that fluctuation of the atmospheric general circulation is quantitatively treated in terms of the characteristics of the ultra-long waves. Year-to-year variation of the ultra-long waves in January derived from the monthly mean 500 mb geopotential pattern are presented for the last 24 winters. A significant tendency can be found in time series of the waves of wavenumber 2 such that the amplitude increases at  $60^{\circ}\text{N}$  and decreases at  $40^{\circ}\text{N}$ .

Hemispherical distributions of anomaly of monthly mean air temperature in January for 7 years, from 1963 to 1969, show that temperature anomaly greater than  $10^{\circ}\text{C}$  can be found somewhere in the northern hemisphere almost every year. The anomaly has a large-scale pattern along the latitudinal circle. That harmonics of the air temperature which are given by zonal harmonic analysis have close relationships with those of the ultra-long waves is suggested with some facts.

## Wind Damage and Wind Load Problems in Japan

By Hatsuo ISHIZAKI

Japan-US Research Seminar on Wind Loads on Structures, at Honolulu,  
Oct. 1970. (in English)

### Abstract

The Japanese people have been troubled with various natural disasters, such as typhoons, earthquakes, floods, droughts, etc., since time immemorial. Typhoons especially have frequently caused severe disasters in every part of Japan, and the frequency of typhoons is a serious problem. To investigate this problem, ancient writings are sometimes useful. Kyoto, populated since the 8th century, was the old capital of Japan for around 1000 years, and old information on storms in this area can be easily obtained from its historical documents. The author selected storms expressed by the word "strong wind" or "big wind" from classical writings, and found the averaged number of typhoons in the Kyoto area to have some regularity.

The next problem related to typhoon damage is on the topographical effects for the strength of winds. This problem is very complicated and has been left unsolved. Here the author only introduces and outlines the problem from the data on the damage distributions in the areas attacked by typhoons.

As to the actual conditions of structural failures, the investigations have been carried out through various approaches in the events of severe typhoons. Some concrete examples are given to clarify the character of wind damages. As a result of the above considerations, some counter measures for wind damages and subjects for a future study are discussed.

## Vibration of a Trussed TV-tower due to Wind

By Tatsuo MUROTA and Hatsuo ISHIZAKI

Japan-US Research Seminar on wind Loads on Structures, at Honolulu,  
Oct. 1970. (in English)

### Abstract

Wind effect measurement was made on a steel-trussed TV-tower 160 m high in the urban district of Osaka. The site of the tower is in the most built-up area of the city and buildings were crowded around the site although most not exceeding 30 m in height. The tower has square sections of  $14\text{ m} \times 14\text{ m}$  up to 100m and  $4\text{ m} \times 4\text{ m}$  up to 140 m, and has two look-out platforms clad with windows at heights of 90 and 95 m.

Velocity pressure at the height of 120 m and horizontal inclinations of the tower at the 75 m level were measured by a vane-type wind pressure gauge and two clinometers, respectively.

Spectral analysis was made for these data and the results are as follows:

- (1) The frequency of the tower vibration is about 0.7 cps, which is very close to the natural frequency.
- (2) The average inclinations of the tower were very small in comparison with fluctuating components.
- (3) Power spectral densities of the tower inclinations were calculated for the frequency range of  $3 \times 10^{-3}$  to 2 cps. A clear energy concentration was found at the frequency of 0.16 cps and 0.7 cps.

## Contributions of Rain Drops to Wind Effects in the Storm

By Yasushi MITSUTA

Japan-US Research Seminar on Wind Loads on Structures. Honolulu,  
Oct. 1970. (in English)

### Abstract

In most stormy conditions, high winds are accompanied by heavy rain. In such case the wind becomes a mixture of air and rain drops moving together. In this paper, the contribution of rain drops to wind effects are studied.

The most distinct contribution is the increase of air density caused by suspended rain drops. The increase of air density however, is negligibly small from a practical point of view, see Heywood (1955).

The second effect is the destructive action of the rain drop itself. As the response time of a rain drop is very small, the rain drop moves horizontally at the speed of a 1 sec gust or more at maximum. Even though its effective area is very small, the pulsive force of rain drop collision is not, as its density is 1000 times as large as that of air. Erosion of rain coating in a storm may be related to this effect.

The third effect is the seeping of rain water on a wall the inside of a building due to wind pressure. The amount of rainfall on a vertical wall was studied on an actual building. The results show that it is proportional to the product of the horizontal rainfall and the wind speed, and its proportional constant is nearly equal to the inverse of the fall speed of the rain drop.

**On the Earthquake Response of Structural Systems Considering  
Interaction Effects of Ground**

By Takuji KOBORI, Ryoichiro MINAI and Yutaka INOUE

Bulletin of the Disaster prevention Research Institute, Kyoto University,  
Vol. 20, Part 2, No. 175, December, 1970, pp. 105-125, (in English).

**Abstract**

In earthquake engineering, it is important and necessary to estimate reasonably the effects of the ground characteristics on earthquake responses of an above-ground structure. In this paper, the ground characteristics in an elastic range are represented as the dynamic ground compliance of a foundation on an elastic half-space, that means a force displacement transfer function of an elastic ground-foundation system. Supposing bilinear hystertic restoring force characteristics of an above-ground structure and an elasto-plastic boundary layer underneath a foundation, nonlinear transient responses of a ground-structure system subjected to horizontal ground acceleration excitations are analyzed in a wide parameter range. The random time functions obtained through a noise generator are used for this response analysis as ground acceleration excitations. As a result of the present study, it is pointed out that an interaction effect of the ground may act advantageously on a structural earthquake response in usual cases, while a disadvantageous effect should be considered in a case where large plastic behaviors of structures are anticipated during earthquakes.



## The Dynamical Ground Compliance of a Rectangular Foundation on a Viscoelastic Stratum

By Takuji KOBORI, Ryoichiro MINAI and Tamotsu SUZUKI

Bulletin of the Disaster Prevention Research Institute, Kyoto University,  
Vol. 20, Part 4, No. 183, March, 1971, pp. 289-329 (in English).

### Abstract

As a basic study in finding the effect of ground-structure interaction on the earthquake responses and the anti-seismic safety of structural systems, it is important to describe the dynamic properties of the sub-soil ground under the foundations of such structures.

Based on the wave propagation theory, this paper deals with the "Dynamical Ground Compliance (D.G.C.)" of a model of foundation-ground systems more realistic than those used in any previous studies on foundation vibrations, namely, a rectangular foundation resting on a viscoelastic stratum over a rigid half-space for cases where the vertical, horizontal, or rotational harmonic excitations act on the foundation. Defined in this paper as the transfer function describing the ratio between the dynamic complex displacement of a massless foundation and a harmonic exciting force, D.G.C. is a collective representation of the dynamic characteristics of the subsoil ground under a foundation. Its limiting expression in zero frequency results in the "Statical Ground Compliance", which means the inverse of the statical ground stiffness. It is assumed that the stratum is composed of a three-dimensional, homogeneous, isotropic, Voigt solid, and lies in welded contact with the supporting rigid half-space.

The analytical expressions of D.G.C. as well as the displacements at the ground surface are obtained through the multiple Fourier transformation technique in the double integral representation including an improper infinite integral. The poles of the integrand are the roots of the frequency equations connected with Rayleigh and Love waves. Detailed discussions on the properties of these free waves are also developed in relation to the attenuation and the resonance phenomena of the viscoelastic stratum. Some numerical calculations of D.G.C. as well as the equivalent coefficients of a Voigt model evaluated according to D.G.C. are given to clarify the effects of various parameters related to the frequency of excitation, the constants of the viscoelastic stratum, and the shape and size of the foundation.

Compared with the results of similar problems obtained in the authors' preceding works for a perfectly elastic half-space and stratum, the present study has led to several principal conclusions concerning the effects of energy attenuation owing to mechanisms of both wave radiation and internal dissipation, the comparison between the cases of a stratum and a half-space especially as to the resonance and energy attenuation phenomena, and the condition under which a stratum can be practically treated as a half-space.

**Vibrational Characteristics of Semi-Infinite Visco-Elastic Medium to Surface  
Excitations on a Rectangular Area (Part 3)**

By Takuji KOBORI, Ryoichiro MINAI and Kaoru KUSAKABE

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 253-262 (in Japanese).

**Abstract**

In order to evaluate coupled vibrations of structures on the ground, it is necessary to know the dynamical characteristics of the ground in the neighbourhood of the foundation. In this paper, we have investigated the vibrational behavior of an isotropic, homogeneous, semi-infinite visco-elastic ground subjected to the rotational harmonic excitations on a rectangular surface area, by using the treatment described in the preceding paper. It is assumed that the distribution of exciting force on the rectangular area is directly proportional to the distance from the axis of the rotation, i. e. the triangular distribution. The numerical results of the amplitude and phase characteristics of the displacement are shown graphically, along two principal axes of the rectangular area on the surface and along the depth below the center of the rectangular surface area. Comparing the dynamical characteristics for the vertical and horizontal excitation which was given in the preceding paper, the most remarkable results for the rotational excitation are summarised as follows:

1) In the case of static loading.

At the point distant from the excited area, the displacement is inversely proportional to the second power of the distance from that area for the rotational loading, though that is inversely proportional to the distance for the vertical and horizontal loadings.

2) In the case of dynamic loading.

(a) The displacement amplitude is a function of the exciting frequency for all case of the vertical, horizontal and rotational excitation. However, the variation of the frequency for the rotational excitation is greater than for the vertical and horizontal excitations.

(b) For the all excited types, the displacement amplitudes are a function of the width of the rectangular area, at any point on the surface of the ground, but they become independent of that width at any point along the depth where there is some distance from the excited area.

(c) For the vertical and horizontal excitation, the amplitude has remarkable maxima and minima at regular intervals which are concerned with the wave-length, along the axis parallel to the exciting force. But, for the rotational excitation, the maxima and minima of the amplitude hardly appears against the wave-length.

(d) When the ground consists of a visco-elastic medium, the farther the distance from the excited area is, the smaller the displacement amplitude becomes for the all types of the vertical, horizontal and rotational excitation.

Response Analysis of Elasto-Plastic Frame Structures  
with Ramberg-Osgood Characteristics

By Takuji KOBORI, Ryoichiro MINAI and Teizo FUJIWARA

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971. pp. 301-313 (in Japanese).

Abstract

To the aseismic design of middle or short height structures, we must give more consideration than to that of high rise building because of frequency characteristics such as structure-foundation interaction, strong plastic behavior, initial gravity effects, combined force interaction and so on.

The detailed response analysis of complex structural models with bi-linear hysteretic local joints, neglecting structure-foundation interaction, was studied in our previous paper considering the interaction between bending moment and axial force of these fixed local joints.

The object of this research is to establish a method for dynamic analysis of inelastic frame structures. The frame is considered to have two distinct structural elements; (1) girders loading at midspan with Ramberg-Osgood type hysteretic characteristics for moment-curvature relation, and (2) columns with Ramberg-Osgood characteristics for equivalent force-deformation relation defined by plastic work and by a yielding condition incorporating the effect of interaction between various forces and deformations at an arbitrary member section. Numerical structural models in this paper are three-story, single bay undamped frame structures which are composed of elastic columns and Ramberg-Osgood girders having lumped masses on each floor level. We analyzed these model structures loading vertically at the midspan of each girders, subjected to normalized nondimensional time function of Vernon earthquake acceleration record and obtain the following remarks.

(1) On the responses related to the comprehensive aseismic safety of structures like nondimensional relative displacement, the influence of initial gravity, that is, the initial force distribution effect is not so remarkable, but the responses corresponding to local aseismic safety such as nondimensional curvature of member section are much more influenced by the initial force condition.

(2) Before earthquake, bending moments of both ends of a girder loaded at midspan are antisymmetric, however, the difference between both end moments, decreases step by step due to repetition of plastic behavior until they have nearly the same moments with each other. Therefore, it is necessary to design such frame members to be sufficiently ductile for the ends of members and to be some what stronger for the middle of these members than static design strength.

**On the Statistical Aseismic Design Determining the Optimum Dynamic Characteristics of Structures (Continued)**

By Takuji KOBORI, Ryoichiro MINAI and Masahiro KAWANO

Annals, Disaster Prevention Research Institute, Kyoto University,  
No. 14 A, April, 1971, pp. 315-332 (in Japanese).

**Abstract**

This paper presents a design method to satisfy the optimum conditions for aseismic safety by making use of statistical techniques. The optimum conditions prepared in the previous paper are re-defined by the Lagrangian function which can be referred to the nonlinear programming problem. As one of the techniques in solving the nonlinear programming problem, the Unconstrained Optimization Method suggested by Carroll is also related here. The optimum conditions adopted in the example case are to limit non-dimensional displacements or ductility factors within the allowable value and to minimize the Performance Index which describes the degree of spacial uniformity of aseismic safety. The dynamic characteristics to be designed are expressed by the product of the stiffness distribution and the reference stiffness. Because the reference stiffness may be considered as a measure of cost and is derived from the constraint for the mean maximum response, it is possible to seek a dynamic parameter to minimize the cost function. To examine the validity of the method above, numerical calculation is executed for three-degree-of freedom, nonlinear, shear type system subjected to a stationary random input. As a result, the standard deviations of all stories coincide closely with the spacial average of them at the corresponding dynamic parameter which also makes reasonable the behavior of a linear structural system. From the similarity between the behavior of an elastic structure and that of an elasto-plastic structure, the design of a nonlinear structural system should depend on the property of a linear structural system. It is also found that the property of displacement response is similar to that of hysteretic dissipated energy. So, the energy response in a nonlinear region may be estimated from the characteristics of displacement response. From the above discussion, it is concluded that the statistical method presented here is also adequately applicable to the aseismic design of a nonlinear structural system.

**On Earthquake Response of Elasto-Plastic Structures  
Considering Ground Characteristics**

By Takuji KOBORI, Ryoichiro MINAI and Yutaka INOUE

Proceedings of the 4th World Conference on Earthquake Engineering,  
Vol. III, A-6, January, 1969, Chile, pp. 117-132, (in English).

**Abstract**

In this paper, the nonlinear earthquake response analysis of the coupled ground-structure system subjected to earthquake type excitations is carried out in order to evaluate the interaction effect of the soil ground on the response of a structure. The earthquake type random excitations in this analysis have a white spectrum and a finite duration-time. The coupled system consists of three models; an aboveground structure, an elasto-plastic boundary layer and a semi-infinite ground. In other words, the aboveground structure is idealized as a lumped mass-spring system with a bilinear hysteretic damping, the boundary layer near the periphery of the foundation mass is a very thin massless soil-layer where the plastic yielding occurs locally during strong earthquakes, and a semi-infinite ground is assumed to be a homogeneous, elastic half-space having dynamic ground compliance approximated by the rational function type, linear transfer function. All the nonlinear earthquake responses are expressed in the nondimensional form defined as the ratio of the relative displacement of each part of this coupled system to the elastic limit deformation of the aboveground structure. And the average and standard deviation of the maximum responses for an ensemble of earthquake random excitations are evaluated. As a result, it is found that the foundation with a boundary layer and a semi-infinite ground does accommodate the earthquake response of the aboveground structure to external energy arriving through the soil-ground.

**On the Optimum Aseismic Design Data of Multistory Structures  
Based on Earthquake Elasto-Plastic Responses**

By Binji HISATOKU and Takuji KOBORI

Proceedings of the 3rd European Symposium on Earthquake Engineering,  
Sofia, Bulgaria, September, 1970, pp. 14-18 (in English).

**Abstract**

For the purpose of obtaining the aseismic design data of tall elasto-plastic building structures, the earthquake responses of a large number of bi-linear elasto-plastic, multi-story shear type structural models are analyzed systematically.

The distributions of stiffness and shear strength of standard model are expressed in the form,  $\{\gamma_i\} = \{\beta_i\} = \left\{ 1 - \lambda \left( \frac{i-1}{n-1} \right)^\nu \right\}$  in which  $\lambda$  and  $\nu$  are variable structural parameters,  $i$  and  $n$  denote the number of mass and the number of the degree-of-freedom of the structural model, respectively.

On the other hand, the mass distribution is supposed to be uniform over the height. As regards the viscous damping characteristics, it is assumed that each structural model has 2% critical damping with respect to the fundamental harmonics. Also, it is assumed that the rigidity ratio of the second to the first branch of the bi-linear hysteresis loop is uniformly 0.2 over the height.

As regards earthquake excitation, the five typical waveshape functions of acceleration records are considered and the maximum amplitude of acceleration records is adjusted so as to give the same level of the average value of the maximum ductility ratios.

Defining the optimum distribution of shear strength as that giving rise to the uniform distribution of the maximum ductility ratio over the height, the following remarks are obtained based on this analysis.

- 1) The distribution of the maximum ductility ratio is strongly dependent on the distribution of shear strength whereas the distribution of the maximum relative displacement depends upon that of stiffness.
- 2) The increment of the average value of the maximum ductility ratios is almost inversely proportional to that of the average value of shear strengths.
- 3) For practical purpose, the optimum distribution of shear strength is presented by averaging the distribution of the maximum shear force, for various models having different distribution characteristics and period parameters and for five earthquake excitations.
- 4) Furthermore, the optimum distribution of shear strength is varied depending upon the level of the average value of the maximum ductility ratios.

## On Earthquake Response of Ground-Structure Systems

By Ryoichiro MINAI and Yutaka INOUE

Proceedings of the 3rd Japan Earthquake Engineering Symposium,  
November, 1970, pp. 41-48, (in English).

### Abstract

This paper presents earthquake responses of a ground-structure interaction system using a theoretical expression for a vibrational characteristic of a foundation on an elastic ground. That is, the displacement of a rectangular foundation on an elastic half-space excited by a harmonic force has been analytically and numerically expressed in the form of ground compliance which is a function of excitation frequency, and transfer characteristics of a foundation in swaying motion to applied horizontal force has been simulated in a transfer function of a rational function type. An idealized structural model considering ground-structure interaction was then obtained by combining a main structure of spring-mass system with a ground-foundation system represented by the above-mentioned transfer function. In addition, it was supposed that a foundation lies in contact with a massless, thin boundary layer having an elasto-plastic restoring characteristic on the elastic ground, since the ground surrounding a foundation would become excessively inelastic during an intense earthquake. This structural model was excited by a class of random ground motions and its elasto-plastic structural responses were discussed in detail. This paper is a part of the serial study on earthquake response analysis of a ground-structure interaction system and is mainly concerned with response characteristics of an elasto-plastic main structure in the relation to the frequency ratio of a main structure to a ground-foundation system, i. e. an index of the interaction effect of ground on structures.

## Foundation Vibrations on a Viscoelastic Multi-Layered Medium

By Takuji KOBORI and Tamotsu SUZUKI

Proceedings of the 3rd Japan Earthquake Engineering Symposium, 1970,  
November, 1970, Tokyo Japan, pp. 493-500 (in English).

### Abstract

On the basis of the elastic wave propagation theory, numerous studies have been recently made on the dynamic responses of foundations on the soil ground. Because of the complexities of the mathematics involved, this kind of analysis has been confined, with several exceptions, almost to cases of a circular foundation on a perfectly-elastic half-space. In the actual soil grounds under foundations, however, it is often observed that they have several layers each of which shows a somewhat dissipative nature. Moreover, most structures have usually a foundation of rectangular shape and seldom circular.

A three-dimensional, horizontally multi-layered, viscoelastic medium is investigated in this paper, which is devoted mainly to the determination of the "Dynamical Ground Compliance" in cases where a massless rigid rectangular foundation on the medium is subjected to the vertical, horizontal and rotational excitations. The general analytical expressions of the Dynamical Ground Compliance prescribing the relation between the foundation displacement and a harmonic disturbing force are obtained in matrix form suitable for computer analysis through the well-known "Thomson-Haskell technique" presented primarily for the computation of the dispersion of surface waves in the multi-layered medium. Including cases of a half-space and a stratum lying over a rigid half-space, both of which have been investigated in previous papers, their expressions correspond to the force-displacement transfer functions of a massless-foundation-ground system.

Considering the conditions of stresses and deformations of actual soils underneath the foundation, the rigid foundation is replaced by an appropriate stress distribution of somewhat general form involving the uniform, the parabolic, and approximate static rigid base distributions. Because of such replacement the surface displacements in the loading area are not obtained in a uniformly distributed form. Thus, the displacement estimated according to one of the following two ways is adopted as a representative foundation displacement; a method of estimating the displacement at a certain fixed point in the loading area and a method of estimating the average displacement over the loading area. The final expressions of the Dynamical Ground Compliance are represented in an improper, complex, infinite, double integral form, so that they must be evaluated numerically in the complex variable plane.

Several numerical examples are presented for an idealized two-layered medium of a Voigt solid. The variations of the Dynamical Ground Compliance with the distortional wave velocity ratio of two layers, the ratio of the surface layer thickness to the foundation half width, and the foundation shape are shown for the vertical and rotational excitations. An another example is calculated for an actual four-layered ground model whose properties have been determined through field measurements such as seismic prospecting.



## Numerical Analysis on Foundation Vibration by Finite Element Technique

By Takuji KOBORI and Shigeru SETOGAWA

Proceedings of the 3rd Japan Earthquake Engineering Symposium,  
November, 1970, pp. 501-508 (in English).

### Abstract

The dynamic characteristics of the soil medium beneath the foundation of structures have been studied based on the wave propagation theory for the elastic or visco-elastic medium. However, the soil medium in the vicinity of the foundation may behave inelastically during strong earthquakes.

Since the analytical treatment of dynamic problems for the inelastic medium seems, in general, to be difficult, this paper intends to apply the so-called finite element method to evaluating the dynamic response of the stratum lying over the rigid half-space subjected to harmonic loading in the finite surfacial region of the stratum. The stratum considered consists of the visco-elastic or the visco-elastic-plastic solid obeying von Mises' yield condition. Two types of loading are supposed, namely, the stress type and the displacement type for which the surfacial loading is given by a stress and displacement distribution, respectively. For simplicity, the plane strain state is considered.

Firstly, in the case of the Voigt type visco-elastic stratum, the dynamical ground compliance, which is defined as the complex amplitude ratio of displacement to force in the loading region, is studied for the two types of loading for each case of the translational and rotational excitations. As a result, it is found that the dynamic ground compliance evaluated from the stress type loading nearly coincides with those from the displacement type loading if the stress distribution in the former is prescribed by the distribution of constraining stress in the case of static displacement type loading.

Secondly, the development of the yielding zone from the neighbourhood of the surfacial loading region to the interior of the elastoplastic stratum is studied in detail for the two types of various static loadings. From the results, it becomes evident that the pattern of progression of the yielding zone is remarkably affected by the stress distribution beneath the foundation and that the degrading of rigidity due to yielding is small in the case of the uniform or triangular displacement type loading as compared with the corresponding stress type loading, particularly for the triangular distribution.

Finally, the dynamic response of the visco-elastic-plastic stratum subjected to the stress type harmonic horizontal loading is evaluated as the convergent response in the transient state. Although the calculation is made only for few cases, the results show that the finite element technique is an efficient method in solving the dynamic problems of the inelastic medium.

## Reliability Analysis of Aseismic Safety of Elasto-Plastic Structures Considering Random Fatigue

By Ryoichiro MINAI and Yoshiyuki SUZUKI

Proceedings of the 3rd Japan Earthquake Engineering Symposium,  
November., 1970, pp. 723-730 (in English).

### Abstract

In relation to the ultimate aseismic design method of building structures which guarantees the safety of elasto-plastic structures subjected to intense earthquakes in their ultimate, state the most important problem is how to evaluate quantitatively the aseismic safety of structures considering their dynamic behaviour during earthquakes and various random factors existing in both structure and earthquake excitations. It is suggested from low-cycle fatigue phenomenon of structural materials that the mechanical properties of structures more or less deteriorate from the cumulative damage due to cyclic behaviour of structures during earthquakes. Therefore, a general measure of the dynamic failure of structures taking account of their deterioration should be adopted for earthquake response. In this study the low-cycle fatigue failure criterion is considered in selecting a measure of dynamic failure of deteriorating elasto-plastic structures and is extensively a general measure of dynamic failures including the instantaneous deformation criterion, such as the ductility ratio capacity, to the cumulative energy criterion represented by the hysteretic energy capacity. Based on the linear damage theory, the damage rate function can be expressed as a continuous time function in terms of the ductility ratio response and its time derivative. On the other hand, the aseismic safety of elasto-plastic structures in ultimate state is statistically estimated in the form of reliability function by taking into consideration the low-cycle fatigue phenomenon. The reliability function means the probability of survival as a function of time and is a comprehensive measure of safety which can be explicitly evaluated by considering various effects of random factors existing in both structures and excitations on the safety of structures.

The statistics of the cumulative damage and the reliability function in the nonstationary random process are evaluated. An numerical example indicates, for a single degree-of-freedom, elasto-plastic, vibrational system subjected to the acceleration excitations represented by a stationary Gaussian white noise, that the reliability of structures is remarkably influenced by the type of low-cycle fatigue represented by an exponent and the static fracture ductility ratio as well as the intensity of the earthquake excitations. It is also found that the reliability function considering low-cycle fatigue decreases abruptly after a certain time-duration while the reliability function without considering fatigue does not show such a tendency. It is suggested that the above-mentioned critical time-duration may have significance in obtaining a pertinent ultimate aseismic design method of elasto-plastic structures when considering low-cycle fatigue.

A Statistical Method of Detecting the Damping Characteristics  
of Structures by Measuring Their Microtremors

By Takuji KOBORI, Ryoichiro MINAI and Yoshihiro TAKEUCHI

Proceedings of the 7th Japan National Congress for Natural Disaster Science,  
November, 1970, pp. 67-68 (in Japanese).

Abstract

In relation to the detection of the dynamic characteristics of actual building structures, we discussed previously several statistical methods for determining the physically realizable transfer matrix of a multi-degree-of-freedom system by understanding the statistical properties of the stationary input and output of the system. This paper deals with a simple, practical method for detecting the damping characteristics of usual building structures by using the statistical properties of their microtremors.

If the transfer matrix of a vibrational system is expressed in the modal representation, the detection of the transfer matrix is a problem of finding two sets of unknown parameters, which are the natural frequency and the critical damping ratio corresponding to each mode, so as to minimize the error functional defined by the sum of the square of difference between the prescribed output spectral density and the synthesized one expressed in terms of the unknown parameters and the elements of a known input spectral density matrix.

As in frequently encountered cases, if a structure is a slightly damped system and its natural frequencies are sufficiently separated from each other so that the input spectral density is approximately considered to be constant in the vicinity of each natural frequency and the spectral contribution of each mode to the total spectral characteristics becomes almost independent without overlapping those of the other modes, the problem is identical to the determination of the unknown parameters of a single-degree-of-freedom vibrational system subjected to white noise excitations by prescribing the output spectral density of the system.

In evaluating the spectral density of the observed microtremors of structures from their auto-correlation function with a finite integration-time, a pertinent window, which is multiplied by the auto-correlation function, is used in order to obtain the resolvability and stability of estimation. Since the effect of the window on the estimated spectral density appears as the weighted average of the true spectral density, the apparent critical damping ratio is usually overestimated as compared with the true critical damping ratio. In order to find the true critical damping ratio from the apparent one, the relation between the apparent and the true critical damping ratio are calculated in cases of the square window and Bartlett's window. By applying this method to an actual five-story steel structure, it is found that the value of critical damping ratio estimated by this simple method agrees with the value obtained by a usual vibration test.

## On a Model of Non-Linear Soil-Ground Supporting a Building Structure

By Ryoichiro MINAI

Proceedings of the 7th Japan National Congress for Natural Disaster Science,  
November, 1970, pp. 69-72 (in Japanese).

### Abstract

In relation to the earthquake response analysis of a building structure on a soft ground, it is important to find a reasonable model of the ground-structural system, depending on the properties of the foundation structure and those of the soft ground, because the aseismic safety of structures are influenced significantly by the dynamic behaviour of the soil-ground as well as the interaction between the structure and sub-soil during earthquakes.

At first, this paper discusses a discrete model of an elasto-plastic building structure supported by foundation piles in a soft ground, and also shows the outline of the method of dynamic analysis of such a ground-structure system subjected to intense earthquakes.

Secondly, this paper deals with a method for deriving a discrete model of a non-linear soil-ground by using the so-called finite element method. The soil-ground considered is a two-phase medium consisting of a non-homogeneous, anisotropic, visco-elastic-plastic solid and a visco-elastic fluid saturated in the pore space.

The stiffness, damping and mass matrices of an arbitrary element are determined by supposing the displacement field expressed in terms of joint displacement vector and by using the instantaneous elastic constant matrix, the viscous constant matrix and the density distribution in the medium.

The instantaneous elastic constant matrix is obtained by using the elastic constants for the elastic strain component, the yield condition considering the work-hardening for the plastic strain component, and the orthogonality condition of the plastic strain rate to the yield surface, and also by assuming that the plastic strain of the solid has no effect on the pressure of fluid. On the other hand, the viscous constant matrix is evaluated by considering the viscosity in the solid as well as the friction induced by the relative velocity between the solid and fluid.

It is shown that if the solid is isotropic and the yield condition is represented by a linear combination of the first order invariant and the square root of the second order invariant of the stress tensor, which is the case for the Von Mises type or the Mohr-Coulomb type yield condition, and if the work-hardening rule associated with the yield condition is of the Ramberg-Osgood type, a comparatively simple expression of the instantaneous elastic matrix is obtained.

## On Experimental Determination of the Dynamic Properties of a Structure

By Takuji KOBORI, Ryoichiro MINAI, Yutaka INOUE and Teruo KAMADA

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November, 1970, pp. 73-76, (in Japanese).

### Abstract

Based on the results of various dynamic tests of a high-rise building, we shall discuss the problems in experimental determination of the basic structural dynamic properties as the natural periods of vibration of all significant modes, the corresponding mode shapes and the amount of energy dissipation or damping associated with each mode. The building tested is a 26-story steel-frame building, about 110 m in height, 37 m square in plan, with two basements and supported directly on a firm ground.

The following quantities are measured and the basic structural properties are estimated for the first five translational modes along each principal axis of the building and the first three torsional modes.

- (1) Microtremors at each floor level for relatively small displacement.
- (2) Damped free vibration of the building to the maximum amplitude by man-excited power.
- (3) Transient response to the inertia force produced by a pendulum of 5 ton in weight, suspended from the center beam of the 25th floor and released with the constant initial deflection angle.
- (4) Steady state response to the sinusoidal exciting force produced by the eccentric masses of the vibration generator.

The structural properties estimated from these tests are different from each other and the determination of the amount of energy dissipation is especially difficult. These differences are mainly due to the magnitude, type, duration time and location of the exciting force for each test. These facts show that the results of various dynamic tests should be synthesized for the experimental determination of the dynamic properties of a structure, especially for a high-rise building with long natural periods and a small amount of energy dissipation.

Lastly, some analytical considerations are presented for a one-mass system coupled with a pendulum, and the qualitative agreement between the analytical and the experimental results is shown.

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#### Volume 14 (1964-65)

##### Part 1 (August, 1964)

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**Part 3 (March, 1965)**

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**Part 4 (March, 1965)**

Abstracts of Papers Published in 1964, and Obituary Notice of Prof. Susumu Tomotika.

**Volume 15 (1965-66)**

**Part 1 (October, 1965)**

No. 86 The Distributions of Damaged Houses and Strong Winds by Typhoons, by Hatsuo Ishizaki.

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**Part 4 (March, 1966)**

Abstracts of Papers Published in 1965.

## Volume 16 (1966-67)

### Part 1 (September, 1966)

- No. 104 Observational Study of Turbulent Structure of High Winds, Part 1, by Hatsuo Ishizaki and Yasushi Mitsuta.
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## Volume 17 (1967-68)

### Part 1 (July, 1967)

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- No. 120 Continuous Observations of the Ground Deformations Related to the Matsushiro Earthquakes, by Tokio Ichinohe, Michio Takada, Torao Tanaka, Masaaki Kato, Tamotsu Furuzawa, Makoto Koizumi and Masaru Yamada.

**Part 2 (October, 1967)**

- No. 121 The Structure of River Turbulence, by Shoitiro Yokoshi.  
 No. 122 Limnological Studies of Lake Yogo-ko (II), by Syoji Horie.  
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**Part 4 (March, 1968)**

Abstracts of Papers Published in 1967.

**Volume 18 (1968-69)****Part 1 (July, 1968)**

- No. 130 The Damage to Structures Caused by the Second Miyakojima Typhoon, by Hatsuo Ishizaki, Junji Katsura and Tatsuo Murota.  
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**Part 3 (February, 1969)**

- No. 141 Studies on the Sand Transport in Streams with Tracers, by Katumasa Yano, Yoshito Tsuchiya and Masanori Michiue.  
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**Part 4 (March, 1969)**

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**Part 5 (August, 1969)**

Abstracts of Papers Published in 1968.

**Volume 19 (1969-1970)****Part 1 (August, 1969)**

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**Part 2 (November, 1969)**

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- No. 159 Investigation of Microearthquakes —On Seismicity—, by Michio Hashizume.

**Part 3 (February, 1970)**

- No. 160 Investigation of Microearthquakes —On the Accuracy of Hypocenter Determination—, by Michio Hashizume.
- No. 161 Internal Waves in Lake Biwa (I) —The Responses of the Thermocline to the Wind Action—, by Seiichi Kanari.
- No. 162 Shear Strength of Sand under a Vibrating Load, by Toru Shibata and Hiroshi Yukitomo.
- No. 163 Forecasting of Atmospheric Stagnation in the Kyoto Basin, by Chotaro Nakajima.

**Part 4 (March, 1970)**

- No. 164 On the Flood Waves in a Prismatic Open Channel, by Tamotsu Takahashi.
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**Part 5 (August, 1970)**

Abstracts of Papers Published in 1969.

## Volume 20 (1970-1971)

### Part 1 (October, 1970)

- No. 168 Strain Steps and the Dislocation Fault Model, by Shuzo Takemoto.  
 No. 169 Aftershock Activity in the Vicinity of Kyoto, by Kennosuke Okano.  
 No. 170 Seismological Study on the Sakurajima Volcano (1) — Classification of Explosions and Some Characteristics of These Explosions —, by Kiyoshi Nishi.  
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 Errata to "Internal waves in Lake Biwa (I) — The Responses of the Thermocline to Wind Action —" Presented in Vol. 19, No. 161, by Seiichi Kanari.

### Part 2 (December, 1970)

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 No. 173 Investigation of Microearthquakes — On Earthquake Occurrence in the Crust —, by Michio Hashizume.  
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### Part 3 (March, 1971)

- No. 176 On the Oscillatory Flow in Turbulent Boundary Layers Induced by Water Waves, by Hideaki Noda.  
 No. 177 On the Nature of the Occurrence of Intermediate and Deep Earthquakes, 1. The World Wide Distribution of the Earthquake Generating Stress, by Kazuo Oike.  
 No. 178 Two-variate Exponential Distribution and Its Numerical Table for Engineering Application, by Masashi Nagao and Mutsumi Kadoya.  
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### Part 4 (March, 1971)

- No. 180 Disasters Caused by Severe Local Storms in Japan, by Hatsuo Ishizaki, Yasushi Mitsuta, Tatsuo Murota, Yuzo Yoshikawa and In Whan Sung.  
 No. 181 Experimental Studies on the Large Plastic Deformation of Frames Due to Horizontal Impact — Measurements of Impact Loading and Vertical Load Effect —, by Minoru Wakabayashi, Taijiro Nonaka, Koichi Minami and Michio Shibata.  
 No. 182 An Analysis of Strong Motion Accelerograms near the Epicenter, by Kojiro Irikura, Kazuko Matsuo and Soji Yoshikawa.  
 No. 183 The Dynamical Ground Compliance of a Rectangular Foundation on a Viscoelastic Stratum, by Takuji Kobori, Ryoichiro Minai and Tamotsu Suzuki.

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