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U. S. NAVAL TECHNICAL MISSION TO JAPAN
CARE OF FLEET POST OFFICE
SAN FRANCISCO, CALIFORNIA

14 January 1946

RESTRICTED

From: Chief, Naval Technical Mission to Japan.
To : Chief of Naval Operations.

Subject: Target Report - Earthquake Resistant Construction in Japan.

Reference: (a)"Intelligence Targets Japan" (DNI) of 4 Sept. 1945.

1. Subject report, dealing with Target X-12 of Fascicle X-1 of reference (a), is submitted herewith.

2. The investigation of the target and the target report were accomplished by Lieut. D.G. Radcliffe, (CEC) USNR, and Lieut. W.F. Reardon, (CEC) USNR, assisted by Lt.(jg) J.R. Thayer, USNR, interpreter and translator.

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30690

RESTRICTED X-12

EARTHQUAKE RESISTANT CONSTRUCTION IN JAPAN

"INTELLIGENCE TARGETS JAPAN" (DNI) OF 4 SEPT. 1945

FACICLE X-1, TARGET X-12

JANUARY 1946

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

MISCELLANEOUS TARGETS

EARTHQUAKE RESISTANT CONSTRUCTION IN JAPAN

Organized study of seismology in Japan dates from the TOKYO Bay earthquake of February 1880, which resulted in the formation of the Seismological Society. This organization, with the aid of the newly invented seismographs, continued its work over a period of about twelve years.

In 1891, after the MINO-OWARI earthquake, the Earthquake Investigation Committee was organized with financial aid from the government. The efforts of the committee were directed toward the study of applied seismology, including observations of the damage resulting from major earthquakes both at home and abroad.

The Earthquake Research Institute and the Earthquake Investigation Council were organized with increased funds from the government after the great KANTO earthquake of 1923.

Continued progress in the study of seismology and its applications to the field of construction has been encouraged by the government and the establishment of courses in geophysics and seismology at the larger universities.

The modification of the Building Law in 1924 by amendments setting up specific requirements intended to make structures more resistant to earthquake forces marked the first official efforts to mitigate the damage from such forces.

Certain standardized requirements and procedures for earthquake-resistant construction have been arrived at through extensive observations of the damage resulting from earthquakes. In addition, several important buildings have been used as field laboratories where careful measurements and observations have been taken to determine the behavior of the structures during seismic disturbances. The engineering schools have kept pace with modern methods of structural analysis and design as developed in America and Europe, and the Japanese engineer has access to a more than adequate supply of technical information on earthquake-resistant design.

This definite progress in the study and theory of earthquake-resistant construction is not reflected in the average type of construction to be seen in Japan, particularly not in dwellings and smaller structures. However, there are many examples of major structures which have been specially designed to be shock-resistant and which have successfully withstood earthquakes of major intensity with only superficial damage.

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REFERENCES

Japanese Personnel who Assisted in Gathering Documents:

Prof. M. KOBAYASHI - Professor of Architectural Design, Tokyo University of Engineering.

Dr. K. MUTO - Professor of Structural Engineering, Tokyo Imperial University, Dept. of Architecture.

Dr. T. TANIGUCHI - Professor of Structural Engineering, Tokyo Imperial University, Dept. of Architecture.

Japanese Personnel Interviewed:

Dr. R. SANO - Honorary Professor of Engineering, Tokyo Imperial University. A pioneer in seismological study in Japan and member of the Earthquake Investigation Council.

Dr. T. NAITO - Dean of the Engineering Department, Waseda University. A pioneer in seismological study and earthquake-proof building design. Member of the Earthquake Investigation Council and author of various treatises on the subject of applied seismology and earthquake-resistant construction.

Dr. A. IMAMURA - Former Professor of Seismology at Tokyo Imperial University. A former member of the Earthquake Investigation Committee (organized in 1892 and disbanded in 1924) and instrumental in organizing the Earthquake Investigation Council and the Earthquake Research Institute, both established in 1924.

Dr. K. MUTO - Professor of Structural Engineering, Tokyo Imperial University, Dept. of Architecture. Authority on methods of analysis for earthquake-resistant building design.

Dr. T. TANIGUCHI - Professor of Structural Engineering, Tokyo University of Engineering. Specialist in the study of the vibration of structural frames of buildings.

Prof. H. FUTAMI - Professor of Structural Engineering, Tokyo University of Engineering.

Prof. K. MINAMI - Professor of Structural Engineering, Waseda University, Tokyo.

INTRODUCTION

The investigation of the subject of shock proof construction, as covered by this report, included the following specific items: (a) the historical background of earthquake-resistant construction and seismological study; (b) progress of seismological study, the development of design practices and construction methods; (c) steps toward standardization of procedures and requirements for earthquake-resistant building construction; (d) research on building vibration and earthquake-resistant construction; and (e) present status of shock resistant design and construction in Japan.

In attacking the problem, key personnel in the fields of seismology and structural engineering were contacted. Conference interviews were held with these key personnel at which the specific items were discussed. Treatises on the subject and reports on research investigations prepared by the Japanese personnel were collected and included in this report as enclosures.

The photographs included in this report were furnished by Prof. H. FUTAMI and were taken by him during an inspection of the damage resulting from the earthquake of 7 December 1944 and the after-shocks of 13 January 1945. The primary shock of 7 December was of approximately 30 minutes duration, exceeding by about 10 minutes the duration of the great KANTO quake of 1923.

THE REPORT

Part I
HISTORICAL BACKGROUND OF SEISMOLOGICAL STUDY IN JAPAN

The TOKYO Bay earthquake in February 1880 served as the impetus for the first organized study of seismology in Japan. A Seismological Society of about one hundred members was formed jointly by certain of the foreign residents and Japanese together with professors of the Imperial Colleges of Science and Engineering for the purpose of studying earthquakes.

At the second meeting of the Society in April 1880 John Milne and Sir Alfred Ewing explained techniques of the newly devised seismographs. These instruments were the fore-runners of the horizontal-pendulum type of seismograph, the invention of which was announced by Ewing in December 1880.

The Seismological Society, together with the Meteorological Observatory, continued their studies over a period of twelve years and published during that time sixteen volumes of transactions. The principal figures in the Society during its twelve year life were Milne, SEKIYA, and OMORI.

The MINO-OWARI earthquake of October 1891 resulted in the formation of the Earthquake Investigation Committee which was given financial support by the government. The original committee consisted of a president, secretary, and twenty-five members; and its object was to investigate methods by which the disastrous effects of earthquakes could be reduced to a minimum and to recommend measures which could result in general adoption of these methods.

Early research conducted by the Committee was mainly concerned with practical problems, including experiments with models and the shaking table. Visits were made by members of the committee to the scenes of major earthquakes abroad, including India in 1905 and Messina in 1908. Dr. SANO was sent to San Francisco after the great earthquake of 1906 and returned to Japan with much information on the superiority of properly constructed steel-framed structures and the newer reinforced concrete buildings.

The great KANTO earthquake of 1923 and the terrific loss of life and damage to property brought a request by the Committe for greater government support. This resulted in the formation of the Earthquake Research Institute and the Earthquake Investigation Council to replace the Earthquake Investigation Committee. At about this time the government added an article to the building code requiring that every building be constructed to resist a horizontal loading equal to 10% of the weight of the building. This was the first official specification of an earthquake coefficient governing earthquake-resistant construction in Japan.

The Earthquake Research Institute, now under the auspices of the Tokyo Imperial University, continued to receive increasing government support up to the advent of the war. During the war, however, the activities of the Institute were severely curtailed.

Part II
PROGRESS OF SEISMOLOGICAL STUDY AND DEVELOPEMENT OF EARTHQUAKE-RESISTANT CONSTRUCTION

The progress of seismological study in Japan from the organization of the Seismological Society in the year 1880 to the present time has been steady and of considerable magnitude.

Japan, with a mean annual earthquake frequency of about 4000, has been a fertile field for the study of seismology. The country, at the outbreak of the war, had a total of more than 160 seismograph stations. In addition, networks of precise levels had been established on which periodic checks were made for the determination of crustal deformations. From the theoretical point of view, SEZAWA'S mathematical investigations on the generation and propagation of different types of seismic waves, NAKANO'S mathematical investigation of seismic waves, and WADACHI'S observations of deep-seated shocks represent contributions of considerable importance to the field of seismology.

Continued progress in the study of seismology in Japan has been encouraged by financial aid from the government and by the establishment of full courses in geophysics and seismology at such universities as Tokyo Imperial University and Waseda University.

The development of earthquake resistant construction in Japan was at a slower rate than the progress made in seismological study. Not until after the great KANTO earthquake of 1923 were general construction methods improved to any great extent. The considerable improvement in construction methods from that time onward was brought about by amendment to the Building Laws. This amendment, encouraged by the Earthquake Investigation Committee, set up specific requirements for design and construction, viz: a seismic coefficient of 10% of weight of the building as a lateral force; wooden buildings limited to a maximum height of 42 feet; brick buildings limited a a maximum height of 42 feet; and other special requirements which are discussed in another section of this report.

Before the KANTO quake, the two principal sources of information in Japanese on the subject of earthquake-resistant design theory were "Earthquake-proof Construction of Buildings" by Dr. SANO and "Earthquake-proof Construction of Skeleton Structures" by Dr. NAITO. Since that time, the Japanese have adopted the modern methods of structural analysis, viz: the method of slope-deflection and that of moment distribution, for use in their calculations of earthquake stresses. Considerable work has been done by Dr. TAGUCHI and Mr. MIZUHARA on the subject of vibrations in building frames and the deflection of structures from earthquake forces.

NavTechJap Documents Numbers ND50-5200 and 5201, "Observations of the Damage to Structures Resulting from Major Shocks," (see Enclosure A) are illustrations of the type of study made by the Japanese in their efforts to mitigate the damage from earthquake forces.

Part III
STANDARDIZATION OF PROCEDURES AND REQUIREMENTS FOR EARTHQUAKE-RESISTANT CONSTRUCTION

By means of extensive observation of the damage resulting from earthquakes and through experiment and research on the subject, the Japanese have arrived at certain standardized requirements and procedures for earthquake-resistant construction. In setting up the standards, three principal types of construction were considered, namely: wood frame, brick or masonry, and rigid frame type employing structural steel or reinforced concrete.

In general, the wooden frame dwelling house in Japan has been built according to the practice which has prevailed for generations. In this type of construction, the walls are formed of strips of bamboo interwoven vertically and horizontally. The strips, where they cross each other, are tied together with straw rope and the woven mat of bamboo thus formed is plastered on both sides with mud to a total thickness of about 6 centimeters. The connections between post and beams or root members are made with a mortise and tenon joint in which the tenon is about one-third the thickness of the material.

In observing the damage to structures of this type, the Japanese have determined the approximate degree of failure resulting from shocks of different seismic intensities. For a seismic intensity of 0.1 gravity, the damage to wood framed structures of this type has been observed to consist principally of cracking of the plastered walls without injury to the main frames. However, a shock of this intensity has normally resulted in the collapse of brick fireplaces and chimneys in the houses.

When the seismic intensity reached 0.2 gravity, the damage was more severe, joints were loosened and crushed and partial collapse or inclination of the structure resulted.

With seismic intensity of 0.3 gravity, the majority of wood-frame dwellings have partially collapsed and as high as 15% have collapsed entirely. Two story houses of Japanese style are invariably collapsed by a shock of this intensity unless specially braced during construction.

A shock of an intensity of 0.4 gravity resulted in the complete destruction of almost all wood-frame houses of the typically Japanese type of construction. In one case, 50% of the houses of this type were totally destroyed and those remaining were displaced as much as 100 centimeters.

With special diagonal bracing and a light roof construction, instead of the ordinary heavy roof tile, the typical Japanese wood-frame dwelling house has been made to resist shocks of an intensity of as high as 0.4g without serious damage.

With respect to wood-frame construction, the Japanese Building Law now specifies the following limitations: (a) maximum height of 42 feet; (b) maximum height of eaves, 30 feet, thereby making a three-story building difficult to build; (c) roof tiles bracing or brackets.

With regard to brick or masonry bearing wall construction, it may be said in general that this type of construction followed the pattern set by Europe and America up to the time of the great KANTO earthquake of July 1923. However, owing to the great damage caused by that earthquake and the resultant amendment to the Building Law which was effected in July 1924, rigid requirements were set up which made that type of construction prohibitive for buildings of large size. The principal requirements for brick or masonry bearing wall construction as specified by the amendment to the Building Law are as follows:

1. Maximum height 42 feet instead of 65 feet.

2. Maximum height of eaves 30 feet instead of 50 feet.

3. The length of unsupported wall must not exceed 30 feet, instead of 36 feet, and the thickness must be 1.3 feet (minimum) for walls 18-30 feet long and 1.0 feet (minimum) for walls under 18 feet in length. Also, the minimum thickness of walls must not be less than 1/15 of the story height.

4. Bearing walls of brick or stone must be reinforced at the top with a rectangular, reinforced concrete beam.

5. A gable or parapet wall higher than 3 feet must be tied into the reinforced concrete roof by dowel bars.

Modern structures in Japan of major size and importance have been constructed with a rigid frame of structural steel or reinforced concrete, or of composite members employing both structural steel shapes and reinforced concrete. In the structural analysis of rigid frames, methods of analysis and design as developed in America and Germany have been adopted by the Japanese. Methods of analysis such as the theory of slope deflection and that of moment distribution have been readily adapted to the solution of frames subject to horizontal forces from earthquakes as well as ordinary vertical loading.

A special committee, appointed by the Architectural Institute of Japan, has published a guide for structural analysis and design, entitled "Standards for Structural Design". This book presents the current methods of analysis and design of modern rigid frame structures subject to earthquake forces as recommended by the Architectural Institute. A copy of this book, with translations of pertinent sections, has been forwarded to WDC as NavTechJap Document No. ND50-5202. However, the J.I.A. method of analysis of rectangular frames subjected to horizontal forces is considered of sufficient interest to include an explanation of the method in the text of this report. There follows an explanation of the J.I.A. method with appropriate references to NavTechJap Document No. ND50-5202.

METHOD OF ANALYSIS OF RECTANGULAR FRAMES SUBJECTED TO HORIZONTAL FORCES J. I. A. METHOD

(From: Chapter II, Section 14, of NavTechJap Document No. ND50-5202 (pages 178-202), "Standards of Design of Reinforced Concrete Structures." Published by the Japanese Institute of Architecture.)

A. Assumptions:

1. The horizontal forces are considered to act in the longitudinal and transverse directions separately.

2. The horizontal displacement of all columns at a given story is assumed to be equal for given horizontal forces. That is, the floor slab is considered as a rigid body that fixes the relative position of the column centers.

3. For frames in which the lower ends of the first story columns may be considered fixed, and the horizontal forces acting at each floor level approximately the same magnitude, the bending moments, shear, and direct stresses are to be computed by the following procedure.

B. Procedure for Analysis:

1. Determination of Shear Distribution in Columns - The shear is distributed to the columns of any story in proportion to the value of D from the formula:

$$D = ak_c$$

where: $a = \frac{k}{(2 + k)}$ in all stories except the lowest and: $a = \frac{(1 + \bar{k})}{(2 + \bar{k})}$

K_c = stiffness of the column = $\frac{I}{\ell}$

$\bar{k} = \frac{1}{2} \times \frac{\text{(sum of girder stiffnesses at top and bottom of column)}}{\text{(column stiffness)}}$
for columns of all stories except the lowest.

$\bar{k} = \frac{\text{(sum of girder stiffnesses at top of column)}}{\text{(column stiffness)}}$ for columns of the lowest story.

2. Location of Points of Contraflexure in Columns - The point of contraflexure of each column is to be determined from the formula:

$$y = (y_0 + y_1 + y_2 + y_3)$$

where: y_0 = Normal position of the point of contraflexure. (Which may be determined from the charts on pages 181 through 188 of ND50-5202).

y_1 = Correction for difference in stiffness of the girders framing into the column at top and bottom. (Omit y_1 for lowest story). Values of y_1 may be determined from the chart on page 189.

y_2 = Correction for difference in story height of story above the column being considered. (Omit y_2 for top story). Values of y_2 may be determined from the chart on page 190.

y_3 = Correction for difference in story height of story below the column being considered. (Omit y_3 for lowest story). Values of y_3 may be determined from the chart on page 190.

3. Determination of Column and Girder Bending Moments - The column bending moments are to be calculated from the column shears and determined points of contraflexure. The girder moments are to be calculated from the column moments at the joint being considered by distribution to the girders in proportion to their relative stiffness.

4. Determination of Girder Shears and Direct Stress in Columns - The girder shears are to be determined from the bending moments acting at the ends of the girders. Direct stress in columns is to be determined by algebraic summation of the girder shears starting from the top of the frame.

C. For frames in which the lower ends of the first story columns may be considered as fixed <u>and</u> in which the <u>stiffness of the members</u>, the <u>story heights</u>, and the <u>horizontal loads at each story</u> are <u>approximately the same</u>, the distribution of the shears to the columns and the location of the points of contraflexure in the columns may be computed as follows:

1. Determination of Column Shears - The shear in all interior columns may be considered the same at any one story. The ratio of distribution of shear between the exterior columns and inferior columns of any one story may be obtained from the chart on page 199, or from the table at the top of that page.

2. Location of Points of Contraflexure in Columns - The location of the points of contraflexure in the columns may be determined from the charts on pages 181 through 188.

where: $k = \frac{\text{Girder stiffness}}{\text{Column stiffness}}$ for exterior columns.

and : $k = 2 \times \frac{\text{Girder stiffness}}{\text{Column stiffness}}$ for the interior columns.

When the value of $\bar{k} = 1$ or greater, the points of contraflexure in the columns may be obtained from the table at the middle on page 199. (This table is reproduced below.)

Value of $\bar{k}$	Bottom story Columns	Intermediate story columns	Top story columns
Over 1 and up to 2	0.6 h	0.5 h	0.4 h
Over 2	0.5 h	0.5 h	0.5 h

D. When walled bents are provided at proper intervals in the frame and are interconnected by strong rigid floors, the value of D for each column and that of the walled bent may be taken from the range of values listed below:

Flexible frame (standard) - D = 1

Walled bent with openings - D = 10 or less (3-5)

Walled bent without openings - D = 15 or less (6-8)

E. Limitations of accuracy:

The accuracy of the J.I.A. Method increases as the value of k becomes larger. When the value of k equals 0.20 or less, the error becomes large and the frame should be analyzed by a more exact method.

(Note: NavTechJap Document No. ND50-5203, compiled by the J.I.A. from the construction plans of actual buildings designed as earthquake-resistant structures, is of interest from the standpoint of observing structural details employed by Japanese engineers and designers.)

Part IV
RESEARCH ON VIBRATIONS OF BUILDINGS AND EARTHQUAKE-RESISTANT CONSTRUCTION

The Japanese have, over a period of many years, conducted extensive research in the field of applied seismology. The various important universities, such as Tokyo Imperial University, Waseda University, Tokyo University of Engineering, and others on the islands of KYUSHU and HOKKAIDO, with chairs established in Geophysics and Seismology, have formed the nucleus for continuous study of the subject. Financial support by the government of such institutions as the Central Meteorological Observatory and the Earthquake Research Institute has been of prime importance in encouraging further research in earthquake-resistant construction. The government has also furnished financial support in the form of grants to individuals or organizations, such as the Japanese Architectural Institute, to conduct research on some specific problems in this field.

Certain buildings, for instance the MARUNOUCHI Building and the YURAKU Building, have been used as field laboratories and observations taken over a period of years with the seismograph by engineers and seismologists. In this way, valuable records and data on vibrations, both free and forced, of buildings before and after major earthquakes have been obtained. Close observations and measurements taken in modern framed structures such as those mentioned above have produced much information on the actual performance of such structures during an earthquake and the points of resulting critical damage.

Laboratory research with models on the shaking table and theoretical research in the field of the mathematics of vibrations and earthquake design calculations have been conducted extensively at the universities.

In connection with the study of vibrations from both the experimental and theoretical angles, Dr. T. TANIGUCHI and Dr. K. MUTO, of the Tokyo Imperial University, are considered among the leaders in this field. Transcripts of papers and reports of laboratory investigations prepared by these men have been forwarded to WDC via ATIS. These papers and reports are considered to be representative of the trend and quality of current research in the field of applied seismology and are designated as NavTechJap Document Nos. ND50-5204 to ND50-5219 inclusive (see Enclosure A).

Part V
PRESENT STATUS OF EARTHQUAKE-RESISTANT DESIGN AND CONSTRUCTION IN JAPAN

In discussing the present status of earthquake-resistant design, it may be said in general that this field has been highly developed in Japan. Structural engineers in Japan have access to a more than adequate supply of technical information dealing with modern methods of structural analysis as adapted to the solution of structures subject to earthquake forces. While it is believed that no entirely original methods of analysis have been developed by Japanese engineers, constant observation of the phenomena of seismic forces and study of the performance of actual structures subjected to earthquakes have given them an excellent background for dealing with the problems of earthquake-resistant design. The influence of European engineers and designers can be noticed in the willingness to place great reliance on the theoretical analysis of a structure in order to save material. The use of tabulated data and curves for the determination of critical bending moments has been encouraged except in the cases of very irregular or unsymmetrical structures.

There is great contrast in Japan between the average type of construction and that employed on important buildings which have been specifically designed to be earthquake-resistant. In spite of the high average annual earthquake frequency, the ordinary structure is no more earthquake-resistant than compliance with the bare requirements of the Building Law would make it. Wood-frame dwellings and other ordinary timber structures appear to be extremely flimsy according to our standards for similar types of buildings. However, in the case of important structures or those of major size, there are numerous examples of structures which have withstood major shocks with no more than superficial damage.

During the war, in order to conserve materials, the allowable stresses for concrete and steel were boosted as much as 85%. Other things being equal, the raising of the allowable stresses used in the design of a structure would amount to the same thing as a reduction in the seismic coefficient as far as the ability of the structure to resist earthquake is concerned. As a result of this conservation measure, wartime construction was, in most cases, extremely light as compared with pre-war construction.

To illustrate the ability of some typical wartime construction to resist an earthquake of major intensity, the following photographs are included in this report. These photographs were furnished by Prof. FUTAMI and were taken by him and others during an inspection trip following the earthquake of 7 December 1944 and the after-shocks of 13 January 1945. The epi-center of the primary shock was located at sea, approximately 150 miles south-east of NAGASHIMA. The principal damage from the earthquake itself was suffered in the area around NAGOYA, which is predominately an area of alluvial deposit. The primary shocks were of major intensity and of about 30 minutes duration. In addition to the damage from the earthquake, a tidal wave, reportedly about 10 meters high, did further damage to the coastal area between NAGASHIMA and KUSHIMOTO.

Figure 1

PARTIAL DESTRUCTION OF TIMBER-FRAME FACTORY BUILDING

Note column head in right foreground broken off just below brackets.

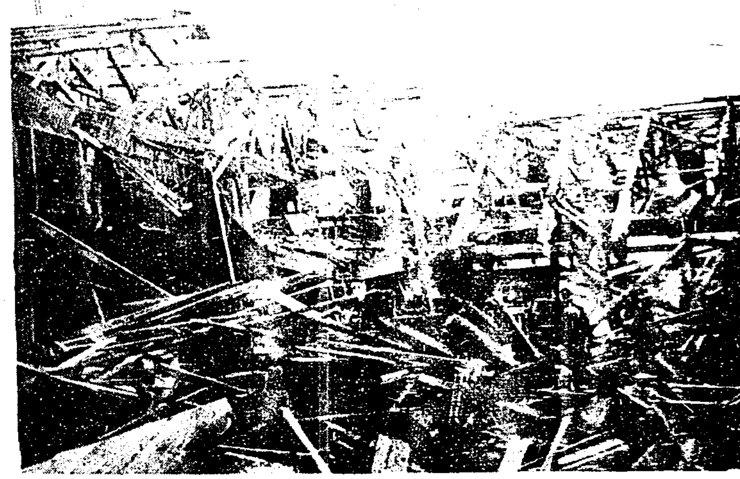

Figure 2

GENERAL DAMAGE AND PARTIAL COLLAPSE OF WARTIME TIMBER-FRAME FACTORY BUILDING NEAR NAGOYA

Note failure of columns which allowed roof trusses to drop.

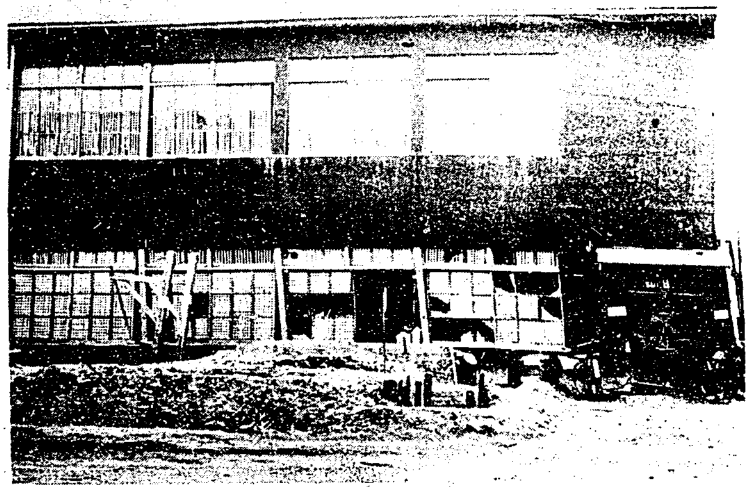

Figure 3

EXTERIOR OF TIMBER FRAME, STUCCO FINISH, FACTORY BUILDING SHOWING HORIZONTAL DISPLACEMENT OF STRUCTURE

Note paper stripping on window panes for shatter protection from bomb blasts.

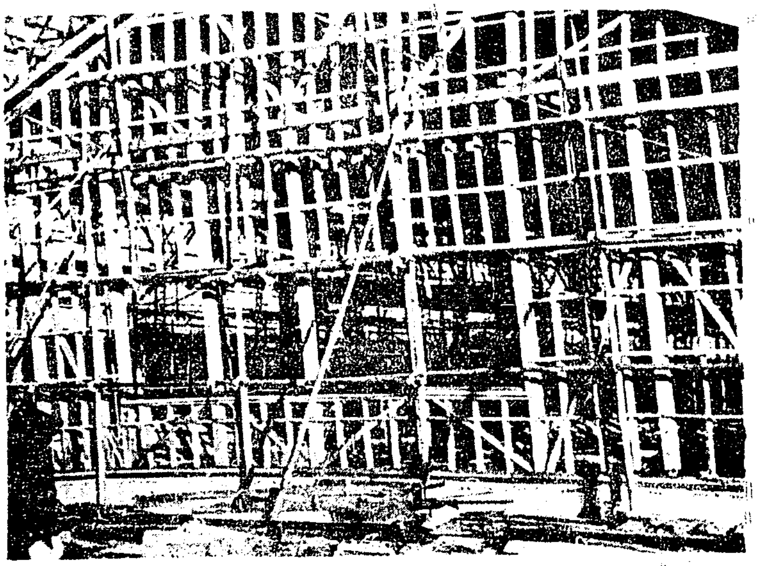

Figure 4

EXTERIOR OF END WALL OF PARTIALLY COMPLETED TIMBER STRUCTURE AT NAGOYA SHIPBUILDING CO.

Note horizontal displacement and unequal settlement of foundation wall.

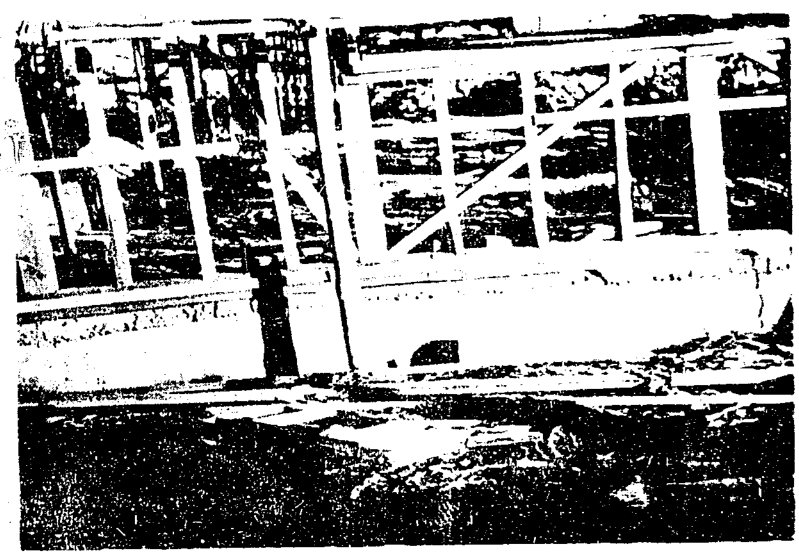

Figure 5

CLOSEUP OF FOUNDATION WALL OF STRUCTURE SHOWN IN FIGURE 4

Note large cracks in concrete resulting from unequal settlement.

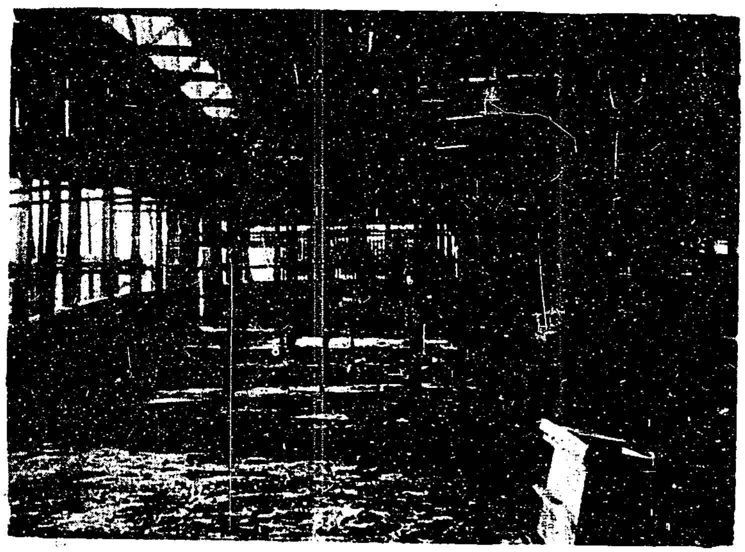

Figure 6
UNEQUAL SETTLEMENT OF FOUNDATIONS RESULTING FROM EARTHQUAKE
Note extremely light construction of this wartime timber structure.

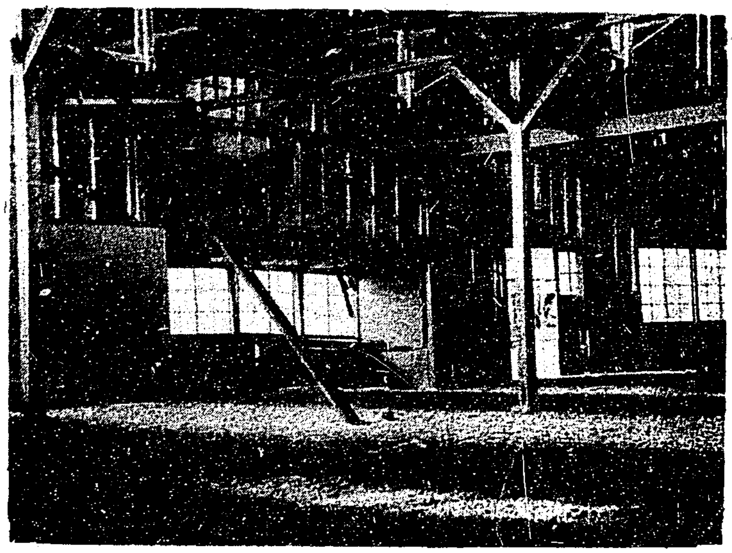

Figure 7
INTERIOR OF TIMBER STRUCTURE SHOWING UNEQUAL SETTLEMENT OF FOUNDATION UNDER END WALL OF BUILDING
Note detail of brackets at column head. See next photo for closeup of damage to concrete slabs in center background.

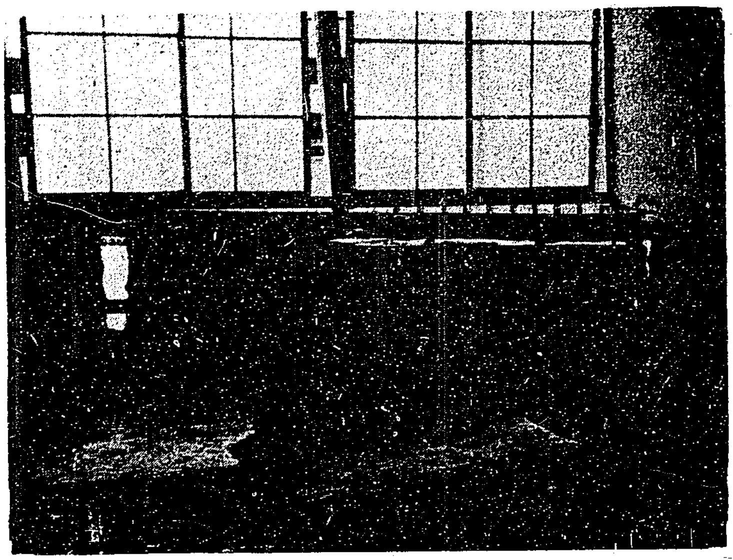

Figure 8

CLOSE-UP OF DAMAGE TO CONCRETE SLABS SHOWN IN CENTER BACKGROUND, FIGURE 7

Note extreme vertical displacement of floor slab and settlement of end wall foundation. Note also absence of reinforcing steel in slab and trough as well as in end wall itself.

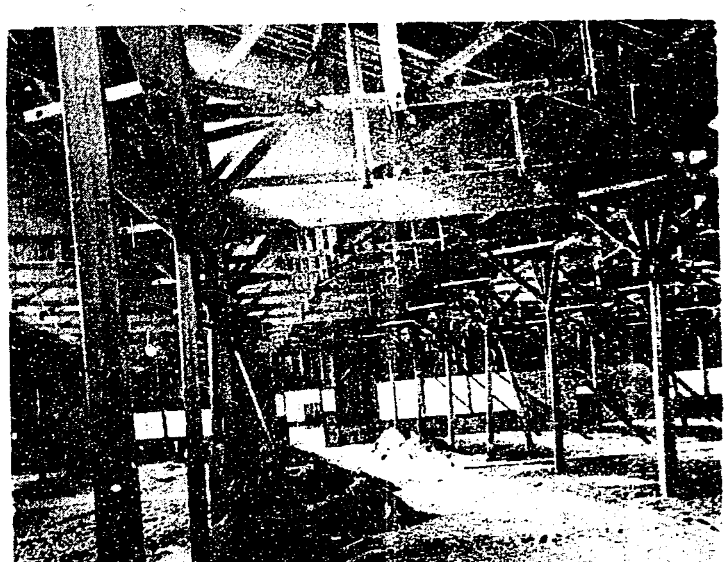

Figure 9

LINE OF COLUMNS AT LEFT ON NEWLY RECLAIMED LAND, COLUMNS AT RIGHT ON PREVIOUSLY RECLAIMED LAND

Note comparative settlement resulting from earthquake. Aichi Clock and Electric C

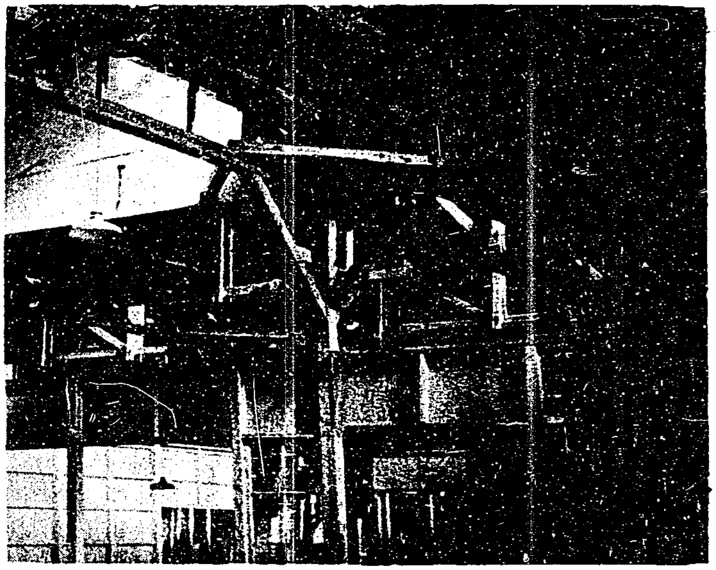

Figure 10

SPLITTING OF HEAD OF BRACKETED COLUMN RESULTING FROM HORIZONTAL DISPLACEMENT OF STRUCTURE

Steel dowel pin connection between column head and cap. No transverse bracing except brackets at column heads and light partitions without diagonal members. Aichi Clock and Electric Co., Nagoya.

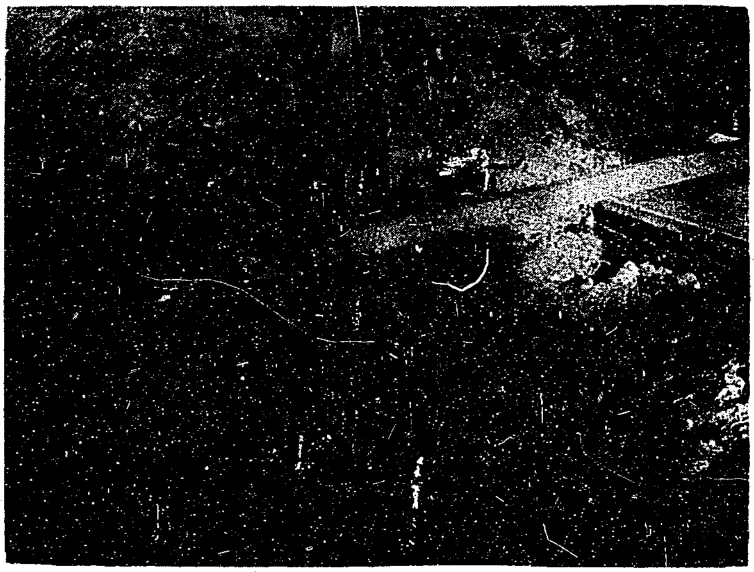

Figure 11

CLOSE-UP VIEW SHOWING SETTLEMENT OF COLUMN FOOTING

Top of footing found to be 7" lower than original level. Newly reclaimed land could not resist punching action of column footing during earthquake.

Figure 12

DAMAGE TO STEEL FRAME STRUCTURE RESULTING FROM HORIZONTAL DISPLACEMENT OF COLUMN FOOTINGS

Aichi Aviation Co.

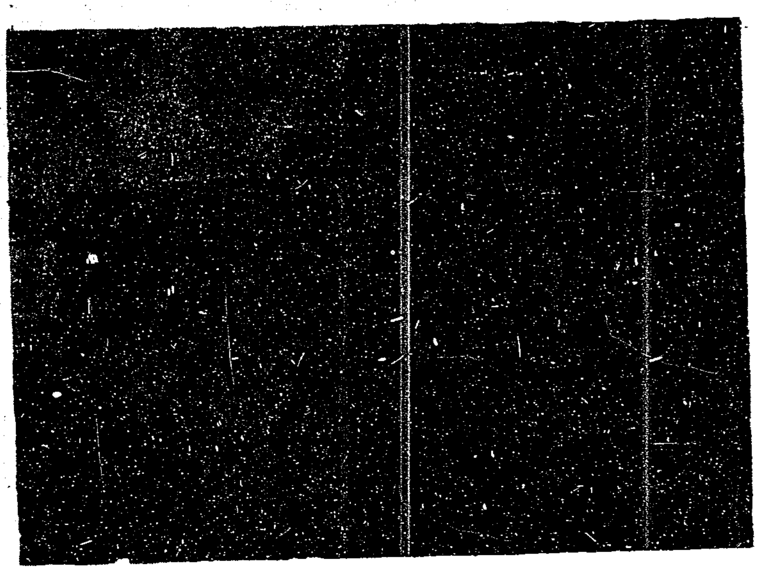

Figure 13

STEEL FRAME STRUCTURE SHOWING DAMAGE FROM UNEQUAL VERTICAL DISPLACEMENT OF FOOTINGS

Vicinity of NAGOYA but exact location unknown.

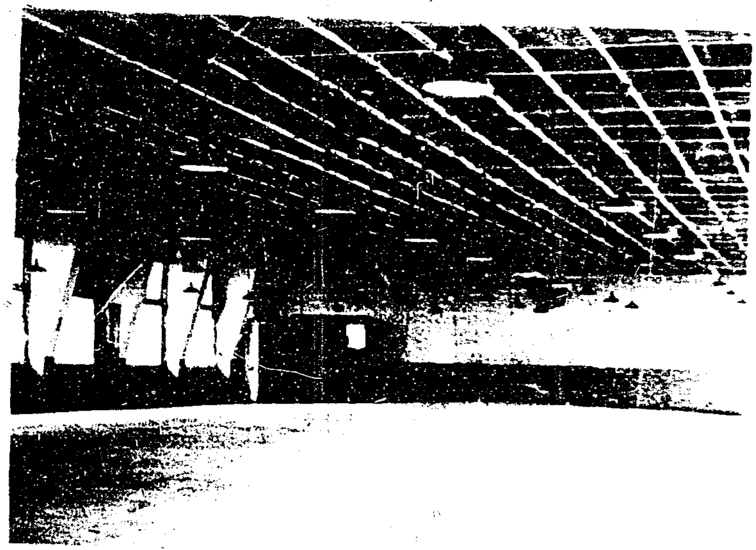

Figure 14

BULGING OF CONCRETE FLOOR SLAB

Prof. FUTAMI stated this was caused by actual upheaval of the earth and not by settlement of the wall foundations as no evidence of settlement could be observed.

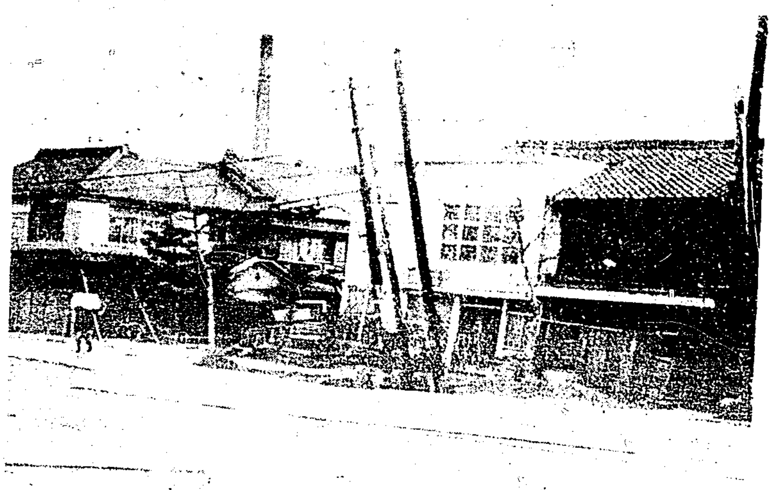

Figure 15

SETTLEMENT OF STREET CAUSED BY ITS SUBSIDENCE ALONG VERTICAL FAULT

Figure 16

SETTLEMENT OF COLUMN FOOTING

Soil unable to resist punching action of footing.

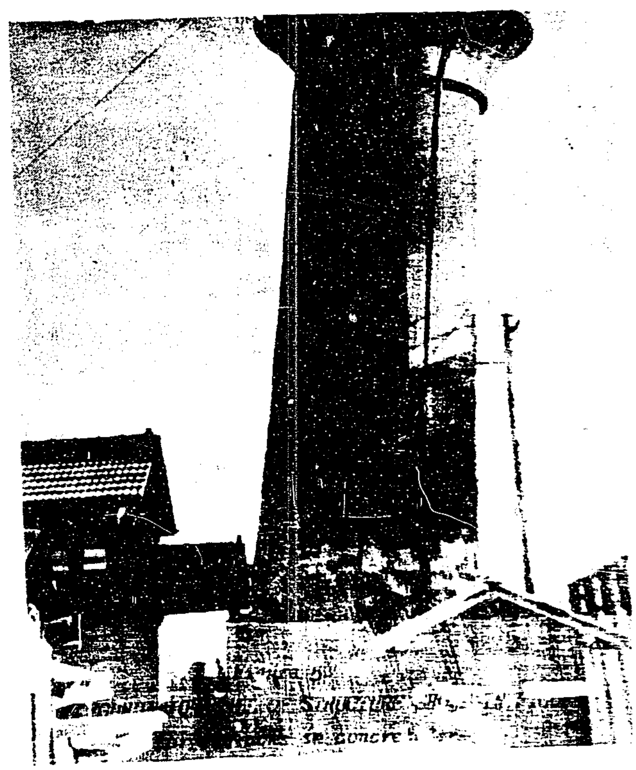

Figure 17

ELEVATED WATER TANK OF REINFORCED CONCRETE SHOWING INCLINED POSITION RESULTING FROM EARTHQUAKE

Note major crack at about 1/3 of height.
See following photo for close-up view.
Daido Steel Works.

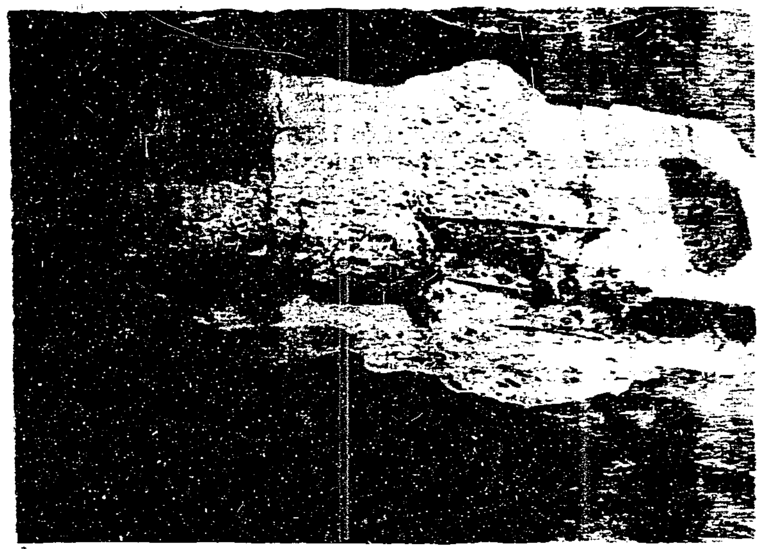

Figure 18

CLOSE-UP VIEW OF CRACK IN TOWER STRUCTURE OF ELEVATED WATER TANK

(See Figure 17)

From appearance, it is possible that construction joint had been made at this level without proper lapping of bars across the joint. However, no definite information is available on this point.

Figure 19

COLLAPSE OF CONCRETE WALLS AND STAIRWAY

Figure 20

FAILURE OF REINFORCED CONCRETE SPANDREL

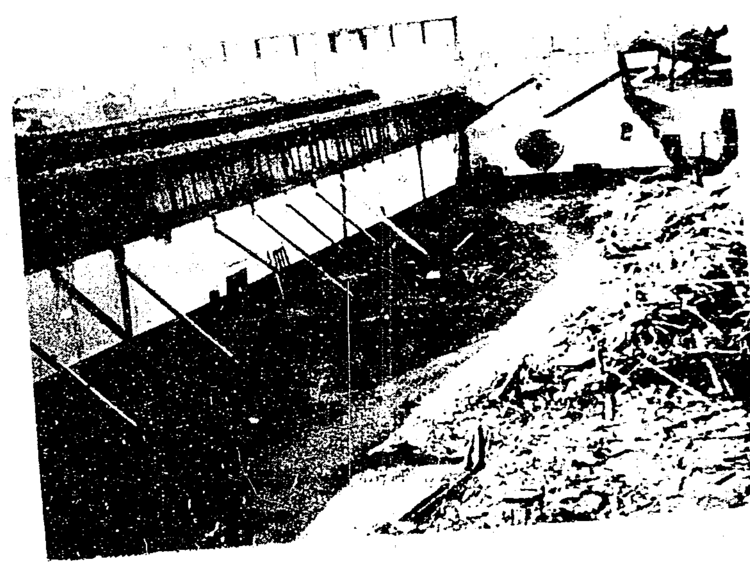

Figure 21

DAMAGE TO MASONRY STRUCTURE

Wood truss-roof construction completely collapsed, masonry walls sufficiently damaged to require razing.

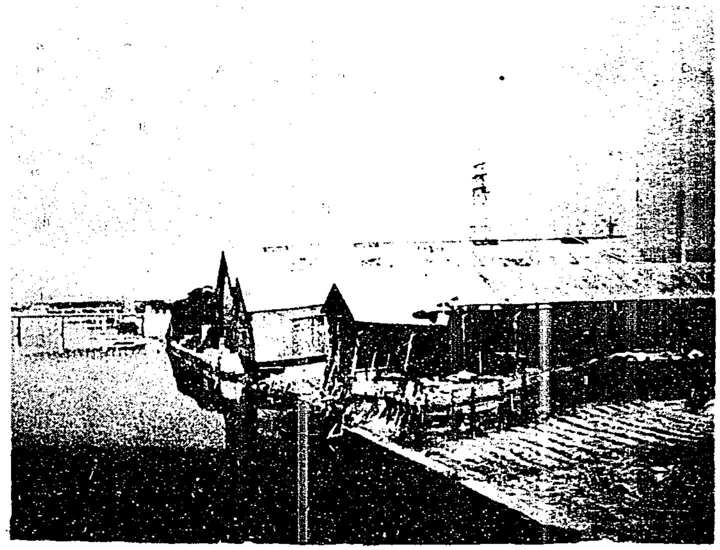

Figure 22

RESULT OF FAILURE OF MASONRY RETAINING WALL

Column footings of two end bents slipped toward canal

Figure 23

RESULTS OF COMPLETE COLLAPSE OF THE FIRST STORY OF A TYPICAL TWO-STORY COMBINATION STORE AND DWELLING

Structure in foreground is second story of original two-story building.

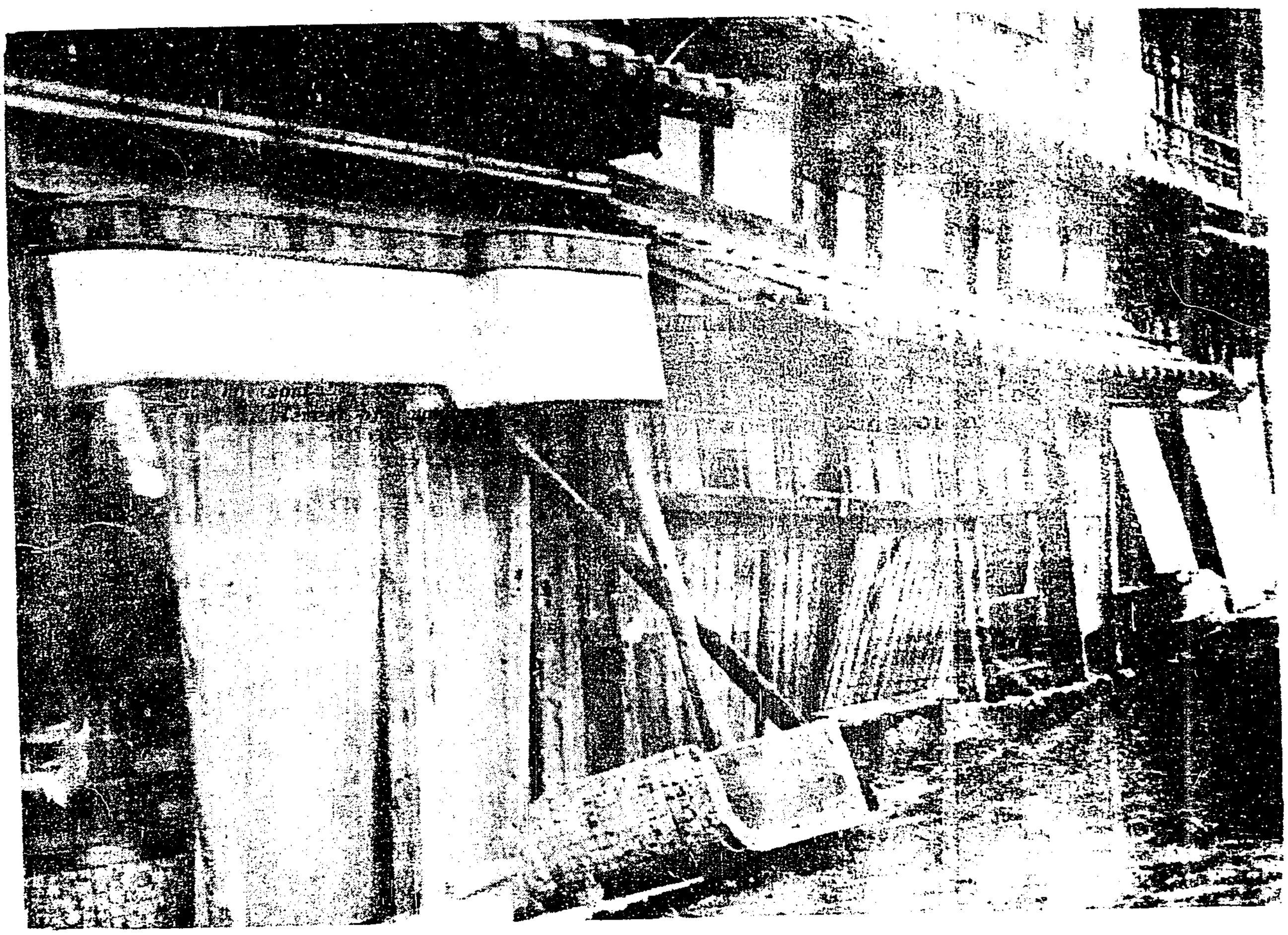

Figure 24

PARTIAL COLLAPSE OF TYPICAL WOOD-FRAME DWELLINGS

ENCLOSURE (A)

LIST OF DOCUMENTS FORWARDED TO
WASHINGTON DOCUMENT CENTER VIA ATIS

NavTechJap No.	Title	ATIS No.
ND50-5201	Observations of the Damage to Structures Resulting from the North-KANTO Earthquake (Sept. 1931). By: TAWABE, MUTO, KIYASHI, DOGI, ICHIMASU, ETSU-SABURO, TSUJII and SEIJI.	3539
ND50-5200	Observations of the Damage to Buildings in the IZU-SAGAMI Region Resulting from the IZU-HAKONE Earthquake of May 1931.	3538
ND50-5202	Standards of Design of Reinforced Concrete Structures. Published by the Japanese Institute of Architecture.	3540
ND50-5203	Typical Structural Details, Compiled from Actual Construction Plans by the Japanese Institute of Architecture.	3541
ND50-5204	Calculations of Bending Moments in Various Parts of a Rectangular Frame Subject to Horizontal Forces. By: Prof. K. MUTO.	3542
ND50-5205	Observations and Recommendations on Earthquake-Resistant Construction for Wood Frame Dwellings. By Special Committee of Earthquake Protection Council.	3543
ND50-5206	Standard Calculations for Steel-Frame Structures. By: T. NAITO, Pres. Japanese Institute of Architecture.	3544
ND50-5207	Theory of Vibration of Structures. By: Prof. K. MUTO.	3545
ND50-5208	A Study Relating to the Vibrations Along Three Dimensions of One-Story Structures of Special Shapes. By: Dr. K. MUTO, Tokyo Imperial University, and H. ASAGA, 10th Administration Section, Army Air Corps Headquarters. (April 1942).	3546
ND50-5209	Study of Vibrations of a One-Story Building Frame, Part I. By: Dr. K. MUTO and M. TAKAHASHI, Tokyo Imperial University.	3547
ND50-5210	Study of Vibrations of a One-Story Building Frame, Part II. By: Dr. K. MUTO and M. TAKAHASHI, Tokyo Imperial University.	3548
ND50-5211	Study of Vibrations of a One-Story Building Frame, Part III. By: Dr. K. MUTO and M. TAKAHASHI, Tokyo Imperial University.	3549
ND50-5212	Study of Vibrations of a One-Story Building Frame, Part IV. By: Dr. K. MUTO and M. TAKAHASHI, Tokyo Imperial University.	3550

ENCLOSURE (A), continued

NavTechJap No.	Title	ATIS No.
ND50-5213	Studies on the Rigidity of the Joints of Rigid Frames. By: Dr. K. MUTO, Tokyo Imperial University.	3551
ND50-5214	Experiments With Models in Regard to the Change in Plasticity of Rigid Frames. By: Dr. K. MUTO, Tokyo Imperial University.	3552
ND50-5215	Temperature Stresses on One-Story Rigid Frames. By: M. TAKAHASHI, Graduate Student, Tokyo Imperial University.	3553
	Studies in Regard to the Nature of Dampened Vibrations in Buildings. By: Dr. T. TANIGUCHI, Tokyo University of Engineering.	
ND50-5216	Dampening Effects in Wooden Structures.	3554
ND50-5217	Modulus of Dampening for Reinforced Concrete Structures.	3555
ND50-5218	Change of Periodic Time and Modulus of Dampening as Affected by Condition of Foundations of a Reinforced Concrete Building.	3556
ND50-5219	Dampened Vibrations in Steel-Frame Structures.	3557