1983 BUILDING TECHNOLOGY PUBLICATIONS

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Special Publication 457-8

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INTRODUCTION

This report presents the National Bureau of Standards' Center for Building Techology (CBT) publications for 1983. It is the eighth supplement to NBS Special Publication 457, *Building Technology Publications*, and lists CBT documents published during the period January 1 to December 31, 1983. It includes titles and abstracts of each NBS publication and each paper published in non-NBS media, key word and author indexes, and general information and instructions on how to order CBT publications.

This report communicates the results of CBT research to various technical audiences and to the general public. Publications constitute a major end product to CBT's efforts and, in 1983, appeared in several NBS publication series (Building Science Series, Technical Notes, Special Publications, NBS Interagency Reports, Grant/Contract Reports, and the Journal of Research) and media such as technical and trade publications. Publications listed as non-NBS media have each been assigned a five-digit number. NBS publication series abbreviations are:

BSS - Building Science Series
TN - Technical Note
SP - Special Publication
J. Res. - Journal of Research
NBSIR - National Bureau of Standards Interagency Report
GCR - Grant/Contract Report

This report is divided into three main sections. The first, *Titles and Abstracts*, provides the report title, author(s), date of publication, selected key words, and an abstract of each NBS publication and each paper published in an outside source. The *Author Index* cites each CBT author and gives the publication title and/or number referencing documents listed in this supplement. The *Key Word Index* is a subject index, listing word summaries of the building research topics for each publication and paper. By selecting a main word or subject, which are listed alphabetically, the user is able to locate reports of interest through the subject-related words found in the key word index.

CBT is part of the National Engineering Laboratory, National Bureau of Standards. NBS undertakes research in various areas. Interested readers will find other NBS publications listed in NBS Special Publication 305-15, *Publications of the National Bureau of Standards 1983*, from which parts of this report have been taken.

OBTAINING PUBLICATIONS

Most current CBT publications (excluding NBS *Interagency Reports and Grant/Contract Reports*) are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Microfiche and paper copies of most CBT publications may be ordered through the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161. Two other sources are depository libraries (libraries designated to receive Government publications) and Department of Commerce District Offices. The current price list and availability of publications listed in this report are given in Appendix C.

The depository libraries listed in Appendix A receive selected publication series of the National Bureau of Standards for general reference use. While every Government publication cannot be sent to all depository libraries, certain designated Regional libraries are required to receive and retain one copy of all Government publications made available either in printed or microfiche form. To obtain information on which publications are available, please contact the depository library in your area.

Department of Commerce District Offices are maintained in the cities listed in Appendix B. Their purpose is to provide ready access at the local level to publications, statistical statements, and surveys. Each District Office serves as an official sales agency of the Superintendent of Documents, U.S. Government Printing Office. These offices make available for local purchase a wide range of Government publications. The reference library maintained by each District Office contains many Government and private publications, periodicals, directories, reports, and other reference materials.

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TITLES AND ABSTRACTS

BUILDING SCIENCE SERIES

Building Science Series reports disseminate technical information developed at the Bureau on building materials, components, systems, and whole structures. The series presents research results, test methods, and performance criteria related to the structural and environmental functions and the durability and safety characteristics of building elements and systems.

BSS146. Fattal, S. G. **Evaluation of construction loads in multistory concrete buildings.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 146;* 1983 February. 139 p. SN003-003-02465-1.

Key words: concrete buildings; concrete casting; construction loads; construction standards; falsework; field measurements; flat plate; floor slab; formwork; instrumented shores; load measurement; multistory construction; shored construction.

Construction loads in a multistory flat plate concrete building were measured using strain-gaged metal shores and an analog recorder. The instrumented shores were placed within an interior bay of the third story under the formwork for the fourth story floor slab, and loads on the shores were measured continuously over a 24-hour period during the casting and partial curing cycle of that slab. The loads on some of these shores, when subsequently used as reshores in the same bay, were measured during an 8-hour period which included the casting of the fifth story floor slab. A time-lapse camera, operating synchronously with the load data acquisition system, gathered simultaneous photographic evidence of the construction activities during load monitoring periods. This report presents a complete documentation of the field data in compact form for subsequent use in related studies. The load data is interpreted and compared with construction load and design provisions of current standards.

BSS150. Kao, J. Y.; Sushinsky, G.; Didion, D. A.; Mastascusa, E. J.; Chi, J. **Low-voltage room thermostat performance.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 150;* 1983 April. 46 p. SN003-003-02478-3.

Key words: room temperature control; temperature controller; thermostat evaluation; thermostat modeling; thermostat test; two-position control.

To predict performance of low voltage electric thermostats in a dynamic building system, a computer model representing two types of thermal feedback was developed. Unlike the information obtained from existing test standards, this model allows thermostat performance to be determined under any load conditions. As input to the model, the basic parameters of thermostat performance were first identified and then determined experimentally in a controlled laboratory facility. The experimental results from the tests were used as input parameters for the simulation model. Based upon the results from the simulation model and test results on four commercially-available thermostats, a switch-feedback model computer simulation is recommended for studying low-voltage room thermostat performance.

BSS151. Simiu, E.; Leigh, S. D. **Turbulent wind effects on tension leg platform surge.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 151;* 1983 March. 46 p. SN003-003-02479-1.

Key words: compliant platforms; ocean engineering; offshore platforms; structural engineering; tension leg platforms; turbulence; waves; wind loads.

A procedure is presented for estimating surge response to turbulent wind in the presence of current and waves. The procedure accounts for the nonlinearity of the hydrodynamic forces with respect to surge and for the coupling of aerodynamic and hydrodynamic effects. It is shown that current wind spectra do not model correctly the wind speed fluctuations at very low frequencies and an alternative model of the wind spectrum, consistent with fundamental principles, is presented. The equation of surge motion under turbulent wind in the presence of current and waves is solved for typical tension leg platforms, and it is shown that under extreme wave conditions the damping provided by the hydrodynamic forces precludes the occurrence of significant wind-induced resonant amplification effects even if the drag coefficient in the Morison equation is very small (e.g., $C_d=0.1$). It is verified that for the platforms being investigated the use of a one-minute wind speed to represent the effect of the mean wind and of the turbulent wind fluctuations is acceptable for the purpose of estimating peak surge response.

BSS152. Gillette, G. **A daylighting model for building energy simulation.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 152;* 1983 March. 135 p. SN003-003-02487-2.

Key words: building computer simulation; building energy performance; clerestory performance; daylighting; skylight performance; window performance.

A computer model is outlined for estimating the annual energy performance of a daylighted building. The daylighting model is a system of FORTRAN subroutines designed for inclusion into larger building energy simulation programs such as DOE-2, BLAST, and NBSLD. Once incorporated into the main energy program, these subroutines will allow the existing program to account for the energy tradeoffs associated with natural illumination.

The daylighting model, DALITE, comprises three separate routines to do three separate functions. The first routine generates hourly sky luminances and sky illuminances as well as direct sun illuminance, taking solar radiation and sun position data as input. The second predicts interior daylight illumination at various points within a room due to any number of windows, skylights or clerestories. The last routine adjusts the electric lighting load (via photoelectric controls) in response to the available daylight. Unlike other daylighting estimation techniques, this model is a dynamic model designed to study how conditions change with time. It has a further advantage in that it can be easily installed into most existing models written in FORTRAN 77.

BSS154. Reed, D. A.; Simiu, E. **Wind loading and strength of cladding glass.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 154;* 1983 May. 49 p. SN003-003-02480-5.

Key words: aerodynamics; buildings; deformation; engineering mechanics; failure; glass; loads (forces); probability theory.

A procedure for investigating glass cladding behavior under arbitrary loads, including fluctuating wind loads, is presented. The procedure accounts for the fact that internal stresses are nonlinear functions of the external loads, that initial glass strengths are random functions of position and direction, and that glass strength undergoes degradation under the action of external loads in accordance with basic fracture mechanics laws. Numerical examples are presented, and corresponding probability distribution curves are calculated, indicating the probability of failure of a specified panel subjected to fluctuating wind loads and to 1-minute constant loads. These curves are used to illustrate a method for assessing current glass cladding design procedures. For the case considered in the paper, it was found that transformation of the peak wind load averaged over 1–2 seconds into an equivalent 1-minute load appears to underestimate the probability of failure of glass cladding. The work reported in the paper is part of an ongoing window cladding research program being conducted at the National Bureau of Standards.

BSS155. Domanski, P.; Didion, D. **Computer modeling of the vapor compression cycle with constant flow area expansion device.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 155;* 1983 May. 162 p. SN003-003-02500-3.

Key words: air conditioner; capillary tube; coil; compressor; condenser; evaporator; expansion device; heat pump; modeling; vapor compression cycle.

An analysis of the vapor compression cycle and the main components of an air source heat pump during steady-state operation has been performed with emphasis on fundamental phenomena taking place between key locations in the refrigerant system. The basis of the general heat pump model formulation is the logic which links the analytical models of heat pump components together in a format requiring an iterative solution of refrigerant pressure, enthalpy and mass balances.

The modeling effort emphasis was on the local thermodynamic phenomena which were described by fundamental heat transfer equations and equation of state relationships among material properties. In the compressor model several refrigerant locations were identified and the processes taking place between these locations accounted for all significant heat and pressure losses. Evaporator and condenser models were developed on a tube-by-tube basis where performance of each coil tube is computed separately by considering the cross-flow heat transfer with the external air stream and the appropriate heat and mass transfer relationships. A capillary tube model was formulated with the aid of Fanno flow theory.

The developed heat pump model has been validated by checking computer results against laboratory test data for full and part load operation for the cooling/dehumidifying mode as well as the heating mode under frosting conditions.

BSS156. Kusuda, T.; Piet, O.; Bean, J. W. **Annual variation of temperature field and heat transfer under heated ground surfaces (slab-on-grade floor heat loss calculation).** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 156;* 1983 June. 67 p. SN003-003-02511-9.

Key words: ASHRAE design values; building heat transfer; Delsante method; earth temperature; slab-on-grade heat transfer; soil temperature.

Seasonal sub-surface ground temperature profiles and surface heat transfer were determined for the condition whereby one and more than one region of the earth's surface temperature were disturbed. The analysis was conducted by numerical integration using a closed form solution based on the Green's function. Monthly profiles of earth temperature isotherms under a house of 20'×20' (6.1m×6.1m) floor area and under a ground of six houses near a wooded area are presented. The heat losses calculated from this approach for square slabs of various sizes were compared with those derived from the recent analytical solution of Delsante et al. resulting in good agreement.

The Delsante solution, which is based upon a Fourier Transform technique, is then extended to generate the frequency domain thermal response factors suitable for the periodic heat transfer calculation for multi-layer slab floors on grade.

In the appendix, this thermal response factor method was used to generate annual cycles of monthly heat loss from several slab floor constructions shown in the 1981 ASHRAE Handbook of Fundamentals. The maximum values of these monthly slab floor heat losses agree relatively well with the ASHRAE design values.

BSS157. Hyland, R. W.; Hurley, C. W. **General guidelines for the on-site calibration of humidity and moisture control systems in buildings.** *Natl. Bur. Stand. (U.S.) Bldg. Sci. Ser. 157;* 1983 September. 56 p. SN003-003-02529-1.

Key words: chilled mirror hygrometer; dew point temperature; humidity generator; humidity sensors; lithium chloride humidity sensors; moisture content of building air; relative humidity; saturated salt solutions; sensor calibration; sensor precision; specific humidity; wet-bulb temperature.

The control of the moisture content in the air in buildings directly affects the comfort of the building occupants and is one of the more important tasks of an energy management and control system (EMCS). Unfortunately, a lack of understanding of the principles of operation and calibration of the various instrumentation used in monitoring the moisture content of air often makes this one of the most difficult and most neglected tasks for those assigned the responsibility of maintaining and operating building heating, ventilating and air-conditioning (HVAC) control systems.

This report was written for the purpose of assisting the managers and operators of EMCS in buildings in the understanding and use of various techniques for on-site measurement of the moisture content in the air. In addition, various methods of on-site calibration of typical types of moisture monitoring instruments are also discussed.

The ideal gas law is reviewed because of its direct application in converting the various humidity units. Relative humidity and dew point temperature are defined and their relationship described. Typical types of moisture monitoring instruments are described together with their method of operation. Several calibration techniques are discussed together with their typical advantages and disadvantages. The last section of this report is devoted to the assessing and reporting of the errors or uncertainties associated with the calibration and functioning of various moisture monitoring instruments. This very important area is often neglected and can result in excessive operating and maintenance costs.

TECHNICAL NOTES

Technical Notes present data which are complete in themselves but are not as comprehensive in scope or as definitive in treatment of the subjects as reported in Building Science Series.

TN1113-3. Flynn, D. R.; Yaniv, S. L. **Highway noise criteria study: Relations among frequency rating procedures.** *Natl. Bur. Stand. (U.S.) Tech. Note 1113-3;* 1983 February. 57 p. SN003-003-02474-1.

Key words: acoustics; environmental pollution; highway noise; motor vehicle noise; noise; noise control; sound; traffic noise; transportation noise.

A series of calculations was performed to ascertain how well one frequency-weighted rating, such as weighted sound level, loudness level, or perceived noise level, may be predicted from another such rating. A total of 103 average sound level spectra, measured at several distances from different types of highways, were used in these calculations. It was found that knowing a single noise rating, such as the A-weighted sound level, enables one to predict other outdoor ratings in this set of 103 spectra with a standard deviation of the order of 1 to 2 dB. If, in addition, traffic speed and mix and the distance to the highway are taken into account, these standard deviations can be reduced to 0.5 to 1 dB, depending upon the particular noise rating of interest. Equations are given for predicting one rating from another; the associated standard deviations are presented as a measure of how well any given rating can be predicted from a single measured, or otherwise known, noise rating. It is concluded that it is not very critical which frequency-weighting procedure is used in conjunction with highway noise criteria since one descriptor can be predicted from another with a rather small statistical uncertainty. Thus, if human response criteria, or stimulus-response relationships, have been developed in terms of one frequency-weighting procedure, these may be translated into equivalent criteria expressed in terms of a metric that is easier to measure or predict.

TN1174. Treado, S.; Barnett, J.; Kusuda, T. **Energy and cost evaluation of solar window film use in an office building.** *Natl. Bur. Stand. (U.S.) Tech. Note 1174;* 1983 March. 127 p. SN003-003-02483-0.

Key words: building energy analysis; cooling loads; heating loads; solar film; solar heat gain; window management.

The impact of solar window film utilization on building HVAC system loads, energy consumption and costs, is examined for a typical office building. The evaluation includes characterization and measurement of important film properties, performance of single-glazing window systems with and without film, simulation of annual building energy performance using the DOE-2 computer program, and a life-cycle cost analysis. Six window film options are compared to clear glass performance for seven climatic regions throughout the United States.

Guidelines are developed for effective solar film utilization in office buildings, in terms of energy performance and cost-effectiveness. Results indicate that solar films can be effective in reducing building energy requirements and costs in areas with high cooling loads, with less savings expected in areas with lower cooling loads and higher heating loads, and no savings in regions with high heating loads.

TN1180. Howett, G. L. **Size of letters required for visibility as a function of viewing distance and observer visual acuity.** *Natl. Bur. Stand. (U.S.) Tech. Note 1180;* 1983 July. 72 p. SN003-003-02502-0.

Key words: acuity, visual; angle, visual; contrast; distance, viewing; letters; luminance; resolution, eye; signs; Snellen chart; stroke width; visual acuity; visual angle.

A formula is derived giving the letter stroke-width needed for legibility of words on a sign at any given distance by an observer with any given visual acuity. The stroke width, in turn, determines the letter size, depending upon the characteristics of the type face used. The derivation is strictly mathematical and is based on the assumption that beyond a distance of a few meters, a person's visual acuity is specifiable by a fixed visual angle, independent of the distance. The information implicit in the formula is also presented graphically, in four plots that apply to four different combinations of length units for measuring stroke width and viewing distance. Also presented are formulas and graphs for correcting the critical stroke width for nonstandard contrast or background luminance. These correction formulas are based on a body of data on visual acuity as a function of contrast and background luminance, and a formula fitting the mid-ranges of the data, both published recently by other researchers.

SPECIAL PUBLICATIONS

This series includes proceedings of conferences sponsored by the Center and other special publications appropriate to this grouping including project summaries, list of publications, wall charts, pocket cards, and bibliographies.

SP446-7. Raufaste, N.; Olmert, M., eds. **Building technology project summaries 1982–1983.** *Natl. Bur. Stand. (U.S.) Spec. Publ. 446-7;* 1983 June. 138 p. Available from: NTIS; PB 83-259622.

Key words: building research; building technology; criteria; codes; measurement and test methods; performance criteria; project summaries; technical bases.

The Center for Building Technology (CBT) provides the technical and scientific bases for criteria and standards that improve the usefulness, safety and economy of buildings. The Center's activities support building technology programs of the Federal, State, and local governments; assist design professions, building officials and the research community by providing criteria that improve buildings; and assist manufacturers of building products by developing criteria for evaluating innovative building materials. This report summarizes the Center's projects for calendar years 1982-83; it provides the reader with a broad overview of CBT's research.

SP457-7. Beavers, L., ed. **Building Technology Publications 1982—Supplement 7.** *Natl. Bur. Stand. (U.S.) Spec. Publ. 457-7;* 1983 June. 78 p. SN003-003-02503-8.

Key words: abstracts; building technology; Center for Building Technology; key words; publications.

This report presents NBS' Center for Building Technology (CBT) publications for 1982. It is the seventh supplement to NBS Special Publication 457, *Building Technology Publications,* and lists CBT reports issued during January 1-December 31, 1982. It includes titles and abstracts of each CBT publication and those papers published in non-NBS media, key word and author indexes, and general information and instructions on how to order CBT publications.

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SP651. Chung, R. M.; Lew, H. S.; Kovacs, W. D., eds. **Wind and seismic effects.** Proceedings of the 14th Joint Panel Conference of the U.S.-Japan Cooperative Program in Natural Resources. *Natl. Bur. Stand. (U.S.) Spec. Publ. 651;* 1983 April. 716 p. SN003-003-02485-6.

Key words: accelerograph; codes; design criteria; disaster; earthquake hazards; earthquakes; geotechnical engineering; ground failure; liquefaction; pipeline; seismicity; solids; standards; structural engineering; structural response; tsunami; wind loads; winds.

The 14th Joint Meeting of the U.S.-Japan Panel on Wind and Seismic Effects was held in Washington, D.C., United States from May 17 through 20, 1982. This publication, which is the proceedings of the Joint Meeting, includes the program, list of members, formal resolutions, technical papers, and the task committee reports. Subjects covered in the papers presented to the panel include: (1) characteristics of strong winds, (2) wind loads on structures and design criteria, (3) earthquake ground motions and dynamic analysis of embankment dams, (4) soil liquefaction study and methods to improve liquefaction resistance, (5) seismic loads on structures and design criteria, (6) stress analyses of pipelines during earthquakes, (7) full-scale seismic experiments, (8) earthquake hazard reduction program, (9) use of microcomputer for earthquake studies, (10) quantitative evaluation of damages caused by winds and earthquakes, and (11) tsunami research projects. *These proceedings include the following papers (indented):*

SP651; 1983 April. 1-19. Okubo, T.; Narita, N.; Yamamoto, K.; Sata, H. **Effects of solidity of trusses on unsteady aerodynamic forces of stiffening trussed-girders.**

Key words: aerodynamic forces; solidity; trussed-girders.

Unsteady aerodynamic forces acting on stiffening trussed-girders are described. The models of stiffening trussed-girders which were used in the previous experiments [1] have trusses of low solidity (about 20 percent). In the present experiment, measurements were made for trusses of various solidity ratios, thus, the effects of solidity on unsteady aerodynamic forces of stiffening trussed-girders were investigated. Furthermore, measures to improve stability to torsional flutter of stiffening trussed-girders of high solidity (about 40 percent) were investigated and some effective measures have been found.

SP651; 1983 April. 20-33. Bampton, M. C. C. **Field studies on the Pasco-Kennewick Cable-Stayed Bridge.**

Key words: bridge motion; cable-stayed bridge; wind data.

This paper briefly describes a recent study to collect bridge motion and natural wind data at the site of the 763 m (2503 ft) Pasco-Kennewick Cable-Stayed Bridge using an automated data collection system. Examples of wind and acceleration spectra as well as coherence and deck frequency measurements are presented. The research was sponsored by the Federal Highway Administration and performed by Battelle Pacific Northwest Laboratories over a 3 year period.

SP651; 1983 April. 34-52. Okada, H.; Murota, T. **Wind load on solar water heaters.**

Key words: heater shape; mounting pattern; roof pitch; roof shape; solar water heaters.

Solar water heaters mounted on house roofs are becoming widely used due to the recent rise of consciousness of saving energy in Japan. This paper describes results of wind tunnel tests conducted to obtain information with regard to wind forces on solar water heaters mounted on house roofs. The effects of heater shape, mounting pattern, roof pitch, roof shape, etc., on wind forces on heaters are discussed.

The paper also describes a field observation of wind forces on a full-scale solar water heater mounted on a cottage.

SP651; 1983 April. 53-74. Joyner, W. B.; Boore, D. M. **Estimation of response-spectral values as functions of magnitude, distance, and site conditions.**

Key words: comparison; earthquakes; force coefficients; horizontal acceleration and velocity; predictive equations; response spectra.

We have developed empirical predictive equations for the horizontal pseudo-velocity response at 5 percent damping for 12 different periods from 0.1 to 4.0 s. Using a multiple linear-regression method similar to the one we used previously for peak horizontal acceleration and velocity, we analyzed response spectra period by period for 64 records of 12 shallow earthquakes in Western North America, including the recent Coyote Lake and Imperial Valley, California, earthquakes. The resulting predictive equations show amplification of the response values at soil sites for periods greater than or equal to 0.5 s, with maximum amplification exceeding a factor of 2 at 1.5 s. For periods less than 0.5 s there is no statistically significant difference between rock sites and the soil sites represented in the data set. These results are consistent with those of several earlier studies. A particularly significant aspect of the predictive equations is that the response values at different periods are different functions of magnitude (confirming earlier results by McGuire and by Trifunac and Anderson). The slope of the least-squares straight line relating log response to moment magnitude ranges from 0.21 at a period of 0.1 s to greater than 0.5 at periods of 1 s and longer. This result indicates that the conventional practice of scaling a constant spectral shape by peak acceleration will not give accurate answers. The Newmark and Hall method of spectral scaling, using both peak acceleration and peak velocity, largely avoids this error. Comparison of our spectra with the Regulatory Guide 1.60 spectrum anchored at the same value at 0.1 s shows that the Regulatory Guide 1.60 spectrum is exceeded at soil sites for a magnitude of 7.5 at all distances for periods greater than about 0.5 s. Comparison of our spectra for soil sites with the corresponding ATC-3 curve of lateral design force coefficients for the highest seismic zone indicates that the ATC-3 curve is exceeded within about 5 km of a magnitude 6.5 earthquake and within about 20 km of a magnitude 7.5 event. The amount by which it is exceeded is largest in the period range from 0.5 to 2.0 s.

SP651; 1983 April. 75-80. Ohtani, K. **Reconsideration of the input waves for dynamic analysis.**

Key words: aseismic design; aseismic safety; dynamic analysis; input waves.

The aseismic design method using dynamic analysis has been well established in Japan. Actual design cases of high rise buildings have been totaled up to about 400 in the past 20 years. In this paper, the present state of aseismic design, especially of the dynamic response analysis is reviewed.

Some problems related to the input waves for design are also discussed, and some future subjects for research and development are proposed.

SP651; 1983 April. 81-94. Brady, A. G. **Some new processing techniques for the Imperial Valley 1979 aftershocks.**

Key words: aftershocks; El Centro Array; Imperial fault; Imperial Valley.

This paper describes some of the features of the latest processing improvements that the U.S. Geological Survey (USGS) is currently applying to strong-motion accelerograms from the national network of permanent stations. At the same time it introduces the application of this processing to the set of Imperial Valley aftershocks recorded following the main shock of October 15, 1979. Earlier processing of the 22 main shock recordings provided corrected accelerations, velocity and displacement, response spectra, and Fourier spectra. The digital data has been available on two tapes from NOAA, in Colorado, for 2 years now, and a report containing computer plots has been available, while supplies last, from the USGS in Menlo Park.

The USGS has taken the opportunity provided by the large number of triggerings at 30 permanent stations in the Imperial Valley to update the processing scheme applied particularly to short duration accelerograms with frequencies possibly as high as 50 Hz.

A total of 67 of the aftershock recordings were selected for digitization, from eight events. The number of stations involved is 20, all of which had previously recorded the main shock. A brief outline of the processing steps that have been developed is included, as they have been applied to the best recorded, M 5.0, aftershock. The selection of a long-period filter and its dependence on the need to remove a predominant 4 sec component is discussed. Displacements from those stations on the El Centro Array with radio time have been plotted so as to indicate visually the total processing package.

SP651; 1983 April. 95-123. Okubo, T.; Arakawa, T.; Kawashima, K. **Dense instrument array observation by the public works research institute and analyses of some records.**

Key words: dense instrument array; differential motion; ground motions; wave propagation.

It is important for large structures such as bridges and lifeline facilities to consider differential motions between points of the ground in estimating the design ground motions. It is well recognized that such motions are significantly dependent on local geological and topological conditions. In order to investigate such effects on earthquake ground motions, the normal type of strong motion observation performed at each individual site is not enough, and installation of a dense instrument array is indispensible.

Besides the laboratory observation array at its campus, the Public Research Institute is now on the way to deploy four local laboratory arrays around the Suruga Bay-Izu area in Shizuoka Prefecture, Japan, within 4 years, starting in the 1981 fiscal year.

This report presents one of the four local laboratory arrays in the Sagara area, at which instrumentation has been completed and observations were initiated in 1981 fiscal year, and shows some analyses of array data obtained at the PWRI campus. Analyses for finite strains induced in ground during earthquakes, effects of differential motion on structural response in terms of multisupport response spectrum, and wave propagation characteristics in vertical and horizontal directions are studied.

SP651; 1983 April. 124-149. Sasaki, Y.; Taniguchi, E. **Gravel drains as a countermeasure to liquefaction of the ground.**

Key words: gravel drains; liquefaction.

This paper presents the effectiveness of gravel drains installed to minimize damage of a "half buried type road" caused by liquefaction of the surrounding sand deposit. Large-scale shaking table tests and finite element analyses were used in the study.

SP651; 1983 April. 150-171. Chung, R. M.; Yokel, F. Y.; Anderson, E. D. **Volume change and excess pore water pressure buildup as a function of degree of saturation of sands during resonant column testing.**

Key words: degree of saturation; ground vibration; pore water pressure buildup.

Torsional resonant column tests were conducted on saturated and partially saturated hollow cylindrical Monterey No. 0 sand specimens to study the characteristics of pore water pressure buildup and volume change of the specimen as a function of degree of saturation.

Results of the tests indicated that there exists a threshold shear strain value of about 2×10^{-3} percent for fully saturated sand specimens, below which there is no buildup of excess pore water pressure. The threshold value was observed at about 5×10^{-3} percent when the volume change during testing was used as the criterion.

The degree of saturation was found to have a considerable effect on the threshold strain and the pore water pressure buildup, but it had no detectable effect on the volume change as measured by the displaced pore water.

SP651; 1983 April. 172-192. Iwasaki, T.; Arakawa, T.; Tokida, K. I.; Kimata, T. **Estimation procedures of liquefaction potential and its application to earthquake resistant design.**

Key words: liquefaction potential; pore water pressure; soil liquefaction.

Simplified methods to evaluate the effects of saturated sandy, soils are needed for the reasonable earthquake resistant design of structures considering soil liquefaction. Iwasaki et al., (1978), proposed two simplified methods which use a liquefaction resistance factor F_L and a liquefaction potential index I_L to evaluate the liquefaction potential of saturated sandy soils. Based on these proposed methods, the liquefaction potential can be estimated simply by using the fundamental properties of soils, i.e., N-values from the Standard Penetration Test, unit weights, mean particle diameters, and the maximum acceleration at the ground surface.

In this paper, the two simplified methods are first introduced, and to prove the effectiveness of the proposed methods, the values of both F_L and I_L at 64 liquefied sites and 23 non-liquefied sites during past six earthquakes are calculated according to these simplified methods. Also, shaking table tests on soil liquefaction are carried out for the saturated sandy model ground. Furthermore, several application methods using the factor F_L, the excess pore water pressure induced in the saturated sandy soils and the effects of soil liquefaction on the resistance properties of the soils surrounding structures are described. Finally, some case studies on earthquake resistant properties of civil engineering structures considering soil liquefaction are carried out according to the proposed procedures on soil liquefaction properties.

SP651; 1983 April. 193-217. Uwabe, T.; Noda, S.; Tsuchida, H. **Coupled hydrodynamic response characteristics and water pressures of large composite breakwaters.**

Key words: composite breakwater; hydrodynamic response characteristics.

In order to prevent damage by tsunami, a large composite breakwater is planned in deep sea at a depth of 60 m at the bay mouth of Kamaishi in the Tohoku district. For the purpose of examining the seismic behavior of the breakwater, an analysis of coupled hydrodynamic response characteristics and water pressures of the breakwater was carried out by means of a shaking table model test and an earthquake response calculation using the Finite Element Method.

In case the caisson of the composite type breakwater does not resonate, the model tests show that the hydrodynamic pressures acting on a caisson is calculated by the Westergaard formula using the water depth and the seismic coefficient at the top of the mound. (Mound means earth and/or rockfill).

In order to use earthquake response calculation for practical application, it is essential to investigate whether the modeling and material property values simulate the actual field condition or not. It is concluded that the method for analyzing structure-water systems using the Finite Element Method is appropriate for simulating the dynamic response and hydrodynamic pressures of the fill type breakwater.

SP651; 1983 April. 218-241. Franklin, A. G.; Hynes-Griffin, M. E. **Dynamic analysis of embankment sections, Richard B. Russell Dam.**

Key words: embankments; liquefaction; visco-elastic shear-beam analysis.

Seismic safety of the Russell Dam embankments was evaluated with a permanent displacement analysis, judged appropriate after laboratory cyclic testing verified the nonsusceptibility of embankment and foundation materials to liquefaction. The analysis included determination of critical or yield accelerations by means of conventional limit analysis, estimation of amplification of ground accelerations in the embankment through a visco-elastic shear-beam analysis, and estimation of deformations by means of a Newmark sliding block model. The results indicate that if the dam is subjected to the maximum possible earthquake for the site, superficial displacements would not exceed 3 ft and displacements on deep-seated surfaces would not exceed 1.5 ft.

SP651; 1983 April. 242-258. Tsuchida, H.; Minami, K. I.; Kiyomiya, O.; Noda, S. **Pipe stresses during earthquakes based on a two-dimensional seismometer array observation.**

Key words: deformation method; dynamic response analysis; pipe stresses; two-dimensional seismometer array observation; wave propagation.

Pipe stresses developed during earthquakes are influenced by the relative displacement of an ambient ground. The strains caused by the relative displacement of the ground are closely related to the magnitude of the earthquakes, the epicentral distances, the subsoil conditions, and the properties of the wave propagation in surface layers. Analyses of records obtained by a two-dimensional seismometer array observation at the Tokyo International Airport were carried out to evaluate the behavior of the pipelines during earthquakes. Pipe stresses are calculated from the ground deformation by the observation. The stresses calculated by the deformation method, which has been used for earthquake resistant design in Japan, and by the dynamic response analysis are compared with those from the observation.

SP651; 1983 April. 259-271. Ariman, T. **Buckling and rupture failure in pipelines due to large ground deformations.**

Key words: ground deformations; lifeline earthquake engineering; rupture failure.

A concise and up-to-date review of buckling and rupture failure in pipelines due to ground deformations is presented. It is shown that, in comparison to surface structures, pipeline systems are particularly vulnerable to local differential movements of ground. It is noted that permanent differential movements may be caused by any earthquake and that the movements can assume a variety of patterns depending on local soil conditions and the presence of faults. Therefore, the response of buried pipelines to permanent ground movement is an important part of lifeline earthquake engineering.

SP651; 1983 April. 272-324. Kuribayashi, E.; Iwasaki, T.; Hagiwara, R. **Experimental studies on seismic behavior of structural members using a dynamic structural testing facility at PWRI.**

Key words: dynamic structural testing facilities; earthquakes; seismic behavior.

Dynamic structural testing facilities of an earthquake engineering laboratory were recently completed in March 1980 at Tsukuba by the Public Works Research Institute, Ministry of Construction. Four experiments as shown in table 1 were conducted so far using the facilities. Outlines of the facilities and two experiments conducted in the fiscal year of 1980 using the facilities are described.

SP651; 1983 April. 325-342. Yasue, T.; Iwasaki, T.; Sasaki, Y.; Asanuma, H.; Nakajima, T. **Report of the Urakawa-oki earthquake of March 21, 1982.**

Key words: civil engineering structures; damage; earthquake, Urakawa-oki.

On Sunday morning, March 21, 1982, a severe earthquake of magnitude 7.3 on the Richter Scale hit Urakawa-oki, off Urakawa, the southern part of Hokkaido Island in Japan. This report briefly describes an outline of the earthquake and damage to civil engineering structures due to the Urakawa-oki Earthquake of March 21, 1982.

SP651; 1983 April. 343-360. Fleming, J. F. **Linear versus nonlinear behavior of cable stayed bridges.**

Key words: cable stayed bridges; nonlinear behavior; static and dynamic response.

The first modern cable stayed bridge was constructed in Sweden in 1955. Since that time over 100 major bridges of this type have been built throughout the world. One of the major difficulties which many designers must face, when confronted with the task of designing a structure of this type, is a lack of knowledge of how they behave under static and dynamic design loads. It is well known that cables exhibit a nonlinear force-elongation relationship due to the change in sag with axial load. The purpose of this paper is to describe the results to date of an ongoing investigation into the effect of nonlinear behavior upon the overall static and dynamic response of cable stayed bridges. Mathematical models representing several actual or proposed bridges, under a variety of static and dynamic loads, were considered in the study.

SP651; 1983 April. 361-401. Narita, N.; Saeki, S.; Kanai, M.; Ohshio, T. **Behavior of concrete-filled steel tubes.**

Key words: bridge piers; concrete-filled steel tubes; earthquake.

In our country, bridge piers are subjected to strong motions due to earthquake. Furthermore, size of bridge piers are strictly limited in metropolitan highways and in monorails. High ductility and high resistance is, therefore, required for bridge piers in Japan. In this regard, use of concrete-filled steel tubes is examined.

Steel tubes have very high resistance; however, steel tubes are liable to yield by local buckling and to lose ductility after yielding. Concrete piers with adequate reinforcing have good ductility; however, they are large-sized. Concrete-filled steel tubes are thin steel tubes with concrete and shear connectors in the tubes. When they are subjected to a strong motion, the concrete prevents the local buckling of thin steel tubes and the steel tubes give adequate reinforcing to the concrete. Therefore, even small-sized concrete-filled steel tubes have excellent ductility and resistance.

Sometimes, concrete-filled steel tubes have been used for bridge piers or building members. However, they were used just to increase the rigidity of the members or to stiffen the steel tubes, and were not designed as composite structures. In our report, the concrete-filled steel tubes are regarded as composite structures to expect higher resistance and ductibility. At present, many problems are not resolved to design concrete-filled steel tubes as composite structures, such as provisions for shear connectors, plate thickness and so on. These problems are examined in detail in this paper. Based on the results of full-size tests, design recommendations are presented.

The following reports are coming in series. Part I—Compression Members; Part II—Long Columns; Part III—Bending Members; Part IV—Beam Columns.

SP651; 1983 April. 402-415. Takahashi, S. K.; Tyrrell, J. V. **Microcomputer for earthquake studies.**

Key words: BASIC; COBOL; earthquake; FORTRAN; microcomputer.

The use of microcomputers is now a practical reality for the small engineering office. The reasons for the immediate popularity are the low initial cost of the system .(

The cost of a typical microcomputer (MC) system, one that is operational at the Naval Civil Engineering Laboratory, with a 64K RAM (Random Access Memory), dual 8 in. disk drives, and letter quality printer, is abou. 8-bit processor (figure 2), but it can be upgraded to a 16-bit processor at any time. Similarly, the memory can be upgraded from 64K to 128K as the need arises. One standard parallel port and two RS-232C serial ports allows the addition of printers, plotters, digitizers, and communications with data bases and other computers. Presently, two drives provide 932,000 characters of storage; the addition of two more drives (figure 3) will bring the total capacity to about two million characters. If a hard disk drive system is utilized, it can access 8.4 million characters. The Daisy Wheel letter quality printer (figure 4) was slected so that drafts and final manuscripts could be written and stored on the diskette for instant retrieval and modifications of the text. Additional information and specifications of the MC can be found in reference 1.

This MC adapts easily to the choice of languages such as BASIC, COBOL, FORTRAN, etc., because the system has no primary language stored in Read Only Memory (ROM). Transfer of information, from one installation that uses a microcomputer which utilizes the CP/M system to another Navy agency also utilizing a microcomputer that uses 8 in. single-sided, single-density diskette, can be made easily on the 8 in. diskette with 128 byte record size because this is the standard international interchange format.

SP651; 1983 April. 416-425. Bernard, E. **A tsunami research plan for the United States.**

Key words: coastal hazards; tsunamigenic earthquake; identification; tsunami research.

In response to the identification of deficiencies in tsunami research, a group of scientists and government representatives developed a coherent research plan to address these problems. The plan is designed to foster a course of action that will focus research on forecasting tsunami dangers and evaluating coastal hazards. A brief review of the status of tsunami research is presented and needs for priority research are identified. The three highest need areas are: 1) tsunami observational program, 2) modeling and design related to terminal effects, and 3) tsunamigenic earthquake identification. Two moderate need areas include the creation of a tsunami data set and the development of emergency preparedness programs.

SP651; 1983 April. 426-432. Lander, J. F. **Digital data services for tsunamis and engineering seismology.**

Key words: engineering seismology; NEDRES; seismographic data; tsunamigenic earthquakes; tsunamis.

The consolidation of NOAA's environmental data banks in one system, the development of dgital data directories, dictionaries, and inventories, the use of data base management systems and mass store, and accessibility of the whole system remotely offer new opportunities for users to directly get data shaped to their needs from multiple discipline files. A National Environmental Data Referral Service can help users find data in the system and elsewhere worldwide. Possibilities of networking with bibliographic and other data bases are also promising.

SP651; 1983 April. 433-439. Wright, J. K. **Construction of the full-scale reinforced concrete test specimen.**

Key words: concrete test specimen; construction practices; reinforcement details.

A short summary of the construction of the full-scale seven-story reinforced concrete building is presented. Differences between Japanese and U.S. construction practices are discussed. Cross section dimensions and reinforcement details for important portions of the structure are also presented.

SP651; 1983 April. 440-456. Okamoto, S.; Nakata, S.; Kitagawa, Y.; Yoshimura, M.; Kaminosono, T. **Progress report on the full-scale seismic experiment of a seven-story reinforced concrete building—Part 1. Pseudo-dynamic test before repair.**

Key words: dynamic loading; earthquake ground motions; pseudo-dynamic test; reinforced concrete building; seismic design; static loading tests.

The appropriate evaluation of strength and deflection characteristics of building structures is a fundamental requirement for the proper estimation of structural safety in the event of major earthquake disturbances. Various unsolved problems yet remain for this evaluation due to complexity of the combination of randomness in earthquake ground motions with nonlinear behavior of structural systems. Effects of scale and construction quality make the precise evaluation more complicated and difficult.

In order to predict the behavior of structures subjected to seven earthquake ground motions, many analytical models of materials, members, and systems were developed, and numerical analyses have been made. Nevertheless, it is uncertain whether or not the results of these studies represent the true behavior of the structures because of various approximations, assumptions, and simplifications in the course of modeling and analysis. Static loading tests of full-scale models provide useful information on strength and deformation characteristics of structures, but the true margin of safety of those structures cannot be estimated.

To simulate the earthquake response of a structural model, the pseudo-dynamic test procedure is considered to be one of the most effective testing techniques if the model is beyond the capacity of a shaking table. In the Building Research Institute (BRI), Ministry of Construction, a computer-actuator on-line system was developed in 1980, and subsequently a series of pseudo-dynamic tests of a full-scale model of a seven-story reinforced concrete building with the cooperation of the Joint Technical Coordination Committee members have been performed. The primary objectives of the test were: (1) to calibrate the accuracy of techniques developed for analyzing structures under static or dynamic loading, and (2) to estimate the true margin of safety of the structure. The test was also expected to provide fundamental data for current seismic design.

SP651; 1983 April. 457-475. Okamoto, S.; Nakata, S.; Kitagawa, Y.; Yoshimura, M.; Kaminosono, T. **A progress report on the full-scale seismic experiment of a seven-story reinforced concrete building—Part 2. Pseudo-dynamic test after repair.**

Key words: pseudo-dynamic test; reinforced concrete building.

After the pseudo-dynamic test of the full-scale reinforced concrete structure, repair works and the installation of nonstructural elements to the damaged structure were carried out. The hinge zone of the beams and the shear wall of the structure were repaired by using epoxy resin. The repair works proved to be economically effective for the reuse of the damaged structure after earthquake damage from the viewpoint of recovering the stiffness and the strength of the structure. The aseismic arrangements of nonstructural elements such as partition walls, spandrel walls, window glasses, etc., were verified through a series of pseudo-dynamic tests.

SP651; 1983 April. 476-488. Morgan, B. J.; Hiraishi, H.; Corley, W. G. **Tests of planar wall assemblies under in-plane static reversing loads.**

Key words: concrete structures; in-plane static reversing loads; planar wall assemblies.

During the 1968 Tokachi-Oki Earthquake in Japan, numerous reinforced concrete school buildings of modern design suffered heavy damage. Following that earthquake, a joint seminar under the sponsorship of the U.S.-Japan Cooperative Science Program was held in Sendai, Japan in 1970. One purpose of the seminar was to identify and define programs of research that could be conducted effectively on a cooperative basis between the United States and Japan.

Prompted by discussions held at Sendai, a U.S.-Japan Cooperative Research Program on Earthquake Engineering was established under the U.S.-Japan Cooperative Science Program. The period of this program was initially 1973 to 1975. A program review meeting was held in Hawaii in 1975. Several formal recommendations grew out of the presentations and discussions at this meeting. One of these recommendations was that a cooperative research program should be established with emphasis on large-scale testing of structural systems. During the period of 1974 to 1978, government delegates on a separate U.S.-Japan Panel on Wind and Seismic Effects arrived at the same conclusions.

Based on conclusions and recommendations of both university and government groups, a planning group was established to define specific details of research to be carried out. After four meetings during 1977 to 1979, the planning group recommended that research should focus on "studies to determine the relationship among full-scale tests, small-scale tests, component tests, and analytical studies."

SP651; 1983 April. 489-506. Watabe, M.; Yamanouchi, H.; Midorikawa, M.; Fukuta, T.; Kaminosono, T. **Research program on the full-scale seismic experiments of steel buildings.**

Key words: pseudo-dynamic tests; seismic experiments; static tests; steel buildings.

This research program is conducted in accordance with recommendations prepared by the U.S.-Japan planning group established in 1977 under the auspices of the U.S.-Japan Panel on

Wind and Seismic Effects, United States-Japan Natural Resources (UJNR) Program. Research activities from these recommendations have been conducted under the Joint Technical Coordinating Committee (JTCC), which consists of researchers from both countries.

In its first year, the Structural Steel Phase was begun by experiments on structural members and subassemblages. These results would support analyses on a full-scale test building. The support tests consist of four experimental programs. They are: (1) static tests on three-story steel planar frames, (2) dynamic and pseudo-dynamic tests on steel frames (designated as a Correlation test), (3) static tests on composite girders, and (4) static tests on column-to-footing connections. The second year's main program is to conduct tests on the full-scale six-story steel building using the pseudo-dynamic testing method. The test building consists of two unbraced moment-resisting frames and a braced frame with K-braces. This structure would represent a portion of an overall building. Two types of K-bracing systems, the concentric K and the eccentric K, should be used in different stages of testing. It should be tested in several stages using a loading procedure simulating realistic seismic conditions. At the final stage of testing, nonstructural elements such as curtain walls and partitions should be added to the structural system and the entire structure should be loaded to failure. In the third year, analyses and estimation on the full-scale test will be done, associated with supplementary tests on subassemblages. Comprehensive consideration will be directed to seismic safety of steel buildings.

SP651; 1983 April. 507-521. Hebenstreit, G. T.; Krumpe, P. F. **United States foreign assistance program on tsunami hazard.**

Key words: computer modeling; earthquake sources; tsunami; tsunami behavior; tsunamigenic earthquake.

The Office of Foreign Disaster Assistance, U.S. AID, and Science Applications, Inc., are developing a program to make the results of current tsunami research techniques available to disaster control officials in developing nations which are subject to potentially severe tsunami hazards. This program uses a combination of historical study of past tsunamis and computer modeling of possible future tsunamis to assess the threat to specific areas. The first application of the program has been to the potential threat arising from tsunamis generated in the Peru-Chile Trench.

This paper outlines the techniques used in the computer modeling, the choice of specific earthquake sources, and the results of early studies. Research is currently underway to examine in more detail tsunami behavior in areas which appear strongly threatened. We discuss briefly our approach to this phase of the problem and our plans for transferring the results of the program to officials in developing nations.

SP651; 1983 April. 522-531. Kamimura, K.; Watabe, M.; Ishiyama, Y.; Yamazaki, Y. **Technical cooperation in developing countries on earthquake engineering.**

Key words: aseismatic building techniques; earthquake disasters; earthquake engineering.

In order to improve earthquake engineering techniques in developing countries, it is necessary, apart from direct technical cooperation, to raise the standards of research and techniques in the country concerned from a long-term point of view. The International Institute of Seismology and Earthquake Engineering, the Building Research Institute, has been conducting training programs in seismology and earthquake engineering since 1962 for the purpose of training researchers and engineers from developing countries. These training programs have played an immeasurable role in raising the standards of research and techniques in developing countries.

This report is intended to outline the surveys on earthquake disasters conducted overseas in connection with the Institute and to introduce the training programs. In addition, the report will also briefly touch upon the cooperation programs for Indonesia and Peru under the Bilateral Earthquake Engineering Cooperation Program with which the Institute is closely associated.

SP651; 1983 April. 532-537. Simiu, E. **Incremental expansion and aseismic design of low-cost housing in sites and services projects.**

Key words: aseismic design; design problems; incremental expansion; shelter core.

In recent years, sites and services projects have evolved into one of the more effective components of urban strategies dealing with the enormous shelter problems faced by developing countries. In sites and services projects the responsibility for building the shelter itself rests to a large extent with the beneficiary.

For reasons of hygiene and fire safety and to facilitate immediate occupancy, sites and services plots are in many instances provided initially with sanitary cores, fire walls, and a rudimentary partial shelter. Depending upon his evolving needs and ability to pay for the requisite materials and labor, the beneficiary then completes the dwelling in incremental stages. His direct involvement in the building effort—usually referred to as self-help—can be expected to yield a product more suitable to his needs and, to the extent that financing costs and overhead are reduced, more economical than would be the case for conventional construction.

The advantages of incremental expansion by self-help should not obscure some potential technical pitfalls, particularly with regard to construction in earthquake and typhoon (cyclone) prone regions. This is true even where the level of conventional technical skills available to the sites and services beneficiaries can be assumed to be reasonably adequate.

It will be shown in this paper that incremental expansion schemes pose special and delicate structural design problems that arise from the evolutionary nature of the building process in sites and services projects. A first type of problems arises if an initial but incomplete shelter core is provided on the site. In that case efficient ways must be found to ensure the structural integrity of the initial construction. A second type of problems is due to the difficulty of tying successive incremental portions of the dwelling both to the initial construction and among themselves in such a manner as to create systems that are structurally sound at all times. Without due attention to such problems the resulting construction can be unnecessarily uneconomical as well as constituting a serious hazard to life and property in case of earthquake or tropical cyclone. These two types of problems will be illustrated by using examples of shelter construction in actual sites and services projects.

SP651; 1983 April. 538-540. Barrientos, C. S. **Storm surge forecasting.**

Key words: forecasting; hurricane; storm surge.

The National Weather Service of the National Oceanic and Atmospheric Administration (NOAA) has the responsibility to provide forecasting and warning of impending storm surges. This presentation will summarize the storm surge forecast models now in use by NOAA and briefly discuss certain other storm surge models.

SP651; 1983 April. 541-555. Sasaki, Y.; Koga, Y. **Vibratory cone penetrometer to assess the liquefaction potential of the ground.**

Key words: artificial vibration; impact loadings; liquefaction; standard penetration tests; vibratory cone penetrometer.

This paper describes a vibratory cone penetrometer that aims to investigate the liquefaction potential of sand deposit in a direct and simple manner in the field, and also the test results in the laboratory using the vibratory cone penetrometer. This cone penetrometer was developed on the basis that the point resistance of the static penetration with vibration or the difference of the point resistance between the above penetration and the static penetration reflects the liquefaction potential of the ground. Such a presumed characteristic was found in the laboratory tests, which were performed on model sand deposits of various relative density and overburden pressure. As a result, the applicability of this new vibratory cone penetrometer was validated.

SP651; 1983 April. 556-564. Watabe, M. **Direct evaluation method for floor response spectra.**

Key words: floor response spectra; random vibration theory; response analyses; seismic design.

Floor response spectra are generally obtained by response analyses when the results by response analyses in time history of structures are employed as input excitations. It is possible to apply the random vibration theory to evaluate the maximum responses of structures and their floor response spectra without response analyses in time history.

In this paper, the calculation procedure of maximum responses of structures and their floor response spectra subjected to nonstationary random earthquake ground motions are proposed. The method herein proposed is verified to be valid and very useful when its results are compared with the results obtained by the general method.

SP651; 1983 April. 565-586. Kuribayashi, E.; Iwasaki, T.; Nakajima, T. **A procedure for estimating indirect effects of earthquakes on economy.**

Key words: earthquakes; economic damage; indirect effects; value-added.

This paper discusses the economic damage caused by the Miyagi-ken-oki Earthquake of 1978. The earthquake has brought about extensive structural damage and the amount of direct losses has reached 269 billion yen. In consequence of the physical damage, the aftermath of the earthquake lasted about four months and one of the severest effects came out in the reduction of value-added in the local economy. This paper studies the reduction of value-added in Miyagi Prefecture after the Miyagi-ken-oki Earthquake of 1978.

SP651; 1983 April. 587-599. Matsumoto, N.; Totoda, M.; Shiga, M. **Dynamic tests of rockfill dam models.**

Key words: dynamic tests; frequency response functions; rockfill dam models.

Dynamic tests of two-dimensional rockfill dam models with a central impervious core were conducted using a shaking table. Heights of the models were 74 cm and 84 cm respectively. Models were excited with horizontal sinusoidal motion and the frequency response functions of the models were obtained.

The response characteristics of the models were compared between full and empty reservoir conditions. The models were also subjected to scaled earthquake motions and the nature of the failure during earthquake motions were compared with the case of the sinusoidal motion input.

SP651; 1983 April. 600-616. Narita, N.; Asanuma, H.; Fukui, J.; Yamamoto, Y. **The connecting method for pile head and footing of pile foundations subjected to a horizontal load.**

Key words: connecting method; load-deformation characteristics; pile foundation; pile heat.

It is necessary for the foundation of a bridge structure to efficiently transmit the load from the superstructure to the ground. In the case of a pile foundation, in particular, it is necessary to give sufficient consideration to the safety of the connection of pile heat and footing because of sudden changes in cross section and rigidity. Various connecting methods have been developed. However, there remain many points which need to be clarified with regard to the ultimate strength, load-deformation characteristics, etc., of the connection.

SP651; 1983 April. 617-654. Rojahn, C.; Borcherdt, R. D. **On the status of in situ strong ground motion and structural response investigations.**

Key words: earthquakes; strong-motion arrays; structural response investigations.

Strong-motion data from large earthquakes provide the basis for the design of buildings, bridges, dams, and other critical structures as well as the basis for research on fundamental problems related to earthquake hazard evaluation, earthquake processes, and internal structure of the earth. Review of existing strong-motion data acquisition programs in the United States shows significant progress in instrument deployment since 1933, but that significant improvements in data acquisition capabilities are needed for scientific and engineering research studies. The need for installation of several additional well-designed strong-motion arrays (free field, structures) in areas of high seismic potential worldwide is readily apparent as well as the need to develop instrumentation to reduce maintenance costs. Review of existing analog and digital strong-motion recording systems indicates that proven reliability and level of technical maintenance expertise still recommend analog systems for applications involving small amounts of data and long-term deployment. Those applications involving highly trained technicians, improved quality data, and large amount of data are facilitated by using digital instrumentation. Recent applications of digital technology in other fields suggests that numerous improvements in digital recorders are feasible and warranted.

Review of recently collected strong-motion data sets shows a significant increase in the strong-motion data base for moderate-sized earthquakes with that from the earthquake in Imperial Valley, California (October 15, 1979) being most complete. Compilations of these data show a critical scarcity of in situ information on near field ground motions and damaging structural response levels for earthquakes larger than magnitude 7.

SP651; 1983 April. 655-668. Goda, Y.; Hashimoto, H. **Storm surge defense works and related researches in Japan.**

Key words: coastal dikes; defense works; storm surge.

Five typhoons on the average land every year because Japan is located in a typhoon attacking zone of the Western Pacific Ocean. They bring storm surges and high waves along a coast. Once the storm surge causes a flood, damage is enormous. Coastal dikes and gates have been constructed to prevent damage. Storm surge defense works have been carried out on the principle established after the Ise-wan Typhoon which caused heavy damage in 1959. In this regard, research related to the numerical estimation of storm surges and waves were made. Experimental investigations were carried out by universities and governmental institutions to determine the wave run-up and overtopping on a dike. The research stopped after the defense works were almost completed.

SP658. Lew, H. S., ed. **Wind and seismic effects.** Proceedings of the 11th Joint Panel Conference of the U.S.-Japan Cooperative Program in Natural Resources; 1979 September 4-7; Tsukuba, Japan. *Natl. Bur. Stand. (U.S.) Spec. Publ. 658;* 1983 July. 755 p. SN003-003-02506-2.

Key words: accelerograph; codes; design criteria; disaster; earthquakes; ground failures; hazards; seismicity; solids; standards; structural engineering; structural responses; tsunamis; wind loads; winds.

The Eleventh Joint Meeting of the U.S.-Japan Panel on Wind Seismic Effects was held in Tsukuba, Japan on September 4-7, 1979. The proceedings of the Joint Meeting include the program, the formal resolution and the technical papers. The subjects covered in the paper include (1) the engineering characteristics of wind, (2) the characteristics of earthquake ground motions, (3) the earthquake response of structures, (4) the wind response of structures, (5) recent design criteria against wind and earthquake disturbances, (6) the design and analysis of special structures, (7) the evaluation, repairing, and retrofitting for wind and earthquake disaster, (8) earthquake disaster prevention planning, (9) storm surge and tsunamis, and (10) technical cooperation with developing countries. *These proceedings include the following papers (indented):*

SP658; 1983 July. 1-14. Thiel, C. C. **New initiatives in earthquake hazards mitigation.**

Key words: earthquake mitigation; post-earthquake recovery activities; seismic design; seismic safety;

Under the National Earthquake Hazards Reduction Program a number of significant steps have been taken to improve national earthquake mitigation policies and practices. The recently established Earthquake Hazards Reduction Coordination Group within the Executive Office of the President, is coordinating a number of efforts to improve building practices, land use, insurance, preparedness, emergency response and post-earthquake recovery activities. An "Interagency Committee on Seismic Safety in Construction" has been established to: develop seismic design and construction standards for Federal projects; develop guidelines to ensure serviceability following an earthquake of vital facilities constructed or financed by the Federal government; and develop guidelines that provide independent and State and local review of seismic considerations in the construction of critical facilities constructed and financed by the Federal government, where appropriate.

In a collateral activity a "Building Seismic Safety Council" has been formed within the private sector to enhance the public safety by providing a national forum to foster improved seismic safety provisions for use by the building community. The scope of the Council's activities encompasses seismic safety of building-type structures with explicit consideration and assessment of the social, technical, administrative, political, legislative, and economic implications of its deliberations and recommendations.

SP658; 1983 July. 15-21. Leyendecker, E. V.; Harris, J. R.; Wright, R. N.; Pfrang, E. O. **Earthquake hazard reduction research at the National Bureau of Standards.**

Key words: earthquake hazard reduction; earthquake-resistant construction; National Bureau of Standards; seismic design.

Current and planned Earthquake Hazard Reduction programs at the National Bureau of Standards in Research and Standards Development are being conducted in order to achieve the responsibilities assigned to NBS under the President's National Earthquake Hazards Reduction Program. These responsibilities, to: 1) provide technical support to the building community in the development of seismic design and construction provisions for building codes and national standards; 2) provide technical support to the Federal agencies in development of seismic design and construction provisions for Federal programs; and 3) perform research on performanc criteria and supporting measurement technology for earthquake-resistant construction; are being carried out in cooperation with the Federal and private sectors. This research is complementary to that of the National Science Foundation (NSF) and U.S. Geological Survey (USGS).

SP658; 1983 July. 23-45. Okubo, T. **On the U.S.-Japan cooperative program of large-scale testing.**

Key words: large-scale testing; U.S.-Japan Joint Earthquake Research Program; wind and seismic effects.

The Implementing Arrangement between the Science and Technology Agency (STA) and the Ministry of Construction (MOC) of Japan and the National Science Foundation (NSF) of the U.S.A. for cooperation in the U.S.-Japan Joint Earthquake Research Program involving Large-Scale Testing, under the auspices of the Panel on Wind and Seismic Effects of the UJNR was signed by Mr. Nobuo Kozu (STA), Mr. Hidenobu Takahide (MOC) and Dr. Jack T. Sanderson (NSF) on August 10, 1979.

The U.S.-Japan Cooperative Program on Large-Scale Testing was initiated in 1974 by this Panel and has begun implementation. In this presentation, the author outlines the Program.

SP658; 1983 July. I-1–I-15. Uchida, E.; Fujiwhara, S.; Tatehira, R.; Tabe, I.; Ohtsuka, K. **Modeling the 1978 Tokyo Tornado that overturned the Tozai subway train.**

Key words: meteorological elements; tornadic cyclone; tornado elements; 1978 Tokyo tornado.

A high wind developed in the evening of February 28, 1978, over areas from Kawasaki City (Kanagawa Prefecture) to Kamagaya City (Chiba Prefecture). The wind caused extensive damage (for example, overturning the Tozai subway train, houses, cars, vessels etc.)

Judging from weather conditions which were detailed by data from weather maps, automatic records of wind direction and speed, of air pressure, radar echo patterns, AMeDAS data, and disaster distributions, we envisage that this high wind was associated with a tornado formed within a tornadic cyclone having $5 \sim 6 \times 10$ km diameter.

We estimate that this tornado was generated within a converging and unstable area near a squall line preceding a cold front, the diameter of the tornado core is estimated as $100 \sim 200$ m (radius $50 \sim 100$ m), the maximum wind velocity $60 \sim 80$ m/s and the propagation speed 25 m/s.

A numerical simulation experiment was carried out in relation to meteorological elements of the tornado (core radius, the maximum-wind velocity, propagation speed) under an assumption of a single tornado having a straight path and a uniform velocity. The most adaptable values of tornado elements, in regard to the kinematical analysis of the overturned train were located within $75 \sim 100$ m in core radius, $70 \sim 80$ m/s in maximum-wind velocity and $25 \sim 35$ m/s in propagation speed.

These results from the engineering aspect nearly coincide with those of the estimated values and the reliability of this model was thereby roughly verified.

SP658; 1983 July. I-16–I-30. Changery, M. J.; Simiu, E.; Filliben, J. J. **Extreme wind speeds at 129 stations in the contiguous United States.**

Key words: building (codes); probability distribution functions; statistical analysis; storms; structural engineering; wind pressure; wind speeds.

The purpose of this report is to present information on recorded and predicted wind speeds at 129 airport stations in the contiguous United States at which reliable records are available over a number of consecutive years. This information is provided to serve as basic documentation from which appropriate decisions can be made on values of design wind speeds to be specified in building codes and standards, and on special projects. Included in the report are: recorded wind speeds and anemometer elevations; predicted wind speeds based on probability distributions of the largest values; estimates of the sampling errors inherent in the predicted wind speeds; a description of the statistical procedure used in the analysis of the data; and a discussion of the results of the analysis.

SP658; 1983 July. I-31–I-45. Naito, K.; Tabata, I.; Banno, N.; Takahashi, K. **Analysis of high wind observations from very tall towers.**

Key words: gust winds; high wind analysis; tall towers; wind turbulence spectrum.

This paper describes the analyzed results of high winds, such as typhoons, observed in Japan and its vicinity from tall towers which vary in height from 200 to 400 meters. The results show that the vertical profile of the average wind velocity is well simulated by the power law: the obtained values of power are 0.12, 0.23, 0.46 and so on, and depend upon the local topography upwind. When the upwind roughness of the ground surface, or the unobstructed "clearness" which represents the reciprocal character of upwind roughness, are introduced to model the characteristics of the strong wind, the power decreases with larger degree of clearness, and vice versa. The power is expected to be around 0.12 or 0.15 in extreme clearness. This seems to agree with what is called the seventh-root formula obtained in wind tunnel experimentation. The power is considered usually to be less than 1.0, but will be over 1.0 in severely obstructed situations. The turbulent intensity decreases generally with the increase of height. It shows the following height dependency: for example it is 0.52 $Z^{-0.31}$ for good clearness, and 1.02 $Z^{-0.42}$ and 2.14 $Z^{-0.54}$ for intermediate, or worse clearness, respectively, where Z represents the height in meters. These results show that the profile of turbulent intensity depends upon the effect of the local terrain. The gust factor shows characteristics somewhat similar to those of turbulent intensity. The energy spectrum of turbulence is simulated quite well by the -5/3 power law, but the local topography affects height variation in the distribution of small spectral peaks.

SP658; 1983 July. II-1–II-12. Otsuka, M. **A proposal for a new parameter in assessing seismic disaster.**

Key words: earthquake prediction; fault dynamics; seismic disaster parameters.

Out of the recent progress in modern seismology, especially in the rapidly increasing body of knowledge about the nature of what the fault generating process looks like, a prospect of practical earthquake prediction in the near future seems reasonable.

Although a general methodology is not at hand for complete forecasting, long-term estimating of earthquake occurrences in limited areas based on past seismicity studies has already been put to practical use in many reported instances. Though this technique is still insufficient for prediction, since it lacks temporal accuracy about the occurrence of the earthquake, it should prove invaluable and be reflected in disaster reduction strategy. What is needed still is the methodology to associate the expected fault geometry to the plausible disasters.

The purpose of this paper is, then, to search for a technique to evaluate the influence of the impending earthquake based only on a geometrical estimate of a 'should be' fault and without any dynamic information.

Through repeated trials, the author has arrived at the conclusion that the intensity of the seismic vibration is closely related to the solid angle extended from the observation site toward the periphery of the fault.

SP658; 1983 July. II-13–II-23. Kubo, T.; Watabe, M. **Simulation of earthquake ground motion and its application to dynamic response analysis.**

Key words: dynamic response analysis; ground motion; modeling; synthetic earthquake motion; waveforms.

Through the relation of Fourier transformation, two types of stochastic modeling of earthquake ground motion are introduced. Twenty samples of synthetic motion, in each case, are generated by use of these two modelings simulating a certain recorded motion. Using these motions, characteristics of synthetic motions such as the cumulative energy distribution (the integration of square acceleration), the maximum elastic response and the maximum elasto-plastic response are evaluated. From a statistical viewpoint, the results are compared with those obtained from the recorded earthquake motion in an attempt to make use of synthetic motions for an engineering application.

SP658; 1983 July. II-24–II-44. Uwabe, T. **Comparison of vertical components of strong-motion accelerograms for Western United States and Japan.**

Key words: earthquake engineering; earthquake resistant structures; earthquakes; ground motion.

Characteristics of the vertical component of 187 strong-motion accelerograms recorded in the Western United States were studied. According to the analysis of the ratio of maximum vertical acceleration to maximum horizontal acceleration, the average ratio of vertical peaks to horizontal peaks is 0.48. Significant correlations between maximum horizontal acceleration, epicentral distance, and earthquake magnitude could not be found. The vertical maximum acceleration occurs near the occurrence time of the horizontal maximum acceleration. But, the coincidence of vertical and horizontal peaks is very rare. At the time when the safety factor against sliding and overturning for gravity-type structures is smallest, the ratio of the vertical acceleration to the resultant horizontal acceleration is less than one-third. A comparison was made of the ratios of vertical peaks to horizontal peaks for Western United States and for 574 strong-motion accelerograms from Japan. The result of this comparison is as follows: The ratio of vertical peaks to horizontal peaks in the Western United States is larger than that in the Japanese recordings. The difference between the accelerograms of the two countries is believed to be caused by dissimilar instruments, dissimilar installation conditions, and differences in focal depth and site conditions. This difference should be kept in mind when the digitized accelerograms of both countries are used together.

SP658; 1983 July. II-45–II-64. Nakano, K.; Kitagawa, Y. **Earthquake observation systems in and around structures in Japan.**

Key words: earthquake observation systems; simulation models; spectral analysis; transfer function; underground amplitudes.

Ever since the observation system for underground earthquake motions are undertaken in 1934, efforts have been made to obtain exact knowledge of the characteristics of ground motions, the dynamic interaction behavior between building and subsoil, and the earthquake motions input to structures.

The number of observation sites has increased year by year. There are now more than 200 in number, and much valuable data has been accumulated. In this paper the state-of-the-art of underground earthquake observation in Japan is reviewed.

SP658; 1983 July. III-1–III-22. Fuller, G. R. **Single-story residential masonry construction in Uniform Building Code Seismic Zone 2.**

Key words: minimum property standards; partially reinforced masonry; residential; roof diaphragms; seismic resistance; shaking table tests; single-story.

The U.S. Department of Housing and Urban Development's (HUD) Minimum Property Standards (MPS) require that all masonry construction in Seismic Zone 2 have partial reinforcement in accordance with the Uniform Building Code (UBC). Since there is a lack of behavioral data on the resistance of single-story masonry houses to earthquake forces, the housing industry has objected to the added cost of providing this reinforcement. HUD therefore contracted with the University of California at Berkeley to determine the behavior of masonry structures under seismic loads, by testing full scale specimens on the shaking table. This paper is a report of the related results of material, timber roof connections and shaking table tests. HUD also engaged the Applied Technology Council (ATC) of Palo Alto to develop design and construction criteria for adoption in the HUD-MPS. Upon completion of that contract in early 1980, a separate report will be presented to the UJNR Panel.

SP658; 1983 July. III-23–III-28. Gergely, P.; Fagundo, F.; White, R. N. **The performance of lapped splices in reinforced concrete under high-level repeated loading.**

Key words: beams; bond; concrete; design; lapped splices; reinforced concrete; seismic design; splices; testing.

The results of two series of experiments on lapped splices in reinforced concrete is reported; one on half-scale beams and the other on full-scale beams. The effects of repeated loading and transverse reinforcement on splices in constant moment regions have been studied to date.

SP658; 1983 July. III-29–III-40. Ohtani, K.; Minowa, C. **Dynamic behavior of reinforced concrete frame structures.**

Key words: earthquake acceleration-displacement analysis; reinforced concrete structures; shaking table simulation; structural testing.

This study presents earthquake simulator test of reinforced concrete structures conducted at the Earthquake Engineering Laboratory of the National Research Center for Disaster Prevention at the Tsukuba New Science City.

Two types of one-story, single-bay reinforced concrete frames in actual size were built on the shaking table. The two reinforced concrete frames had different slab weights; about 60 tons for the first tested frame and about 130 tons for the second one. Using this large-scale shaking table, both reinforced concrete frames were subjected to simulated and modified earthquake ground motions with intensities large enough to cause inelastic behavior and dynamic property changes to the frames.

Test results of both frames are described, as is the yielding of reinforcing steel bars, the varying properties of the overall frame responses, natural frequencies, and damping ratios.

Finally, computer simulations to evaluate inelastic responses and the correlation with measured performance are described using bi-linear or tri-linear analytical models.

SP658; 1983 July. III-41–III-64. Becker, J. M.; Llorente, C.; Mueller, P. **Seismic response of precast concrete walls.**

Key words: dynamic analysis; friction; post-tensioning; precast concrete; seismic response; shear walls.

Large panel precast concrete structures have been widely utilized in major seismic regions throughout the world. The seismic behavior of such structures is strongly dependent upon the characteristics of both the horizontal and vertical connections. The limiting behavior of precast systems, however, is basically dependent upon the horizontal connection. The influence of horizontal connections can be studied in term of the behavior of a simple wall—a vertical stack of panels having only horizontal connections.

This paper reports on research into the seismic behavior of simple precast concrete walls. The research was carried out through the development of computer-based modeling techniques capable of including the typical behavioral characteristics associated with horizontal joints. The model assumes that all nonlinear, inelastic behavior is concentrated in the connection regions and that the precast panels remain linear elastic. This assumption allows the precast panels to be modeled as statically condensed 'super-elements' and the connection regions as interface elements. The above modeling technique allows for nonlinear-inelastic seismic analysis that is capable of handling both rocking type motions throughout the height of the structure and slippage due to shear in the plane of the connection.

A series of parametric studies are presented to illustrate the potential influence of rocking and slip on precast walls using both regular reinforcement and post-tensioning. These studies demonstrate the period elongation associated with the non-linear elastic rocking phenomenon. Shear slip is found to occur only when friction coefficients are extremely low or when the normal forces across the connections are low. This latter case occurs only in low buildings or in the upper floors of tall buildings.

The paper concludes with a brief discussion of the design implications of these results. Particular attention is paid to the problems stemming from the force concentrations associated with rocking and shear slip.

SP658; 1983 July. III-65–III-86. Ohashi, M.; Iwasaki, T.; Kawashima, K. **Seismic response analysis of the Itajima Bridge through use of strong motion acceleration records.**

Key words: bridge-pier foundations; bridge seismology; earthquake frequency characteristics; foundation structure response; ground surface accelerations.

In analyzing the seismic behavior of highway bridges constructed on soft soil deposits, it is important to take into account soil-structure interaction effects. In this paper, the seismic response of a bridge pier-foundation is analyzed from earthquake acceleration records taken simultaneously from the pier crest and the ground surface near the bridge. Four motions were used in the analysis, i.e., two were induced by two earthquakes with magnitudes of 7.5 and 6.6, and two by their aftershocks. In the former two earthquakes, the maximum accelerations were 186 and 441 gals on the ground surface, and 306 and 213 gals on the pier top. Analyses of frequency characteristics of the motions showed that the predominant frequencies of the pier-foundation were always almost identical to the fundamental natural frequency of the subsoil. Analytical models were formulated to calculate the seismic response of the pier-foundation assuming the subsoil and pier-foundation to be a shear column model with an equivalent linear shear modulus and an elastically supported beam on the subsoil, respectively. Bedrock motions were computed from the measured ground surface motions and then applied to the bedrock of the analytical model. The seismic responses of the pier-foundation were thus calculated and compared with the measured records and produced a good agreement.

SP658; 1983 July. III-87–III-118. Marcuson III, W. F.; Curro, J. R., Jr. **Field and laboratory determination of soil moduli.**

Key words: damping; dynamic properties; field testing; geophysical; laboratory testing; resonant column test; shear modulus; wave velocities.

A field geophysical investigation was performed to determine the shear and Young's moduli as a function of depth for a site in southern Ohio. This investigation included crosshole, downhole, and surface refraction investigation techniques. A supplementary set of laboratory resonant column tests were performed with the Drnevich resonant column device. Laboratory undisturbed specimens were excited in both the longitudinal and torsional modes to obtain both Young's and shear moduli as a function of strain. Both laboratory and field data are presented, compared, and discussed.

An idealized soil profile for boring 821-UD is presented. This soil profile includes recommended design values of moduli and damping. At this boring location, bedrock lies approximately 36 ft (11 m) below the ground surface. The 36 ft (11 m) thick soil deposit has been subdivided into four layers whose shear moduli range from 3.4×10^3 to 86×10^3 psi (23.4×10^3 to 592×10^3 kPa). The moduli increase as a function of depth. The Young's moduli for this soil profile range from 10×10^3 to 225×10^3 psi (59×10^3 to 1551×10^3 kPa) and also increase with depth. The internal damping of the soil deposit was found to range from 3 to 5 percent for low dynamic strain amplitudes and is constant with depth. The bedrock has a shear modulus of 125×10^3 (861×10^3 kPa) and a Young's modulus of 370×10^3 psi (2551×10^3 kPa).

SP658; 1983 July. III-119–III-132. Asama, T.; Shioi, Y. **An experimental study on the liquefaction of sandy soils in a cohesive soil layer.**

Key words: cohesion in soil; liquefaction; sandy soils; strain levels; stress levels.

Experimental and theoretical researches on liquefaction have been made by many researchers. There is a general understanding that liquefaction occurs when the shear stress reaches a critical value which is determined by the type of soil, its density, its normal stress, and the like. The previous research shows that an essential factor should be stress levels in the soils. But the authors observe that liquefaction chiefly depends upon strain levels of soils. Especially where a sand layer lies on a soft cohesive soil layer, the strain can be amplified by the response of the cohesive soils.

SP658; 1983 July. III-133–III-162. Oh-oka, H.; Itoh, K.; Sugimura, Y.; Hirosawa, M. **Stress-strain behavior of dry sand and normally consolidated clay by inter-laboratory cooperative cyclic shear tests.**

Key words: damping ratios; dynamic soil properties; shear modulus; shear-strain testing of sand and clay; stress-strain soil behaviors; test procedures.

Inter-laboratory cooperative cyclic shear tests were conducted to obtain fundamental information about stress-strain behavior of dry sand and normally consolidated clay by using various kinds of dynamic shear apparatus which have been developed in Japan.

The tests were carried out in order to examine the characteristics of test apparatus and test procedures under as nearly identical conditions as possible. The results obtained by these tests are compared and discussed.

SP658; 1983 July. IV-1–IV-19. Bampton, M. C. C.; Bosch, H.; Cheng, D. H.; Scheffey, C. F. **Wind and structure motion study for Pasco-Kennewick Bridge.**

Key words: aerodynamic response; bridges; cable-stayed bridges.

A program to study the responses to the natural wind of the 2507 ft (763 m) Pasco-Kennewick Bridge is described using an automatic data collection system. The study consists of three phases: preliminary investigation, data collection and data analysis. The study is sponsored by the Federal Highway Administration and will last two years.

SP658; 1983 July. V-1–V-5. Cooper, J. D.; Scheffey, C. F.; Sharpe, R. L.; Mayes, R. L. **Draft seismic design guidelines for highway bridges.**

Key words: bridges; design guidelines; seismic design.

Seismic design guidelines for highway bridges in the United States have been under development since 1977. The draft guidelines represent the collective thinking of a distinguished group of academicians, consultants and highway bridge engineers. The guidelines were formulated and based on both the observed performance of bridges during past earthquakes and on recent research conducted in the United States and abroad. They are currently undergoing evaluation by bridge designers and based on their comments are subject to change. The final version of the guidelines will be available in 1981.

SP658; 1983 July. VI-1–VI-8. Gergely, P.; White, R. N. **Analysis and design of cracked reinforced concrete nuclear containment shells for earthquakes.**

Key words: concrete; containment vessels; cracking; dynamic analysis; hysteresis; nuclear structures; reinforced concrete; seismic effects; shear; stiffness; testing.

Cracking reduces the shear stiffness of reinforced concrete cylindrical containment shells. An extensive experimental program on specimens carrying biaxial tension and cyclic shear produced highly nonlinear shear-slip curves, relatively high sliding shear strength, and low shear stiffness. The effects of this behavior on seismic response and design are discussed.

SP658; 1983 July. VI-9–VI-43. Iida, R.; Matsumoto, N.; Kondo, S. **Comparison of the measured and computed responses of the Yuda Dam during the July 6, 1976 and June 12, 1978 earthquakes.**

Key words: arched gravity dam; dynamic analysis; earthquake accelerogram; frequency response functions; hydrodynamic pressure.

Two accelerograms were recorded at the foundation and dam crest of the Yuda Dam, an arched gravity dam, during the July 8, 1976 and June 12, 1978 earthquakes. The frequency response functions for dam crest to foundation were calculated from these accelerograms. The ground acceleration was used as an input, and the dynamic response was calculated using two-dimensional FEM analysis to compare with the measured response.

The essential conclusions may be enumerated as follows: 1) The displacements at the crest of Yuda Dam were calculated from recorded accelerograms using a digital filtering procedure in which the cutoff frequency of the weighting function was slightly lower than the fundamental frequency of the dam. 2) According to the frequency response functions obtained from two accelerograms, the performance of the dam body may be considered to be linear elastic. The water level of the reservoir influences the frequency response function. 3) The computed response of the dam crest using the foundation accelerogram as an input from the two-dimensional FEM analysis coincides with the measured one. Comparing Westergaard's method and Chopra's method in the evaluation of hydrodynamic pressure, Chopra's method gives the response which contains more low frequency components than Westergaard's method. However, there is not much difference between them. Westergaard's added mass when computed by neglecting the compressibility of water provides a satisfactory approximation of the hydrodynamic pressure.

SP658; 1983 July. VII-1–VII-21. Watabe, M.; Matsushima, Y.; Ishiyama, Y.; Kubo, T.; Ohashi, Y. **Report on the 1978 Miyagi-Ken-Oki Earthquake.**

Key words: ground motions; Miyagi-Ken-Oki Earthquake; subducting plate actions.

The damage features and the causes of damage due to the Miyagi-Ken-Oki Earthquake June 1978 are summarized as follows: (1) Earthquake Ground Motions, (2) Damage of Structural Members, (3) Damage of Non-Structural Members, and (4) Overall Views.

SP658; 1983 July. VII-22–VII-35. Haruyama, H.; Kobayashi, M. **Disastrous ground failures in a residential area over a large-scale cut-and-fill in the Sendai region caused by the earthquake of 1978.**

Key words: artificial fill; disaster prevention; earthquake disaster; ground failure; slope steepness.

This paper examines the relationship between the disastrous ground failures in a hilly residential area and the land properties, due to the Miyagi-Ken-Oki earthquake of 1978.

We measured the change of landforms by comparisons of two maps based on aerial photographs taken before and after major area earthworks. As the first step, we prepared a landform map at a scale of 1/2,500 with a 2 meter contour interval, from a time just before the earthworks for residential development (1957) and after the earthworks (1978).

Then we constructed a thickness isopleth map of the artificial fill with a 2 meter interval and many profiles across the earthworks.

Then we examined the interrelationships between the distribution of ground cracks, the damage to destroyed houses, the retaining walls, the maps described above, and the original landforms.

SP658; 1983 July. VII-36–VII-61. Okubo, T.; Ohashi, M.; Iwasaki, T.; Kawashima, K.; Tokida, K. **Damage features of civil engineering structures due to the Miyagi-Ken-Oki Earthquake of 1978.**

Key words: earthquake history; ground motions; Miyagi-Ken-Oki Earthquake; subsoil conditions.

At 17h 14m (JST), June 12, 1978, a destructive earthquake took place offshore Miyagi-ken and caused extensive damage to buildings, highway facilities, river dykes, water supply, sewage systems, electrical and gas supply systems, and others.

Major observed damage characteristics shows: (i) the influence of subsoil conditions was great, and (ii) losses in commercial and industrial sectors and residential housings comprise a high percentage of the total damage amount.

This paper describes the outline of the earthquake, the earthquake history in the affected area, the geological and subsoil conditions, the recorded ground motions and damage features to civil engineering structures which were caused by the earthquake, especially bridge damage.

SP658; 1983 July. VII-62–VII-78. Yamamura, K.; Sasaki, Y.; Koga, Y.; Taniguchi, E. **Damage to river dykes caused by the Miyagi-Ken-Oki Earthquake of June, 1978.**

Key words: earthquake-resistant dykes; river dyke damage; soil liquefaction; soil relationships.

A large number of engineering structures were severely damaged by the Miyagi-Ken-Oki Earthquake of June, 1978. This paper describes the damage to the river dykes in the Kitakami, Naruse, Eai, and Yoshida Rivers by this earthquake.

Field surveys and laboratory investigations were performed on subsoils underlying the dykes and following conclusions drawn: i) River dykes in the Miyagi prefecture were extensively damaged by this earthquake. ii) The seismic resistance of river dykes is affected by the stability of supporting subsoils during an earthquake: either by a tendency toward liquefaction, or by the bearing capacity of the subsoils. iii) The damage of river dykes has a close relationship to the micro-topographical features. Dykes on a "former river bed" have a high potential to be damaged by earthquakes. It is suggested by the analyses on Eai River that the Land Form Classification Map for Flood Control Planning is useful in predicting river dyke damage. iv) Re-liquefaction may or may not occur at the same place. It was observed not to occur at a layer which had been compacted by previous earthquakes.

SP658; 1983 July. VII-79–VII-109. Tsuchida, H.; Noda, S. **Damage to port structures by the 1978 Miyagi-Ken-Oki Earthquake.**

Key words: earthquake damage; seaport damage characteristics; site liquefaction; stability analysis; strong motion accelerograms.

The 1978 Miyagi-Ken-Oki Earthquake (M=7.4) caused damage to port facilities. From field investigations and analyses, the following lessons concerning earthquake engineering were learned: 1) Strong-motion accelerograms were recorded by an observation network of the Port and Harbour Research Institute. The largest peak ground acceleration of 280 gals was recorded at Shiogama Port. 2) Port facilities were damaged seriously when a backfill liquefied. Otherwise, they suffered only lightly. 3) Current procedures for estimating liquefaction potential can lead to an appropriate judgement for actual sites. 4) A relationship between the seismic coefficient and the maximum ground acceleration for gravity quaywalls: $e = 1/3(g)^{1/3}$ agrees with the investigations of this earthquake. 5) The above-mentioned relationship may be equally applicable to a stability calculation for sheetpile quaywalls with anchor plates.

SP658; 1983 July. VII-110–VII-129. Agbabian, M. S. **Wood diaphragms in masonry buildings.**

Key words: analytical model; dynamic response; seismic hazard; unreinforced masonry; wood diaphragms.

Reports of damage from past earthquakes indicate that wood diaphragms supported on masonry walls have suffered little or no damage during excitation. However, the supporting masonry walls have suffered degrees of damage varying from minor tension cracks to separation from the diaphragms and complete collapse.

The interaction of a diaphragm with the masonry walls has a critical effect on the dynamic behavior of the structure. Numerical analyses of plywood, diagonal- and straight-sheathed floor and roof diaphragms indicate that highly nonlinear and hysteretic load-deflection relationships are needed to describe the response of wood diaphragms. Experiments are planned to improve the analytical model by obtaining performance characteristics of wall anchorages to diaphragms as well as deformations of diaphragms under cyclic excitations. Finally, candidate retrofit/strengthening techniques will be incorporated into typical wood diaphragms, and the tests will be repeated in order to develop structural systems that will survive disastrous earthquakes.

SP658; 1983 July. VII-130–VII-142. Agbabian, M. S. **Mitigation of seismic hazards in existing unreinforced masonry buildings.**

Key words: earthquake hazard mitigation; masonry buildings; mitigation; seismic hazards.

Analytical and experimental investigations to determine resistance of structures in various seismic zones of the United States are combined in an ongoing study. The study is being carried out by a joint venture of three consulting engineering firms in Los Angeles under the sponsorship of the National Science Foundation.

A survey was initially made of unreinforced masonry (URM) buildings in seven geographic areas in the United States. The selection of types of structures for investigation considered construction materials, size, distribution of walls around the perimeter and within the building, connection details, and the application or absence of seismic design criteria.

The structures selected for study consist of: a) Rectangular, six-story industrial buiding; b) Rectangular, four-story public school; c) Irregular, four-story plus basement public building; d) U-shaped, four-story apartment building; e) Rectangular, six-story and three-story office buildings; f) Rectangular, one-story and three-story industrial buildings. A methodology for earthquake hazard mitigation is being developed that will be applicable to the broad range of buildings surveyed. Concurrent with these analyses, tests are planned for masonry walls in the out-of-plane and in-plane directions, anchorage of walls to diaphragms, and wood and steel diaphragm characteristics. Tests of repaired and/or retrofitted elements will also be carried out.

The effect of the following rehabilitation techniques is being investigated: Strengthening of masonry walls; Adding or improving anchorages; Repair and strengthening of diaphragms; Amelioration of foundation settlement.

SP658; 1983 July. VII-143–VII-156. Murota, T.; Ishiyama, Y. **Development of a universal fastener for wooden building roof frames.**

Key words: joint fasteners; roofing damage; structural performance; tension tests; universal fasteners; wooden roofs.

A new type of joint fastener to be used in reinforcing wood building roof frames was developed at the Building Research Institute. This fastener, its behavior and strength developed in tension tests are described and shown in this paper. The structural performance of this fastener is also compared to those of conventional joint fasteners such as cramp irons.

SP658; 1983 July. VIII-1–VIII-22. Scalzi, J. B.; McDonough, G. F., Jr.; Costes, N. C. **The NASA/MSFC experimental facilities at Huntsville, Alabama.**

Key words: foundation tests; large scale testing; structures soils; test facilities.

An evaluation of National Aeronautics and Space Administration (NASA) facilities and supporting capabilities for earthquake engineering research was made during a site visit and workshop held at George C. Marshall Space Flight Center (MSFC), Alabama, on February 22, 23, and 24, 1979. Workshop participants included twenty-six earthquake engineering specialists from the academic community, industry, and government. The workshop was sponsored by the National Science Foundation and NASA, and it was hosted by MSFC. The chairmanship and overall direction of the workshop was assumed by the Earthquake Engineering Research Institute.

The results of the workshop indicate that the NASA/MSFC facilities and supporting capabilities offer unique opportunities for conducting earthquake engineering research. Specific features that are particularly attractive for large-scale static and dynamic testing of natural and man-made structures include the following: large physical dimensions of buidings and test bays; high loading capacity, wide range and large number of test equipment and instrumentation devices; multichannel data acquisition and processing systems; technical expertise for conducting large-scale static and dynamic testing; sophisticated techniques for systems dynamics analysis, simulation and control; and capability for managing large-size and technologically complex programs.

This paper will describe the pertinent facilities at MSFC including their capabilities, original purpose and utilization and potential uses, both in their current state and with modification, to support seismic testing of structures.

SP658; 1983 July. VIII-23–VIII-27. Thiel, C. C.; Anderson, W. A.; Gaus, M. P.; Hakala, W.; Krimgold, F.; Liu, S. C.; Scalzi, J. B. **Earthquake hazards reduction research supported in 1978.**

Key words: earthquake design; earthquake hazards research; geotechnical engineering; seismic design standards.

Research activities supported by the National Science Foundation in 1978 are reviewed. Abstracts of 153 awards are presented to describe the diversity of research activities underway as part of the National Earthquake Hazards Reduction Program.

SP658; 1983 July. VIII-28–VIII-112. Nakazawa, K.; Kuribayashi, E.; Tazaki, T.; Hadate, T.; Hagiwara, R. **Functional damage and rehabilitation of lifelines in the Miyagi-Ken-Oki Earthquake of 1978.**

Key words: functional damage; lifeline systems; Miyagi-Ken-Oki Earthquake.

The Miyagi-Ken-Oki Earthquake of June 12th, 1978 with a magnitude of 7.4 brought many disasters to Sendai City, population six hundred thousand, and the adjacent area. The disaster is deemed one of the biggest earthquake disasters since the Kanto Earthquake of 1923. Since then earthquake disasters in modernized prefectural cities have been experienced in the Fukui Earthquake of 1948 and the Niigata Earthquake of 1964. However, Sendai City was more greatly urbanized than Fukui City and Niigata City was in those days.

In this survey, the facts connected with earthquake disaster prevention measures were investigated cooperatively with the organizations listed later. This paper aims primarily at a successful analysis of the functional losses and the rehabilitation of lifeline systems.

SP658; 1983 July. VIII-113–VIII-120. Anderson, W. A. **Social aspects of earthquake mitigation and planning in the United States.**

Key words: hazard awareness; mitigation and preparedness measures; socioeconomic factors.

A number of social scientists in the United States have recently turned their attention to the pre-disaster responses of individuals and social units and are investigating the socioeconomic factors related to mitigation and preparedness. This research is important because it promises to result in the identification of the principal factors which influence the utilization of known and developing social and technological adjustments to earthquakes, including building codes, land use regulations, public education and earthquake prediction. As a result of on-going and recently completed social science studies, increased knowledge is developing on a number of important topics. The emerging findings on the following questions are discussed in this paper: How is the earthquake hazard perceived by officials and the public? What types of mitigation and preparedness measures are citizens and officials willing to accept? What is the impact of some existing hazard mitigation programs? What are some of the social factors to consider in trying to enhance the benefits of future earthquake predictions?

SP658; 1983 July. IX-1–IX-7. Takahashi, H.; Fujinawa, Y. **Orientation of tsunami research in Japan.**

Key words: disaster warning; earthquake detection; flood warning; tsunami prediction; tsunami research.

We have been struck by large tsunamis which were induced by earthquakes occurring near the Tonankai area of Japan on an average of every thirteen years in a 350 year period. It is conjectured by some seismologists that a large earthquake may occur in the area of Tonankai. We have experienced nine earthquakes which are considered to be grouped in the Tonankai earthquake zone. All of these earthquakes were accompanied by tsunamis. Victims rose to 31,000 in 1498 (Meio), 3,906 in 1605 (Keicho), 4,924 in 1707 (Hoei, and 3,427 in 1854 (Ansei), respectively. We urgently need to plan countermeasures against tsunamis, especially to develop a warning system for tsunamis which take less than about ten minutes to reach our coasts. Tsunami research in Japan is briefly reviewed from the standpoint of developing an effective warning system.

SP658; 1983 July. IX-8–IX-18. Hashimoto, H.; Uda, T. **Wave setup caused by typhoon 7010.**

Key words: storm surge; typhoon damage; wave setup.

Typhoon 7010 caused heavy damage to Kochi city brought on by flooding from the storm surge. Numerical computations were carried out but they do not explain fully the abnormally high rise of the sea level. As one explanation, it is suggested that wave setup contributes to an abnormally high rise since a typhoon is usually accompanied by high waves.

Experimental investigation and numerical calculations were carried out to make clear the magnitude of wave setup at the mouth of Kochi harbor. Generally, on a straight coast, the normal component of radiation stress caused by breaking waves generates wave setup and the tangential component generates along-shore current. Investigations, however, show that the along-shore current is obstructed by a breakwater at Kochi harbor and wave setup is generated by the tangential component together with the normal one. The wave setup contributes to the anomaly, and its height is estimated to range from 0.5 m to 1.0 m. Numerical calculations confirm the experimental results though they need further improvement.

SP658; 1983 July. IX-19–IX-24. Barrientos, C. S.; Hess, K. W. **Specification and prediction of surface wind forcing for ocean current and storm surge models.**

Key words: hurricane; ocean current; oil spill trajectory; storm surge; wind forcing; wind models.

Forecast methods to predict movements of oil spills in the ocean are being developed in the Techniques Development Laboratory of the National Weather Service (NWS). An operational model for oil movement forecast is being implemented in NWS. The model will be available for routine use in the event of oil spills and for assessment studies of probable impacts of oil spills.

The most important component in the movement of an oil spill is due to the surface wind forcing. Surface wind stress acts on the spilled oil in two ways: (1) to generate ocean surface currents, and (2) to drag directly the oil on the surface. We examined different boundary layer wind formulations and assessed the resulting surface currents response.

A dynamical storm surge model has been developed in NWS and is being used in real time forecasting of surges when a hurricane is approaching land. The model has proved useful in routine use during the last 10 years. Recently, a model has been developed that forecast surges in bays and estuaries.

Storm surge is generated by the action of the wind and low atmospheric pressure in the storm (inverted barometer effect). The wind forcing is the dominant factor in surge generation. The spatial distribution of the wind in a storm or typhoon determines the resulting characteristics of the surge, such as, maximum surge and location on the coast, extent of the coastline affected by the surge and the height variation of the surge along the coast. We tested different storm wind models and determined the response of the storm surge model.

SP658; 1983 July. IX-25–IX-28. Jelesnianski, C. P.; Barrientos, C. S.; Chen, J. **A dynamic model to predict storm surges and overland flooding in bays and estuaries.**

Key words: forecast and warning; hurricane; overland flooding; storm surge.

In the United States, most of the damages caused by hurricanes are attributed to storm surges. NOAA provides forecast and warning services to prevent loss of lives and property. A dynamical model was developed to forecast storm surges in bays and estuaries. The development of the model and the operational application for forecasting will be described.

SP658; 1983 July. IX-29–IX-37. Goda, Y. **Topics on tsunami protection along the port areas in Japan.**

Key words: disaster planning; seawall protection; tsunami breakwaters; tsunami prediction.

The major Japanese tsunamis since the 15th century and a general description of counter-measures against them are briefly introduced. Particular reference is made on tsunami break-waters used to protect port areas. The performance of the Ofunato tsunami breakwater in the instance of the Tokachi-oki Earthquake Tsunami in 1968 is discussed, and a new plan for a Kamaishi tsunami breakwater is introduced. Also mentioned are several tsunami prediction plans in progress.

SP658; 1983 July. X-1–X-16. Hattori, S. **Seismic risk maps (maximum acceleration and maximum particle velocity) in the Southeast Asian countries of the Philippines, Indonesia, and Indo-China.**

Key words: disaster prediction; earthquake motions; hypocenters; seismic risk maps; seismic zoning.

Seismic risk maps in the Southeast Asian Countries of the Philippines, Indonesia, and Indo-China were made using existing seismic data, attenuation models, and the method of extreme value fitting. The maps consist of the following two kinds: (i) The maximum particle velocity (kine) on the base rock, and (ii) The maximum acceleration (gal) on the ground. The return periods of these maps are 50, 100 and 200 years, respectively.

This paper is a modification of the report which the author is going to present at the International Conference on Engineering for Protection from Natural Hazard, which was held in the Conference Center of the Asian Institute of Technology in Thailand January 7-10, 1980.

SP658; 1983 July. X-17–X-38. Meehan, J. F. **California school and hospital ceilings.**

Key words: anchorage; applied ceilings; plaster ceilings; seismic forces; T-bar ceilings.

A description of the methods of anchoring plaster, panel applied and T-bar ceilings against seismic forces is presented which is acceptable to the Structural Safety Section of the Office of the State Architect for public school and hospital buildings in California.

SP659. Cullen, W. C.; Rossiter, W. J., Jr.; Mathey, R. G.; Clifton, J. R. **Low sloped roofing research plan.** *Natl. Bur. Stand. (U.S.) Spec. Publ. 659;* 1983 July. 40 p. SN003-003-02507-1.

Key words: low-sloped roofing; mathematical modeling; membranes; repair; research plan; roofs; standards; thermal insulations.

This report presents a long-range plan for roofing research. The plan was developed in response to a need for roofing research addressing major materials problems and changes in low-sloped roofing materials technology. The intent of the plan is to establish the technical basis for developing standards and minimum levels of performance to assist in the selection of cost-effective and durable roofing materials. Four major areas of needed research are identified: (1) low-sloped roofing systems, (2) roofing membranes including single-ply and built-up, (3) thermal insulation for roofing systems, and (4) condition assessment and repair of roofs. Within each research area, a goal is given as well as a number of objectives to achieve the goal. A recommended approach to accomplish each objective is also given.

JOURNAL OF RESEARCH

The Journal of Research of the National Bureau of Standards reports NBS research and development in those disciplines of the physical and engineering sciences in which the Bureau is active. These include physics, chemistry, engineering, mathematics, and computer sciences. Papers cover a broad range of subjects, with major emphasis on measurement methodology, and the basic technology underlying standardization. Also included from time to time are survey articles on topics closely related to the Bureau's technical and scientific programs. As a special service each issue contains complete citations to all recent NBS publications in NBS and non-NBS media.

Mahajan, B. M. **Analysis of liquid flow-induced motion of a discrete solid in a partially filled pipe.** *J. Res. Natl. Bur. Stand. (U.S.). 88(4):* 261-288; 1983 July-August.

Key words: analysis; flow; force; liquid; model; momentum; partially-filled; pipe; solid; solid-liquid channel flow; steady; uniform; velocity.

An analysis is presented for the liquid flow-induced motion of a solid in partially filled pipes. A general equation of the flow-induced motion of a solid is developed. Two alternate force models, one (F_v) based on free stream velocity and another (F_m) based on free stream momentum flux, are formulated to simplify the general equation.

The equation of motion is solved for the motion of a cylindrical solid with steady-uniform liquid flows and the effects of relevant variables on the motion of a solid are predicted. The variables considered include: volume rate of liquid flow, Q; pipe diameter, D; Manning coefficient, n; and slope, S; solid diameter, d; length, L; specific gravity, σ; coefficient of friction between a solid and the pipe wall, η; and the two force functions, F_v and F_m.

The flow rate, Q_t, required to initiate the motion of a solid increases with an increase in D, n, d, L, σ, and η_s, and decreases with an increase in S. The force function F_m predicts a lower value of Q_t than does the force function F_r.

The velocities of a solid increase with an increase in Q and S and decrease with an increase in D, n, d, L, σ, and η. The force function F_m predicts higher values of the velocity of a solid than does the force function F_r.

The effects of the variables Q_o, D, S, d, L, and η_s on the velocities of a solid are qualitatively consistent with the available experimental data. The qualitative agreement between the predicted results and experimental data demonstrate the validity of the analysis presented.

NBS INTERAGENCY REPORTS

The Interagency Reports are a special series of interim or final reports on work generally performed by NBS for outside sponsors (both government and non-government). When released by the National Bureau of Standards and the Sponsor, initial distribution is handled by the Sponsor. Public availability is by the National Technical Information Service (NTIS), Springfield, VA 22161. This series must be ordered from NTIS by the order number listed at the end of each entry.

NBSIR 81-2456. Barnett, J. P. **Selected measured data from residential housing for use in testing and verification of building energy analysis programs.** 1982 January. 62 p. Available from: NTIS; PB 83-216341.

Key words: building energy analysis program; data tape; measured hourly data; testing and verification.

A set of measured residential data has been culled from three larger data sets for use in the testing and verification of building energy analysis programs. The data consist of hourly values for heating/cooling system performance and weather conditions that are sufficient in detail, it is believed, for all existent computer programs. These data have been encoded onto a magnetic tape. In addition, general information has been collected on the houses, occupants/occupant use, and heating/cooling systems.

NBSIR 82-2485. Collins, B. L.; Lerner, N. D.; Pierman, B. C. **Symbols for industrial safety.** 1982 June. 157 p. Available from; NTIS: PB 82-237850.

Key words: communication; hazard; pictogram; safety; signs; standards; symbols; visual alerting; warnings.

Written signs are commonly used in industrial sites to provide hazard warnings and safety information. The use of safety symbols may increase the effectiveness of safety communication, because such signs are language-free, and because they can be recognized more rapidly and accurately than written text even under some conditions of interference and distraction. The effectiveness of safety symbols critically depends upon the selection of symbolic images which are readily understandable to the intended audience. A four phase evaluation of a set of selected industrial worksite symbols is described. The four phases involved identification of 33 key safety messages, selection of candidate symbols for each message, evaluation of the understandability of the candidate symbols, and determination of the preference for the 87 candidate images, using both industrial and nonindustrial (naive) personnel. Symbol understandability, in terms of percentage of correct responses and confusions, varied widely for the thirty-three referents. Despite standardized use for a number of years, the radiation, biohazard, and laser symbols were frequently misidentified. Symbols for protective gear, first aid, and emergency equipment were generally correctly identified. The different images selected for various hazards show the greatest range in understandability, with the results for symbolic versions of entanglement, electricity, corrosion, and overhead hazard being quite different. The most frequently correct image was usually also the most preferred.

NBSIR 82-2489. Parken, W. H.; Kao, J. Y.; Kelly, G. E. **Strategies for energy conservation in small office buildings.** 1982 July. 55 p. Available from: NTIS; PB 82-245820.

Key words: building control strategies; building energy conservation; building thermal performance; HVAC.

A comparative analysis is made of the thermal performance of a small office building using various HVAC systems and commonly employed strategies. The comparisons are made for seven geographical locations representing wide climatic variations within the continental United States.

Results were obtained for fan, space heating hot water, and chilled water energy consumption through hour-by-hour simulations using the BLAST computer program. A small office building model was used in the simulations along with several HVAC systems; a constant volume reheat unit (serving the entire building), dual constant volume reheat units (serving separate zones of the building), and a variable air volume reheat unit. The strategies investigated included supply air temperature reset (constant, zone-controlled, and outdoor air-controlled), economy cycles (temperature and enthalpy), continuous conditioning versus conditioning only during occupied hours, changes in reheat set point temperature, and changes in minimum variable air volume ratio. For comparable control strategies, the variable-air volume terminal reheat system exhibited the least energy consumption for chilled water, hot water and circulating fan. The system incorporating two independently-operating constant volume terminal reheat units ranked second in energy consumption while the single constant volume terminal reheat unit ranked last. Changes in thermal performance resulting from implementing one strategy in place of or in combination with another were found to vary significantly by climate and the type of HVAC system employed.

NBSIR 82-2510. Chang, Y. M. L.; Grot, R. A. **Quality of inspections utilizing infrared technology on weatherization retrofit installations.** 1982 November. 109 p. Available from: NTIS; PB 83-146936.

Key words: building heat losses; comparison of inspections; infrared scanning systems; insulation voids; interpretation of thermograms; thermal deficiencies; thermographic inspections; weatherization retrofits.

A comparative evaluation of various portable infrared sensing systems used for detecting heat loss anomalies within building envelopes was performed. This is the second of a two-stage applied research program sponsored by the Department of Energy to assess the application and reliability of using infrared technology. Twelve single-family residences in three cities from the Weatherization Program of the Community Services Administration were employed as field samples. The results of infrared surveys carried out by thermographic surveying firms and those by the National Bureau of Standards were analyzed and compared in the categories of: completeness of scanning, identification of defects, weather condition of inspection, and method of equipment operation. The thermograms of uninsulated areas, sketches of observed thermal deficiencies, and total areas of defects for each dwelling are presented. Through the comparison, the degree of completeness of inspecting the residences thoroughly was evaluated to be the most important factor for defect identification. The results of thermographic inspection of the homes showed that serious thermal anomalies still existed in most of these 'weatherized' residences, with a majority exhibiting between 5 percent and 15 percent of the wall areas uninsulated, or defective. The total uninsulated areas observed by each surveyor was found to be affected by the quality of thermograms submitted.

NBSIR 82-2568. Chung, R. M.; Yokel, F. Y. **Contribution to the ASTM resonant column round robin testing program.** 1982 December. 64 p. Available from: NTIS; PB 83-151161.

Key words: damping; resonant column; round robin tests; shear modulus; soil dynamics; test methods; torsional vibrations.

Results from National Bureau of Standards (NBS) resonant column tests to determine shear moduli and damping ratios for Monterey No. 0 sand are presented to supplement the ASTM resonant column round robin program. In addition to testing solid specimen as specified for the initial ASTM round robin program, hollow cylindrical specimens were tested to provide an independent check on the validity of the results.

The NBS test data on shear moduli are consistently lower than the average values obtained from the initial round robin program, but they are within the range of the initial round robin test data. It is believed that, at least in part, the difference between the NBS and the round robin data was caused by the fact the NBS specimens had a lower average relative density which was also closer to 60 percent relative density specified for the round robin tests. Damping ratios obtained by NBS fit rather closely the curve obtained from the initial round robin program.

No significant difference was found between the maximum shear moduli and damping ratios obtained from the testing of solid specimens and hollow cylindrical specimens.

NBSIR 82-2589. Harris, J. R.; Leyendecker, E. V., eds. **Plan for a trial design program to assess amended ATC 3-06 tentative provisions for the development of seismic regulations for buildings.** 1982 November. 28 p. Available from: NTIS; PB 83-172676.

Key words: building structures; earthquake codes; earthquake engineering; earthquake standards; seismic design; trial designs.

This report presents a trial design program to establish the technical viability of the recommendations contained in the report *The Tentative Provisions for the Development of Seismic Regulations for Buildings* developed by the Applied Technology Council and subsequently modified in a review project conducted by the building Seismic Safety Council (BSSC) and the National Bureau of Standards. The trial design program is intended to provide information for estimating the impact of adopting the recommendations in the *Tentative Provisions,* evaluate the useability of the *Tentative Provisions,* establish the technical viability of the *Tentative Provisions* and obtain objective information for the future resolution of disputes concerning specific provisions. The trial design program is a phased program. Phase 1, being conducted by the BSSC, consists of designs of twenty-seven buildings and is underway. The BSSC is actively pursuing completion of the trial design program through additional funding and voluntary effort.

NBSIR 82-2602. Winter, F.; Galowin, L. **Experimental evaluation of circulation loop drain and vent plumbing modifications for building rehabilitation.** 1982 December. 94 p. Available from: NTIS; PB 83-162339.

Key words: innovative venting; plumbing; plumbing renovation; rehabilitation; vents for plumbing.

Rehabilitation or modernization of existing buildings frequently imposes increased loads on the plumbing water supply and drainage system. The requirement for venting in U.S. practice is intended to prevent trap seal loss from exceeding values prescribed in model plumbing codes. The vent piping in older buildings may be marginal for retrofit under code requirements for new construction with the same or increased numbers of fixtures and devices installed into the plumbing system.

An experimental laboratory investigation of a "circulation loop" modification to a drain-waste-vent (DWV) system was conducted to determine the change in performance. An experimental evaluation of the performance of the modified system and a conventional system were undertaken for a variety of simulated wastewater-loads with various plumbing fixtures and multi-story soil stack loads. The performance parameters considered were trap seal failures, backflow, and the siphonic action of the water closets. Also, the dynamic responses to pressure excursions and air flow rates in the branches were measured. Both systems were tested to the limiting condition for single-stack performance over a range of air flow rates into the soil and vent stack.

The circulation loop system was found to decrease the pressure difference in the upper portion of the soil stack, and to provide limited benefits in reducing trap seal failures and failure due to reduced siphonic action in the lower level water closets. With vent valves open, both the conventional and modified loop systems provided satisfactory venting except at the highest loads. Additional research should be undertaken to develop methods for sizing the soil stack and vent connection fitting connection to the circulation loop. Further testing should also be done with small regulated air flows into the vent stack.

NBSIR 82-2605. Grot, R. A.; Burch, D. M.; Silberstein, S. **Measurement methods for diagnostic procedures in evaluation of thermal integrity of building envelopes.** 1982 November. 140 p. Available from: NTIS; PB 83-180174.

Key words: air infiltration rates; envelope thermal performance; infrared imaging; radiometers; thermal bridges; thermographic surveys; tracer gas techniques.

This report presents reviews of various measurement and inspection techniques appropriate for the development of detailed diagnostic procedure for assessing the thermal performance of the exterior envelopes of federal buildings. The inspection techniques include the use of ground-based infrared thermographic surveys, aerial infrared surveys, tracer gas air infiltration measurement, pressurization tests for measuring the tightness of the building envelope, and spot radiometer surveys for detecting gross defects. Heat flow meters, a portable calorimeter, and a microprocessor-driven envelope testing unit are also considered.

For each technique recommended procedures are provided; they include equipment requirements, conditions under which the techniques can be carried out, calibration, accuracy, and limitations. The detailed diagnostic procedures specific to small and large federal buildings require further development from on-site field testing of representive buildings.

An Executive Summary provides an overview of the Building Diagnostic Program of which Phase 1 is covered in this report. Field test evaluations will be carried out in Phase 2 and implementation under Phase 3.

NBSIR 82-2606. Klein, S. A. **A model of the steady-state performance of an absorption heat pump.** 1982 October. 56 p. Available from: NTIS; PB 83-152314.

Key words: absorption heat pump; ammonia-water; ARKLA water chiller; experimental performance; mathematical model; steady-state performance.

A mathematical model of the steady-state performance of an absorption heat pump is described. The model is compared with experimental data from a residential-sized water chiller. It is also used to determine the sensitivity of the heat pump performance to its design variables.

NBSIR 82-2610. Yaniv, S. L.; Flynn, D. R. **Highway noise criteria study: Executive summary.** 1982 October. 38 p. Available from: NTIS; PB 83-149831.

Key words: acoustics; general adverse response to noise; noise measurement; sound.

This report summarizes a multifaceted research program carried out by the acoustics staff of the National Bureau of Standards at the request of the Federal Highway Administration. The program was designed to (1) identify and quantify the important physical parameters associated with time-varying highway noise caused by various densities of both free-flowing and stop-and-go traffic conditions; (2) investigate, evaluate and compare measures and computational procedures for rating time-varying noise in terms that are relevant to human response; and (3) determine by means of a laboratory study which among several time-varying rating schemes best predicts acceptability and annoyance caused by traffic noise as heard both outdoors and indoors. The results of this program are briefly described and the implications of the major findings discussed.

NBSIR 82-2614. Swaffield, J. A. **The prediction of floating solid velocities in unsteady partially filled pipe flow.** 1983 July. 35 p. Available from: NTIS; PB 83-258598.

Key words: floating solids; partially filled pipe flows; pipe flow with solids; plumbing drains.

The method of characteristics is applied to solve the unsteady partially filled pipe flow equations and to predict the velocity of floating solids assumed to travel at a fixed percentage of the local flow velocity.

Experimental verification for the technique is provided for cylindrical solids in 100 mm diameter drainage pipe at a range of gradients from 1/40 to 1/150.

The system upstream boundary conditions are shown to be capable of representation in terms of the inflow energy at the pipe entry section.

Steady flow floating solid to flow velocity ratios are presented at 1/150 pipe gradient and further areas of experimental work to determine the variation of these ratios with pipe gradient and flow depth are identified.

NBSIR 82-2621 (DoE). Liu, S. T. **Thermal comfort conditions in the NBS/DoE direct gain passive solar test facility.** 1982 December. 48 p. Available from: NTIS; PB 83-162032.

Key words: ASHRAE Comfort Standard 55-1981; black globe temperature; comfort envelope; direct gain room; operative temperature; passive solar test facility; solar radiation; thermal comfort.

The thermal comfort conditions in a direct gain cell of the NBS/DoE passive solar test facility were analyzed in accordance with the criteria specified in the recently revised ASHRAE Comfort Standard 55-1981, using test data collected during the month of October 1981 and the month of January 1982. It was found that the daytime operative temperature (as measured by the black globe temperature sensors) in an area near the large south glazing exceeded the upper boundary of the ASHRAE comfort envelope by a large amount in a clear day during both the thermal transition month of October and the cold winter month of January. The generally accepted method of computing the mean radiant temperature based only on the interior surface temperatures was found to produce large errors. The reflected solar radiation from the interior surfaces and the snow covered ground was believed to play a significant role on the measured black globe temperature and should be included in the computation of the mean radiant temperature for a space with large glazed areas.

NBSIR 82-2626. Leyendecker, E. V., ed. **Amendments to ATC 3-06 Tentative Provisions for the development of seismic regulations for buildings for use in trial designs.** 1982 December. 91 p. Available from: NTIS; PB 83-158543.

Key words: building structures; earthquake codes; earthquake engineering; earthquake standards; seismic design; trial designs.

The report presents amendments to the seismic design recommendations contained in the report "Tentative Provisions for the Development of Seismic Regulations for Buildings" developed by the Applied Technology Council. These amendments were prepared in a review project conducted by the Building Seismic Safety Council and the National Bureau of Standards. The amendments plus the Tentative Provisions will be used in a trial design program to provide information for estimating the impact of adopting the recommendations.

NBSIR 82-2630. Kopetka, P.; Galowin, L. **Development and evaluation of a test method for shower heads.** 1983 February. 64 p. Available from: NTIS; PB 83-180406.

Key words: plumbing; showerheads; water conservation; water supply devices.

A proposed test method for the evaluation of low-flow shower heads or flow-restrictor-modified shower heads was developed. The test method provides for the measurement of the principal operating characteristics, i.e., pressure-flow rate dependency and the shower spray distribution. The requirements for laboratory instrumentation suitable for application to the apparatus and the procedures for testing were established. A water collection device, "sector rig," was designed and constructed for the measurement of spray distribution patterns. Experiments were conducted with a small number of shower heads to determine the suitability of the proposed test method. The experimental results indicated the applicability of the method for measurement of spray distribution patterns and other conventional hydraulic performance parameters. A proposed test method for evaluation of shower heads was prepared based upon the analysis of the test results. The test method includes the specification of instrumentation, apparatus, procedures, measurements, and data reduction.

NBSIR 82-2632. Spellerberg, P. A.; Welborn, J. Y. **A review of the Bituminous Reference Sample Program of the AASHTO Materials Reference Laboratory.** 1982 December. 24 p. Available from: NTIS; PB 83-164608.

Key words: coefficient of variation; laboratory performance; test precision.

The Bituminous Reference Sample Program of the AASHTO Materials Reference Laboratory has been operating for more than fifteen years. This paper provides an overview of the accomplishments of this important cooperative undertaking of the National Bureau of Standards and the American Association of State Highway and Transportation Officials.

Background information on the development of standard specifications and methods of test, the AASHTO and the AMRL, is presented to give a historical perspective and to identify the need for the program. Details concerning its operation are reviewed. The coefficients of variation derived from the analysis of laboratory test data from a number of selected tests are plotted and evaluated. The value of the laboratory rating system and the laboratory performance charts which have been developed is discussed. conclusions are made regarding the effectiveness of the program and the accuracy of established test precision limits.

NBSIR 83-2635. Walton, G. N. **A computer algorithm for estimating infiltration and inter-room air flows.** 1983 February. 35 p. Available from: NTIS; PB 83-174904.

Key words: building energy analysis; building heat transfer; computer modeling; convection; infiltration; ventilation.

This report discusses the extension of an infiltration predicting technique to the prediction of inter-room air movements. The air flow through openings is computed from the ASHRAE crack method together with a mass balance in each room. Simultaneous solution of the mass balances in all rooms having both large and small openings is accomplished by a slightly modified Newton's method. A simple theory for two-way flow through large openings is developed from consideration of density differences caused by different temperatures in adjoining rooms. The technique is verified by comparison to published experimental results. The results indicate that the simple model provides reasonable results for complex two way flows through openings. The model is as accurate as the available data, that is, about ±20%. The air flow algorithm allows infiltration and forced air flows to interact with the doorway flows to provide a more general simulation capability.

NBSIR 83-2638. Chi, J.; Didion, D. **A commercial heating boiler transient analysis simulation model (DEPAB2).** 1983 January. 93 p. Available from: NTIS; PB 83-165480.

Key words: boilers; computer model; energy conservation; fire tube boilers; heat transfer.

This report documents a second generation boiler transient analysis computer program DEPAB2. It treats in detail the boiler controllers and different modes of heat transfer (which include conductive, convective and radiative) in the boiler environment; and it is built upon 7 principal subroutines for the controller and interface flux calculations and 16 auxiliary subroutines for fluid properties, fuel/air combustion and heat transfer parameters.

Also included is a guide on using DEPAB2. Included are: (1) Input data requirements for DEPAB2 runs, (2) Procedures for DEPAB2 runs, and (3) Output data interpretation. In addition, a worked example is described and discussed in detail to illustrate: (1) the DEPAB2 runs, (2) quantitative information generated by DEPAB2 runs, and (3) use of information from DEPAB2 runs to design energy conservation strategies.

NBSIR 83-2648. Mulroy, W. J.; Park, C. **Experimental and analytical investigation of a residential hot water boiler with finned copper tube heat exchangers.** 1983 March. 64 p. Available from: NTIS; PB 83-201467.

Key words: annual efficiency; annual operating costs; boilers; fossil fuel heating systems; jacket loss; modulating control gas fueled; part-load performance; rating procedures; seasonal efficiency.

In response to a request by a manufacturer of a nontypical boiler, the Department of Energy requested the National Bureau of Standards to perform laboratory measurements under controlled conditions of the effect on seasonal performance of several features (finned copper tube heat exchanger, water circulating pump delay, and gas valve modulation) of this boiler that might cause it to be unfairly treated by the existing test procedure. As a result of this study, recommended changes to the existing test procedure to allow rating tests with water circulating pump delay are presented. A recommended change to the assigned cyclic jacket loss factor and a simplified procedure for experimentally determining this factor are also presented. No change tc the current test procedure treatment of gas valve modulation or flue gas mass flow as a function of temperature are recommended.

NBSIR 83-2653. Wise, R. A. **Field test results on the performance of a refrigerator-freezer in a single-family residence.** 1983 February. 23 p. Available from: NTIS; PB 83-179010.

Key words: consumer; defrost; door-openings; energy use; field test; home; ice cubes; ice-maker; refrigerator; refrigerator-freezer.

The operation of a side-by-side 623 L (22 cubic foot) refrigerator-freezer in use in a single family residence was continuously monitored for over two years. During this time, the daily cumulative number of freezer and fresh-food door openings, ice-maker operations, defrost cycles, and compressor cycles were recorded. In addition, the lengths of time the doors were open, the length of defrost heater "on" time, and the watt-hours energy use were recorded. On a weekly basis the amount of accumulated defrost water was measured. All information was entered into a computer file and analyzed to determine the magnitudes, variations, and trends of the data. The effects of such variables as the season of the year, number of people using the test unit, and a slow refrigerant leak were evaluated.

Graphic representations of many of the variables vs. time and vs. each other are included in the report. The small effect that ambient or variable use conditions had on long term cumulative energy use and the great variation found in the use conditions on both a daily and weekly basis are typical observations. Averaged over the entire data collection period, the fresh food compartment door was opened 32.5 times per day for a total of 3.8 minutes per day. The freezer compartment door was opened seven times per day for a total of 1 minute per day, and the ice-maker operated 2.4 times per day producing 14 ice cubes.

NBSIR 83-2655. Walton, G. N. **Thermal Analysis Research Program Reference Manual.** 1983 February. 286 p. Available from: NTIS; PB 83-194225.

Key words: building energy analysis; building heat transfer; computer modeling; load calculation.

The Thermal Analysis Research Program (TARP) has been developed as a research tool for the thermal analysis of buildings. It especially aims to study the interactions of many complex heat transfer phenomena. TARP uses the detailed heat balance method for the simultaneous calculation of the energy requirements of multiple rooms. Interroom conductive and convective processes are simulated in detail. This program reference manual describes the algorithms, input, output, and program structure of TARP. The program is written to be portable and modifiable. It is written in FORTRAN 77 and has run on CDC and UNIVAC computers. Future expansions of the program are anticipated, particularly for the simultaneous simulation of equipment performance and building thermal response.

NBSIR 83-2662. Ventre, F. T. **Documentation and assessment of the GSA/PBS Building Systems Program: Background and research plan.** 1983 February. 67 p. Available from: NTIS; PB 83-192807.

Key words: building measurement; building systems; Federal buildings; field assessment; office buildings; performance specification; post-occupancy evaluation; procurement; technical innovation.

This report documents the origins and conduct of the General Services Administration/Public Buildings Service (GSA/PBS) Building Systems Program (BSP) undertaken during the 1970s and recommends a research plan for assessing the effectiveness of the BSP. The report proposes specific methods for assessing two outcomes of the BSP: the delivery of specified levels of performance for four attributes in the six buildings completed under the BSP and the wider effects of the BSP on the building community.

NBSIR 83-2671. Stahl, F. I. **The Standards Interface for Computer-Aided Design.** 1983 March. 48 p. Available from: NTIS; PB 82-193094.

Key words: building codes and standards; building delivery process; building design process; computer-aided building design; computer-aided design; computer-integrated construction; engineering database management; structural engineering computer programs.

Building quality can be improved and building costs reduced through more effective computer utilization in design and construction. To accomplish these objectives improved interfaces are needed between building project databases and computer-based procedures for analysis and design, and between computer-based engineering procedures and applicable design standards. This latter task involves a set of problems termed the Standards Interface for Computer-Aided Design (SI/CAD). These problems comprise the focus of the current report. The SI/CAD is shown to be a critical determinant of computer-aided design (CAD) system effectiveness, particularly in the domain of structural engineering design. This report examines the hypotheses that: (1) the ability to easily maintain design standards data is fundamental to CAD system effectiveness; (2) the configuration of presently available computer-aided structural design (CASD) system software inhibits efficient design standards data modification, requiring costly maintenance to avoid software obsolescence and limiting the overall usefulness of these systems; and (3) methods to enhance the efficiency of criterion checking and standards data maintenance are required to increase the utilization of

CAD technology. Support for hypotheses (1) and (2) is developed from anecdotal engineering experience and from the technical literature drawn principally from CASD. No evidence was found to support hypothesis (3).

NBSIR 83-2674. Rennex, B. **Error analysis for the National Bureau of Standards 1016 mm guarded hot plate.** 1983 April. 47 p. Available from: NTIS; PB 83-202481.

Key words: apparent thermal conductivity; error analysis; guarded hot plate; thermal insulation; thermal resistance.

An error analysis is given for the 1-meter Guarded Hot Plate at the National Bureau of Standards. This apparatus is used to measure the thermal resistance of insulation materials. The individual contributions to uncertainty in thermal resistance are discussed in detail. The total uncertainty is estimated to be less than 0.5 percent at sample thicknesses up to 150 mm (6 inches) and less than 1 percent at a thickness of 300 mm (12 inches).

NBSIR 83-2675. Collins, B. L.; Lerner, N. D. **An evaluation of exit symbol visibility.** 1983 April. 52 p. Available from: NTIS; PB 83-202424.

Key words: exit symbols; fire safety; legibility; symbols; understandability; visibility; visual alerting.

The performance of exit symbols was assessed in a laboratory experiment using viewing conditions degraded to resemble smoke. Research participants were presented with color slides showing symbol signs designed to be used in buildings. For each slide the participant indicated if the symbol conveyed the message of "exit." A total of 108 symbol slides were used, of which 18 were exit symbols. Each of the 42 participants were familiarized with a random set of 9 of the 18 exit symbols, prior to data collection. During the experiment, the symbol of slides were presented under three levels of viewing difficulty. In general, errors increased as the viewing conditions became more degraded but the increase in errors became much more severe for some symbols than others. Fewer errors were made for some of the symbols that had been familiarized. The data suggested that increased errors under degraded viewing conditions were related to graphic features of the symbols. A number of specific symbol features that influence exit symbol effectiveness were identified along with features of nonexit symbols that produce confusions. Finally, recommendations for exit symbol design are presented that may lessen egress-related confusions during building emergencies.

NBSIR 83-2676. Chang, Y. M.; Grot, R. A. **Technique for tracking the effect of weatherization retrofits on low-income housing.** 1983 April. 51 p. Available from: NTIS; PB 83-203026.

Key words: balance point temperature; computer graphics; degree days; energy conservation; energy consumption; fuel usage records; tracking technique; weatherization retrofit.

This report presents a technique for analyzing the effect of energy saving retrofits installed in low-income housing under a nationwide weatherization demonstration program. This program was undertaken by the Community Services Administration (CSA) with the technical support of the National Bureau of Standards (NBS).

A tracking technique, based on the calculated balance-point temperature of each home prior to the weatherization, was developed to estimate the would-be fuel consumption over a period of time if the house had not been weatherized. The savings in fuel consumption for a home can be determined from the difference between the actual usage after retrofit and the calculated usage if it were not retrofitted. Besides the overall reduction, the saving in energy usage during different time periods while the house is being weatherized can be visualized from the graphical representation of the tracking technique.

Fuel reduction is reported for more than 100 homes using different fuels in seven cities across the nation, selected to represent various climate zones and geographical locations. It was found that the average saving in fuel consumption for dwellings in each city is about 30 percent.

NBSIR 83-2680. Rudder, F. F., Jr. **Method for assessing benefits of airborne noise isolation requirements in residential and educational buildings.** 1983 April. 66 p. Available from: NTIS; PB 83-198556.

Key words: acoustical design; benefit analysis; building codes; model code; noise control; noise impact; outdoor-indoor noise isolation.

This report presents a method for estimating benefits accruing from implementing acoustical performance requirements for new buildings. The method can be applied to a wide range of environmental noise conditions and noise isolation requirements for building envelopes. Benefits are estimated based upon the distribution of population with outdoor noise level and the noise isolation provided by the building envelope. A method is described for estimating noise isolation performance of existing construction based upon local conditions.

NBSIR 83-2688. Pielert, J. H.; Mathey, R. G. **Guidelines for assessment and abatement of asbestos-containing materials in buildings.** 1983 May. 75 p. Available from: NTIS; PB 83-208470.

Key words: abatement of asbestos; asbestos; buildings; fireproofing; insulation; regulations; structural steel.

This report presents guidelines for the assessment and abatement of asbestos-containing materials in buildings based on available information. Background information is given on the history and use of asbestos-containing products in buildings, and regulations pertaining to their use. Included are control measures for buildings containing asbestos materials, procedures for determining condition of the materials, and abatement techniques for containment and removal. A summary is presented of recent guide specifications and standards developed by industry, government agencies, and a standards organization which are related to asbestos-containing materials in existing buildings. These documents include guidance for the control, assessment, and abatement of such materials.

NBSIR 83-2693, Vol. I. Yokel, F. Y.; Stanevich, R. L. **Development of draft construction safety standards for excavations—Volume I.** 1983 April. 124 p. Available from: NTIS; PB 84-100569.

Key words: braced excavations; construction; Federal regulations; retaining structures; safety; shoring; slope stability; soil classification; soil pressures; standards; trenching.

A record of an interim stage in the development of revisions to existing Occupational Safety and Health Administration (OSHA) regulations governing excavations, trenching and shoring practices in the construction industry, Subpart P 29 CFR 1926, is presented. The National Bureau of Standards (NBS) prepared a working draft of recommended changes to the regulations based on previous NBS technical studies. Five regional industry workshops were held to discuss the proposed revisions. Included in the report is a copy of the recommended revisions, which were submitted to the workshops, and a record of industry's response in the form of suggestions, commentary and summaries of workshop activities. The key section of the report presents an analysis of industry response and resulting recommendations. The document is a record intended to aid OSHA during subsequent stages of the rule-making process.

NBSIR 83-2693, Vol. II. Yokel, F. Y.; Stanevich, R. L. **Development of draft construction safety standards for excavations—Volume I.** 1983 April. 314 p. Available from: NTIS; PB 83-233353.

Key words: braced excavations; construction; Federal regulations; retaining structures; safety; shoring; slope stability; soil classification; soil pressures; standards; trenching.

A record of an interim stage in the development of revisions to existing Occupational Safety and Health Administration (OSHA) regulations governing excavations, trenching and shoring practices in the construction industry, Subpart P 29 CFR 1926, is presented. The National Bureau of Standards (NBS) prepared a working draft of recommended changes to the regulations based on previous NBS technical studies. Five regional industry workshops were held to discuss the proposed revisions. Included in the report is a copy of the recommended revisions, which were submitted to the workshops, and a record of industry's response in the form of suggestions, commentary and summaries of workshop activities. The key section of the report presents an analysis of industry response and resulting recommendations. The document is a record intended to aid OSHA during subsequent stages of the rule-making process.

NBSIR 83-2694. Glass, R. A.; Howett, G. L.; Lister, K.; Collins, B. L. **Some criteria for colors and signs in workplaces.** 1983 April. 97 p. Available from: NTIS; PB 83-201442.

Key words: chromaticity; color; color appearance; energy-efficient lights; illumination; light source; safety; safety sign; safety symbols; visual acuity; visual sensitivity.

The use of safety-related visual displays such as signs and colors in workplaces is discussed. The discussion includes a review of relevant national and international standards for safety colors and signs. It also includes a review of measures of spatial resolution in human vision, as well as of color sensitivity and color appearance. In addition, research on the effectiveness of safety signs, symbols, and colors is reviewed. Based on the initial literature review, the appearance of safety colors under energy efficient light sources was identified as an area for detailed research. As a result, a laboratory study was conducted in which the color appearance of 45 different color samples under five light sources including energy efficient ones was determined for seven subjects. The color samples were contained in four color series: standard colors; experimental colors; retroreflective and retroreflective-fluorescent colors; and fluorescent-only colors. The results indicated the existence of a set of colors which was more identifiable under all light sources than the current standard safety colors. This set contains a number of fluorescent and retroreflective colors, unlike the current safety colors. Recommendations are made for further research, including field research, to determine the effectiveness of the suggested color set on safety signs under an even broader range of illuminants. The need to assess color appearance under mixed light sources is also addressed.

NBSIR 83-2709. Pielert, J. H. **Status of safety net standards for construction and research needs.** 1983 September. 41 p. Available from: NTIS; PB 84-102045.

Key words: construction; construction safety; occupational safety; perimeter nets; safety nets.

This report represents the status of standards for safety nets used in construction and identifies areas of technical inconsistency. Typical applications of safety nets are reviewed including the results of literature and field surveys. Major technical sections of six standards are compared in a tabular format to highlight areas of agreement, as well as, requirements which vary and indicate lack of consensus. This information is analyzed and used to develop a prioritized research plan for safety nets.

NBSIR 83-2713. May, W. B., Jr. **Time of day control and duty cycling algorithms for building management and control systems.** 1983 July. 60 p. Available from: NTIS; PB 83-241919.

Key words: Building Management and Control Systems (EMCS, BMCS); computer control; control algorithms; control software; duty cycling; energy management; heating, ventilating and air conditioning (HVAC); scheduled start/stop; time of day control.

Software is an important component of building management and control systems (BMCS). Although much software is available in proprietary or system dependent form, public domain control software and algorithms are rare. This report describes concepts, algorithms, and software used in BMCS components developed in the NBS building systems and controls laboratory. The concepts and basic algorithms for time of day (scheduled start/stop) control and duty cycling of electrical equipment in building heating, ventilating, and air conditioning systems are presented. Time of day control results in control events occurring at predetermined times of the day on selected days of the week. Duty cycling is the periodic turning off and on of loads, usually electrical, to reduce energy consumption under part heating and cooling load conditions. Considerations for use of duty cycling with other control strategies such as demand limiting, selection of duty cycling parameters, and dynamic adjustment of duty cycling, are discussed. All algorithms presented were implemented in software on a specific BMCS, and the actual computer programs used are presented as examples.

NBSIR 83-2720. Park, C. **An optimum start/stop control algorithm for heating and cooling systems in buildings.** 1983 June. 69 p. Available from: NTIS; PB 83-242222.

Key words: digital control systems; energy conservation; energy management and control systems; heating and cooling systems; optimum start/stop time; preheat time.

When a building structure is occupied intermittently, energy savings can be realized from the optimal start-up and shut-down of the heating or cooling system. This strategy, known as optimum start/stop control, reduces energy consumption by delaying the start-up of the space conditioning system until the last moment and then initiating shut-down as early as possible, while maintaining a preset level of comfort during the period of building occupancy.

Based on the bang–bang control theory, a simple optimum start/stop control algorithm is developed for computerized control systems in buildings. The optimum start time is obtained by finding the intersection of cool-down and heat-up curves that are approximated by exponential fitting of the previous and current day's data.

Information is presented in this report on the input and output variables, logic flow, and methodology employed in developing the algorithm. A computer program listing of the optimum start/stop control algorithm written in FORTRAN 77 and sample input and output data are included in the appendices.

NBSIR 83-2723. Harris, J. E. **Performance of add-on type heat pump water heaters using two different test methods.** 1983 June. 30 p. Available from: NTIS; PB 83-222703.

Key words: appliances; energy; heat pump water heaters; testing; test procedures; water heaters.

Two different makes of add-on (without tank) heat pump water heaters (HPWH) were tested. Each of the HPWH's was subjected to a series of recovery tests similar to the Department of Energy (DOE) recovery test for conventional electric water heaters. The results of the tests (recovery efficiency, standby loss, input power, storage tank capacity and energy used) were used to compute an energy factor which could be used to calculate the estimated annual operating cost of such HPWH's. The energy factor was also determined by a series of simulated use tests consisting of four equal draws totaling 64.3 gallons of hot water per day. The average energy factor derived from the recovery tests was about 13 percent higher than that derived from the simulated use tests. Based upon the results of this limited test program it was recommended that a simulated use test be used to determine the energy factor for HPWH's without tank.

NBSIR 83-2724. Hastings, S. R.; Ruggli, R. **Swiss research in building heating conservation.** 1983 July. 153 p. Available from: NTIS; PB 83-241034.

Key words: energy conservation in buildings; European building research; field measurement of building energy use; passive solar heating; Switzerland; test method development.

Swiss research on heating energy conservation in buildings is presented to encourage communication among researchers. A background on Switzerland's climate, geography, construction industry, and energy situation is included to provide a context for the subsequent review of a sample of research projects. Each project is described with a statement of research objectives, technical approach taken, project status, brief findings, future work planned or recommended, and resulting publications. The sample of projects is taken from the subjects of community scale solar concepts, mathematical simulation, instrumented test cabins, instrumented buildings, and design tools and data bases. The final section discusses a structure for surveying research projects in a country in order to examine where efforts are now concentrated and what subjects are not addressed. Swiss research is examined using this structure and an assessment is presented.

NBSIR 83-2726. Treado, S.; Gillette, G.; Kusuda, T. **Evaluation of the daylighting and energy performance of windows, skylights, and clerestories.** 1983 June. 26 p. Available from: NTIS; PB 83-240481.

Key words: building energy analysis; clerestories; daylighting; skylights; windows.

This paper examines the impact of several fenestration options on building space heating, cooling, and lighting loads. The use of skylights, windows, and clerestories is evaluated for a single floor commercial building, using the NBSLD-2 building energy analysis computer program, which possesses a fully integrated daylight model (DALITE). The evaluation focuses on: a) the impact of daylighting on heating and cooling energy and equipment sizing, b) the potential reduction in electric lighting energy requirements through daylight utilization, c) the relative daylighting/thermal performance of skylights, clerestories, and windows, and d) the effect of building orientation on fenestration optimization and selection.

The NBSLD-2 computer procedure performs a dynamic simulation of hour-by-hour building thermal performance and energy requirements for a one-year period. The thermal and daylighting characteristics of each fenestration aperature are modeled to enable evaluation of the trade-offs associated with the use of each fenestration type. The results are correlated in the form of design guidelines to enable the preliminary design decisions to be made regarding fenestration location, type, configuration, and size. The energy calculations are presented as functions of fenestration characteristics, so that the potential energy advantages can be estimated for different fenestration designs.

NBSIR 83-2727. Wu, S. T.; Leyendecker, E. V. **Lateral-torsional response of structures subjected to seismic waves.** 1983 June. 30 p. Available from: NTIS; PB 83-239582.

Key words: accidental eccentricity; building codes and standards; design eccentricity; dynamic eccentricity; parametric study; seismic waves; structural response.

The behavior of coupled lateral-torsional systems subjected to seismic waves is investigated analytically. The report presents the numerical results of a parametric study for structures subjected to S-H waves. Case studies are provided to show the contribution of each of the selected parameters to the rotational response of the systems. These parameters are: geometric eccentricity, aspect-ratio of the foundation mat, damping ratio, and the ratio of the rotational to translational frequencies. Dynamic eccentricity is selected as an index to represent the level of the response. The sensitivity due to the deviation of the input spectrum is investigated. Accidental eccentricities due to seismic waves are also evaluated. Design concerns are given on how the design eccentricity should be considered based on this study.

NBSIR 83-2728. Treado, S. J. **Automated control of lighting and fenestration.** 1983 July. 18 p. Available from: NTIS; PB 83-250423.

Key words: automatic control; daylighting; lighting control; microprocessor; window management.

This paper describes an automatic system for controlling the lighting and window shading in a commercial building. The system utilizes a microcomputer to monitor solar radiation and illumination levels and interior and exterior air temperatures, processing the input parameters to determine the optimum lighting level, window area, and solar film position to minimize building heating and cooling loads due to windows and lighting. The control methodology and logical flow are presented, along with a sample control program written in FORTRAN. The response of the system to various combinations of weather conditions is examined.

NBSIR 83-2746. Kao, J. Y. **Strategies for energy conservation for a large office building.** 1983 July. 69 p. Available from: NTIS; PB 83-249722.

Key words: building control strategies; building energy conservation; building thermal performance; HVAC systems.

A comparative analysis is made of the thermal performance of selected HVAC systems and control strategies commonly employed in large office buildings. The comparisons are made for six geographical locations representing wide climatic variations within the continental United States.

Hour-by-hour simulations with the BLAST computer program are used to obtain the yearly heating, cooling, and fan energy consumption of a twelve-story large office building. The HVAC systems simulated are constant volume reheat, variable air volume, dual-duct, and fan-coil systems. The control strategies tested are dry bulb temperature economy cycles, enthalpy economy cycle, supply air temperature resetting, and the combinations of these strategies. The results of these simulations are presented and discussed. Substantial energy consumption differences are shown to exist.

NBSIR 83-2751. Carino, N. J., ed. **Proceedings of the international workshop on the performance of offshore concrete structures in the Arctic environment.** 1983 July. 72 p. Available from: NTIS; PB 84-121904.

Key words: arctic; concrete; construction; design; inspection; offshore structures; repair; research; structural engineering; technology assessment; workshop.

A workshop was held March 1 and 2, 1983 at the U.S. National Bureau of Standards. The objective was to bring together an international group of experts for the purpose of information exchange on the subject of the performance of Arctic offshore concrete structures. The workshop participants were divided into four working groups to discuss the following subjects related to Arctic offshore concrete structures: 1) design; 2) materials; 3) construction; and 4) inspection and repair. Each working group addressed the following topics within their subject: past experiences, current projects, and recommended research areas. The chairmen of each group prepared reports summarizing their group's deliberations. These reports are incorporated into this workshop summary.

NBSIR 83-2756. Mulroy, W. J.; Didion, D. A. **A laboratory investigation of refrigerant migration in a split unit air conditioner.** 1983 August. 47 p. Available from: NTIS; PB 83-262873.

Key words: central air conditioners; cyclic testing; heat pumps; refrigerant migration.

The relationship between cyclic refrigerant migration and cyclic loss for a residential, split-system air conditioner has been investigated. The cyclic refrigerant migration was measured at different points in the operating cycle by simultaneously shutting five pneumatic valves which isolated the refrigerant in the major system components. The refrigerant was then removed, weighed, and returned to the system. The unit tested was found to have a high initial capacity as migrated refrigerant was removed from the evaporator and then a low, slowly increasing capacity as trapped refrigerant was returned to the system from the accumulator. The unit performance was also compared to single and double time constant regressive approximations and to the time constant calculated from the evaporator mass and heat transfer coefficient. Although relationships between migrated refrigerant and cyclic capacity were observed, no practical refrigerant migration test method that would be less burdensome than the cyclic tests of ASHRAE Std. 116 appears possible at this time.

NBSIR 83-2768. Grot, R. A.; Chang, Y. M.; Persily, A. K.; Fang, J. B. **Interim report on NBS thermal integrity diagnostic tests on eight GSA Federal office buildings.** 1983 September. 50 p. Available from: NTIS; PB 84-104249.

Key words: air infiltration; building diagnostics; building thermal integrity; fan pressurization; field measurements; thermographic inspections; tracer gas technique; U-value tests.

This report summarizes preliminary results of diagnostic tests to evaluate the thermal integrity of eight Federal Office buildings located throughout the country. The test results include tracer gas measurements of air infiltration rates, pressurization tests of the air tightness of the building shell, and inspections of the envelope employing infrared thermography. In addition, the thermal U-values of exterior walls were measured with both heat flow meters and a portable calorimeter box. The data collected on these buildings are still undergoing analysis and therefore are to be considered preliminary.

NBSIR 83-2770 (GSA). Silberstein, S.; Grot, R. A.; Pruitt, D. O.; Engers, P.; Lane, P.; Schweinfurth, S. E. **Air exchange rate measurements in the National Archives Building.** 1983 September. 26 p. Available from: NTIS; PB 84-102110.

Key words: air exchange rate; archives; building envelope infiltration; pressurization; records storage; ventilation.

Air exchange measurements were carried out at the National Archives Building under various combinations of temperature and wind speed. The average air exchange rate under normal operation of the heating, ventilating, the air-conditioning system (HVAC) was 0.9 h^{-1} for an average temperature difference of 11.3°C and an average wind speed of 2.7 m/s. This rate is approximately twice those for new General Services Administration (GSA) office buildings. No clear dependence of air exchange rate on temperature differences up to 17°C or wind speeds up to 5 m/s was found.

With outdoor air dampers closed and fans operating, the average air exchange rate was 1.2 h^{-1} for an average temperature difference of 8.2°C and an average wind speed of 2.8 m/s.

A test of interzone air movement showed that air migrates rapidly from non-stack to stack areas with fans operating normally.

The building could not be pressurized beyond an indoor-outdoor pressure difference of 14 Pa. At this pressure difference, the air exchange rate was 1.5 h^{-1}. As in the case of normal operation of the HVAC system, this rate is also approximately twice those for new GSA office buildings.

NBSIR 83-2780. Woodward, K.; Rankin, F. **Behavior of concrete block masonry walls subjected to repeated cyclic displacements.** 1983 October. 178 p. Available from: NTIS; PB 84-122092.

Key words: cracking; cyclic; fatigue; masonry; shear; strain rate; walls.

An experimental investigation into the behavior of unreinforced, ungrouted concrete block masonry walls subjected to repeated in-plane cyclic displacements was undertaken. A total of 15 walls were tested of which 10 were 64 in×64 in planar walls and 5 were 64 in higher corner walls having equal leg lengths of 48 in. The primary parameter varied in the investigation was loading history. Monotonic tests at both slow and rapid strain rates were done. The cyclic tests included fully reversed displacement patterns and reversed displacement patterns superimposed on static displacement offsets. The cyclic tests included at least 100,000 repetitions. The test results indicated a pronounced effect of loading history on the wall performance, but only at load/displacements nearing the load capacity failure point.

NBSIR 83-2784-1. Rubin, A. I. **The automated office—An environment for productive work, or an information factory?: A report on the state-of-the-art.** 1983 November. 207 p. Available from: NTIS; PB 84-122530.

Key words: acoustic privacy; design criteria; ergonomics; lighting; office automation; office design criteria; quality-of-life; space planning; thermal comfort; VDT's (video display terminal); work station.

This study is a report of research findings and recommendations covering topics which influence automated office design. The subjects covered are: office design, office information systems, organizational factors, ergonomics, technology and communications. Advances in technology, coupled with the explosive growth of office-based work have resulted in the automation of many offices. To date, technology has provided the major impetus for automation, with mixed results. Systems frequently do not meet the needs of the end-user because of the lack of appropriate planning. Design issues are particularly neglected during planning, resulting in problems with the visual, thermal, and acoustic environment in many offices. These effects are particularly detrimental since many office automation, management, and design experts agree that the quality of the environment is especially important in the electronic office—to offset the impersonality of many office tasks, and changes in work procedures resulting in limited social interaction with colleagues. These issues are discussed as they relate to the development of design guidelines and criteria for automated offices. The report contains an extensive bibliography, dealing with the topics cited above.

GRANT/ CONTRACT REPORTS

Grant/contract reports are prepared by non-NBS persons or organizations working under a grant or contract from the National Bureau of Standards. The contract reports listed below may be ordered, using the indicated order number, directly from the National Technical Information Service (NTIS), Springfield, VA 22161, in paper or microfiche form.

NBS-GCR-81-341. Sabatiuk, P. A. **Statistical analysis of thermal performance predictions of passive solar heated residences.** 1982 January. 88 p. Available from: NTIS; PB 83-151308.

Key words: data base; energy; passive solar; solar contribution; solar fraction; storage capacity.

In support of the development of thermal performance criteria for residential passive solar buildings, a statistical and graphical analysis of design, climatic, and predicted performance data was performed for houses in the HUD Passive Residential Design Competition and the HUD Cycle 5 Residential Solar Demonstration Program. These passive residences are located in all regions of the United States requiring space heating, and they represent a variety of passive solar systems types including direct gain, indirect gain, and solarium (isolated gain) type systems. The results of these analyses are being used to develop proposed minimum acceptable levels of thermal performance for the residential passive performance criteria.

A large data base was compiled for the houses in these two HUD cycles, including parameters such as solar aperture area, January net solar contribution, and auxiliary energy use. Through the use of DATAPLOT, a statistical analysis computer program, relationships between these data base parameters were explored and the mean values and standard deviations of these parameters were calculated. The direct gain systems were found to perform slightly better than the indirect and solarium systems and storage capacity was found to vary greatly for all three system types. It appears that the annual depletable energy use of these houses will on the whole be less than the proposed BEPS annual heating and cooling levels.

NBS-GCR-83-434. Schmitz, G. R.; Csizmadia, T. D. **Office structures and enclosures: Directions in innovative technology.** 1983 July. 71 p. Available from: NTIS; PB 83-250563.

Key words: building enclosure systems; building structural systems; innovative building technologies; office building enclosures; office building structures; structures.

Selected issues and innovative technological responses related to structures and enclosures of office buildings are presented. Innovations are based on a better use or improvement of existing technology, or a transfer of superior technology. Structural support system innovations are often concerned with economy, flexibility of use and human safety and comfort in highrise and long-span structures. Wind and seismic forces constitute major problems which can be solved through innovative structural systems and/or their new combinations, through mass reduction, structural damping devices, aerodynamic shapes, choice of materials and methods. Structural innovations are further related to specific elements such as roofs, floors, bearing walls, columns, bracings, and foundations. Enclosure system issues are concerned with the design, construction, maintenance and operation of the roof, the exterior wall and their components. New materials, products and design features are often used for the purposes of energy conservation and/or energy "gain." Solar access and systems (active and passive), water and air infiltration, adaptability to user requirements and change, issues of health and safety and visual aspects of the enclosure system are discussed.

NBS-GCR-83-438. Johnson, W. B.; Lull, W. P.; Madson, C. A.; Turk, A.; Westlin, K. L.; Woods, J. E.; Banks, P. N. **Final report on January 19-20, 1983 NBS workshop: Environmental control for archival record storage.** 1983 July. 52 p. Available from: NTIS; PB 83-242230.

Key words: air quality; archival storage; criteria; design parameters; environmental conditions; environmental control; environmental conditioning systems.

A summary of the January 19-20, 1983 National Bureau of Standards Workshop on Environmental Conditions for Archival Records Storage is presented that proposes criteria and addresses control of environmental conditions in spaces used for storage of paper-based archival records. The objectives of the Workshop were to explore rationale for establishing levels of air quality for archival storage and to review equipment technology with regard to its capability to provide optimum environmental conditions for archival storage facilities.

The proposed criteria gives levels of air quality for different categories of archival storage for the four environmental variables, temperature, relative humidity, gaseous contaminants, and particulate contaminants, that primarily effect paper-based archival records. Other design parameters are addressed and recommendations made regarding factors to consider in the design of archival storage facilities. The types of environmental conditioning equipment, components, and systems for providing indoor air quality for preservation of paper-based archival records are reviewed and discussed with regard to environmental variables. Methods of thermal and air quality control are discussed and recommendations made for performance evaluation of environmental conditioning systems. Monitoring and assessment procedures to evaluate performance of environmental conditioning systems and components are addressed.

NBS-GCR-83-443. Brown & Root Development, Inc. **State-of-the-art report of guyed tower platforms.** 1983. 126 p. Available from: NTIS; PB 83-253005.

Key words: compliant platforms; guyed towers; ocean engineering; offshore platforms; structure dynamics.

This state-of-the-art report reviews general concepts, design considerations, the modeling of dynamic and fatigue behavior, methods of analysis, and problems of fabrication and installation, pertaining to offshore guyed tower platforms. In addition, a list of references is provided, complemented by a bibliography on dynamic problems in platform design.

PAPERS PUBLISHED IN NON-NBS MEDIA

Reprints from the journals listed in this section may often be obtained from the authors. Each entry has been assigned a five-digit number for NBS identification and listing purposes.

21572. Simiu, E.; Filliben, J. J.; Shaver, J. R. **Short-term records and extreme wind speeds,** *ASCE* **108,** No. ST11, 2571-2576 (Nov. 1982).

Key words: climatology; extreme values; short-term records; statistics; structural engineering; wind forces.

An empirical study was conducted to determine whether design wind speeds can be estimated confidently from short records, i.e., records extending over periods of a few years. The study was based upon the analysis of records of daily, weekly, and monthly largest wind speeds taken at 36 United States weather stations over periods ranging from three to 10 years and upon largest yearly wind speeds recorded at these stations over periods ranging from approximately 25–45 years. Investigations were presented into the type of probability distributions that best fit sets of largest daily, weekly, and monthly wind speeds and into the relationship between extreme winds estimated from short records of largest daily and weekly wind speeds on the one hand, and from 25-year to 45-year records of largest yearly wind speeds on the other hand. The main effort in the paper was focused on the relationship between estimates of 50-year wind speeds based on three-year records of largest monthly speeds and on 25-year to 45-year records of largest yearly speeds. It was found that 50-year speeds can be estimated confidently from 3-year records of the largest monthly speeds.

21581. Ellingwood, B.; Galambos, T. V. **Probability-based criteria for structural design,** *Struct. Safety* **1,** 15-26 (1982).

Key words: buildings (codes); design (buildings); limit states; loads (forces); masonry; probability theory; reinforced concrete; reliability; safety; specifications; standards; steel; structural engineering.

Probability-based loading and resistance criteria are presented that are suitable for routine safety checking in design. The criteria are based on a comprehensive analysis of statistical data on structural loads and resistances and an examination of levels of reliability implied by the use of current design standards and specifications. The criteria are intended to be used in specifications that are oriented towards limit states design.

21591. Ellingwood, B.; Galambos, T. V.; MacGregor, J. G.; Cornell, C. A. **A probability-based load criterion for structural design,** *Civ. Eng.*, pp. 74-76 (July 1981).

Key words: buildings (codes); design (buildings); limit states;

loads (forces); probability theory; reliability; specifications; standards; structural engineering.

Recommended load factors and load combinations are presented which are compatible with the loads recommended in the proposed 1980 version of American National Standards A58, Building Code Requirements for Minimum Design Loads in Buildings and Other Structures (ANSI A58.1-1980 D). The load effects considered are due to dead, occupancy live, snow, wind and earthquake loads. The load factors were developed using concepts of probabilistic limit states design which incorporates state-of-the-art load and resistance models and available statistical information. The load factors are intended to apply to all types of structural materials used in building construction.

21617. Lew, H. S.; Carino, N. J.; Fattal, S. G. **Cause of the condominium collapse in Cocoa Beach, Florida,** *Concr. Int.* **4,** No. 8, 64-73 (Aug. 1982).

Key words: buildings; concrete construction; failure; flat concrete plates; punching shear; shear strength; strength analysis; structural analysis.

This paper gives the results of an investigation into the collapse of a five-story, flat-plate condominium building in Cocoa Beach, Fla. The collapse occurred on March 27, 1981, while the casting of the roof slab was in progress. Eleven workers were killed and 23 were injured. The investigators conducted on-site inspections, made laboratory tests, and made analytical studies. It was concluded that the most probable cause of the collapse was inadequate punching shear capacity in the fifth-floor slab to resist the imposed construction loads. The analysis indicated that punching shear stresses at many slab/column connections were close to the ultimate capacity specified by the Code, (ACI 318-77). Consequently, it was concluded that a punching shear failure at a heavily stressed location triggered a succession of failures at other locations, resulting in the downward collapse of the entire structure.

21618. Ellingwood, B. **Safety checking formats for limit states design,** *J. Struct. Div. Soc. Am. Civ. Eng. Tech. Note* **108,** No. ST7, 1481-1493 (July 1982).

Key words: buildings (codes); design (structures); concrete; limit states; loads; masonry; probability theory; reliability; specifications; standards; steel; strength designs; structural engineering; timber.

The growing need for a unified approach to structural design for different construction materials and technologies is met by the limit states design approach. Several standards-writing committees currently are considering how best to implement practical limit states design criteria. This paper examines the relative advantages of several approaches proposed for this purpose, with regard to their ability to provide desired levels of reliability for all probable design situations. The choice of an appropriate approach is found to depend on fundamental characteristics of structural behavior, and thus might not be the same for different construction materials.

21620. Carino, N. J. **Application of maturity concept to form removal and reshoring schedule,** *Proc. Int. Conf. Forming Economical Concrete Buildings, Lincolnshire (Chicago), IL, Nov. 8-10, 1982,* pp. 8.1-8.19 (Portland Cement Association, Skokie, IL, 1982).

Key words: concrete; compressive strength; curing temperature; formwork; hydration; maturity; mortar; scheduling; temperature effects.

A brief account of the historical development of the maturity concept is presented. This is followed by a derivation to illustrate the basis of the maturity concept. It is shown that the commonly used Saul-maturity function is, at best, an approximation of the combined effects of temperature and time on strength development of concrete. However, the accuracy can be improved by using the correct value of the datum temperature. Finally, examples are presented to illustrate the application of the maturity concept in construction practice.

21621. Ellingwood, B. **Wind and snow load statistics for probabilistic design,** *J. Struct. Div. Soc. Am. Civ. Eng. Tech. Notes* **107,** No. ST7, 1345-1350 (July 1981).

Key words: buildings (codes); design (buildings); loads (forces); probability theory; reliability; standards; statistical analysis; structural engineering.

Structural reliability analyses and probability-based limit states design require statistical descriptions of structural load and load effect variables. Frequently, data are only available for the basic variables (e.g., wind speed, ground snow load, etc.) from which the loads are calculated through mathematical relationships. While early first-order, second-moment reliability analyses required only estimates of means and variances in the basic variables, more recent methods utilize the probability distributions also. In this note, suitable probability distributions and statistical parameters for wind and snow loads are derived using recent statistical data. These distributions have been used to develop a set of tentative load factors for possible use in a future edition of the A58 Standard.

21622. Ellingwood, B. **Analysis of reliability for masonry structures,** *J. Struct. Div. Soc. Am. Civ. Eng. Tech. Notes* **107,** No. ST5, 757-773 (May 1981).

Key words: brick masonry; buildings (codes); concrete masonry; design; limit states design; loads (forces); probability theory; reliability; statistical analysis; structural engineering.

Strength design and the use of loading criteria based on probabilistic limit states design principles are relatively new concepts in the masonry area. However, these procedures afford a number of advantages for design. Implementation of these concepts requires an assessment of statistical data on masonry strength, the establishment of appropriate measures of reliability for design, and the development of safety factors to be applied to material and load variables. Available strength data on brick and concrete masonry construction are summarized and a few reliability calculations are made to show how masonry compares with other engineered construction materials.

21623. Ellingwood, B. **Reliability of wood structural elements,** *J. Struct. Div. Am. Soc. Civ. Eng. Tech. Notes* **107,** No. ST1, 73-87 (Jan. 1981).

Key words: buildings (codes); limit states design; probability theory; reliability; standards; statistical analysis; structural engineering; timber construction.

Recent trends in development of standards for design have been toward the use of probabilistic limit states concepts. The development of such criteria requires that a large amount of data be examined by the appropriate standards writing organizations. This paper describes basic statistical information that currently is available for developing probability based limit states design criteria for timber structures. A number of problem areas are discussed where additional study appears necessary or desirable prior to implementing such criteria practice.

21624. Ellingwood, B.; MacGregor, J. G.; Galambos, T. V.; Cornell, C. A. **Probability based load criteria: Load factors and load combinations,** *J. Struct. Div. Am. Soc. Civ. Eng. Tech. Notes* **108,** No. ST5, 978-997 (May 1982).

Key words: buildings (codes); design (buildings); limit states; loads (forces); probability theory; reliability; safety; specifications; standards; structural engineering.

This is the second of two papers that describe a study conducted to develop probability-based load factors and load combinations suitable for use with common construction materials and technologies. In the second phase of the study, described in this paper, the checking equation format for the proposed load criteria was selected, and the load factors and load combinations were computed using a constrained optimization procedure. Comparisons of reliabilities obtained using the proposed procedure with existing criteria are made. Guidance is provided for material specification-writing groups to enable them to select compatible resistance criteria without further numerical computations.

21625. Carino, N. J. **Maturity functions for concrete,** *Proc. Int. Conf. Concrete at Early Ages, Paris, France, Apr. 6-8, 1982,* pp. 123-128 (Ecole Nationale Des Ponts et Chaussees, Paris, France, 1982).

Key words: concrete; curing temperature; hydration; inplace testing; maturity; mortar; strength.

This paper deals with the characteristics of a temperature-time function to account for the combined effects of temperature and time on the strength development of concrete. Starting with a differential equation to describe the rate of strength gain under isothermal curing conditions, it is shown that the product of age and the rate constant is the sought after function. Assuming a linear variation of the rate constant with temperature results in a temperature-time function identical to the traditional Saul-maturity-function. By using the Arrhenius equation to represent the variation of rate constant with temperature, a function, called "effective age," is proposed which better describes the effects of temperature and time on strength development for isothermal curing.

21627. Ellingwood, B. R.; Reinhold, T. A. **Reliability analysis of steel beam-columns,** *J. Struct. Div. Am. Soc. Civ. Eng. Tech. Notes* **106,** No. ST12, 2560-2564 (Dec. 1980).

Key words: beams; buildings (codes); columns; limit states design; probability theory; reliability; steels; structural engineering.

Probabilistic analyses of the safety of structural members frequently have relied on a formulation of the ultimate limit state equation in which load carrying capacity (resistance) is measured by a single variable *R*, such as the fully plastic moment for a beam (1,3,5). Safety or reliability is defined by the condition where the effects of the applied loads do not exceed resistance *R*. However, there is a feeling that alternate formulations in terms of the basic variables that determine resistance, e.g., yield stress, section modulus, etc., may be more desirable in certain instances. This note compares measures of reliability calculated from the *R*-variable and basic variables formulations of the safety problem for hot-rolled steel beam-columns subjected to dead and live loads and considers some of the implications for reliability based design.

21629. Salomone, L. A. **Improving geotechnical investigations for underground transmission lines,** (Proc. Symp. Underground Cable Thermal Backfill, Toronto, Ontario, Canada, Sept. 17-18, 1981), Chapter 3 in *Underground Cable Thermal Backfill,* pp. 57-71 (Pergamon Press Canada Ltd., Suite 104, 150 Consumers Rd., Willowdale, Ontario, Canada M2J1P9, 1982).

Key words: design; soil mechanics; thermal conductivity; thermal resistivity; transmission lines.

An evaluation of the thermal properties of the soils that surround underground transmission lines is an important part of existing design procedures for underground power cables. Geotechnical investigations consisting of in-situ and laboratory thermal probe tests, soil sampling and determinations of moisture and density are frequently performed to evaluate the thermal resistivity of soils encountered along proposed transmission line routes. These investigations often are based on routine procedures adopted over the years but not necessarily reflecting all the information and techniques now available in the fields of agronomy and geotechnical engineering.

The paper demonstrates how information and techniques used by agronomists and geotechnical engineers can be correlated and then used to improve our capability of predicting in-situ thermal soil properties. Also, suggestions for improving existing procedures for evaluating the thermal resistivity of soils are provided.

21635. Bartel, T. W.; Yaniv, S. L. **Curvature of sound decays in partially reverberant rooms,** *J. Acoust. Soc. Am.* **72,** No. 6, 1838-1844 (Dec. 1982).

Key words: architectural acoustics; decay rate; ensemble averaging; reverberant sound field; reverberation room; sound absorption.

Measurements were conducted to investigate the departure from linearity of sound decays in partially reverberant rooms—that is, rooms, such as are found in office buildings and residences, that are less reverberant than laboratory reverberation chambers. The extent to which the nonlinearities in the decay curves could be reduced by means of an ensemble-averaging procedure was determined. Decay curves for five partially reverberant rooms, ranging in size from 45 to 425 m^3, were tape recorded and played back at reduced speed into a real-time analyzer. Decay measurements were also performed in the NBS 425-m^3 reverberation chamber. It was found that "smooth" decay curves, displaying a curvature characterized by a monotonically decreasing decay rate, could be obtained provided that the ensemble averages included decays recorded at several source and receiver locations. Thus, the rate of decay at any point in time for partially reverberant rooms could be precisely and unambiguously determined. The magnitude of the curvature was such that the percentage difference between the early decay rate and the decay rate averaged over a 25-dB range varied from approximately 2% to 40%, with the greatest differences occurring in rooms containing an absorptive ceiling and floor or an opening connecting them to other rooms.

21649. Galambos, T. V.; Ellingwood, B.; MacGregor, J. G.; Cornell, C. A. **Probability based load criteria: Assessment of current design practice,** *J. Struct. Div. Am. Soc. Civ. Eng., Tech. Notes* **108,** No. ST5, 959-976 (May 1982).

Key words: buildings (codes); design (buildings); loads (forces); probability theory; reliability; safety; specifications; standards; structural engineering.

This is the first of two papers that describe a study conducted to develop probability-based load factors and load combinations suitable for use with the loads specified in American National Standard A58 on design loads and with all common construction materials and technologies. The first part of the study, described in this paper, involved the selection of a probabilistic methodology for performing the necessary reliability analyses and the collection and examination of statistical data on structural resistance and loads. Levels of reliability implied by the use of current design standards and specifications for common design situations in which performance generally is felt to be satisfactory were then estimated.

21669. Salomone, L. A.; Kovacs, W. D. **The determination of thermal soil properties for energy transfer modeling of buildings,** *Proc. Energy Conservation in Building Design, Construction and Management Conf., Minneapolis, MN, Sept. 15-16, 1982,* pp. 137-161 (Dept. of Conferences University of MN, 315 Pillsbury Drive, SE., Minneapolis, MN 55455, Sept. 1982).

Key words: Atterberg limit tests; field tests; heat flow; laboratory tests; soil moisture; soil tests; thermal conductivity; thermal resistivity.

Field thermal probe tests were performed in the vicinity of test houses at the National Bureau of Standards (NBS) annex in Gaithersburg, Maryland. The test houses were constructed to validate the mathematical model being used to predict surrounding earth temperatures and floor heat loss of the test houses. Also, laboratory thermal probe tests were performed at the NBS geotechnical laboratory on an AASHTO Material Reference (AMRL) soil. The laboratory tests were performed to confirm the correlation between soil thermal behavior with the limit states of fine-grained soil behavior and to identify an approach for predicting the thermal performance of fine-grained soils. Using the approach and field thermal probe measurements, the thermal behavior of the soils surrounding the test houses was assessed.

The paper presents the factors that affect the thermal conductivity of soils that surround buildings and demonstrates the importance of predicting in-situ soil thermal properties. The state-of-the-art field and laboratory procedures used to evaluate the thermal conductivity of fine-grained soils are presented. Results demonstrate the need for incorporating changes in thermal resistivity caused by changes in soil moisture in computer models of the thermal performance of buildings.

21692. Pommersheim, J. M.; Clifton, J. R.; Frohnsdorff, G. J. **Mathematical modeling of tricalcium silicate hydration. II. Hydration sub-models and the effect of model parameters,** *Cem. Concr. Res.* **12,** 765-772 (1982).

Key words: cement; hydration; mechanisms; models; particle size; tricalcium silicate; water-to-cement radio.

Further details are reported for a previously developed mathematical model for the hydration of tricalcium silicate. The model is based on conceptual models for the different stages of hydration. Sub-models are given which consider the effects of the particle size, thickness of the barrier layer, and diffusivities through the hydrate layers. Model predictions were consistent with experimental data.

21696. Ventre, F. T. **Building in eclipse, architecture in seccession,** *Prog. Archit.* **63,** No. 12, 58-61 (Dec. 1982).

Key words: architectural design; building performance; building research; building technology; capital investment; knowledge; productivity.

Paper documents gradual shifts in the Nation's investment mix and more abrupt changes in market share among the professions providing design and consulting services to the building industry. The article suggests reasons for these shifts and identified possible responses by the design and consulting professions and, particularly, by the growing community of building researchers.

21701. Kao, J. Y.; Pierce, E. T. **A study of sensor errors on building energy consumption,** *Proc. Seventh Energy Management and Controls Society Conf., Salt Lake City, UT, Nov. 14-17, 1982,* 9 pages (Energy Management and Controls Society, 1925 North Lynn Street, Suite 1002, Arlington, VA 22209, 1982).

Key words: building energy conservation; building energy consumption; building temperature control; HVAC system control; sensor error.

A computer simulation was used to examine the effects of errors in the sensors of automatic controls for HVAC systems. The simulation examined two types of sensors, dry-bulb temperature and dew point temperature, used in air handling systems. Four sensor functions were studied: outside air and return dry-bulb temperature sensor, outside air and return dew point sensor, mixed air temperature sensor, and cooling coil discharge air sensor. Errors in these sensors may result from inferior quality, improper calibration, or drift. The BLAST computer program was used to simulate errors in each of these sensor functions for a hypothetical small office building located in Washington, D.C. This building was assumed to have a constant volume terminal reheat system with a chilled water cooling coil. The computer calculations indicated that sensor errors could increase the annual energy requirements attributable to the air handling system by as much as 30 to 50 percent. Errors in the mixed air temperature sensor and the cooling coil sensor appear to be most critical for the type of HVAC studied.

21712. Simiu, E.; Batts, M. E. **Wind-induced cladding loads in hurricane-prone regions,** *J. Struct. Div. Am. Soc. Civ. Eng.* **109,** No. 1, 262-266 (Jan. 1983).

Key words: building (codes); climatology; hurricanes; statistical analysis; structural engineering; wind (meteorology); wind direction.

A brief review is presented of a procedure for estimating wind-induced pressures on cladding which is rigorous statistically and convenient for practical application. The procedure, as originally proposed in Ref. 5, takes into account the dependence of the extreme wind speeds upon direction, but is not applicable to the estimation of cladding loads in hurricane-prone regions. An extension of that procedure for application to such regions is then presented. The theory that makes this extension possible is explained, and a computer program for calculating cladding pressures induced by hurricane winds is described. Examples are given which show that procedures which do not take into account the dependence of the extreme wind speeds upon direction may result in gross over-estimates of cladding pressures, and inevitably result in strongly nonuniform probabilities of cladding failure for the various panels of a building facade.

21717. Frohnsdorff, G.; Dise, J. R.; Clifton, J. R. **A reference sample program for fly ashes as a stimulus to technological progress,** *Proc. Workshop Res. Develop. Needs for Use of Fly Ash in Cement Concrete, Subsec. 5.4,* 5-14–5-21 (Electric Power Research Institute, 3412 Hillview Avenue, Palo Alto, CA 94304, Sept. 1982).

Key words: blended cement; cement; data base; fly ash; reference sample.

The ultimate level of acceptance of fly ashes for use in concrete will depend upon their performance in concrete and upon the predictability of their performance. The desired level of knowledge about fly ash performance and uniformity is not yet available because of the scarcity of suitable data for the testing of hypotheses about factors affecting performance and also uncertainty about the appropriateness and reliability of current standard tests of performance. A practical way of simultaneously contributing to the data base for research and promoting assurance of fly ash quality would be establishment of a fly ash reference sample program. The potential benefits are: 1) improved quality of standard testing, 2) improved knowledge of differences between fly ashes, 3) establishment of a large data base for use by researchers and others, and 4) establishment of a source of well-characterized fly ashes for further research. An ASTM-sponsored reference sample program for blended cements, specifically portland-fly ash cements, was established in 1979. The establishment of a similar reference sample program for fly ashes for use in concrete is recommended.

21727. Jenkins, D. R.; Knab, L. I.; Mathey, R. G. **Laboratory studies of infrared thermography in roofing moisture detection,** *Am. Soc. Test. Mater. Spec. Tech. Publ. 779,* pp. 207-220 (1982).

Key words: heat transmission; infrared detection; insulation; moisture in roofing; nondestructive testing; roofing; temperature measuring instruments; thermal resistance; thermography.

A laboratory evaluation of infrared thermography for detecting moisture in roofing specimens is presented. This study was based on laboratory controlled specimen preparation and testing conditions. For steady state heat flow, and in a few cases, transient heat flow, the effects of moisture on the surface temperature of the roofing specimens were determined by thermocouples and thermography. Surface temperatures determined by infrared thermography were shown to correlate well with the thermocouple temperatures. Two system performance parameters were assessed: threshold moisture content and the slope of the instrument response versus moisture content curve.

21736. Knab, L, I.; Clifton, J. R. **Cumulative damage of reinforced concrete subjected to repeated impact,** *Cem. Concr. Res.* **12,** 359-370 (1982).

Key words: damage; fiber reinforced concrete; impact penetration resistance; ultrasonic.

This study was performed to develop methods of measuring the cumulative damage of steel reinforced concrete slabs subjected to repeated impact. Cumulative damage was monitored by measuring the crater depth and the reduction in ultrasonic pulse velocity across the impact region. Crater depth generally increased with increasing number of impacts and therefore was determined to be a reasonable indicator of cumulative damage. The percent reduction in velocity generally increased with increasing number of impacts up to about 40 percent or more of the total number of impacts to failure. Beyond that, interpretation of the ultrasonic results with respect to the failure mechanism appears necessary. The addition of steel fibers to the bar grid reinforcement resulted in substantial increases (about 2 to 7 times or more) in the total number of impacts to failure as compared to specimens with only bar grid or expanded metal placed at the midpoint of the slab thickness.

21750. Collins, B. L.; Lerner, N. D. **Assessment of fire-safety symbols,** *Hum. Factors* **24,** No. 1, 75-84 (Feb. 1982).

Key words: fire-safety; internationally proposed symbols; International Organization for Standardization (ISO); modes of symbol presentation.

Twenty-five internationally proposed symbols for fire-safety alerting were evaluated for understandability by 91 U.S. participants. Three modes of symbol presentation (slides, placards, and booklets) and two modes of participant response (definition and multiple choice) were studied. Confidence ratings and production data (drawings) were also obtained. Mode of symbol presentation had no significant effect, while definition and multiple-choice response procedures led to generally similar conclusions. Confidence ratings were useful in reconciling discrepancies between the two response methods. The understandability of the 25 symbols ranged from near zero to virtually complete comprehension. The poor performance of some critical symbols such as "exit" was noted, and some potentially dangerous confusions in meaning were revealed.

21777. Waksman, D.; Walton, W. D. **Fire testing of solar collectors by ASTM E 108,** *Fire Technol.* **18,** No. 2, 174-186 (May 1982).

Key words: fire tests; roofing fire resistance; roofing fire tests; solar collectors.

A study was undertaken to investigate the use of ASTM E 108 (NFPA 256, UL 790), Fire Tests of Roof Coverings, for testing roof-mounted solar energy collectors. Data are presented showing the results of the testing conducted. An evaluation of the testing procedures as they apply to roof-mounted solar collectors is given.

21801. Raufaste, N. J. **Safety research programs conducted at the Center for Building Technology,** *South. Build.*, pp. 7-8 (Apr.-May 1983).

Key words: building technology; construction safety; guardrails; occupancy safety; slips; trenching.

This paper reviews safety research at the Center for Building Technology, National Bureau of Standards. This research addresses safety during construction and in use and provides a sound technical basis for the codes and standards development process.

21805. Persily, A. K.; Grot, R. A. **Air infiltration and building tightness measurements in passive solar residences,** *Proc. Fifth Annu. Conf. ASME Solar Energy Division, Orlando, FL, Apr. 18-21, 1983,* pp. 116-121 (The American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017, 1983).

Key words: air infiltration; air tightness; building diagnostics; building tightness; passive solar buildings; pressurization; tracer gas.

The airtightness of about fifty passive solar homes located throughout the United States was studied using low cost measurement techniques. These homes are part of the Solar Energy Research Institute Class B program to evaluate the thermal performance of passive solar residential buildings. These tests provide the first set of building tightness measurements on a large group of passive solar buildings. The measurements include pressurization tests to measure airtightness and tracer gas measurements to determine air infiltration rates.

The pressure tests show a variation in the airtightness of these homes from 3 to 30 exchanges/hour at 50 Pascal, with a median of 9.5 exchanges/hour. The air infiltration measurements cover a wider range from 0.05 to 3.0 exchanges/hour, with a median of 0.5 exchanges/hour. In comparing the tightness of these homes to other U.S. homes, one finds that these passive solar homes are not significantly tighter than homes built with less of an emphasis on energy use.

21807. Ellingwood, B.; Redfield, R. **Ground snow loads for structural design,** *J. Struct. Eng., Am. Soc. Civ. Eng.* **109,** No. 4, 950-964 (Apr. 1983).

Key words: climatology; design (buildings); loads; probability theory; roofs; snow; statistical analysis; structural engineering.

Snow loads for structural design are calculated as the product of the ground snow load and a snow load coefficient that transforms the ground load to a roof load. This paper presents a statistical analysis of annual extreme water-equivalents (reported as inches of water) of ground snow measured at 76 weather stations in the northeast quadrant of the United States through the winter of 1979–1980. The analysis suggests that the lognormal distribution is preferable to a Type I distribution of extreme values for describing annual extreme ground snow loads at a majority of sites. Sampling errors and the selection of design loads from the statistical analysis are also described.

21827. Rossiter, W. J., Jr.; Ballard, D. B.; Sleater, G. A. **Elevated temperature and humidity effects on urea-formaldehyde foam insulations observed by scanning electron microscopy,** (Proc. Conf. Thermal Insulation, Materials, and Systems for Energy Conservation in the 80's, Clearwater Beach, FL, Dec. 8-11, 1981), *Am. Soc. Test. Mater. Spec. Tech. Publ. 789,* pp. 665-687 (Mar. 1983).

Key words: cellular structure; foam; humidity; insulation; scanning electron microscopy; shrinkage; temperature; urea-formaldehyde.

Exposure of urea-formaldehyde foam insulation to elevated temperature and relative humidities may result in its deterioration, as evidenced by shrinkage, mass loss, and under severe conditions, by disintegration. This paper describes the results of a scanning electron microscope (SEM) study undertaken to determine the effect on the cellular microstructure of urea-formaldehyde foam insulations from exposure to elevated temperature and relative humidity conditions. Recommendations for a temperature-humidity exposure test for these insulations are given.

Four commercially-available foam samples, typical of those installed in residences, were prepared in wooden boxes. The percent linear shrinkage in the boxes was determined at various time intervals after filling. Specimens of each foam sample (after drying) were exposed to a variety of elevated temperature and humidity conditions. Changes in mass and volume of the specimens were periodically recorded during exposure. Three foam samples showed slight changes in volume under all exposure conditions. One sample was more susceptible to the exposures at the elevated conditions. SEM was used to investigate changes in cellular structure upon exposure. Results indicated that samples which underwent slight changes in volume during exposure had cellular structures which were not apparently altered. Conversely, SEM photomicrographs indicated cellular degradation in the sample which was affected by the elevated exposure conditions.

21832. Ellingwood, B.; Leyendecker, E. V.; Yao, J. T. P. **Probability of failure from abnormal load,** *J. Struct. Eng., Am. Soc. Civ. Eng.* **109,** No. 4, 875-890 (Apr. 1983).

Key words: abnormal loads; buildings (codes); design; loads; probability theory; progressive collapse; reliability; structural engineering.

Abnormal loads, which usually are not considered in structural design because of their low probability of occurrence, may initiate a catastrophic failure if they occur. A case study shows that the probability of structural failure due to a gas explosion in a residential compartment may exceed probabilities associated with unfavorable combinations of ordinary design loads. Therefore, specific provision in design standards to mitigate the effects of abnormal loads appear warranted.

21837. Carino, N. J.; Lew, H. S.; Volz, C. K. **Early age temperature effects on concrete strength prediction by the maturity method,** *J. Am. Concr. Inst.* **80,** No. 2, 93-101 (Mar.-Apr. 1983).

Key words: age-strength relation; compressive strength; concretes; curing; cylinders; temperature; tests.

A comparison was made between the strength-maturity relations of concrete cylinders cured outdoors and cylinders cured in a laboratory. It was found that when early age (assumed as 48 hr) temperatures of the outdoor-cured and laboratory-cured cylinders were similar, the strength-maturity relations were similar despite temperature fluctuations experienced by the outdoor-cured specimens. The relations were dissimilar when their early age temperatures differed. Another series of tests further investigated and confirmed the importance of early age temperature on the strength-maturity relation.

21839. Simiu, E. **Aerodynamic coefficients and risk-consistent design,** *J. Struct. Eng., Am. Soc. Civ. Eng.* **109,** No. 5, 1278-1289 (May 1983).

Key words: aerodynamics; climatology; extreme winds; loads; structural engineering; wind (meteorology).

A simple procedure is presented for estimating the reliability of wind-sensitive structures whose orientation is not specified. The procedure is based on a second moment reliability approach and makes use of: (1) Aerodynamic coefficients obtained experimentally as functions of wind direction, and (2) climatological data consisting of sets of largest annual speeds associated with winds blowing from each of the 8 (or 16) compass directions. An illustration of the procedure, based on sets of actual data, is presented. It is then shown that the tools presented in the paper can be applied to develop, from directional aerodynamic, and climatological data, nominal aerodynamic coefficients which in effect reduce wind loads with respect to those inherent in current U.S. practice, in a manner that reflects the directional dependence of both the aerodynamic behavior of structures and the extreme wind climate, while being consistent with respect to failure risk. These tools are first developed for the general case where the orientation of the structure is not known. It is then shown that criteria for risk-consistent design for buildings with specified orientation can be derived immediately as a particular case from the criteria applying to structures whose orientation is unknown.

21851. Knab, L. I.; Blessing, G. V.; Clifton, J. R. **Laboratory evaluation of ultrasonics for crack detection in concrete,** *Am. Concr. Inst. J., Tech. Pap. Title No. 80-3,* pp. 17-27 (Jan.-Feb. 1983).

Key words: amplitude; concretes; cracking (fracturing); evaluation; nondestructive tests; ultrasonic tests; velocity.

A laboratory study was performed to quantify the capabilities of ultrasonic through-transmission methods to detect cracks in concrete. Pulse velocity and amplitude measurements were taken perpendicular to the crack plane (in cracked concrete) and compared with measurements parallel to the crack plane (in uncracked concrete). The direct path length was 152 mm (6 in). Parallel crack surfaces, approximately 0.05 mm (0.002 in) apart and having depths of 19, 38, and 57 mm (0.75, 1.50, and 2.25 in) and widths of 152 mm (6 in), were fabricated in the specimens. Transducer frequencies of 150 and 54 kHz were used. Concrete specimens with a 28 day compressive strength of about 36 MPa (5.2 ksi) were tested at several ages.

A sensitivity ratio was used to determine if the cracks could be detected. The numerator of the sensitivity ratio was the difference between velocity or amplitude values in the cracked as compared to uncracked concrete, while the denominator represented the variability of the velocity or amplitude values in both the cracked and uncracked concrete. With the 57 and 38 mm (2.25 and 1.5 in) deep cracks, nearly all the sensitivity values for velocity and amplitude indicated that these crack depths could be detected under the test conditions. The velocity and amplitude sensitivity values with the 19 mm (0.75 in) crack depth were lower, indicating that the 19 mm (0.75 in) crack depth could not be clearly detected. In this study, it was concluded, that both velocity and amplitude were meaningful parameters in crack detection. Based on the sensitivity values, however, velocity appeared to be the more meaningful parameter.

21853. Swaffield, J. A.; Bridge, S.; Galowin, L. S. **Mathematical modelling of time dependent wave attenuation and discrete solid body transport in gravity driven partially filled pipe flows,** *Proc. 4th Int. Conf. Finite Elements in Water Resources, Hannover, Germany, June 21-25, 1982,* 11 pages (Springer-Verlag Berlin, Heidelberg, New York, 1982).

Key words: drains; partially filled pipe flow; plumbing; solid transport in pipes; unsteady pipe flow.

The method of characteristics is applied to solve the unsteady partially filled pipe flow equations applying to the flow in building drainage systems. Wave attenuation, together with the propagation of steep fronted waves and the transport of discrete solids, is modelled and comparisons drawn with experimental investigations undertaken with representative pipe size and flow loading values.

21857. Swaffield, J. A.; Bridge, S.; Galowin, L. S. **Unsteady flow in long drainage systems,** *Build. Res. Pract.* **11,** No. 1, 48-59 (Jan.-Feb. 1983).

Key words: drains; partially filled pipe flow; plumbing; solid transport in pipes; unsteady pipe flow; wave attenuation.

The effect of flow attenuation on drainage design is identified and is shown to be modelled by the partially filled unsteady pipe flow equations. Numerical solutions to these equations are presented and validated against laboratory testing at flow rates appropriate to installed drainage systems. Application of the method to both steep fronted waves and solids moving through the pipe system are also presented.

21858. Mahajan, B. M.; Liu, S. T. **Initial results from the NBS passive solar test facility,** *Proc. ASME Solar Energy Division Fifth Annu. Conf., Orlando, FL, Apr. 18-20, 1983,* pp. 109-115 (The American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017, Apr. 1983).

Key words: hybrid; passive; performance; solar; storage; thermal test.

The National Bureau of Standards (NBS), under the sponsorship of the U.S. Department of Energy (DoE), has constructed a passive/hybrid solar test facility for the purpose of acquiring carefully measured performance data for various passive subsystems under different experimental conditions. The test facility contains several types of generic passive solar features, such as a direct gain system, a collector/storage wall, and clerestory windows. Such carefully measured data are needed both for: (1) assessing the adequacy of performance monitoring procedures for passive heating and cooling systems, and (2) validation of passive solar analysis/design tools. Performance data have been acquired from the initial testing of the direct gain system under two different experimental conditions.

This paper briefly describes the test facility, instrumentation, experimental conditions for the initial tests and planned experimental work. The paper contains representative results from the initial test data. The performance of the concrete floor as the thermal storage medium, the occurrence of overheating, and the thermal comfort conditions within the cell are discussed.

21871. Galowin, L. S.; Winter, F. **Upgrading old plumbing vent systems,** *Build. Res. Pract.* **11,** No. 1, 22-35 (Jan.-Feb. 1983).

Key words: modifications for plumbing; plumbing; rehabilitation; vents in plumbing.

Rehabilitation, modernization, or renovation of existing buildings, as a resource to be conserved or recycled and reused, frequently imposes increased loads on the plumbing water supply and drainage system. The requirement for venting in U.S. practice is intended to prevent trap seal loss from exceeding values prescribed in model plumbing codes. The vent piping in older buildings may be marginal for retrofit under current requirements with the same or increased numbers of fixtures and devices installed into the plumbing system.

An experimental laboratory investigation of "circulation loop" modification to the drain-waste-vent (DWV) system to relieve the marginal performance of existing installations is reported. The experimental evaluations of the performance of the modified system and a conventional system were undertaken for a variety of wastewater load simulated conditions with various plumbing fixtures and multistory soil stack loads. The performance parameters considered were evaluation of trap seal failures and siphonic action of the water closets. Also, the dynamic responses to pressure excursions and air flow rate distributions in the branches were measured. Both systems were tested to the limiting condition for single-stack performance over a range of air flow variations into the soil and vent stack.

The circulation loop system was found to level out a portion of the soil stack pressure distributions to provide benefits in reducing trap seal failures and reduced siphonic action failures of water closets. With vent valves open, both conventional and modified loop systems provided satisfactory venting. Acceptable performance with installation of additional sanitary fixture waste loads was demonstrated by the circulation loop. Additional research requirements were identified for sizing the circulation loop vent connection fitting, and further testing with small regulated air flows into the vent stack to establish marginal performance limits.

21886. Reed, D. A.; Scanlan, R. H. **Time series analysis of cooling tower wind loading,** *J. Struct. Eng.* **109,** No. 2, 538-554 (Feb. 1983).

Key words: concrete structures; cooling towers; turbulence; wind loads.

This paper considers full-scale wind velocity and wind pressure time series data collected on two cooling towers. ARIMA time series models are shown to describe these data adequately. The advantage of using these models is that they provide a convenient method for loading simulation. Transfer function models in the time domain relating input wind velocity to output wind pressure-difference at three circumferential tower locations are presented and discussed.

21897. Rossiter, W. J.; Mathey, R. G. **A methodology for developing tests to aid service-life prediction of single-ply roofing membranes,** *Proc. NBS/NRCA 7th Conf. Roofing Technology, Gaithersburg, MD, Apr. 14-15, 1983,* pp. 4-11 (NRCA, 8600 Berwyn Mawr Ave., Chicago, IL 60631, 1983).

Key words: durability prediction; membrane; methodology roofing service life; service-life testing; single-ply membranes.

The rapid growth in the use of single-ply roofing membranes has created a need for performance standards which include requirements and tests for evaluating their service life. A methodology is described for developing tests for aiding service-life prediction of single-ply membranes. The methodology is based on ASTM practice for developing short-term tests to aid in the prediction of the service life of building materials and components. The ASTM practice outlines a sequence of steps to be taken which are applicable to aid in predicting the service life of membrane materials. A summary of the ASTM practice is given and examples of the application of many of its steps to single-ply roofing systems are presented. Service-life prediction investigations are complex and have limitations. It is expected that the development of short-term tests according to the ASTM practice will lead to increased confidence in service-life predictions.

21907. Frohnsdorff, G.; Masters, L. W. **The meaning of durability and durability prediction,** *Proc. 1st Int. Conf. Durability Building Materials Components, Ottawa, Canada, Aug. 21-23, 1978,* pp. 17-30 (American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, 1980).

Key words: accelerated tests; building components; building materials; durability; durability prediction; recommended practice; service life.

The concept of durability is not well defined. The term durability is often used to imply the possession of qualities associated with long-life. In some standards for building components, it is nonquantitative and implies that design requirements are likely to be exceeded for the design service life or some other specified period. The new ASTM Recommended Practice for Developing Short-Term Accelerated Tests for Prediction of the Service Life of Building Components and Materials (E 632–78), is outlined. The application of the recommended practice to service life prediction is illustrated by an example for work being planned on protective coatings for steel.

21944. Gross, J. G. **Application of the performance concept to rehabilitation—Field application and evaluation, Final Report.** *Proc. 3d ASTM/CIB/RILEM Symp. Performance Concept in Building, Lisbon, Portugal, Mar. 29-Apr. 2, 1982,* **2,** Section III.2, 227-231 (Laboratorio Nacional de Engenharia Civil Avenido do Brasil, 1799 Lisboa Codex, Portugal, 1982).

Key words: economic methods; evaluation guides; performance concept; regulations; rehabilitation; research; research needs; test methods.

This paper summarizes the Session III.2 *Application of the Performance Concept to Rehabilitation,* "Field Application and Evaluation," of the 3rd ASTM/CIB/RILEM Symposium on the *Performance Concept in Building,* held in Lisbon, Portugal, March 29, 30, 31, and April 1 and 2, 1982. Provided is a session summary with identified research and technical needs to facilitate the application of the performance concept to rehabilitation of existing buildings.

21945. Gross, J. G. **Application of the performance concept to rehabilitation—Field application and evaluation,** *Proc. 3d ASTM/CIB/RILEM Symp. Performance Concept in Building, Lisbon, Portugal, Mar. 29-Apr. 2, 1982,* **2,** Section III.2, 205-218 (Laboratorio Nacional de Engenharia Civil Avenido do Brasil, 1799 Lisboa Codex, Portugal, 1982).

Key words: building; evaluation; performance; rehab; research; test methods.

This report presents the author's review of five papers presented to Section III, *Application of the Performance Concept to Rehabilitation,* Group III.2, Field Application and Evaluation, of the Third International Symposium on the *Performance Concept in Building,* sponsored by ASTM, CIB, and RILEM. Discussed is the need for and the importance of pre-rehabilitation evaluation for the success of any rehab project. Summarized is the need for evaluation research in the area of the physical sciences, engineering, economics, and user needs.

22041. Carino, N. J.; Lew, H. S. **Temperature effects on strength-maturity relations of mortar,** *Am. Concr. Inst. J., Title No.* **80-17,** No. 3, 177-182 (May/June 1983).

Key words: age-strength relation; compression tests; compressive strength; concretes; cubes; curing; hydration; mortars (material); setting (hardening); temperature.

Two questions are addressed: 1) What are the quantitative effects of curing temperature on the strength-maturity relations of concrete? 2) At what age will curing temperature no longer affect the strength-maturity relation? To answer the first question, mortar cubes were cast and cured at five different temperatures from 5 to 43 C, and compression tests were performed at seven maturity values. A three-parameter equation was used to represent the strength-maturity relations, while regression analysis was used to evaluate the coefficients. It was found that the parameters in the strength-maturity function for each curing condition varied systematically with temperature.

To answer the second question, mortar cubes were cast and stored at 5 and 32 C; they were then transferred to a 23 C environment for subsequent curing. Compression tests were performed at five maturity values. Resulting data were analyzed to determine the age beyond which initial curing temperature no longer affected the strength-maturity relation. Results indicate that an alternative to the traditional approach for computing maturity may exist which may better account for combined effects of temperature and time on the strength development of concrete.

22046. Rudder, F. F.; Weber, S. F. **Minimum cost design for noise insulation in building construction,** *Noise Control Eng. J.* **20,** No. 3, 104-121 (May/June 1983).

Key words: architectural acoustics; constrained optimization; construction cost; cost minimization; noise insulation.

A method is described for estimating the construction cost of building components designed to achieve a specified level of noise insulation. The method also determines the noise insulation value of each component of a multi-component wall such that the wall achieves a design level of noise insulation at the minimum construction cost. Curves of minimum construction cost as a function of design noise insulation are easily generated using the method. All calculations can be performed using a pocket calculator. The adjustment of construction cost estimates to account for inflation and geographic variation is discussed. Detailed examples illustrate the application of the method to design problems.

22060. Kusuda, T. **An approximate method for determining monthly heat loss from earth-contact floors,** *Proc. Fourth Int. Symp. Use Computers Environmental Engineering Related to Buildings, Kenchiku Kaikan, Tokyo, Japan, Mar. 30-Apr. 2, 1983,* pp. 110-118 (The Society of Heating, Air-Conditioning & Sanitary Engineers of Japan, 1-8-1 Kitashinjuku, Shinjuku-ku, Tokyo, Japan, 1983).

Key words: Delsante calculation; earth temperature; monthly floor heat loss; slab-on-grade floor.

Based on extensive earth temperature calculations using a Green's function type solution of the heat conduction equation, a simplified procedure was developed to permit the evaluation of monthly heat loss from the slab-on-grade floor. The results obtained by the method developed herein were compared against those determined by Delsante's more rigorous and analytical formula. Good agreements were obtained between the monthly floor heat loss determined by these two methods, provided that the average earth temperature at 0.15 m below the floor surface is used for the heat transfer calculation and that the perimeter width of 0.15 m is used for the Delsante calculations.

22062. Carino, N. J.; Woodward, K. A.; Leyendecker, E. V.; Fattal, S. G. **A review of the Skyline Plaza collapse,** *Concr. Int.* **5,** No. 7, 35-42 (July 1983).

Key words:: apartment buildings; collapse; compressive strength; concrete construction; concrete slabs; failure; form removal; high-rise buildings; punching shear; reinforced concrete; shear stress.

On March 2, 1973, portions of the Skyline Plaza apartment building, under construction in Fairfax County, Va., collapsed. The failure resulted in the death of 14 workers; 34 others were injured.

This article summarizes the results of the failure investigation carried out by the National Bureau of Standards. Based on structural analyses and estimates of concrete strength at the time of collapse, NBS investigators concluded that the probable cause was a punching shear failure of the 23rd floor slab. The critical condition was attributed to: (1) premature removal of shoring below the 23rd floor slab at the time the 24th floor was being placed, and (2) the low strength of that portion of the 23rd floor which was unshored.

22167. Ellingwood, B. **Towards unified probability-based design,** *Build. Res. Pract.* **9,** No. 2, 162-171 (Mar./Apr. 1983).

Key words: buildings (codes); concrete (reinforced); design (buildings); limit states; loads (forces); masonry; probability theory; reliability; standards; statistical analysis; steel; structural engineering.

Throughout the world there are moves to achieve a common basis for structural design applicable to concrete, steel, timber and masonry, but the problems are considerable. They are exemplified in the USA, but recent advances there in applying probabilistic methods have made the objective more feasible. The Center for Building Technology of the U.S. National Bureau of Standards has an important role in this unifying process, and an engineer at the Center here discusses the progress achieved in that country and the problems ahead.

22181. Yokel, F. Y.; Salomone, L. A.; Gray, R. E. **Housing construction in areas of mine subsidence,** *Am. Soc. Civ. Eng. J. Geotech. Eng. Div.* **108,** No. GT9, 1133-1149 (Sept. 1982).

Key words: foundation design; housing construction; mine subsidence; mining settlement; structural design.

Many areas in the United States are underlain by abandoned mines and many more areas will be undermined in the future. As mine cavities collapse they cause settlement and ground distortions on the surface which may damage or destroy buildings and utilities. Many of these subsidence-prone areas are presently used or will be used in the future for residential housing development. Three problems associated with the development of mine subsidence areas are addressed: site exploration and evaluation; site development; and housing construction in mine subsidence areas. This paper is derived from a study sponsored by the Department of Housing and Urban Development.

22242. Rennex, B. G.; Jones, R. R.; Ober, D. G. **Development of calibrated transfer specimens of thick, low-density insulation,** *Proc. Seventeenth Int. Thermal Conductivity Conf., National Bureau of Standards, Gaithersburg, MD, June 15-18, 1981,* pp. 419-426 (Plenum Press, 233 Spring Street, New York, NY 10013, Jan. 1983).

Key words: finite element models; guarded hot plate; low-density thick insulation; standard reference material; thickness effect.

The Thermal Insulation Group at the National Bureau of Standards has been developing the techniques necessary to provide thick, low-density calibrated specimens to the thermal testing community. Previous research has indicated the need to measure the apparent thermal conductivity or resistance at thicknesses up to 6 inches in order to account for apparatus systematic errors, and in order to understand better the "thickness effect" due to radiation heat transfer. In order to provide consistency among the heat-flow-meter and guarded-hot-plate apparatuses in the United States, NBS has agreed to provide the above-mentioned samples, in addition to the high-density specimens already provided.

The following conditions must be met to provide the calibrated specimens. First, the guarded-hot-plate apparatus must be large enough to approximate one-dimensional heat flow in the meter area. Then careful design and construction make possible the accurate determination of the experimental variables of plate-to-plate thickness, plate temperature, and heat flow. An error analysis must be performed. Finally, the highly variable low-density insulation samples must be well characterized. The NBS efforts to meet these conditions are the subject of this paper.

22276. Persily, A. **Repeatability and accuracy of pressurization testing,** *Proc. Thermal Performance Exterior Envelopes Buildings II, Las Vegas, NV, Dec. 6-9, 1982,* pp. 380-390 (American Society of Heating, Refrigerating & Air-Conditioning Engineers, Inc., 1791

Tullie Circle, N.E., Atlanta, GA 30329, 1983).

Key words: air leakage; airtightness; blower; building diagnostics; doors; leakage testing; pressurization.

Pressurization testing is used to evaluate the airtightness of building envelopes. To experimentally determine the repeatability of pressurization test results, a home was pressure tested about eighty times in one year. The effect of weather conditions on the test results was studied, along with changes in the results over time. For local wind speeds less than 5.5 mph (2.5 m/s), the 0.2 in H_2O (50 Pa) leakage rate has a standard deviation of about 2% of the mean over short time periods. For stronger winds, errors as large as 15% compared to the calm weather test results occurred. A seasonal variation in the leakiness of the house, on the order of 25%, was also found. This variation is due to changes in the moisture content of the building materials caused by yearly variation in the moisture content of the outside air.

22279. McCabe, M. E.; Lecourte, J.; Robinson, S. **Calorimetric test facility for field measuring thermal performance of passive/hybrid solar components,** *Proc. Thermal Performance Exterior Envelopes of Building II, Las Vegas, NV, Dec. 6-9, 1982,* pp. 673-686 (American Society of Heating, Refrigerating & Air-Conditioning Engineers, 1791 Tullie Circle, N.E., Atlanta, GA 30329, 1983).

Key words: calorimeter; energy storage; heat transfer; passive solar component; solar energy; test procedure.

Studies of the thermal performance of passive solar buildings have indicated a need for precise field measurement of solar heat gain and thermal heat loss or gain for modular passive/hybrid solar components. A description of the conceptual design and the major assemblies and subsystems for a new calorimetric test facility is presented in this paper. The facility is designed for field testing of passive solar components at the National Bureau of Standards in Gaithersburg, MD. It is anticipated that the test facility will provide a substantial improvement in the field measuring techniques for passive and hybrid solar components over the test cells currently in use and thereby provide a firm technical basis from which laboratory test procedures can be evaluated.

Computer studies of the thermal performance of the metering chamber assembly made with a 65-node finite-difference thermal model are described. The model was used to compute the heat balance for the solar absorber panel and the air-conditioning units, located in the metering chamber. Design days in both summer and winter were studied for a worst-case test article, which consisted of a single sheet of window glass. A description of the passive/hybrid solar components proposed for testing in the calorimeter during the winter season of 1982–1983 is also provided.

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traffic noise; transportation noise; acoustics; environmental pollution; highway noise; motor vehicle noise; noise; noise control; sound; *TN1113-3.*
transfer function; underground amplitudes; earthquake observation systems; simulation models; spectral analysis; *SP658*; 1983 July. II-45–II-64.
transmission lines; design; soil mechanics; thermal conductivity; thermal resistivity; *21629.*
transportation noise; acoustics; environmental pollution; highway noise; motor vehicle noise; noise; noise control; sound; traffic noise; *TN1113-3.*
trenching; braced excavations; construction; Federal regulations; retaining structures; safety; shoring; slope stability; soil classification; soil pressures; standards; *NBSIR 83-2693, Vol. II.*
trenching; braced excavations; construction; Federal regulations; retaining structures; safety; shoring; slope stability; soil classification; soil pressures; standards; *NBSIR 83-2693, Vol. I.*
trenching; building technology; construction safety; guardrails; occupancy safety; slips; *21801.*
trial designs; building structures; earthquake codes; earthquake engineering; earthquake standards; seismic design; *NBSIR 82-2589.*
trial designs; building structures; earthquake codes; earthquake engineering; earthquake standards; seismic design; *NBSIR 82-2626.*
tricalcium silicate; water-to-cement radio; cement; hydration; mechanisms; models; particle size; *21692.*
trussed-girders; aerodynamic forces; solidity; *SP651*; 1983 April. 1-19.
tsunami; tsunami behavior; tsunamigenic earthquake; computer modeling; earthquake sources; *SP651*; 1983 April. 507-521.
tsunami; wind loads; winds; accelerograph; codes; design criteria; disaster; earthquake hazards; earthquakes; geotechnical engineering; ground failure; liquefaction; pipeline; seismicity; solids; standards; structural engineering; structural response; *SP651.*
tsunami behavior; tsunamigenic earthquake; computer modeling; earthquake sources; tsunami; *SP651*; 1983 April. 507-521.
tsunami breakwaters; tsunami prediction; disaster planning; seawall protection; *SP658*; 1983 July. IX-29–IX-37.

tsunamigenic earthquake; computer modeling; earthquake sources; tsunami; tsunami behavior; *SP651*; 1983 April. 507-521.
tsunamigenic earthquake; identification; tsunami research; coastal hazards; *SP651*; 1983 April. 416-425.
tsunamigenic earthquakes; tsunamis; engineering seismology; NEDRES; seismographic data; *SP651*; 1983 April. 426-432.
tsunami prediction; disaster planning; seawall protection; tsunami breakwaters; *SP658*; 1983 July. IX-29–IX-37.
tsunami prediction; tsunami research; disaster warning; earthquake detection; flood warning; *SP658*; 1983 July. IX-1–IX-7.
tsunami research; coastal hazards; tsunamigenic earthquake; identification; *SP651*; 1983 April. 416-425.
tsunami research; disaster warning; earthquake detection; flood warning; tsunami prediction; *SP658*; 1983 July. IX-1–IX-7.
tsunamis; engineering seismology; NEDRES; seismographic data; tsunamigenic earthquakes; *SP651*; 1983 April. 426-432.
tsunamis; wind loads; winds; accelerograph; codes; design criteria; disaster; earthquakes; ground failures; hazards; seismicity; solids; standards; structural engineering; structural responses; *SP658*.
turbulence; waves; wind loads; compliant platforms; ocean engineering; offshore platforms; structural engineering; tension leg platforms; *BSS151*.
turbulence; wind loads; concrete structures; cooling towers; *21886*.
two-dimensional seismometer array observation; wave propagation; deformation method; dynamic response analysis; pipe stresses; *SP651*; 1983 April. 242-258.
two-position control; room temperature control; temperature controller; thermostat evaluation; thermostat modeling; thermostat test; *BSS150*.
typhoon damage; wave setup; storm surge; *SP658*; 1983 July. IX-8–IX-18.

U

ultrasonic; damage; fiber reinforced concrete; impact penetration resistance; *21736*.
ultrasonic tests; velocity; amplitude; concretes; cracking (fracturing); evaluation; nondestructive tests; *21851*.
underground amplitudes; earthquake observation systems; simulation models; spectral analysis; transfer function; *SP658*; 1983 July. II-45–II-64.
understandability; visibility; visual alerting; exit symbols; fire safety; legibility; symbols; *NBSIR 83-2675*.
uniform; velocity; analysis; flow; force; liquid; model; momentum; partially-filled; pipe; solid; solid-liquid channel flow; steady; *J. Res. 88(4)*: 261-288; 1983 July-August.
universal fasteners; wooden roofs; joint fasteners; roofing damage; structural performance; tension tests; *SP658*; 1983 July. VII-143–VII-156.
unreinforced masonry; wood diaphragms; analytical model; dynamic response; seismic hazard; *SP658*; 1983 July. VII-110–VII-129.
unsteady pipe flow; drains; partially filled pipe flow; plumbing; solid transport in pipes; *21853*.
unsteady pipe flow; wave attenuation; drains; partially filled pipe flow; plumbing; solid transport in pipes; *21857*.
urea-formaldehyde; cellular structure; foam; humidity; insulation; scanning electron microscopy; shrinkage; temperature; *21827*.
U.S.-Japan Joint Earthquake Research Program; wind and seismic effects; large-scale testing; *SP658*; 1983 July. 23-45.
U-value tests; air infiltration; building diagnostics; building thermal integrity; fan pressurization; field measurements; thermographic inspections; tracer gas technique; *NBSIR 83-2768*.

V

value-added; earthquakes; economic damage; indirect effects; *SP651*; 1983 April. 565-586.
vapor compression cycle; air conditioner; capillary tube; coil; compressor; condenser; evaporator; expansion device; heat pump; modeling; *BSS155*.
VDT's (video display terminal); work station; acoustic privacy; design criteria; ergonomics; lighting; office automation; office design criteria; quality-of-life; space planning; thermal comfort; *NBSIR 83-2784-1*.
velocity; amplitude; concretes; cracking (fracturing); evaluation; nondestructive tests; ultrasonic tests; *21851*.
velocity; analysis; flow; force; liquid; model; momentum; partially-filled; pipe; solid; solid-liquid channel flow; steady; uniform; *J. Res. 88(4)*: 261-288; 1983 July-August.
ventilation; air exchange rate; archives; building envelope infiltration; pressurization; records storage; *NBSIR 83-2770 (GSA)*.
ventilation; building energy analysis; building heat transfer; computer modeling; convection; infiltration; *NBSIR 83-2635*.
vents for plumbing; innovative venting; plumbing; plumbing renovation; rehabilitation; *NBSIR 82-2602*.
vents in plumbing; modifications for plumbing; plumbing; rehabilitation; *21871*.
vibratory cone penetrometer; artificial vibration; impact loadings; liquefaction; standard penetration tests; *SP651*; 1983 April. 541-555.
visco-elastic shear-beam analysis; embankments; liquefaction; *SP651*; 1983 April. 218-241.
visibility; visual alerting; exit symbols; fire safety; legibility; symbols; understandability; *NBSIR 83-2675*.
visual acuity; visual angle; acuity, visual; angle, visual; contrast; distance, viewing; letters; luminance; resolution, eye; signs; Snellen chart; stroke width; *TN1180*.
visual acuity; visual sensitivity; chromaticity; color; color appearance; energy-efficient lights; illumination; light source; safety; safety sign; safety symbols; *NBSIR 83-2694*.
visual alerting; exit symbols; fire safety; legibility; symbols; understandability; visibility; *NBSIR 83-2675*.
visual alerting; warnings; communication; hazard; pictogram; safety; signs; standards; symbols; *NBSIR 82-2485*.
visual angle; acuity, visual; angle, visual; contrast; distance, viewing; letters; luminance; resolution, eye; signs; Snellen chart; stroke width; visual acuity; *TN1180*.
visual sensitivity; chromaticity; color; color appearance; energy-efficient lights; illumination; light source; safety; safety sign; safety symbols; visual acuity; *NBSIR 83-2694*.

W

walls; cracking; cyclic; fatigue; masonry; shear; strain rate; *NBSIR 83-2780*.
warnings; communication; hazard; pictogram; safety; signs; standards; symbols; visual alerting; *NBSIR 82-2485*.
water conservation; water supply devices; plumbing; showerheads; *NBSIR 82-2630*.
water heaters; appliances; energy; heat pump water heaters; testing; test procedures; *NBSIR 83-2723*.
water supply devices; plumbing; showerheads; water conservation; *NBSIR 82-2630*.
water-to-cement radio; cement; hydration; mechanisms; models; particle size; tricalcium silicate; *21692*.
wave attenuation; drains; partially filled pipe flow; plumbing; solid transport in pipes; unsteady pipe flow; *21857*.
waveforms; dynamic response analysis; ground motion; modeling; synthetic earthquake motion; *SP658*; 1983 July. II-13–II-23.
wave propagation; deformation method; dynamic response analysis; pipe stresses; two-dimensional seismometer array observation; *SP651*; 1983 April. 242-258.
wave propagation; dense instrument array; differential motion; ground motions; *SP651*; 1983 April. 95-123.
waves; wind loads; compliant platforms; ocean engineering; offshore platforms; structural engineering; tension leg platforms; turbulence; *BSS151*.
wave setup; storm surge; typhoon damage; *SP658*; 1983 July. IX-8–IX-18.
wave velocities; damping; dynamic properties; field testing; geophysical; laboratory testing; resonant column test; shear modulus; *SP658*; 1983 July. III-87–III-118.
weatherization retrofit; balance point temperature; computer graphics;

degree days; energy conservation; energy consumption; fuel usage records; tracking technique; *NBSIR 83-2676.*
weatherization retrofits; building heat losses; comparison of inspections; infrared scanning systems; insulation voids; interpretation of thermograms; thermal deficiencies; thermographic inspections; *NBSIR 82-2510.*
wet-bulb temperature; chilled mirror hygrometer; dew point temperature; humidity generator; humidity sensors; lithium chloride humidity sensors; moisture content of building air; relative humidity; saturated salt solutions; sensor calibration; sensor precision; specific humidity; *BSS157.*
wind and seismic effects; large-scale testing; U.S.-Japan Joint Earthquake Research Program; *SP658*; 1983 July. 23-45.
wind data; bridge motion; cable-stayed bridge; *SP651*; 1983 April. 20-33.
wind direction; building (codes); climatology; hurricanes; statistical analysis; structural engineering; wind (meteorology); *21712.*
wind forces; climatology; extreme values; short-term records; statistics; structural engineering; *21572.*
wind forcing; wind models; hurricane; ocean current; oil spill trajectory; storm surge; *SP658*; 1983 July. IX-19–IX-24.
wind loads; compliant platforms; ocean engineering; offshore platforms; structural engineering; tension leg platforms; turbulence; waves; *BSS151.*
wind loads; concrete structures; cooling towers; turbulence; *21886.*
wind loads; winds; accelerograph; codes; design criteria; disaster; earthquake hazards; earthquakes; geotechnical engineering; ground failure; liquefaction; pipeline; seismicity; solids; standards; structural engineering; structural response; tsunami; *SP651.*
wind loads; winds; accelerograph; codes; design criteria; disaster; earthquakes; ground failures; hazards; seismicity; solids; standards; structural engineering; structural responses; tsunamis; *SP658.*
wind (meteorology); aerodynamics; climatology; extreme winds; loads; structural engineering; *21839.*
wind (meteorology); wind direction; building (codes); climatology; hurricanes; statistical analysis; structural engineering; *21712.*
wind models; hurricane; ocean current; oil spill trajectory; storm surge; wind forcing; *SP658*; 1983 July. IX-19–IX-24.
window management; automatic control; daylighting; lighting control; microprocessor; *NBSIR 83-2728.*
window management; building energy analysis; cooling loads; heating loads; solar film; solar heat gain; *TN1174.*
window performance; building computer simulation; building energy performance; clerestory performance; daylighting; skylight performance; *BSS152.*
windows; building energy analysis; clerestories; daylighting; skylights; *NBSIR 83-2726.*
wind pressure; wind speeds; building (codes); probability distribution functions; statistical analysis; storms; structural engineering; *SP658*; 1983 July. I-16–I-30.
winds; accelerograph; codes; design criteria; disaster; earthquake hazards; earthquakes; geotechnical engineering; ground failure; liquefaction; pipeline; seismicity; solids; standards; structural engineering; structural response; tsunami; wind loads; *SP651.*
winds; accelerograph; codes; design criteria; disaster; earthquakes; ground failures; hazards; seismicity; solids; standards; structural engineering; structural responses; tsunamis; wind loads; *SP658.*
wind speeds; building (codes); probability distribution functions; statistical analysis; storms; structural engineering; wind pressure; *SP658*; 1983 July. I-16–I-30.
wind turbulence spectrum; gust winds; high wind analysis; tall towers; *SP658*; 1983 July. I-31–I-45.
wood diaphragms; analytical model; dynamic response; seismic hazard; unreinforced masonry; *SP658*; 1983 July. VII-110–VII-129.
wooden roofs; joint fasteners; roofing damage; structural performance; tension tests; universal fasteners; *SP658*; 1983 July. VII-143–VII-156.
workshop; arctic; concrete; construction; design; inspection; offshore structures; repair; research; structural engineering; technology assessment; *NBSIR 83-2751.*
work station; acoustic privacy; design criteria; ergonomics; lighting; office automation; office design criteria; quality-of-life; space planning; thermal comfort; VDT's (video display terminal); *NBSIR 83-2784-1.*

X

Y

Z

1978 Tokyo tornado; meteorological elements; tornadic cyclone; tornado elements; *SP658*; 1983 July. I-1–I-15.

APPENDICES

APPENDIX A. DEPOSITORY LIBRARIES IN THE UNITED STATES

ALABAMA

Alexander City: Alexander City State Junior College, Thomas D. Russell Library (1967).
Auburn: Auburn University, Ralph Brown Draughon Library (1907).
Birmingham:
- Birmingham Public Library (1895).
- Birmingham Southern College Library (1932).
- Jefferson State Junior College, James B. Allen Library (1970).
- Miles College, C. A. Kirkendoll Learning Resource Center (1980).
- Samford University Library (1884).

Enterprise: Enterprise State Junior College, Learning Resources Center (1967).
Fayette: Brewer State Junior College, Learning Resources Center Library (1979).
Florence: University of North Alabama, Collier Library (1932).
Gadsden: Gadsden Public Library (1963).
Huntsville: University of Alabama in Huntsville Library (1964).
Jacksonville: Jacksonville State University Library (1929).
Mobile:
- Mobile Public Library (1963).
- Spring Hill College, Thomas Byrne Memorial Library (1937).
- University of South Alabama Library (1968).

Montgomery:
- Alabama State Department of Archives and History Library (1884).
- Alabama Supreme Court and State Law Library (1884).
- Auburn University at Montgomery Library (1971)-REGIONAL.

Maxwell A.F. Base: Air University Library (1963).
Normal: Alabama Agricultural and Mechanical College, J. F. Drake Memorial Learning Resources Center (1963).
Troy: Troy State University Library (1963).
Tuskegee Institute: Tuskegee Institute, Hollis Burke Frissell Library (1907).
University:
- University of Alabama Library (1860)-REGIONAL.
- University of Alabama, School of Law Library (1967).

ALASKA

Anchorage:
- Anchorage Municipal Libraries, Z. J. Loussac Public Library (1978).
- Supreme Court of Alaska Library (1973).
- University of Alaska at Anchorage Library (1961).
- U.S. Department of Interior, Alaska Resources Library (1981).

Fairbanks: University of Alaska, Elmer E. Rasmuson Library (1922).
Juneau:
- Alaska State Library (1900).
- University of Alaska-Juneau Library (1981).

Ketchikan: Ketchikan Community College Library (1970).

ARIZONA

Coolidge: Central Arizona College, Instructional Materials Center (1973).
Flagstaff: Northern Arizona University Library (1937).
Mesa: Mesa Public Library (1983).
Phoenix:
- Department of Library, Archives, and Public Records (unknown)-REGIONAL.
- Grand Canyon College, Fleming Library (1978).
- Phoenix Public Library (1917).

Prescott: Yavapai College Library (1976).
Tempe:
- Arizona State University, College of Law Library (1977).
- Arizona State University Library (1944).

Thatcher: Eastern Arizona College Library (1963).
Tucson:
- Tucson Public Library (1970).
- University of Arizona Library (1907)-REGIONAL.

Yuma: Yuma City-County Library (1963).

ARKANSAS

Arkadelphia: Ouachita Baptist University, Riley Library (1963).
Batesville: Arkansas College Library (1963).
Clarksville: College of the Ozarks, Dobson Memorial Library (1925).
Conway: Hendrix College, Olin C. Bailey Library (1903).
Fayetteville:
- University of Arkansas Universities Libraries (1907).
- University of Arkansas, School of Law Library (1978).

Little Rock:
- Arkansas State Library-REGIONAL. (1978).
- Arkansas Supreme Court Library (1962).
- Little Rock Public Library (1953).
- University of Arkansas at Little Rock Library (1973).
- University of Arkansas at Little Rock Law Library (1979).

Magnolia: Southern Arkansas University, Magale Library (1956).
Monticello: University of Arkansas at Monticello Library (1956).
Pine Bluff: University of Arkansas at Pine Bluff, Watson Memorial Library (1976).
Russellville: Arkansas Tech University, Tomlinson Library (1925).
Searcy: Harding University, Beaumont Memorial Library (1963).
State University: Arkansas State University, Dean B. Ellis Library (1913).
Walnut Ridge: Southern Baptist College, Felix Goodson Library (1967).

CALIFORNIA

Anaheim: Anaheim Public Library (1963).
Arcadia: Arcadia Public Library (1975).
Arcata: Humboldt State University Library (1963).
Bakersfield:
- California State College, Bakersfield Library (1974).
- Kern County, Beale Memorial Library (1943).

Berkeley:
- University of California, Law Library (1963).
- University of California, General Library (1907).

Carson:
- California State University, Dominguez Hills Educational Resources Center (1973).
- Carson Regional Library (1973).

Chico: California State University at Chico Library (1962).
Claremont: Claremont Colleges' Libraries, Honnold Library (1913).
Coalinga: West Hills Community College Library (1978).
Compton: Compton Library (1972).
Culver City: Culver City Library (1966).
Davis:
- University of California, Shields Library (1953).
- University of California at Davis, Law Library (1972).

Downey: Downey City Library (1963).
Fresno:
California State University, Henry Madden Library (1962).
Fresno County Free Library (1920).
Fullerton: California State University at Fullerton Library (1963).
Garden Grove: Garden Grove Regional Library (1963).
Gardena: Gardena Public Library (1966).
Hayward: California State University at Hayward Library (1963).
Huntington Park: Huntington Park Library, San Antonio Region (1970).
Inglewood: Inglewood Public Library (1963).
Irvine: University of California at Irvine, General Library (1963).
La Jolla: University of California at San Diego, Central University Library (1963).
Lakewood: Angelo Iacoboni Public Library (1970).
Lancaster: Lancaster Regional Library (1967).
La Verne: University of La Verne, College of Law Library (1979).
Long Beach:
California State University at Long Beach Library (1962).
Long Beach Public Library (1933).
Los Angeles:
California State University at Los Angeles, John F. Kennedy Memorial Library (1956).
Los Angeles County Law Library (1963).
Los Angeles Public Library (1891).
Loyola Marymount University, Charles Von der Ahe Library (1933).
Loyola Law School, Law Library (1979).
Occidental College Library (1941).
Pepperdine University Library (1963).
Southwestern University, School of Law Library (1975).
University of California at Los Angeles Research Library (1932).
University of California, Los Angeles, Law Library (1958).
University of Southern California, Doheny Memorial Library (1933).
University of Southern California, Law Library (1978).
U.S. Court of Appeals, 9th Circuit Library (1981).
Whittier College, School of Law Library (1978).
Menlo Park: Department of Interior, Geological Survey Library (1962).
Montebello: Montebello Library (1966).
Monterey: U.S. Naval Postgraduate School, Dudley Knox Library (1963).
Monterey Park: Bruggemeyer Memorial Library (1964).
Northridge: California State University at Northridge, Oviatt Library (1958).
Norwalk: Norwalk Public Library (1973).
Oakland:
Mills College Library (1966).
Oakland Public Library (1923).
Ontario: Ontario City Library (1974).
Palm Springs: Palm Springs Public Library (1980).
Pasadena:
California Institute of Technology, Millikan Memorial Library (1933).
Pasadena Public Library (1963).
Pleasant Hill: Contra Costa County Library (1964).
Redding: Shasta County Library (1956).
Redlands: University of Redlands, Armacost Library (1933).
Redwood City: Redwood City Public Library (1966).
Reseda: West Valley Regional Branch Library (1966).
Richmond: Richmond Public Library (1943).
Riverside:
Riverside Public Library (1947).
University of California at Riverside Library (1963).
Sacramento:
California State Library (1895)–REGIONAL.
California State University at Sacramento Library (1963).
Sacramento County Law Library (1963).
Sacramento Public Library (1880).
University of the Pacific, McGeorge School of Law Library (1978).
San Bernardino: San Bernardino County Free Library (1964).
San Diego:
San Diego County Law Library (1973).
San Diego County Library (1966).
San Diego Public Library (1895).
San Diego State University Library (1962).
University of San Diego, Kratter Law Library (1967).
San Francisco:
Golden Gate University, School of Law Library (1979).
Hastings College of Law Library (1972).
Mechanics' Institute Library (1889).
San Francisco Public Library (1889).
San Francisco State University, J. Paul Leonard Library (1955).
Supreme Court of California Library (1979).
U.S. Court of Appeals, Ninth Circuit Library (1971).
University of San Francisco, Richard A. Gleeson Library (1963).
San Jose: San Jose State University Library (1962).
San Leandro: San Leandro Community Library Center (1961).
San Luis Obispo: California Polytechnic State University Library (1969).
San Rafael: Marin County Free Library (1975).
Santa Ana:
Orange County Law Library (1975).
Santa Ana Public Library (1959).
Santa Barbara: University of California at Santa Barbara Library (1960).
Santa Clara: University of Santa Clara, Orradre Library (1963).
Santa Cruz: University of California at Santa Cruz, McHenry Library (1963).
Santa Rosa: Sonoma County Library (1896).
Stanford:
Stanford University Libraries (1895).
Stanford University, Robert Crown Law Library (1978).
Stockton: Public Library of Stockton and San Joaquin County (1884).
Thousand Oaks: California Lutheran College Library (1964).
Torrance: Torrance Civic Center Library (1969).
Turlock: California State College, Stanislaus Library (1964).
Vallejo: Solano County, John F. Kennedy Library (1982).
Valencia: Valencia Regional Library (1972).
Ventura: Ventura County Library (1975).
Visalia: Tulare County Free Library (1967).
Walnut: Mount San Antonio College Library (1966).
West Covina: West Covina Regional Library (1966).
Whittier: Whittier College, Wardman Library (1963).

CANAL ZONE

Balboa Heights: Panama Canal Commission, Library Services Branch (1963).

COLORADO

Alamosa: Adams State College, Learning Resources Center (1963).
Boulder: University of Colorado at Boulder, Government Publications Library (1879)–REGIONAL.
Colorado Springs:
Colorado College, Tutt Library (1880).
University of Colorado at Colorado Springs, Library (1974).
Denver:
Auraria Library (1978).
Colorado State Library (unknown).
Colorado Supreme Court Library (1978).
Denver Public Library (1884)–REGIONAL.
Department of the Interior, Water and Power Resources Service Library (1962).
Regis College, Dayton Memorial Library (1915).
University of Denver, Penrose Library (1909).
University of Denver, School of Law Library (1978).
U.S. Court of Appeals, Tenth Circuit Library (1973).
Fort Collins: Colorado State University Libraries (1907).
Golden: Colorado School of Mines, Arthur Lakes Library (1939).

Grand Junction: Mesa County Public Library (1975).
Greeley: University of Northern Colorado, James A. Michener Library (1966).
Gunnison: Western State College, Leslie J. Savage Library (1932).
La Junta: Otero Junior College, Wheeler Library (1963).
Lakewood: Jefferson County Public Library, Lakewood Library (1968).
Pueblo:
Pueblo Library District (1893).
University of Southern Colorado Library (1965).
U.S. Air Force Academy: Academy Library (1956).

CONNECTICUT

Bridgeport:
Bridgeport Public Library (1884).
University of Bridgeport School of Law Library (1979).
Danbury: Western Connecticut State University, Ruth A. Haas Library (1967).
Danielson: Quinebaug Valley Community College Library (1975).
Enfield: Enfield Central Library (1967).
Hartford:
Connecticut State Library (unknown)–REGIONAL.
Hartford Public Library (1945).
Trinity College Library (1895).
Middletown: Wesleyan University, Olin Library (1906).
Mystic: Mystic Seaport Museum Inc., G. W. Blunt White Library (1964).
New Britain: Central Connecticut State University, Elihu Burritt Library (1973).
New Haven:
Southern Connecticut State University, Hilton C. Buley Library (1968).
Yale Law Library (1981).
Yale University Library (1859).
New London:
Connecticut College Library (1926).
U.S. Coast Guard Academy Library (1939).
Stamford: The Ferguson Library (1973).
Storrs: University of Connecticut Library (1907).
Waterbury:
Post College, Traurig Library (1977).
Silas Bronson Public Library (1869).
West Hartford: University of Connecticut, School of Law Library (1978).
West Haven: University of New Haven, Peterson Library (1971).

DELAWARE

Dover:
Delaware State College, William C. Jason Library (1962).
State Law Library in Kent County (unknown).
Georgetown:
Delaware Technical and Community College Library (1968).
Sussex County Law Library (1976).
Newark: University of Delaware Library (1907).
Wilmington:
Delaware Law School Library (1976).
New Castle County Law Library (1974).

DISTRICT OF COLUMBIA

Washington:
Administrative Conference of the United States Library (1977).
Advisory Commission on Intergovernmental Relations Library (1972).
American University, Washington College of Law Library (1983).
Antioch School of Law Library (1982).
Catholic University of America, Robert J. White Law Library (1979).
Civil Aeronautics Board Library (1974).
Department of the Army Library (1969).
Department of Commerce Library (1955).
Department of Energy Library (1963).
Department of Health and Human Services (1954).
Department of Housing and Urban Development Library (1969).
Department of the Interior Library (1895).
Department of Justice Main Library (1895).
Department of Labor Library (1976).
Department of the Navy Library (1895).
Department of State Library (1895).
Department of State Law Library (1966).
Department of Transportation Main Library (1982).
Department of Transportation, National Highway Traffic Safety Administration Library (1968).
Department of Transportation, U.S. Coast Guard Law Library (1982).
Department of the Treasury Library (1895).
District of Columbia Court of Appeals Library (1981).
District of Columbia Public Library (1943).
Executive Office of the President, Office of Administration, Library and Information Service Division (1965).
Federal Deposit Insurance Corporation Library (1972).
Federal Election Commission Library (1975).
Federal Labor Relations Authority Law Library (1982).
Federal Mine Safety & Health Review Commission Library (1979).
Federal Reserve System, Board of Governors Research Library (1978).
Federal Reserve System Law Library (1976).
General Accounting Office Library (1974).
General Services Administration Library (1975).
Georgetown University Library (1969).
Georgetown University Law Center, Fred O. Dennis Law Library (1978).
George Washington University, Melvin Gelman Library (1983).
George Washington University, National Law Center, Jacob Burns Law Library (1978).
Library of Congress, Congressional Research Service (1978).
Library of Congress, Serial and Government Publications (1977).
Merit Systems Protection Board Library (1979).
National Defense University Library (1895).
University of the District of Columbia Library (1970).
U.S. Court of Appeals, Judges' Library (1975).
U.S. Office of Personnel Management Library (1963).
U.S. Postal Service Library (1895).
U.S. Senate Library (1979).
U.S. Supreme Court Library (1978).
Veterans' Administration, Central Office Library (1967).

FLORIDA

Boca Raton: Florida Atlantic University, S. E. Wimberly Library (1963).
Clearwater: Clearwater Public Library (1972).
Coral Gables: University of Miami Library (1939).
Daytona Beach: Volusia County Library Center (1963).
De Land: Stetson University, duPont-Ball Library (1887).
Fort Lauderdale:
Broward County Library (1967).
Nova University, Center for Study of Law Library (1967).
Fort Pierce: Indian River Community College Library (1975).
Gainesville:
University of Florida, College of Law Library (1978).
University of Florida Libraries (1907)–REGIONAL.
Jacksonville:
Haydon Burns Library (1914).
Jacksonville University, Swisher Library (1962).
University of North Florida, Thomas G. Carpenter Library (1972).

Lakeland: Lakeland Public Library (1928).
Leesburg: Lake-Sumter Community College Library (1963).
Melbourne: Florida Institute of Technology Library (1963).
Miami:
  Florida International University Library (1970).
  Miami-Dade Public Library (1952).
North Miami: Florida International University, North Miami Campus Library (1977).
Opa Locka: Biscayne College Library (1966).
Orlando: University of Central Florida Library (1966).
Palatka: St. Johns River Community College Library (1963).
Pensacola: University of West Florida, John C. Pace Library (1966).
Port Charlotte: Charlotte County Library System (1973).
St. Petersburg:
  St. Petersburg Public Library (1965).
  Stetson University College of Law, Charles A. Dana Library (1975).
Sarasota: Selby Public Library (1970).
Tallahassee:
  Florida Agricultural and Mechanical University, Coleman Learning Resources Center (1936).
  Florida State University, College of Law Library (1978).
  Florida State University, Robert M. Strozier Library (1941). (1941).
  Florida Supreme Court Library (1974).
  State Library of Florida (1929).
Tampa:
  Tampa-Hillsborough County Public Library (1965).
  University of South Florida Library (1962).
  University of Tampa, Merl Kelce Library (1953).
Winter Park: Rollins College, Mills Memorial Library (1909).

GEORGIA

Albany: Albany-Dougherty Public Library (1964).
Americus: Georgia Southwestern College, James Earl Carter Library (1966).
Athens:
  University of Georgia Libraries (1907)–REGIONAL.
  University of Georgia, School of Law Library (1979).
Atlanta:
  Atlanta Public Library (1880).
  Atlanta University Center, Robert W. Woodruff Library (1962).
  Emory University, Woodruff Library (1928).
  Emory University, School of Law Library (1968).
  Georgia Institute of Technology, Price Gilbert Memorial Library (1963).
  Georgia State Library (unknown).
  Georgia State University, College of Law Library (1983).
  Georgia State University, William Russell Pullen Library (1970).
  U.S. Court of Appeals, 5th Circuit Library (1980).
Augusta: Augusta College, Reese Library (1962).
Brunswick: Brunswick-Glynn County Regional Library (1965).
Carrollton: West Georgia College, Irvine Sullivan Ingram Library (1962).
Columbus: Columbus College, Simon Schwob Memorial Library (1975).
Dahlonega: North Georgia College, Stewart Library (1939).
Dalton: Dalton Junior College Library (1978).
Decatur: DeKalb Community College, South Campus Learning Resources Center (1973).
Macon:
  Mercer University, Stetson Memorial Library (1964).
  Mercer University, Walter F. George School of Law Library (1978).
Marietta: Kennesaw College Memorial Library (1968).
Milledgeville: Georgia College at Milledgeville, Ina Dillard Russell Library (1950).
Mount Berry: Berry College Memorial Library (1970).
Savannah: Chatham-Effingham Liberty Regional Library (1857).
Statesboro: Georgia Southern College Library (1939).
Valdosta: Valdosta State College Library (1956).

GUAM

Agana: Nieves M. Flores Memorial Library (1962).
Mangilao: University of Guam, Robert F. Kennedy Memorial Library (1978).

HAWAII

Hilo: University of Hawaii at Hilo Library (1962).
Honolulu:
  Hawaii Medical Library, Inc. (1968).
  Hawaii State Library (1929).
  Municipal Reference & Records Center (1965).
  Supreme Court Law Library (1973).
  University of Hawaii Library (1907)–REGIONAL.
  University of Hawaii, School of Law Library (1978).
Laie: Brigham Young University, Hawaii Campus, Joseph F. Smith Library (1964).
Lihue: Kauai Regional Library (1967).
Pearl City: Leeward Community College Library (1967).
Wailuku: Maui Public Library (1962).

IDAHO

Boise:
  Boise Public Library and Information Center (1929).
  Boise State University Library (1966).
  Idaho State Law Library (unknown).
  Idaho State Library (1971).
Caldwell: College of Idaho, Terteling Library (1930).
Moscow:
  University of Idaho, College of Law Library (1978).
  University of Idaho Library (1907)–REGIONAL.
Pocatello: Idaho State University Library (1908).
Rexburg: Ricks College, David O. McKay Library (1946).
Twin Falls: College of Southern Idaho Library (1970).

ILLINOIS

Bloomington: Illinois Wesleyan University Libraries (1964).
Carbondale:
  Southern Illinois University, Morris Library (1932).
  Southern Illinois University, School of Law Library (1978).
Carlinville: Blackburn College, Lumpkin Library (1954).
Carterville: Shawnee Library System (1971).
Champaign: University of Illinois, Law Library (1965).
Charleston: Eastern Illinois University, Booth Library (1962).
Chicago:
  Chicago Public Library (1876).
  Chicago State University, Paul and Emily Douglas Library (1954).
  DePaul University, Law Library (1979).
  Field Museum of Natural History Library (1963).
  Illinois Institute of Technology, Chicago-Kent College of Law Library (1978).
  Illinois Institute of Technology, Kemper Library (1982).
  John Crerar Library (1909).
  John Marshall Law School Library (1981).
  Loyola University of Chicago, E. M. Cudahy Memorial Library (1966).
  Loyola University, School of Law Library (1979).
  Northeastern Illinois University Library (1961).
  Northwestern University, School of Law Library (1978).
  University of Chicago, Law Library (1964).
  University of Chicago Library (1897).
  University of Illinois at Chicago Circle Library (1957).
  William J. Campbell Library of the U.S. Courts (1979).

Decatur: Decatur Public Library (1954).
De Kalb:
Northern Illinois University, College of Law Library (1978).
Northern Illinois University, Founders' Memorial Library (1960).
Des Plaines: Oakton Community College, Learning Resource Center (1976).
Edwardsville: Southern Illinois University, Lovejoy Memorial Library (1959).
Elsah: Principia College, Marshall Brooks Library (1957).
Evanston: Northwestern University Library (1876).
Freeport: Freeport Public Library (1905).
Galesburg: Galesburg Public Library (1896).
Jacksonville: MacMurray College, Henry Pfeiffer Library (1957).
Kankakee: Olivet Nazarene College, Benner Library and Learning Resource Center (1946).
Lake Forest: Lake Forest College, Donnelley Library (1962).
Lebanon: McKendree College, Holman Library (1968).
Lisle: Illinois Benedictine College, Theodore F. Lownik Library (1911).
Macomb: Western Illinois University Libraries (1962).
Moline: Black Hawk College, Learning Resources Center (1970).
Monmouth: Monmouth College, Hewes Library (1860).
Mt. Carmel: Wabash Valley College, Bauer Media Center (1975).
Mt. Prospect: Mt. Prospect Public Library (1977).
Normal: Illinois State University, Milner Library (1877).
Oak Park: Oak Park Public Library (1963).
Oglesby: Illinois Valley Community College, Jacobs Memorial Library (1976).
Palos Hills: Moraine Valley Community College Library (1972).
Park Forest South: Governors' State University Library (1974).
Peoria:
Bradley University, Cullom-Davis Library (1963).
Peoria Public Library (1883).
River Forest: Rosary College, Rebecca Crown Library (1966).
Rockford: Rockford Public Library (1895).
Romeoville: Lewis University Library (1952).
Springfield: Illinois State Library (unknown)–REGIONAL.
Streamwood: Poplar Creek Public Library District (1980).
Urbana: University of Illinois Library (1907).
Wheaton: Wheaton College Library (1964).
Woodstock: Woodstock Public Library (1963).

INDIANA

Anderson: Anderson College, Charles E. Wilson Library (1959).
Bloomington:
Indiana University Library (1881).
Indiana University, School of Law Library (1978).
Crawfordsville: Wabash College, Lilly Library (1906).
Evansville:
Evansville and Vanderburgh County Public Library (1928).
Indiana State University, Evansville Campus Library (1969).
Fort Wayne:
Indiana-Purdue Universities, Helmke Library (1965).
Allen County Public Library (1896).
Franklin: Franklin College Library (1976).
Gary:
Gary Public Library (1943).
Indiana University, Northwest Campus Library (1966).
Greencastle: De Pauw University, Roy O. West Library (1879).
Hammond: Hammond Public Library (1964).
Hanover: Hanover College, Duggan Library (1892).
Huntington: Huntington College, Loew Alumni Library (1964).
Indianapolis:
Butler University, Irwin Library (1965).
Indianapolis-Marion County Public Library (1906).
Indiana State Library (unknown)–REGIONAL.
Indiana Supreme Court, Law Library (1975).
Indiana University, School of Law Library (1967).
Indiana University-Purdue University Library (1979).
Kokomo: Indiana University at Kokomo, Learning Resource Center (1969).
Lafayette: Purdue University Libraries and Audio-Visual Center (1907).
Muncie:
Ball State University Library (1959).
Muncie Public Library (1906).
New Albany: Indiana University, Southeastern Campus Library (1965).
Notre Dame: University of Notre Dame, Memorial Library (1883).
Rensselaer: St. Joseph's College Library (1964).
Richmond:
Earlham College, Lilly Library (1964).
Morrison-Reeves Library (1906).
South Bend: Indiana University at South Bend Library (1965).
Terre Haute: Indiana State University, Cunningham Memorial Library (1906).
Valparaiso:
Valparaiso University, Moellering Memorial Library (1930).
Valparaiso University, Law Library (1978).

IOWA

Ames: Iowa State University Library (1907).
Cedar Falls: University of Northern Iowa Library (1946).
Council Bluffs:
Free Public Library (1885).
Iowa Western Community College, Herbert Hoover Library (1972).
Davenport: Davenport Public Library (1973).
Des Moines:
Drake University, Cowles Library (1966).
Drake University, Law Library (1972).
Public Library of Des Moines (1888).
State Library of Iowa (unknown).
Dubuque:
Carnegie-Stout Public Library (unknown).
Loras College, Wahlert Memorial Library (1967).
Fayette: Upper Iowa University, Henderson-Wilder Library (1974).
Grinnell: Grinnell College Library (1874).
Iowa City:
University of Iowa College of Law, Law Library (1968).
University of Iowa Libraries (1884)–REGIONAL.
Lamoni: Graceland College, Frederick Madison Smith Library (1927).
Mason City: North Iowa Area Community College Library (1976).
Mount Vernon: Cornell College, Russell D. Cole Library (1896).
Orange City: Northwestern College, Ramaker Library (1970).
Sioux City: Sioux City Public Library (1894).

KANSAS

Atchison: Benedictine College Library, North Campus (1965).
Baldwin City: Baker University, Collins Library (1908).
Colby: Colby Community College, H. F. Davis Memorial Library (1968).
Emporia: Emporia State University, William Allen White Library (1909).
Fort Scott: Fort Scott Community College, Learning Resources Center Library (1979).
Hays: Fort Hays State University, Forsyth Library (1926).
Hutchinson: Hutchinson Public Library (1963).
Lawrence:
University of Kansas, Law Library (1971).
University of Kansas, Spencer Research Library (1869)–REGIONAL.
Manhattan: Kansas State University, Farrell Library (1907).
Pittsburg: Pittsburg State University, Leonard H. Axe Library (1952).
Salina: Kansas Wesleyan University, Memorial Library (1930).
Shawnee Mission: Johnson County Library (1979).
Topeka:

Kansas State Historical Society Library (1877).
Kansas State Library (unknown).
Kansas Supreme Court Law Library (1975).
Washburn University of Topeka, Law Library (1971).
Wichita: Wichita State University Ablah Library (1901).

KENTUCKY

Ashland: Boyd County Public Library (1946).
Barbourville: Union College, Abigail E. Weeks Memorial Library (1958).
Bowling Green: Western Kentucky University, Helm-Cravens Graduate Center and Library (1934).
Crestview Hills: Thomas More College Library (1970).
Danville: Centre College, Grace Doherty Library (1884).
Frankfort:
Kentucky Department of Libraries and Archives (1967).
Kentucky State Law Library (unknown).
Kentucky State University, Blazer Library (1972).
Highland Heights: Northern Kentucky University, W. Frank Steely Library (1973).
Hopkinsville: Hopkinsville Community College Library (1976).
Lexington:
University of Kentucky Law Library (1968).
University of Kentucky Libraries (1907)–REGIONAL.
Louisville:
Louisville Free Public Library (1904).
University of Louisville, Ekstrom Library (1925).
University of Louisville, Law Library (1975).
Morehead: Morehead State University, Camden-Carroll Library (1955).
Murray: Murray State University, Waterfield Library (1924).
Owensboro: Kentucky Wesleyan College Library Learning Center (1966).
Richmond: Eastern Kentucky University, John Grant Crabbe Library (1966).

LOUISIANA

Baton Rouge:
Louisiana State Library (1976).
Louisiana State University, Middleton Library (1907)–REGIONAL.
Louisiana State University, Paul M. Hebert Law Center Library (1929).
Louisiana State University Library (1907)–REGIONAL.
Southern University Law School Library (1979).
Southern University Library (1952).
Eunice: Louisiana State University at Eunice, LeDoux Library (1969).
Hammond: Southeastern Louisiana University, Sims Memorial Library (1966).
Lafayette: University of Southwestern Louisiana Library (1938).
Lake Charles: McNeese State University, Lether E. Frazar Memorial Library (1941).
Monroe: Northeast Louisiana University, Sandel Library (1963).
Natchitoches: Northwestern State University, Watson Memorial Library (1887).
New Orleans:
Law Library of Louisiana (unknown).
Loyola University Library (1942).
Loyola University, Law Library (1978).
New Orleans Public Library (1883).
Our Lady of Holy Cross College Library (1982).
Southern University in New Orleans Library (1962).
Tulane University, Howard-Tilton Memorial Library (1942).
Tulane University Law Library (1976).
University of New Orleans Earl K. Long Library (1963).
U.S. Court of Appeals, Fifth Circuit Library (1973).
Pineville: Louisiana College, Richard W. Norton Memorial Library (1969).
Ruston: Louisiana Technical University, Prescott Memorial Library (1896)–REGIONAL.
Shreveport:
Louisiana State University at Shreveport Library (1967).
Shreve Memorial Library (1923).
Thibodaux: Nicholls State University, Ellender Memorial Library (1962).

MAINE

Augusta:
Maine Law and Legislative Reference Library (1973).
Maine State Library (unknown).
Bangor: Bangor Public Library (1884).
Brunswick: Bowdoin College Library (1884).
Castine: Maine Maritime Academy, Nutting Memorial Library (1969).
Lewiston: Bates College, George and Helen Ladd Library (1883).
Orono: University of Maine, Raymond H. Fogler Library (1907)–REGIONAL.
Portland:
Portland Public Library (1884).
University of Maine School of Law Library (1964).
Presque Isle: University of Maine at Presque Isle, Library/Learning Resources Center (1979).
Springvale: Nasson College Library (1961).
Waterville: Colby College, Miller Library (1884).

MARYLAND

Annapolis:
Maryland State Law Library (unknown).
U.S. Naval Academy, Nimitz Library (1895).
Baltimore:
Enoch Pratt Free Library (1887).
Johns Hopkins University, Milton S. Eisenhower Library (1882).
Morgan State College, Soper Library (1940).
University of Baltimore, University Library (1973).
University of Baltimore Law Library (1980).
University of Maryland School of Law, Marshall Law Library (1969).
U.S. Court of Appeals, 4th Circuit Library (1982).
Bel Air: Harford Community College Library (1967).
Beltsville: Department of Agriculture, National Agricultural Library (1895).
Bethesda: Department of Health and Human Services, National Library of Medicine (1978).
Catonsville: University of Maryland, Baltimore County, University Library (1971).
Chestertown: Washington College, Clifton M. Miller Library (1891).
College Park: University of Maryland, McKeldin Library (1925)–REGIONAL.
Cumberland: Allegany Community College Library (1974).
Frostburg: Frostburg State College Library (1967).
Patuxent River: U.S. Naval Air Station Library (1968).
Rockville: Montgomery County Department of Public Libraries (1951).
Salisbury: Salisbury State College, Blackwell Library (1965).
Towson:
Goucher College, Julia Rogers Library (1966).
Towson State University, Cook Library (1979).
Westminster: Western Maryland College, Hoover Library (1886).

MASSACHUSETTS

Amherst:
Amherst College Library (1884).
University of Massachusetts, Goodell Library (1907).
Boston:
Boston Athenaeum Library (unknown).

Boston Public Library (1859)–REGIONAL.
Boston University School of Law, Pappas Law Library (1979).
Northeastern University Dodge Library (1962).
State Library of Massachusetts (unknown).
Suffolk University, Law Library (1979).
Supreme Judicial Court, Social Law Library (1979).
U.S. Court of Appeals, First Circuit Library (1978).
Brookline: Public Library of Brookline (1925).
Cambridge:
Harvard College Library (1860).
Harvard Law School Library (1981).
Massachusetts Institute of Technology Libraries (1946).
Chestnut Hill: Boston College, Bapst Library (1963).
Chicopee: College of Our Lady of the Elms, Alumnae Library (1969).
Lowell: University of Lowell, Alumni-Lydon Library (1952).
Lynn: Lynn Public Library (1953).
Marlborough: Marlborough Public Library (1971).
Medford: Tufts University Library (1899).
Milton: Curry College, Levin Library (1972).
New Bedford: New Bedford Free Public Library (1858).
Newton Centre: Boston College Law School Library (1979).
North Dartmouth: Southeastern Massachusetts University Library (1965).
North Easton: Stonehill College, Cushing-Martin Library (1962).
Springfield:
Springfield City Library (1966).
Western New England College, Law Library (1978).
Waltham:
Brandeis University Library (1965).
Waltham Public Library (1943).
Wellesley: Wellesley College Library (1943).
Wenham: Gordon College, Winn Library (1963).
Williamstown: Williams College Library (unknown).
Worcester:
American Antiquarian Society Library (1814).
University of Massachusetts Medical Center, Lamar Soutter Library (1972).
Worcester Public Library (1859).

MICHIGAN

Albion: Albion College, Stockwell Memorial Library (1966).
Allendale: Grand Valley State College, Zumberge Library (1963).
Alma: Alma College Library (1963).
Ann Arbor:
University of Michigan, Harlan Hatcher Library (1884).
University of Michigan, Law Library (1978).
Benton Harbor: Benton Harbor Public Library (1907).
Bloomfield Hills: Cranbrook Institute of Science Library (1940).
Dearborn:
Henry Ford Centennial Library (1969).
Henry Ford Community College Library (1957).
Detroit:
Detroit College of Law Library (1979).
Detroit Public Library (1868)–REGIONAL.
Marygrove College Library (1965).
Mercy College of Detroit Library (1965).
University of Detroit Library (1884).
University of Detroit, School of Law Library (1978).
Wayne State University, G. Flint Purdy Library (1937).
Wayne State University, Arthur Neef Law Library (1971).
Dowagiac: Southwestern Michigan College, Matthews Library (1971).
East Lansing: Michigan State University Library (1907).
Farmington Hills: Oakland Community College, Martin L. King Learning Resources Center, (1968).
Flint:
Flint Public Library (1967).
University of Michigan-Flint Library (1959).
Grand Rapids:
Calvin College & Seminary Library (1967).
Grand Rapids Public Library (1876).
Houghton: Michigan Technological University Library (1876).
Jackson: Jackson District Library (1965).
Kalamazoo:
Kalamazoo Public Library (1907).
Western Michigan University, Dwight B. Waldo Library (1963).
Lansing:
Michigan State Library (unknown)–REGIONAL.
Thomas M. Cooley Law School Library (1978).
Livonia: Schoolcraft College Library (1962).
Madison Heights: Madison Heights Public Library (1982).
Marquette: Northern Michigan University, Olson Library (1963).
Monroe: Monroe County Library System (1974).
Mt. Clemens: Macomb County Library (1968).
Mt. Pleasant: Central Michigan University Library (1958).
Muskegon: Hackley Public Library (1894).
Olivet: Olivet College Library (1974).
Petoskey: North Central Michigan College Library (1962).
Port Huron: Saint Clair County Library (1876).
Rochester: Oakland University, Kresge Library (1964).
Saginaw: Hoyt Public Library (1890).
Sault Ste. Marie: Lake Superior State College, Kenneth Shouldice Library (1982).
Traverse City: Northwestern Michigan College, Mark Osterlin Library (1964).
University Center: Delta College Learning Resources Center (1963).
Warren: Warren Public Library, Arthur J. Miller Branch (1973).
Wayne: Wayne Oakland Library Federation (1957).
Ypsilanti: Eastern Michigan University Library (1965).

MICRONESIA

Community College of Micronesia Library (1982).

MINNESOTA

Bemidji: Bemidji State University, A. C. Clark Library (1963).
Collegeville: St. John's University, Alcuin Library (1954).
Cottage Grove: Washington County Library-Park Grove (1983).
Duluth: Duluth Public Library (1909).
Edina: Southdale-Hennepin Area Library (1971)
Mankato: Mankato State University Library (1962).
Minneapolis:
Anoka County Library (1971).
Minneapolis Public Library (1893).
University of Minnesota, Law School Library (1978).
University of Minnesota, Wilson Library (1907)–REGIONAL.
Moorhead: Moorhead State University Library (1956).
Morris: University of Minnesota, Morris, Rodney Briggs Library (1963).
Northfield:
Carleton College Library (1930).
St. Olaf College, Rolvaag Memorial Library (1930).
St. Cloud: St. Cloud State University, Learning Resources Center (1962).
St. Paul:
Hamline University, School of Law Library (1978).
Minnesota Historical Society Library (1867).
Minnesota State Law Library (unknown).
St. Paul Public Library (1914).
University of Minnesota, St. Paul Campus Library (1974).
William Mitchell College of Law Library (1979).
St. Peter: Gustavus Adolphus College Library (1941).
Willmar: Crow River Regional Library (1958).
Winona: Winona State University, Maxwell Library (1969).

MISSISSIPPI

Cleveland: Delta State University, W. B. Roberts Library (1975).

Columbus: Mississippi State University for Women, John Clayton Fant Memorial Library (1929).
Hattiesburg: University of Southern Mississippi, Joseph A. Cook Memorial Library (1935).
Jackson:
Jackson State University, Henry Thomas Sampson Library (1968).
Millsaps College, Millsaps-Wilson Library (1963).
Mississippi College, School of Law Library (1977).
Mississippi Library Commission (1947).
Mississippi State Library (unknown).
Lorman: Alcorn State University Library (1970).
Mississippi State: Mississippi State University, Mitchell Memorial Library (1907).
University:
University of Mississippi Library (1833)–REGIONAL.
University of Mississippi, Law Library (1967).

MISSOURI

Cape Girardeau: Southeast Missouri State University, Kent Library (1916).
Columbia:
University of Missouri at Columbia Library (1862).
University of Missouri-Columbia, Law Library (1978).
Fayette: Central Methodist College, George M. Smiley Library (1962).
Fulton: Westminster College, Reeves Library (1875).
Jefferson City:
Lincoln University, Inman E. Page Library (1944).
Missouri State Library (1963).
Missouri Supreme Court Library (unknown).
Joplin: Missouri Southern State College Library (1966).
Kansas City:
Kansas City Public Library (1881).
Rockhurst College, Greenlease Library (1917).
University of Missouri at Kansas City, General Library (1938).
University of Missouri-Kansas City, Leon E. Bloch Law Library (1978).
Kirksville: Northeast Missouri State University, Pickler Memorial Library (1966).
Liberty: William Jewell College, Charles F. Curry Library (1900).
Maryville: Northwest Missouri State University, Wells Library (1982).
Rolla: University of Missouri-Rolla, Curtis Laws Wilson Library (1907).
St. Charles: Lindenwood Colleges, Margaret Leggat Butler Library (1973).
St. Joseph: St. Joseph Public Library (1891).
St. Louis:
Maryville College Library (1976).
St. Louis County Library (1970).
St. Louis Public Library (1866).
St. Louis University Law Library (1967).
St. Louis University, Pius XII Memorial Library (1966).
University of Missouri at St. Louis, Thomas Jefferson Library (1966).
U.S. Court of Appeals, Eighth Circuit Library (1972).
Washington University, John M. Olin Library (1906).
Washington University Law Library (1978).
Springfield:
Drury College Walker Library (1874).
Southwest Missouri State University Library (1963).
Warrensburg: Central Missouri State University, Ward Edwards Library (1914).

MONTANA

Billings: Eastern Montana College Library (1924).
Bozeman: Montana State University Renne Library (1907).
Butte: Montana College of Mineral Science and Technology Library (1901).
Havre: Northern Montana College Library (1980).
Helena:
Carroll College Library (1974).
Montana Historical Society Library (unknown).
Montana State Library (1966).
State Law Library of Montana (1977).
Missoula: University of Montana Maurene & Mike Mansfield Library (1909)–REGIONAL.

NEBRASKA

Blair: Dana College, Dana-LIFE Library (1924).
Crete: Doane College, Perkins Library (1944).
Fremont: Midland Lutheran College Luther Library (1924).
Kearney: Kearney State College, Calvin T. Ryan Library (1962).
Lincoln:
Nebraska Library Commission (1972)–REGIONAL.
Nebraska State Library (unknown).
University of Nebraska-Lincoln, College of Law Library (1981).
University of Nebraska-Lincoln, D. L. Love Memorial Library (1907)–REGIONAL.
Omaha:
Creighton University, Alumni Memorial Library (1964).
Creighton University Law Library (1979).
Omaha Public Library, W. Dale Clark Library (1880).
University of Nebraska at Omaha, University Library (1939).
Scottsbluff: Scottsbluff Public Library (1925).
Wayne: Wayne State College, U.S. Conn Library (1970).

NEVADA

Carson City:
Nevada State Library (unknown).
Nevada Supreme Court Library (1973).
Las Vegas:
Clark County Library District (1974).
University of Nevada at Las Vegas, James Dickinson Library (1959).
Reno:
National Judicial College, Law Library (1979).
Nevada Historical Society Library (1974).
University of Nevada Library (1907)–REGIONAL.
Washoe County Library (1980).

NEW HAMPSHIRE

Concord:
Franklin Pierce Law Center Library (1973).
New Hampshire State Library (unknown).
Durham: University of New Hampshire Library (1907).
Hanover: Dartmouth College Library (1884).
Henniker: New England College Danforth Library (1966).
Manchester:
Manchester City Library (1884).
New Hampshire College, H. A. B. Shapiro Memorial Library (1976).
St. Anselm's College, Geisel Library (1963).
Nashua: Nashua Public Library (1971).

NEW JERSEY

Bayonne: Bayonne Free Public Library (1909).
Bloomfield: Bloomfield Public Library (1965).
Bridgeton: Cumberland County Library (1966).
Camden:
Rutgers University, Camden Library (1966).
Rutgers University, School of Law Library (1979).

Convent Station: College of St. Elizabeth, Mahoney Library (1938).
East Brunswick: East Brunswick Public Library (1977).
East Orange: East Orange Public Library (1966).
Elizabeth: Free Public Library of Elizabeth (1895).
Glassboro: Glassboro State College, Savitz Learning Resource Center (1963).
Hackensack: Johnson Free Public Library (1966).
Irvington: Free Public Library of Irvington (1966).
Jersey City:
- Jersey City Public Library (1879).
- Jersey City State College, Forrest A. Irwin Library (1963).

Lawrenceville: Rider College, Franklin F. Moore Library (1975).
Madison: Drew University, Rose Memorial Library (1939).
Mahwah: Ramapo College Library (1971).
Mount Holly: Burlington County Library (1966).
New Brunswick:
- New Brunswick Free Public Library (1908).
- Rutgers University Alexander Library (1907).

Newark:
- Newark Public Library (1906)-REGIONAL.
- Rutgers, The State University, John Cotton Dana Library (1966).
- Rutgers, The State University, Law School, Newark (1979).
- Seton Hall University Law Library (1979).

Passaic: Passaic Public Library (1964).
Pemberton: Burlington County College Library (1979).
Phillipsburg: Phillipsburg Free Public Library (1976).
Plainfield: Plainfield Public Library (1971).
Pomona: Stockton State College Library (1972).
Princeton: Princeton University Library (1884).
Randolph Township: County College of Morris Sherman H. Masten Learning Resource Center (1975).
Rutherford: Fairleigh Dickinson University, Messler Library (1953).
Shrewsbury: Monmouth County Library (1968).
South Orange: Seton Hall University, McLaughlin Library (1947).
Teaneck: Fairleigh Dickinson University, Teaneck/Hackensack Campus Library (1963).
Toms River: Ocean County College, Learning Resources Center (1966).
Trenton:
- New Jersey State Library (unknown).
- Trenton Free Public Library (1902).

Union: Kean College of New Jersey, Nancy Thompson Library (1973).
Upper Montclair: Montclair State College, Harry S. Sprague Library (1967).
Wayne: Wayne Public Library (1972).
West Long Beach: Monmouth College, Guggenheim Memorial Library (1963).
Woodbridge: Free Public Library of Woodbridge (1965).

NEW MEXICO

Albuquerque:
- University of New Mexico, Medical Center Library (1973).
- University of New Mexico, School of Law Library (1973).
- University of New Mexico, General Library (1896)-REGIONAL.

Hobbs: New Mexico Junior College, Pannell Library (1969).
Las Cruces: New Mexico State University Library (1907).
Las Vegas: New Mexico Highlands University, Donnelly Library (1913).
Portales: Eastern New Mexico University, Golden Library (1962).
Santa Fe:
- New Mexico State Library (1960)-REGIONAL.
- New Mexico Supreme Court Law Library (unknown).

Silver City: Western New Mexico University, Miller Library (1972).

NEW YORK

Albany:
- Albany Law School Library (1979).
- New York State Library (unknown)-REGIONAL.
- State University of New York at Albany, University Library (1964).

Auburn: Seymour Library (1972).
Bayside: Queensborough Community College Library (1972).
Binghamton: State University of New York at Binghamton, Glenn G. Bartle Library (1962).
Brockport: State University of New York at Brockport, Drake Memorial Library (1967).
Bronx:
- Fordham University Library (1937).
- Herbert H. Lehman College Library (1967).
- New York Public Library, Mott Haven Branch (1973).
- State University of New York, Maritime College, Stephen B. Luce Library (1947).

Brooklyn:
- Brooklyn College Library (1936).
- Brooklyn Law School Library (1974).
- Brooklyn Public Library (1908).
- Polytechnic Institute of New York, Spicer Library (1963).
- Pratt Institute Library (1891).
- State University of New York, Downstate Medical Center Library (1958).

Buffalo:
- Buffalo and Erie County Public Library (1895).
- State University of New York at Buffalo, Charles B. Sears Law Library (1978).
- State University of New York at Buffalo, Lockwood Memorial Library (1963).

Canton: St. Lawrence University, Owen D. Young Library (1920).
Cheektowaga: Cheektowaga Public Library, Reinstein Memorial Branch (1978).
Corning: Corning Community College, Arthur A. Houghton, Jr., Library (1963).
Cortland: State University of New York at Cortland, Memorial Library (1964).
Delhi: State University Agricultural and Technical College Library (1970).
Douglaston: Cathedral College Library (1971).
East Islip: East Islip Public Library (1973).
Elmira: Elmira College, Gannett Tripp Learning Center (1956).
Farmingdale: State University of New York at Farmingdale Library (1917).
Flushing: Queens College, Paul Klapper Library (1939).
Garden City: Adelphi University, Swirbul Library (1966).
Geneseo: State University of New York at Geneseo, Milne Library (1967).
Greenvale: Long Island University, B. Davis Schwartz Memorial Library (1964).
Hamilton: Colgate University, Everett Needham Case Library (1902).
Hempstead:
- Hofstra University Library (1964).
- Hofstra University, School of Law Library (1979).

Ithaca:
- Cornell University Library (1907).
- Cornell Law Library (1978).
- New York State College of Agriculture and Human Economics, Albert R. Mann Library (1943).

Jamaica:
- Queens Borough Public Library (1926).
- St. John's University Library (1956).
- St. John's University, School of Law Library (1978).

Kings Point: U.S. Merchant Marine Academy Library (1962).
Long Island City: Fiorello H. LaGuardia Community College Library (1981).
Mount Vernon: Mount Vernon Public Library (1962).
New Paltz: State University College at New Paltz, Sojourner Truth Library (1965).
New York City:
- Cardoza Law School Library (1979).
- City University of New York, City College Library (1884).

College of Insurance Library (1965).
Columbia University Libraries (1882).
Columbia University, School of Law Library (1981).
Cooper Union for the Advancement of Science and Arts Library (1930).
Medical Library Center of New York (1976).
New York Law Institute Library (1909).
New York Law School Library (1979).
New York Public Library, Astor Branch (1907).
New York Public Library, Lenox Branch (1884).
New York University Law Library (1902).
New York University, Elmer Holmes Bobst Library (1967).
U.S. Court of Appeals, Second Circuit Library (1976).
Yeshiva University, Pollack Library (1979).

Newburgh: Newburgh Free Library (1909).
Niagara Falls: Niagara Falls Public Library (1976).
Oakdale: Dowling College Library (1965).
Oneonta: State University College at Oneonta, James M. Milne Library (1966).
Oswego: State University College at Oswego, Penfield Library (1966).
Plattsburgh: State University College at Plattsburgh, Benjamin F. Feinberg Library (1967).
Potsdam:
Clarkson College of Technology, Harriet Call Burnap Memorial Library (1938).
State University College at Potsdam, Frederick W. Crumb Memorial Library (1964).

Poughkeepsie: Vassar College Library (1943).
Purchase: State University of New York, College at Purchase Library (1969).
Rochester:
Rochester Public Library (1963).
University of Rochester Rush Rhees Library (1880).

St. Bonaventure: St. Bonaventure University, Friedsam Memorial Library (1938).
Saratoga Springs: Skidmore College Library (1964).
Schenectady: Union College, Schaffer Library (1901).
Southampton: Southampton College Library (1973).
Staten Island: Wagner College, Horrmann Library (1953).
Stony Brook: State University of New York at Stony Brook, Main Library (1963).
Syracuse:
Onondaga County Public Library (1978).
Syracuse University Library (1878).
Syracuse University, William C. Ruger Law Library (1978).

Troy: Troy Public Library (1869).
Uniondale: Nassau Library System (1965).
Utica:
Utica Public Library (1885).
SUNY College of Technology Library (1977).

West Point: U.S. Military Academy Cadet Library (unknown).
White Plains: Pace University, Law School Library (1978).
Yonkers:
Sarah Lawrence College Library (1969).
Yonkers Public Library, Getty Square Branch (1910).

Yorktown Heights: Mercy College Library (1976).

NORTH CAROLINA

Asheville: University of North Carolina, D. Hiden Ramsey Library (1965).
Boiling Springs: Gardner-Webb College, Dover Memorial Library (1974).
Boone: Appalachian State University Library (1963).
Buies Creek: Campbell College, Carrie Rich Memorial Library (1965).
Chapel Hill:
University of North Carolina at Chapel Hill, Wilson Library (1884)-REGIONAL.
University of North Carolina Law Library (1978).

Charlotte:
Public Library of Charlotte and Mecklenburg County (1964).
Queens College, Everett Library (1927).
University of North Carolina at Charlotte, Atkins Library (1964).

Cullowhee: Western Carolina University, Hunter Library (1953).
Davidson: Davidson College Library (1893).
Durham:
Duke University, School of Law Library (1978).
Duke University, William R. Perkins Library (1890).
North Carolina Central University, Law Library (1979).
North Carolina Central University, James E. Shepard Memorial Library (1973).

Elon College: Iris Holt McEwen Library (1971).
Fayetteville: Fayetteville State University, Charles W. Chesnutt Library (1971).
Greensboro:
North Carolina Agricultural and Technical State University, F. D. Bluford Library (1937).
University of North Carolina at Greensboro, Walter Clinton Jackson Library (1963).

Greenville: East Carolina University, J. Y. Joyner Library (1951).
Laurinburg: St. Andrews Presbyterian College, DeTamble Library (1969).
Lexington: Davidson County Public Library (1971).
Mount Olive: Mount Olive College, Moye Library (1971).
Murfreesboro: Chowan College, Whitaker Library (1963).
Pembroke: Pembroke State University, Mary H. Livermore Library (1956).
Raleigh:
Department of Cultural Resources, Division of State Library (unknown).
North Carolina State University, D. H. Hill Library (1923).
North Carolina Supreme Court Library (1972).
Wake County Public Library (1969).

Rocky Mount: North Carolina Wesleyan College Library (1969).
Salisbury: Catawba College Library (1925).
Wilmington: University of North Carolina at Wilmington, William M. Randall Library (1965).
Wilson: Atlantic Christian College, Hackney Library (1930).
Winston-Salem:
Forsyth County Public Library (1954).
Wake Forest University, Z. Smith Reynolds Library (1902).

NORTH DAKOTA

Bismarck:
North Dakota State Library (1971).
North Dakota Supreme Court Law Library (unknown).
State Historical Society of North Dakota Library (1907).
Veterans' Memorial Public Library (1967).

Dickinson: Dickinson State College, Stoxen Library (1968).
Fargo:
Fargo Public Library (1964).
North Dakota State University Library (1907)-REGIONAL, in cooperation with University of North Dakota, Chester Fritz Library.

Grand Forks: University of North Dakota, Chester Fritz Library (1890).
Minot: Minot State College, Memorial Library (1925).
Valley City: Valley City State College Library (1913).

OHIO

Ada: Ohio Northern University, J. P. Taggart Law Library (1965).
Akron:
Akron-Summit Public Library (1952).
University of Akron, Bierce Library (1963).
University of Akron, C. Blake McDowell Law Center, School of Law Library (1978).

Alliance: Mount Union College Library (1888).
Ashland: Ashland College Library (1938).

Athens: Ohio University Library (1886).
Batavia: University of Cincinnati at Batavia, Clermont General and Technical College Library (1973).
Bluffton: Bluffton College, Musselman Library (1951).
Bowling Green: Bowling Green State University Library (1933).
Canton: Malone College, Everett L. Cattell Library (1970).
Chardon: Geauga County Public Library (1971).
Cincinnati:
Public Library of Cincinnati and Hamilton County (1884).
University of Cincinnati, Central Library (1929).
University of Cincinnati, College of Law, Marx Law Library (1978).
Cleveland:
Case Western Reserve University, Freiberger Library (1913).
Case Western Reserve University, School of Law Library (1979).
Cleveland Heights-University Heights Public Library (1970).
Cleveland Public Library (1886).
Cleveland State University, Cleveland-Marshall College of Law, Joseph W. Bartunek III Law Library (1978).
Cleveland State University Library (1966).
John Carroll University, Grasselli Library (1963).
Municipal Reference Library (1970).
Columbus:
Capital University Law School Library (1980).
Capital University Library (1968).
Ohio State University Libraries (1907).
Ohio Supreme Court Law Library (1973).
Public Library of Columbus and Franklin County (1885).
State Library of Ohio (unknown)–REGIONAL.
Dayton:
Dayton and Montgomery County Public Library (1909).
University of Dayton, Roesch Library (1969).
Wright State University Library (1965).
Delaware: Ohio Wesleyan University, L. A. Beeghly Library (1845).
Elyria: Elyria Public Library (1966).
Findlay: Findlay College, Shafer Library (1969).
Gambier: Kenyon College Library (1873).
Granville: Denison University Libraries, William H. Doane Library (1884).
Hiram: Hiram College, Teachout-Price Memorial Library (1874).
Kent: Kent State University Libraries (1962).
Marietta: Marietta College, Dawes Memorial Library (1884).
Marion: Marion Public Library (1979).
Middletown: Miami University-Middletown, Gardner-Harvey Library (1970).
New Concord: Muskingum College Library (1966).
Oberlin: Oberlin College Library (1858).
Oxford: Miami University at Oxford, King Library (1909).
Portsmouth: Portsmouth Public Library (unknown).
Rio Grande: Rio Grande College and Community College, Jeanette Albiez Davis Library (1966).
Springfield: Warder Public Library (1884).
Steubenville:
Public Library of Steubenville and Jefferson County (1950).
College of Steubenville, Starvaggi Memorial Library (1971).
Tiffin: Heidelberg College, Beeghly Library (1964).
Toledo:
Toledo-Lucas County Public Library (1884).
University of Toledo, College of Law Library (1981).
University of Toledo Library (1963).
Westerville: Otterbein College Courtright Memorial Library (1967).
Wooster: College of Wooster, Andrews Library (1966).
Youngstown:
Public Library of Youngstown and Mahoning County (1923).
Youngstown State University, William F. Maag Library (1971).

OKLAHOMA

Ada: East Central Oklahoma State University, Linscheid Library (1914).
Alva: Northwestern Oklahoma State University Library (1907).
Bartlesville: U.S. Department of Energy, Bartlesville Energy Research Center Library (1962).
Bethany: Bethany Nazarene College, R. T. Williams Library (1971).
Durant: Southeastern Oklahoma State University Library (1929).
Edmond: Central State University Library (1934).
Enid: Public Library of Enid and Garfield County (1908).
Langston: Langston University, G. Lamar Harrison Library (1941).
Muskogee: Muskogee Public Library (1971).
Norman:
University of Oklahoma Libraries, Bizzell Memorial Library (1893).
University of Oklahoma, Law Library (1978).
Oklahoma City:
Metropolitan Library System (1974).
Oklahoma City University Library (1963).
Oklahoma Department of Libraries (1893)–REGIONAL.
Shawnee: Oklahoma Baptist University Library (1933).
Stillwater: Oklahoma State University Library (1907)–REGIONAL.
Tahlequah: Northeastern Oklahoma State University, John Vaughan Library (1923).
Tulsa:
Tulsa City-County Library System (1963).
University of Tulsa College of Law Library (1979).
University of Tulsa, McFarlin Library (1929).
Weatherford: Southwestern Oklahoma State University, Al Harris Library (1958).

OREGON

Ashland: Southern Oregon State College Library (1953).
Corvallis: Oregon State University Library (1907).
Eugene:
University of Oregon Law Library (1979).
University of Oregon Library (1883).
Forest Grove: Pacific University, Harvey W. Scott Library (1897).
Klamath Falls: Oregon Institute of Technology, Learning and Resources Center (1982).
La Grande: Eastern Oregon College, Walter M. Pierce Library (1954).
McMinnville: Linfield College, Northup Library (1965).
Monmouth: Western Oregon State College Library (1967).
Portland:
Lewis and Clark College, Aubrey R. Watzek Library (1967).
Library Association of Portland (1884).
Northwestern School of Law, Paul L. Boley Law Library (1979).
Portland State University Library (1963)–REGIONAL.
Reed College Library (1912).
U.S. Department of Energy, Bonneville Power Administration Library (1962).
Salem:
Oregon State Library (unknown).
Oregon Supreme Court Library (1974).
Willamette University, College of Law Library (1979).
Willamette University, Main Library (1969).

PENNSYLVANIA

Allentown: Muhlenberg College, Haas Library (1939).
Altoona: Altoona Area Public Library (1969).
Bethel Park: Bethel Park Public Library (1980).
Bethlehem: Lehigh University Libraries, Linderman Library (1876).
Blue Bell: Montgomery County Community College, Learning Resources Center (1975).
Bradford: University of Pittsburgh at Bradford (1979).
Carlisle:
Dickinson College, Boyd Lee Spahr Library (1947).
Dickinson School of Law, Sheeley-Lee Law Library (1978).
Cheyney: Cheyney State College, Leslie Pinckney Hill Library (1967).
Collegeville: Ursinus College, Myrin Library (1963).

Coraopolis: Robert Morris College Library (1978).
Doylestown: Bucks County Free Library (1970).
East Stroudsburg: East Stroudsburg State College, Kemp Library (1966).
Erie: Erie County Library System (1897).
Greenville: Thiel College, Langenheim Memorial Library (1963).
Harrisburg: State Library of Pennsylvania (unknown)–REGIONAL.
Haverford: Haverford College, Magill Library (1897).
Hazleton: Hazleton Area Public Library (1964).
Indiana: Indiana University of Pennsylvania, Rhodes R. Stabley Library (1962).
Johnstown: Cambria County Library System (1965).
Lancaster: Franklin and Marshall College, Fackenthal Library (1895).
Lewisburg: Bucknell University, Ellen Clarke Bertrand Library (1963).
Mansfield: Mansfield State College Library (1968).
Meadville: Allegheny College, Lawrence Lee Pelletier Library (1907).
Millersville: Millersville State College, Helen A. Ganser Library (1966).
Monessen: Monessen Public Library (1969).
New Castle: New Castle Public Library (1963).
Newtown: Bucks County Community College Library (1968).
Norristown: Montgomery County-Norristown Public Library (1969).
Philadelphia:
- Drexel University Library (1963).
- Free Library of Philadelphia (1897).
- St. Joseph's University, Drexel Library (1974).
- Temple University, Paley Library (1947).
- Temple University Law Library (1979).
- Thomas Jefferson University, Scott Memorial Library (1978).
- U.S. Court of Appeals, Third Circuit Library (1973).
- University of Pennsylvania, Biddle Law Library (1974).
- University of Pennsylvania Library (1886).

Pittsburgh:
- Allegheny County Law Library (1977).
- Carnegie Library of Pittsburgh, Allegheny Regional Branch (1924).
- Carnegie Library of Pittsburgh (1895).
- Duquesne University Law Library (1978).
- La Roche College, John J. Wright Library (1974).
- University of Pittsburgh, Hillman Library (1910).
- University of Pittsburgh Law Library (1979).
- U.S. Department of Interior, Bureau of Mines Library (1962).

Pottsville: Pottsville Free Public Library (1967).
Reading: Reading Public Library (1901).
Scranton: Scranton Public Library (1895).
Shippensburg: Shippensburg State College, Ezra Lehman Memorial Library (1973).
Slippery Rock: Slippery Rock State College, Bailey Library (1965).
Swarthmore: Swarthmore College Library (1923).
University Park: Pennsylvania State University Libraries (1907).
Villanova: Villanova University Law School, Pulling Law Library (1964).
Warren: Warren Library Association, Warren Public Library (1885).
Washington: Washington and Jefferson College, U. Grant Miller Library (1884).
Waynesburg: Waynesburg College Library (1964).
West Chester: West Chester State College, Francis Harvey Green Library (1967).
Wilkes-Barre: King's College, D. Leonard Corgan Library (1949).
Williamsport: Lycoming College Library (1970).
York: York College of Pennsylvania, Schmidt Library (1963).
Youngwood: Westmoreland County Community College, Learning Resources Center (1972).

PUERTO RICO

Mayaguez: University of Puerto Rico, Mayaguez Campus Library (1928).
Ponce:
- Catholic University of Puerto Rico, Encarnacion Valdes Library (1966).
- Catholic University of Puerto Rico, School of Law Library (1978).

Rio Piedras: University of Puerto Rico, General Library (1928).

RHODE ISLAND

Kingston: University of Rhode Island Library (1907).
Newport: U.S. Naval War College Library (1963).
Providence:
- Brown University, John D. Rockefeller, Jr. Library (unknown).
- Providence College, Phillips Memorial Library (1969).
- Providence Public Library (1884).
- Rhode Island College, James P. Adams Library (1965).
- Rhode Island State Law Library (1979).
- Rhode Island State Library (before 1895).

Warwick: Warwick Public Library (1966).
Westerly: Westerly Public Library (1909).
Woonsocket: Woonsocket Harris Public Library (1977).

SOUTH CAROLINA

Charleston:
- Baptist College at Charleston, L. Mendel Rivers Library (1967).
- The Citadel, Daniel Library (1962).
- College of Charleston, Robert Scott Small Library (1869).

Clemson: Clemson University Library (1893).
Columbia:
- Benedict College, Payton Learning Resources Center (1969).
- South Carolina State Library (before 1895).
- University of South Carolina, Thomas Cooper Library (1884).

Conway: University of South Carolina, Coastal Carolina College, Kimbel Library (1974).
Due West: Erskine College, McCain Library (1968).
Florence:
- Florence County Library (1967).
- Francis Marion College, James A. Rogers Library (1970).

Greenville:
- Furman University Library (1962).
- Greenville County Library (1966).

Greenwood: Lander College, Larry A. Jackson Library (1967).
Orangeburg: South Carolina State College, Miller F. Whittaker Library (1953).
Rock Hill: Winthrop College, Dacus Library (1896).
Spartanburg: Spartanburg County Public Library (1967).

SOUTH DAKOTA

Aberdeen: Northern State College Library (1963).
Brookings: South Dakota State University, H. M. Briggs Library (1889).
Pierre:
- South Dakota State Library (1973).
- South Dakota Supreme Court Library (1978).

Rapid City:
- Rapid City Public Library (1963).
- South Dakota School of Mines and Technology, Devereaux Library (1963).

Sioux Falls:
- Augustana College, Mikkelsen Library and Learning Resource Center (1969).
- Sioux Falls Public Library (1903).

Spearfish: Black Hills State College Library Learning Center (1942).
Vermillion: University of South Dakota, I. D. Weeks Library (1889).
Yankton: Yankton College, James Lloyd Library (1904).

TENNESSEE

Bristol: King College, E. W. King Library (1970).
Chattanooga:
Chattanooga-Hamilton County Bicentennial Library (1908).
U.S. Tennessee Valley Authority Technical Library (1976).
Clarksville: Austin Peay State University, Felix G. Woodward Library (1945).
Cleveland: Cleveland State Community College Library (1973).
Columbia: Columbia State Community College, John W. Finney Memorial Library (1973).
Cookeville: Tennessee Technological University, Jere Whitson Memorial Library (1969).
Jackson: Lambuth College, Luther L. Gobbel Library (1967).
Jefferson City: Carson-Newman College Library (1964).
Johnson City: East Tennessee State University, Sherrod Library (1942).
Knoxville:
Public Libraries Knoxville-Knox County, Lawson McGhee Library (1973).
University of Tennessee at Knoxville, James D. Hoskins Library (1907).
University of Tennessee Law Library (1971).
Martin: University of Tennessee at Martin, Paul Meek Library (1957).
Memphis:
Memphis-Shelby County Public Library and Information Center (1896).
Memphis State University, Cecil C. Humphreys School of Law Library (1979).
Memphis State University, John W. Brister Library (1966).
Murfreesboro: Middle Tennessee State University, Todd Library (1912).
Nashville:
Fisk University Library (1965).
Public Library of Nashville and Davidson County (1884).
Tennessee State Law Library (1976).
Tennessee State Library and Archives (unknown).
Tennessee State University, Brown-Daniel Library (1972).
Vanderbilt University Law Library (1976).
Vanderbilt University Library (1884).
Sewanee: University of the South, Jesse Ball duPont Library (1873).

TEXAS

Abilene:
Abilene Christian University, Margaret and Herman Brown Library (1978).
Hardin-Simmons University, Rupert and Pauline Richardson Library (1940).
Arlington:
Arlington Public Library (1970).
University of Texas at Arlington Library (1963).
Austin:
Texas State Law Library (1972).
Texas State Library (unknown)–REGIONAL.
University of Texas at Austin, Perry-Castaneda Library (1884).
University of Texas at Austin, Lyndon B. Johnson School of Public Affairs Library (1966).
University of Texas at Austin, Tarlton Law Library (1965).
Baytown: Lee College Library (1970).
Beaumont: Lamar University, Mary and John Gray Library (1957).
Brownwood: Howard Payne University, Walker Memorial Library (1964).
Canyon: West Texas State University, Cornett Library (1928).
College Station: Texas Agricultural and Mechanical University Library (1907).
Commerce: East Texas State University Library (1937).
Corpus Christi: Corpus Christi State University Library (1976).
Corsicana: Navarro College, Gaston T. Gooch Library (1965).
Dallas:
Bishop College, Zale Library (1966).
Dallas Baptist College, Vance Memorial Library (1967).
Dallas Public Library (1900).
Southern Methodist University, Fondren Library (1925).
University of Texas Health Science Center–Dallas Library (1975).
Denton: North Texas State University Library (1948).
Edinburg: Pan American University Library (1959).
El Paso:
El Paso Public Library (1906).
University of Texas at El Paso Library (1966).
Fort Worth:
Fort Worth Public Library (1905).
Texas Christian University, Mary Couts Burnett Library (1916).
Galveston: Rosenberg Library (1909).
Houston:
Houston Public Library (1884).
North Harris County College, Learning Resource Center (1974).
Rice University, Fondren Library (1967).
South Texas College of Law Library (1981).
Texas Southern University, Thurgood Marshall School of Law Library (1982).
University of Houston at Clear Lake City Library (1980).
University of Houston Library (1957).
University of Houston, School of Law Library (1979).
Huntsville: Sam Houston State University Library (1949).
Irving: Irving Public Library System (1974).
Kingsville: Texas Arts and Industries University, Jernigan Library (1944).
Laredo: Laredo Junior College, Harold R. Yeary Library (1970).
Longview: Nicholson Memorial Public Library (1961).
Lubbock:
Texas Tech University Library (1935)–REGIONAL.
Texas Tech University, School of Law Library (1978).
Marshall: Wiley College, Thomas Winston Cole, Sr. Library (1962).
Nacogdoches: Stephen F. Austin State University, Steen Library (1965).
Plainview: Wayland Baptist University, Van Howeling Memorial Library (1963).
Richardson: University of Texas at Dallas Library (1972).
San Angelo: Angelo State University, Porter Henderson Library (1964).
San Antonio:
San Antonio College Library (1972).
San Antonio Public Library, (1899).
St. Mary's University, Academic Library (1964).
St. Mary's University, Law Library (1982).
Trinity University Library (1964).
University of Texas at San Antonio Library (1973).
San Marcos: Southwest Texas State University Library (1955).
Seguin: Texas Lutheran College, Blumberg Memorial Library (1970).
Sherman: Austin College, Arthur Hopkins Library (1963).
Texarkana: Texarkana Community College, Palmer Memorial Library (1963).
Victoria: Victoria College/University of Houston, Victoria Campus Library (1973).
Waco:
Baylor University, Law Library (1982).
Baylor University, Moody Memorial Library (1905).
Wichita Falls: Midwestern University, Moffett Library (1963).

UTAH

Cedar City: Southern Utah State College Library (1964).
Ephraim: Snow College, Lucy A. Phillips Library (1963).
Logan: Utah State University, Merrill Library and Learning Resources Center (1907)–REGIONAL.
Ogden: Weber State College, Stewart Library (1962).
Provo:
Brigham Young University, Harold B. Lee Library (1908).
Brigham Young University, J. Reuben Clark Law Library (1972).
Salt Lake City:

University of Utah, Eccles Health Sciences Library (1970).
University of Utah, Law Library (1966).
University of Utah, Marriott Library (1893).
Utah State Library (unknown).
Utah State Supreme Court, Law Library (1975).

VERMONT

Burlington: University of Vermont, Bailey/Howe Library (1907).
Castleton: Castleton State College, Calvin Coolidge Library (1969).
Johnson: Johnson State College, John Dewey Library (1955).
Lyndonville: Lyndon State College, Samuel Reed Hall Library (1969).
Middlebury: Middlebury College, Egbert Starr Library (1884).
Montpelier: Vermont Department of Libraries (before 1895).
Northfield: Norwich University Library (1908).
South Royalton: Vermont Law School Library (1978).

VIRGIN ISLANDS

St. Croix: Florence Williams Public Library (1974).
St. Thomas:
College of the Virgin Islands, Ralph M. Paiewonsky Library (1973).
Enid M. Baa Library and Archives (1968).

VIRGINIA

Alexandria: Dept. of the Navy, General Law Library (1963).
Arlington: George Mason University School of Law Library (1981).
Blacksburg: Virginia Polytechnic Institute and State University, Carol M. Newman Library (1907).
Bridgewater: Bridgewater College, Alexander Mack Memorial Library (1902).
Charlottesville:
University of Virginia, Alderman Library (1910)–REGIONAL.
University of Virginia Law School, Arthur J. Morris Law Library (1964).
Chesapeake: Chesapeake Public Library (1970).
Danville: Danville Community College, Learning Resources Center (1969).
Emory: Emory and Henry College, Kelly Library (1884).
Fairfax: George Mason University, Fenwick Library (1960).
Fredericksburg: Mary Washington College, E. Lee Trinkle Library (1940).
Hampden-Sydney: Hampden-Sydney College, Eggleston Library (1891).
Hampton: Hampton Institute, Huntington Memorial Library (1977).
Harrisonburg: James Madison University, Madison Memorial Library (1973).
Hollins College: Hollins College, Fishburn Library (1967).
Lexington:
Virginia Military Institute, Preston Library (1874).
Washington and Lee University, University Library (1910).
Washington and Lee University, Wilbur C. Hall Law Library (1978).
Martinsville: Patrick Henry Community College Library (1971).
Norfolk:
Norfolk Public Library (1895).
Old Dominion University Library (1963).
U.S. Armed Forces Staff College Library (1963).
Petersburg: Virginia State University, Johnston Memorial Library (1907).
Quantico:
Federal Bureau of Investigation, Academy Library (1970).
Marine Corps Education Center, James Carson Breckinridge Library (1967).
Reston: Department of the Interior, Geological Survey, National Center Library (1962).
Richmond:
University of Richmond, Boatwright Memorial Library (1900).
University of Richmond, Law School Library (1982).
U.S. Court of Appeals, Fourth Circuit Library (1973).
Virginia Commonwealth University, James Branch Cabell Library (1971).
Virginia State Law Library (1973).
Virginia State Library (unknown).
Roanoke: Roanoke Public Library (1964).
Salem: Roanoke College Library (1886).
Williamsburg:
College of William and Mary, Marshall-Wythe Law Library (1978).
College of William and Mary, Swem Library (1936).
Wise: Clinch Valley College, John Cook Wyllie Library (1971).

WASHINGTON

Bellingham: Western Washington University, Mabel Zoe Wilson Library (1963).
Cheney: Eastern Washington University, JFK Library (1966).
Ellensberg: Central Washington University Library (1962).
Everett: Everett Public Library (1914).
Olympia:
Evergreen State College, Daniel J. Evans Library (1972).
Washington State Law Library (1979).
Washington State Library (unknown)–REGIONAL.
Port Angeles: North Olympic Library System (1965).
Pullman: Washington State University Library (1907).
Seattle:
Seattle Public Library (1908).
University of Washington Libraries (1890).
University of Washington, Mary Gould Gallagher Law Library (1969).
U.S. Court of Appeals, 9th Circuit Library (1981).
Spokane:
Gonzaga University, School of Law Library (1979).
Spokane Public Library (1910).
Tacoma:
Tacoma Public Library (1894).
University of Puget Sound, Collins Memorial Library (1938).
University of Puget Sound, School of Law Library (1978).
Vancouver: Fort Vancouver Regional Library (1962).
Walla Walla: Whitman College, Penrose Memorial Library (1890).

WEST VIRGINIA

Athens: Concord College Library (1924).
Bluefield: Bluefield State College, Hardway Library (1972).
Charleston:
Kanawha County Public Library (1952).
West Virginia Library Commission (unknown).
West Virginia Supreme Court Law Library (1977).
Elkins: Davis and Elkins College Library (1913).
Fairmont: Fairmont State College Library (1884).
Glenville: Glenville State College, Robert F. Kidd Library (1966).
Huntington: Marshall University, James E. Morrow Library (1925).
Institute:
West Virginia College of Graduate Studies Library (1977)
West Virginia State College, Drain-Jordan Library (1907).
Morgantown: West Virginia University Library (1907)–REGIONAL.
Salem: Salem College Library (1921).
Shepherdstown: Shepherd College, Ruth Scarborough Library (1971).
Weirton: Mary H. Weir Public Library (1963).

WISCONSIN

Appleton: Lawrence University, Seeley G. Mudd Library (1869).
Beloit: Beloit College, Col. Robert H. Morse Library (1888).
Eau Claire: University of Wisconsin-Eau Claire, William D. McIntyre

Library (1951).
Fond du Lac: Fond du Lac Public Library (1966).
Green Bay: University of Wisconsin-Green Bay, Library Learning Center (1968).
La Crosse:
- La Crosse Public Library (1883).
- University of Wisconsin-La Crosse, Murphy Library (1965).

Madison:
- Madison Public Library (1965).
- State Historical Society of Wisconsin Library (1870)–REGIONAL, in cooperation with University of Wisconsin-Madison.
- University of Wisconsin-Madison Law Library (1981).
- University of Wisconsin-Madison, Memorial Library (1939).
- Wisconsin State Law Library (unknown).

Milwaukee:
- Alverno College Library/Media Center (1971).
- Medical College of Wisconsin, Inc., Todd Wehr Library (1980).
- Milwaukee County Law Library (1934).
- Milwaukee Public Library (1861)–REGIONAL.
- Mount Mary College Library (1964).
- University of Wisconsin-Milwaukee Library (1960).

Oshkosh: University of Wisconsin-Oshkosh, Forrest R. Polk Library (1956).
Platteville: University of Wisconsin-Platteville, Karrmann Library (1964).
Racine: Racine Public Library (1898).
Ripon: Ripon College Library (1982).
River Falls: University of Wisconsin-River Falls, Chalmer Davee Library (1962).
Stevens Point: University of Wisconsin-Stevens Point, Learning Resources Center (1951).
Superior:
- Superior Public Library (1908).
- University of Wisconsin-Superior, Jim Dan Hill Library (1935).

Waukesha: Waukesha Public Library (1966).
Wausau: Marathon County Public Library (1971).
Whitewater: University of Wisconsin-Whitewater, Harold Anderson Library (1963).

WYOMING

Casper: Natrona County Public Library (1929).
Cheyenne:
- Wyoming State Law Library (1977).
- Wyoming State Library (unknown)–REGIONAL.

Gillette: George Amos Memorial Library (1980).
Laramie:
- University of Wyoming, Coe Library (1907).
- University of Wyoming Law Library (1978).

Powell: Northwest Community College, John Taggart Hinckley Library (1967).
Riverton: Central Wyoming College Library (1969).
Rock Springs: Western Wyoming College Library (1969).
Sheridan: Sheridan College Griffith Library (1963).

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Supplement 8: 1983

5. AUTHOR(S)

Linda Beavers, Editor

6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions)

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This report presents NBS' Center for Building Technology (CBT) publications for 1983. It is the eighth supplement to NBS Special Publication 457, Building Technology Publications, and lists CBT reports issued during January 1 - December 31, 1983. It includes titles and abstracts of each CBT publication and those papers published in non-NBS media, key word and author indexes, and general information and instructions on how to order CBT publications.

This document is divided into three main sections. The first, Titles and Abstracts, provides the report title, author(s), date of publication, selected key words, and an abstract of each NBS publication and each paper published in an outside source. The Author Index cites CBT authors and their publication number which is listed in this supplement. The Key Word Index is a subject index, listing word summaries of the building research topics for each publication and paper. By selecting a main word or subject, the user is able to locate reports of interest through these subject-related words.

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