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Abnormal Loading on Buildings and Progressive Collapse. An Annotated Bibliography

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NBS Building Science Series no. 67

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SI Conversion Units

In view of present accepted practice in this technological area, U.S. customary units of measurement have been used throughout this report. It should be noted that the U.S. is a signatory to the General Conference on Weights and Measures which gave official status to the metric SI system of units in 1960. Readers interested in making use of the coherent system of SI units will find conversion factors in ASTM Standard Metric Practice Guide, ASTM Designation E 380–72 (available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103). Conversion factors for units used in this paper are:

Length

1 in = 0.0254* meter
1 ft = 0.3048* meter

Area

1 $in^2 = 6.4516^* \times 10^{-4}$ $meter^2$
1 $ft^2 = 9.2903 \times 10^{-2}$ $meter^2$

Force

1 lb (lbf) = 4.448 newton
1 kip = 4448 newton

Pressure, Stress

1 psi = 6895 pascal (N/m^2)
1 psf = 47.88 pascal (N/m^2)

Moment

1 lbf-ft = 1.3558 newton-meter

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* Exact value

Contents

Abnormal Loading on Buildings and Progressive Collapse. An Annotated Bibliography

Edgar V. Leyendecker, John E. Breen,* Norman F. Somes, and M. Swatta **

This bibliography on the subjects of abnormal loading and progressive collapse is an annotated listing of articles that have appeared in the technical literature from 1948 through 1973. The entries have been arranged chronologically by year and alphabetically within years. Both subject and author indexes have been included. The references listed have been selected as most representative of the historical background and best representing the origin and present state-of-the-art of current practice without undue repetition of data.

References pertaining to characteristics, frequencies, incidents, tests, design procedures, and regulations for many types of abnormal loadings are included. Among these are various types of accidental impacts, construction loads, explosions, faulty practices, and extreme atmospheric loads. Heavy emphasis was placed on referencing applicable building codes and regulations pertaining to the subjects of progressive collapse and abnormal loadings. This bibliography also contains numerous references to contemporary professional opinion as expressed in editorials and discussions of the subject and, particularly, on the various regulations proposed. A large number of proposed analysis and design procedures, as well as applicable test results, are referenced. In addition to the general reference material, a careful search was made of the ten most recent years (1964-1973) of Engineering News Record to identiy and annotate possible progressive collapse examples from building failures reported by that publication.

Key words: Abnormal loading; alternate path; annotated bibliography; bibliography; building regulations; collapse; failures; progressive collapse; specific resistance.

1. Introduction

There has been growing international concern that buildings, particularly multistory buildings, may be subjected to loading conditions not normally considered in design, i.e., abnormal loadings. This concern was intensified with the Ronan Point apartment collapse in London, England, in 1968. In this 22-story building of precast concrete panel construction, collapse was triggered by a gas explosion in the kitchen of an apartment on the 18th floor. The explosion blew out an exterior wall panel; the loss of support provided by the panel resulted in a chain reaction of collapse to the roof. The collapse also progressed almost to the ground as debris from above fell on successive floors below (see figure 1). This type of chain reaction or propagation of failure following damage to a relatively small portion of a structure has been termed "progressive collapse."

A Commission of Inquiry Report [84] [1] and subsequent studies of the Ronan Point collapse revealed a number of deficiencies in existing codes and standards, particularly as they applied to multistory construction. In the United Kingdom interim criteria for the appraisal and strengthening of existing buildings and the design of new structures were quickly implemented. Several other countries in Europe introduced additional design criteria to deal explicitly with the risks exposed by the incident.

This bibliography [2] on the subjects of abnormal loading and progressive collapse is an annotated listing of articles that have appeared in the technical literature from 1948 through 1973. The references listed in this bibliography have been selected as most representative of the historical background and best representing the origin and present state-of-the-art of current practice without undue repetition of data. Since the bibliography is intended as a reference document on the subject of progressive collapse, it was made as complete as possible. The references cover a broad range of structures, such as apartment buildings and bridges, both during and after construction. Thus, the reader with a narrow interest, such as completed apartment buildings, will find the literature of direct interest, while at the same time having available a comprehensive listing of references covering the broad category of progressive collapse.

Because the heightened interest in the subjects of abnormal loadings and progressive collapse both stemmed from the Ronan Point incident, it was impractical to attempt to divide the bibliography into exclusive subsections. Instead, the entries have been arranged chronologically by year and alphabetically within years. For the convenience of the user, both subject and author indexes have been included. The numbers following the subjects or names in the index refer to the individual references in the bibliography.

Annotations have been included throughout. Some have been obtained from such sources as the Engineering Index, Building Science Abstracts, Applied Mechanics Reviews, and the Geodex Structural Index. Many were prepared by the project staff.

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[1] Figures in brackets designate literature references listed in the bibliography.

[2] Research sponsored by the Office of Policy Develoment and Research, Department of Housing and Urban Development, Washington, D. C. 20410.

FIGURE 1. *Ronan Point apartment building after the collapse, with a second identical building in the background.*

(Courtesy of London Express News and Feature Services.)

Examination of the subject index indicates the far-reaching scope of the bibliography. References pertaining to characteristics, frequencies, incidents, tests, design procedures, and regulations or many types of abnormal loadings are included. Among these are various types of accidental impacts, construction loads, explosions, faulty practices, and extreme atmospheric loads. References are multiple listed as appropriate with particular collapse examples identified by geographical location as well as by type of failure. In addition to the general reference material, a careful search was made of the ten most recent years of Engineering News-Record to identify possible progressive collapse examples from structural failures reported by that publication. In keeping with the general nature of this bibliography, failure of different types of structures is included. These items list many examples of both vertical and horizontal progressive collapse which have occurred in recent years other than the well-known Ronan Point incident. Also included are a number of examples involving major abnormal loadings such as large scale gas explosions and formwork failures where progressive collapse might be expected but did not occur, since this helps focus on the resistance of many conventionally designed and constructed buildings. For all specific failure examples, an attempt was made to classify the failure mode and to identify possible progressive collapses in the subject index under the heading Failure Modes, Progressive.

Heavy emphasis was placed on referencing applicable building codes and regulations pertaining to the subjects of progressive collapse and abnormal loadings. Subject index headings such as Building Code and Recommendations lead to major regulations issued to cope with this subject area. Numerous citations are included under the headings Alternate Path and Specific Resistance, which have come to represent the most general way of codifying requirements for ensuring safety against progressive collapse.

This bibliography contains numerous references to contemporary professional opinion as expressed in editorials and discussions of the subject and, particularly, on the various regulations proposed. A large number of proposed analysis and design procedures, as well as appplicable test results, are referenced. The general subject of risk analysis with emphasis on applications to multistory buildings is included.

2. Chronological Bibliography, 1948 through 1973

1948

1. Baker, J. F., Williams, E. L., and Lax, D., The Design of Framed Buildings Against High Explosive Bombs, The Civil Engineer in War, London, Institution of Civil Engineers, Vol. **3,** 1948, pp. 80–112.

The experience of engineers in England during World War II is documented. It was concluded that one of the outstanding facts to come out of the war was the high resistance of framed buildings to the effects of high explosives.

1949

2. Thompson, N. F., and Cousins, E. W., Explosion Tests on Glass Windows. Effect on Glass Breakage of Varying the Rate of Pressure Application, Journal of the American Ceramic Society, Vol. **32,** No. 10, 1949, pp. 313–315.

Tests were made to determine the effectiveness of glass windows in preventing building damage from internal explosions involving combustible dusts or vapors. It was found that the effective strength of glass panes increases in an approximately linear ratio with increased rate of pressure application. It was concluded that window glass is of dubious value for explosion venting purposes, except possibly for explosions of high pressure but of very short duration, such as those that might occur if small quantities of high explosive were placed relatively near the windows.

1950

3. Amirikian, A., Design of Protective Structures, NAVDOCKS P51, Department of the Navy, Bureau of Yards and Docks, Washington, D.C., August 1950.

Protective design is a common problem for military installations as well as for civil and industrial buildings. This paper presents certain data and design procedures in two parts. The first part includes declassified experimental data and a procedure used by the Bureau of Yards and Docks of the Navy Department in designing structures to resist conventional weapons of World War II, such as bombs and projectiles. The second part develops a discussion of atomic bomb blast and a new concept of structural resistance. Based on this concept, an analysis is presented, together with a simplified procedure for the design of structures to resist atomic blast.

1951

4. Cousins, E. W., and Cotton, P. E., Design of Closed Vessels to Withstand Internal Explosions, Chemical Engineering, London, Vol. **58,** No. 8. August 1951, pp. 133–137.

Tests were conducted with rupture disks to provide data on the effect of disk strength and vent area on the maximum explosion pressure of an internal explosion in closed vessels. Variables included vessel size and strength; mixtures of hydrogen and air; and mixtures of propane and air.

5. Damage Control in Wartime, Studies in Business Policy No. 53, National Industrial Conference Board, September 1951.

The results of an extensive study of how European companies protected personnel and minimized industrial damage during World War II are contained in this and the companion report, Protecting Personnel in Wartime. It is pointed out that damage can be controlled by action taken before, during and after attack. The principal hazards are blast, splinters, and fire, and of these, fire is the most destructive. Preparatory measures dealing with these factors are explained. Contains tables and graphs which simplify determination of blast pressures for various sizes and types of bomb explosions and distances from center of explosion.

1952

6. Nielsen, K., Loads on Reinforced Concrete Floor Slabs and Their Deformations during Construction, Proceedings N:R 15, Swedish Cement and Concrete Research Institute at the Royal Institute of Technology, Stockholm, 1952.

This report summarizes analytical and experimental studies of the magnitude of construction loads on reinforced concrete slabs in multistory apartment buildings. The study indicates that in typical cases measured loads up to 200 percent of slab dead load were observed while calculations indicate possible loads up to 250 percent of slab dead weight. The influence of rate construction, method of slab support, rigidity of formwork and moisture content of form lumber were studied.

7. Windowless Structures, A Study in Blast-Resistant Design, TM–5–4, Federal Civil Defense Administration, U.S. Government Printing Office, Washington, D.C., June 1952.

This manual is one of a series of publications dealing with protective construction and provides technical data for architects and engineers interested in designing buildings which will afford protection from atomic blasts. Methods and procedures for designing windowless structures based on the dynamic properties of loading are described. These principles are applicable to windowless portions of conventional buildings. Principles, methods, and formulas for determining the magnitude, duration, and distribution of atomic blasts loads on windowless structures are also presented. This publication is of interest to architects and engineers concerned with the design of conventional structures because many such structures can be made blast-resistant in whole or in part by the addition of relatively inexpensive design features.

1955

8. Brook, D. H., and Westwater, R., The Use of Explosives for Demolition, Proceedings, Institute of Civil Engineers, London, Vol. 4, No. 3, P. III, December 1955, pp. 862–899.

The authors feel that the use of explosives in civil demolitions involves problems sufficiently different from military demolitions to justify this paper. After outlining types of commercial explosives and accessories most suitable for demolition work and dealing with the methods of initiating them, the paper points out that there are only three ways in which explosives can be used for demolitions, namely, as lay-on charges, as concussion charges, and as shot-hole charges. Each of these ways in which explosives can be used is considered and examples are given of actual operations.

9. Whitney, C. S., Anderson, B. G., and Cohen, E., Design of Blast Resistant Construction for Atomic Explosions, Journal of the American Concrete Institute, Vol. 26. No. 7, March 1955, pp. 589–683.

Methods and principles used in designing the first full scale blast resistant structures tested at Eniwetok are presented and the test results are cited in support of the procedures outlined. Economic and other practical considerations are discussed. Radiation hazards and methods of dealing with them are described. Appendices are included which give detailed procedures for computing the blast loading, for designing individual structural elements and single and multistory buildings in both the elastic and plastic range for this loading, for computing ultimate strength of structural elements and frames under rapid loading, and for dealing with some special problems.

1956

10. Granstrom, S. A., Loading Characteristics of Air Blasts from Detonating Charges, Transactions of the Royal Institute of Technology, Nr. 100, Stockholm, Sweden, 1956.

The purpose of the report is to clarify the loading effects produced on structures by air blasts from detonating charges. Pressure-time curves are presented to show the effect of a 1 kg charge of TNT at selected distances.

11. Newmark, N. M., An Engineering Approach to Blast Resistant Design, Transactions of the American Society of Civil Engineers, Vol. 121, 1956, pp. 45–64.

The problem of blast-resistant design is approached directly by means of reasonable sim-

plifying assumptions. The resulting design procedure avoids time-consuming and misleading analysis. The author presents the procedure and the necessary mathematical relationships and explains their practical application.

1957

12. Teichmann, G. A., and Westwater, R., Blasting and Associated Vibrations, Engineering, London, Vol. **183,** No. 4753, April 12, 1957, pp. 460–465.

The major differences between blasting vibrations and what might be termed industrial vibrations is the continuity of the latter over the sudden arrival and dying of the former. The authors have studied this problem in an endeavor to clear up some of the misconceptions relating to blasting vibrations and explain present-day views and methods applied to counteract problems arising from this cause.

1958

13. Monk, C. B. Jr., Resistance of Structural Clay Masonry to Dynamic Forces, Research Report No. 7, Structural Clay Products Research Foundation, Geneva, Illinois, November 1958.

This reports the results of the Structural Clay Products Research Foundation studies of the problems of blast resistant design. Tests to gain some insight on the behavior of clay masonry subjected to high impulsive forces revealed that effective designs in clay masonry could be achieved through the use of reinforced brick masonry and the arching of unreinforced masonry walls. Included in the report are criteria for blast resistant design, structural theory, and structural design techniques.

1959

14. Norris, C. H. et al., Structural Design for Dynamic Loads, McGraw-Hill, New York, 1959.

To cover the broad field of structural design for dynamic loading, the book is divided into four parts, covering behavior of materials, analysis of dynamic response, definition of dynamic loads, etc., as well as specific proportioning and dimensioning of structural members as follows:

(1) Behavior of Materials under Dynamic Loading.
(2) Calculation of Response of Structural Systems to Dynamic Loading.
(3) Modern Computational Techniques Applicable to Response Calculations.
(4) Application of Structural Design and Analysis to Specific Cases Involving Dynamic Loading.

1960

15. Collapse Blamed on Bearing Failure, Engineering News-Record, December 15, 1960, p. 28.

A building collapse near Harrisonburg, Virginia, has been attributed to bearing failures at the beam-column connection. The accident occurred as erection crews started on a new bay adjacent to a 24,000 ft^2 area that had been erected. Framing of the one story bays were prestressed double tees of 50 ft span bearing on the top flange of prestressed I-beams.

16. Legget, R. F., and Schriever, W. R., Realistic Assessment of Loads Acting on Structures with Particular Reference to Snow and Wind Loads on Buildings, VI Congress of the International Association of Bridge and Structural Engineers (Preliminary Report), 1960, pp. 85–95.

The paper points out that no structure, no matter how conservatively designed, provides for absolute safety, because loads and carrying capacities of structures are variables whose upper and lower limits respectively, cannot be predicted with certainty but only in terms of probability of failure. Advances in structural design must be accompanied by corresponding improvement in the knowledge of actual loads on structures. Canadian studies of live loads on buildings, and particularly a countrywide survey of snow loads on roofs, are described with relation to their application in the National Building Code of Canada.

1961

17. Design of Structures to Resist Nuclear Weapons Effects, American Society of Civil Engineers, Manual of Engineering Practice, No. 42, New York, 1961.

While this reference principally treats design for nuclear blast, sections on choice of materials, details, dynamic strength of materials, and dynamic design are generally applicable for any type explosion.

1962

18. Firnkas, S., Continuity of Prestressed Concrete Girders Under Ultimate Load Conditions, Prestressed Concrete Institute Journal, Vol. 7, No. 3, June 1962, pp. 45–54.

The paper discusses the possibilities of an accident-proof continuity connection of precast/prestressed concrete beams, and outlines the basic considerations that went into the design of the connection. In addition, it was indicated how a precast concrete structural system using individual parts and beams designed for simple spans can obtain the additional advantages of a continuous system under ultimate conditions. Furthermore, it is an important step in preventing accidents and injuries in an industrial plant with operations that can cause damage to the structure by unintentional negligence.

19. McKaig, T. H., Building Failures, Case Studies in Construction and Design, McGraw-Hill Book Company, New York, 1962.

A review of numerous cases of building failures which have occurred in the United States. Although the book was written well prior to the entry of the term "progressive collapse" into general engineering vocabulary, several cases of chain reaction can be seen.

1963

20. Flat-Slab Garage Roof Caves In, Engineering News-Record, January 3, 1963, p. 16.

A three year old concrete roof over an underground garage collapsed in New York City on December 23. The 16 in deep grid flat slab roof supported a 4,500 ft^2 landscaped area at street level. According to an official of the New York Department of Buildings, shear caps shown in the design drawings were omitted in construction. The slab apparently failed in diagonal tension at six interior columns with missing shear caps.

21. Grundy, P., and Kabaila, A., Construction Loads on Slabs with Shored Formwork in Multistory Buildings, Journal of the American Concrete Institute, Vol. **60,** No. 12, December 1963, pp. 1729–1738.

Construction loads in a concrete structure where upper floors are shored from lower floors may exceed design service loads by an appreciable amount. A method for determining these erection loads is presented for flat slab or flat plate construction. The effect of shoring different numbers of floors and the effect of construction loads on design are also discussed.

22. Northwood, T. D., Crawford, R., and Edwards, A. T., Blasting Vibrations and Building Damage, The Engineer, London, Vol. **215,** No. S 601, May 1963, pp. 973–978.

Building vibration and building damage resulting from blasting operations were studied in a series of experiments on expendable buildings. Sixty charges ranging from 0.3 lb to 1600 lb were set off at distances of 3 ft to 300 ft from the buildings under study. Observations were made of vibration displacement, velocity, acceleration and strain of the building structures. The results supported previous conclusions that particle velocity is the most useful indicator of the onset of damage.

23. Shapiro, G. A., and Sokolov, M. E., O Procnosti I Deformativnosti Gorizontalnycm Stykov Krupnopanelnych Zanij (On the Strength and Deformability of Horizontal Joints in Large Panel Walls), Beton i Zelezobeton, 6, 1963.

Based on test results of a number of typical wall-floor joint details, design recommendations are given for determining horizontal joint strength as a percentage of wall strength considering important parameters such as the relative strength of the mortar in the joint and the concrete strength of the wall, the width of the wall and the width of beaming of the slabs. The relative thickness of the slabs to be joined at a joint is also shown to be an important factor.

1964

24. Cairo Building Collapse Kills 31, Engineering News-Record, October 29, 1964, p. 15.

The sudden complete collapse of a five-story bearing wall reinforced concrete apartment building in Cairo, Egypt took 31 lives. The owner started with a two-story structure and progressively added new floors. Overloading of the soil foundation resulting from the continued addition of new floors allegedly caused the collapse.

25. Chandler, S. E., Fire Incidents Involving Explosions, Joint Fire Research Organization, Fire Research Note No. 541, England, March 1964.

This statistical survey pertains to the number of fires in which explosions occurred during the years 1961 and 1962. The number of fire incidents involving explosions, estimated from 1 in 2 samples of all reports, were 426 in 1961 and 498 in 1972. Of those, the numbers in which water or space heating equipment was the heat source were 144 in 1961 and 192 in 1962. Space and water heating equipment were revealed as the main sources of dàmage. The principle causes of explosions in 1962 were gas (town) leaks (40 incidents), domestic back boilers (18 incidents) and foreign matter on coal fires (17 incidents).

26. Feld, J., Lessons from Failures of Concrete Structures, American Concrete Institute Monograph No. 1, ACI/Iowa State University Press, 1964.

A survey of concrete structure failures reported over a 60-year period with selected cases illustrating major factors causing such failures. Monograph includes a discussion of formwork and construction problems leading to progressive collapses and has several examples of roof structures which experienced horizontally propagating progressive collapses.

27. Mayes, W. H., and Edge, Jr., P. M., Effects of Sonic Boom and Other Shock Waves on Buildings, Materials Research and Standards, Vol. 4, No. 11, November 1964 pp. 588–593.

This paper discusses the sonic boom damage problem, summarizes 3000 complaints received by the Air Force because of military flights, and describes experiments with a building exposed to sonic boom overpressures, acoustic loading from a rocket, and overpressures from explosive blasts. Complaints from building residents suggest that secondary components such as plaster, masonry, and glass are susceptible to damage. Building response measurements indicate that only small loads are felt by the primary structure, and that the response frequencies are in a readily observable range. Data show that stresses developed by sonic boom overpressure are small.

28. Newberry, C. W., Measuring the Sonic Boom and Its Effect on Buildings, Materials Research and Standards, Vol. 4, No. 11, November 1964, pp. 601–611.

Tests were made during the supersonic flight of an aircraft to measure the shock pressures of the sonic boom and the vibrations produced by them in typical buildings. Shock pressures of up to about 5 lb/ft^2 on the ground were recorded in the central part of the boom area. Focus zones, where higher pressures were expected, did not fall within the measuring positions. Accelerations of roof structures of up to 1.0g and roof vibrations of 0.087 in (peak-to-peak) were recoreded. There was evidence of resonant vibration of parts of the buildings under suitable incident shock conditions, and it appears that such resonant vibration could be harmful at certain discrete points within a boom area should a boom fall on an extensive built-up area.

29. Paris Building Collapse Kills 15, Engineering News-Record, January 23, 1964, p. 39.

The collapse of a 10-story, steel framed apartment being erected by a tilt-up method in Paris killed 15 workmen and injured 17. The accident occurred as the final 10-story bent swung into position. It went out of control, and the entire steel frame collapsed.

30. Power, J. K., Some Results of the Oklahoma City Sonic Boom Tests, Materials Research and Standards, Vol. 4, No. 11, November 1964, pp. 617–623.

In the sonic boom tests conducted in Oklahoma City in the summer of 1964, no significant structural damage of any kind was observed in any of the test houses from an exposure of 1253 sonic booms producing pressures from 1.0 to approximately 4.80 lb/ft^2. No wooden structural member of the test houses was stressed beyond 59 psi. The overpressures did not cause good-quality, propery installed window glass to break. Deflection of the main structural elements of the test houses was negligible.

31. Ramsay, W. A., Damage to Ottawa Air Terminal Building Produced by a Sonic Boom, Materials Research and Standards, Vol. 4, No. 11, November 1964, pp. 612–616.

Damage amounting to approximately $300, 000 to an almost completed air terminal building by a supersonic fighter aircraft accidentally passing over the building in a demonstration flight is described. The aircraft had flown along the runway at an altitude of less than 1000 ft and was in an accelerated climbing turn when it passed over the building, but unfortunately, precise information on the height and path of the aircraft and its speed and acceleration in relation to the building is lacking. There were no casualties or injuries because very few workmen were in the building at the time of the accident. Damage to glass, curtain walls, suspended ceilings, and roofing was fairly extensive, but the structural steel frame was unaffected by the boom.

32. Wall Splits Bowling Alley Building, Engineering News-Record, October 29, 1964, p. 15.

A two-story brick building partly collapsed in Ottawa, Ontario when a contractor excavating for a wall next door undermined a footing.

1965

33. Blakey, F. A., and Beresford, F. D., Stripping of Formwork for Concrete in Buildings in Relation to Structural Design, Civil Engineering Transactions, Australia, Vol. CE7, No. 2, October 1965, pp. 92–96.

Analytical determination of the loads which might be applied to concrete floors of multistory structures during construction by props from floors above is discussed in this article.

34. Low Friction and High Density of Fill Toppled Wall, Engineering News-Record, July 8, 1965, pp 40–41.

The article discusses the collapse of a 310 ft long section of a 60-ft-high reinforced concrete retaining wall which occurred in 1958. It explores the design and workmanship and concludes that the coefficient of friction for backfill was underestimated by the designers. When one section of the wall collapsed, adjacent sections were overturned because they were pulled forward by the horizontal reinforcement between the affected sections of the wall. The horizontal reinforcement stripped the cover from the vertical steel and caused bond failure.

35. Ostenfeld, C., Ship Collisions Against Bridge Piers, Publications of the International Association for Bridge and Structural Engineers, Vol. **25,** 1965, pp. 233–277.

In recent years characteristic features of shipping have been steadily increasing traffic and a very conspicuous increase of the tonnage of the ships. As a consequence, the risk of ships colliding with bridge piers has increased, and, considering that only a very small number of the existing bridge piers possess masses exceeding the mass of the very large ships built in present days, it is obvious that the consequences to a bridge exposed to a collision of this nature may have the character of a catastrophe. Details of a number of case histories relating to the collision of ships with bridge piers, etc., detailed calculations of the collision of a ship with a lighthouse, an analysis of the effects on a bridge pier of impact produced by a ship, and some preliminary conclusions for use in design are included.

36. Precast Girder Collapse Kills Two, Engineering News-Record, May 13, 1965, p. 29.

Undermining of an interior column triggered the collapse of 20,000 ft^2 of precast concrete roof framing of a one-story building in Atlanta. The precast double T-sections sat on neoprene bearing pads and were alternating cantilevers with projected bearing to support interior girders.

37. Seven Die in Collapse of Italian Apartment, Engineering News-Record, May 20, 1965, p. 24.

Seven workmen were killed when one wing of an eight-story apartment building collapsed on the Italian Riviera. Construction was nearly completed on the reinforced concrete L-shaped structure when it crumbled into a pile of ruins.

38. Stanger, R. H. H., Loading Tests of Insitu Joints as Used in the Wates System, Test Reports, Ove Arup and Partners, London, October 1965.

Tests on various joints of the Wates building system to determine their resistance to shear loads are reported.

39. Supermarket Roof Falls on Shoppers, Engineering News-Record, May 27, 1965, p. 59.

The truss-supported roof of an old supermarket building in Brooklyn, suddenly collapsed, dropping tons of concrete and steel on the patrons below. It was basically a one-story structure, with mezzanine offices at the front and back of the building. Examining the trusses, building officials discovered severe corrosion in the encased bottom chord of at least one truss. A tensile failure of one truss probably triggered the collapse. The trusses were interconnected with bracing and failure of one would cause twisting of neighboring trusses.

1966

40. Birkeland, P. W., and Birkeland, H. W., Connections in Precast Concrete Construction, Journal of the American Concrete Institute, Vol. **63,** No. 3, March 1966, pp. 345–367.

Requirements for connections in precast concrete buildings are discussed and examples from completed structures where these requirements have been met are given. A time-proven hypothesis explaining shear behavior at concrete to steel and concrete-to-concrete interfaces is presented. Examples illustrate beam-to-column connections using this hypothesis. Suggestions for further study are outlined.

41. Collapse Verdict, Engineering News-Record, May 5, 1966, p. 11.

Premature stripping of forms, coupled with an overload of reinforcing steel on a recently concreted floor above, was cited by structural engineer Ernest Butts as the cause of the collapse of a reinforced concrete building under construction in Ottawa (see 47).

42. Collapses, Failures Take Heavy Toll, Engineering News-Record, May 19, 1966, pp. 30–31.

The article discusses major failures occurring recently involving a formwork failure, a steel erection collapse, a roof collapse and a floor collapse. Particularly interesting is a collapse occurring in Athens during an expansion of a paper mill. A 4,500 ft^2 section of wet concrete suddenly collapsed, raining 200 tons of wet concrete and reinforcing steel on the first floor slab, 29 ft below. Designed to carry heavy papermaking machinery, the first floor slab held under the impact.

43. Crane Pulled Roof Dome Down, Engineering News-Record, November 17, 1966, p. 66.

A 300 ft diameter dome had 15 of 24 radial, trussed steel ribs in place when it collapsed in Jamaica. Premature removal of temporary falsework supporting the central compression ring was one unofficial explanation offered at the time. But some engineering detective work later showed that a crane boom had brushed against one of the ribs just prior to the accident causing the collapse.

44. Cziesielski, E., Berechnung Von Wanden Des Gross-Tafelbaues Die Aus Mehreren Einzelwanden Zu Einer Grossen Wandscheibe Zusammengeschlossen Werden (Computations for Large Panel Walls Consisting of Individual Wall Elements Connected into a Large Shear Wall.) Die Bautechnik, March 1966, p. 73.

Treats analytically the problem of design of large shear walls made up of individual panels. Contrasts behavior with monolithically cast shear walls and outlines proper requirements for detailing such shear walls comprised of large panels.

45. Faulty Girder Connection Blamed in Motel Collapse, Engineering News-Record, December 8, 1966, p. 17.

A slipped welded connection plate was blamed for a structural failure that set off a five-story reaction at a motel in New Orleans. The connection plate joined a second floor girder to an interior column. Loss of this column set off a chain reaction in upper stories causing 25 percent of the building's interior to settle between 8 and 14 in. The structure was approximately 2 years old.

46. Feld, J., Reshoring of Concrete Buildings, Engineering News-Record, October 6, 1966, p. 33.

Faster progress schedules in construction of tall concrete buildings require a careful analysis of formwork requirements, especially the reshoring of floors after forms are removed for reuse. This article outlines a procedure for determining the number of floors that require reshoring assuming that a completed and cured floor can carry 1.33 times its final design load as an interim construction load.

47. Four Groups Investigate Collapse, Engineering News-Record, April 7, 1966, p. 72.

The collapse of three floors of a 12-story flat plate reinforced concrete building under construction in Ottawa occurred one day after the concreting of the fourth floor. Portions of the third floor, which supported the shoring for the recently concreted fourth floor, had apparently not been reshored. Four Canadian government agencies are investigating the collapse in which several bays approximately a block long sheared away from columns which were left standing (see 41).

48. Gusting Wind Fells Steel Frame, Engineering News-Record, June 9, 1966, p. 18.

One hundred eighty tons of structural steel collapsed like a house of cards when winds gusting to 50 miles per hour hit the Pittsburgh area on May 28. The damage extended to four stories of partially erected structural steel in part of Duquesne University's new science building under construction. The construction was guyed and bolts had been inserted in every connection but connections had not been completed.

49. Ice and Snow End Curling Match, Engineering News-Record, Feb. 24, 1966, p. 17.

Snow and ice totaling an estimated 64 psf collapsed the timber-framed roof of a curling rink in Sweden. This was probably over three times the design load of 20 psf. Seven of the structure's ten 15 ft bays collapsed.

50. Lewicki, B., Building with Large Prefabricates, American Elsevier Publishing Company, New York, N. Y., 1966.

A design oriented text treating design, detailing, and construction of structures made from assembles of large concrete panels. De tailed treatment of joint design with examples. Based largely on Russian and Eastern European practice, a considerable variety of test results and practical experiences are included. Does not specifically refer to design for progressive collapse and can be taken as a representative sample of Eastern bloc design procedures prior to the Ronan Point occurrance.

51. Marchand, P. E., Report of the Canadian Technical Mission of Prefabricated Concrete Components in Industrialized Buildings in Europe, September 2–22, 1966, Department of Industry, Materials Branch, Ottawa, Canada, 1966.

The introduction of industrialized building systems and techniques has brought about new contractural and working relationships between clients, architects, manufacturers and builders. It has also given added importance to the rational organization of work on the building site. In Europe industrialized building has achieved greater productivity—in terms of the value of building per man hour worked—and greater speed of erection than traditional building methods. In this report several European systems and techniques are discussed in detail, and some indications are given of possible future trends in the development of industrialized buildings in Canada.

52. Natural Gas Pipelines Safe Enough? FPC Has Doubts, Engineering News-Record, June 23, 1966, pp. 20–21.

The Federal Power Commission wants the authority to set federal safety standards for the 150,000 mile interstate network of natural gas pipelines. In its report to the Senate Commerce Committee, the FPC noted that ". . . the maximum credible single accident possibility for a transmission line failure is high, possibly higher than that for railroad, motor car or air transportation." It also pointed out that 28 percent of pipeline failures was caused by damage from earth moving equipment.

53. Porl, M. K. (Translator), Common Directives for the Agrément of Building Systems with Large and Heavy Prefabricated Panels (Directives commones pour l'agrément des procédés

de construction par grands panneaux lourds préfabriqués), Union Européene Pour l'Agrément Techniques Dans La Construction, Livraison 80, June 1966.

Detailed requirements for structural safety, stability, hability, and durability of large panel structures of precast concrete for international acceptance under the agrement system. Contains standards for joint and tie beam design as well as overall stability. Contains both performance requirements and outlines of acceptable tests and calculation procedures for meeting standards.

54. Quadruple Floor Overload Blamed in Building Failure, Engineering News-Record, February 3, 1966, p. 17.

Overloading was blamed for the floor failure of a factory building which triggered a collapse following a falling domino pattern. A section of the fifth floor gave way, dropping machinery and materials which successively caused the failure of portions of the fourth and third floors. Building officials estimated the top floor was carrying an overload four times the posted 120 psf capacity (see 56).

55. Russoff, B. B., Transportation and Erection Problems, Proceedings, Symposium on Industrialized Building and the Structural Engineer, London, 1966, pp. 117–124.

The influence on structural design and detailing of transportation, handling and erection considerations for precast concrete building elements is shown by describing how construction stresses are induced in relation to the size and shape of the elements. The use of manufacturing equipment and erection cranes is described by examples.

56. Sheared Bolts Caused Collapse, Engineering News-Record, February 24, 1966, p. 18.

Century-old ¾ in diameter bolts, which connected an eccentric bracket to the cap of a cast iron column, failed at shearing stress nearly twice the ultimate shearing capacity of carbon steels manufactured during the Civil War. This was part of the New York City Building Department's analysis of the three floor progressive collapse of the 100-year-old Manhatten factory building (see 54). In addition to severe overloading, an unauthorized alteration to the antique structure contributed to the collapse.

57. Shell Roof Topples in Atlanta, Engineering News-Record, September 1, 1966, p. 12.

The 120 ton precast concrete roof of a chapel under construction collapsed in Atlanta. Observers reported the failure of a weld in the peripheral steel tension ring that allegedly resulted in rotation of a steel I-beam ring segment about its longitudinal axis. All twelve segments fell when the tension ring connection gave way.

58. Snow, Wind Triggered Dome Collapse, Engineering News-Record, May 19, 1966, p. 31.

A 170 ft diameter wood lamella dome collapsed March 3, 1966. An investigator blamed snow load and wind for the collapse and also declared that he believed the dome was improperly designed and fabricated.

59. Somerville, G., and Burhouse, P., Tests on Joints Between Precast Concrete Members, Proceedings, Symposium on Industrialized Building and the Structural Engineer, London, 1966, pp. 125–142.

A well-documented review of experimental studies on joints between precast concrete members (i.e., column-column, beam-column, beam-beam joints, and joints in large-panel structures), with detailed tabulations of test results and drawings of test specimens. A bibliography lists 73 references to such studies.

60. Sports Hall Roof Collapses, Engineering News-Record, January 6, 1966, p. 15.

Swedish authorities are investigating the collapsed. A possible cause of failure was intype of steel-reinforced, laminated wood I-beam. One of the two brick end walls also collapsed. A posible cause of failure was insufficient bond of the reinforcing bars with laminated wood 80 ft span girders. Collapse of the brick bearing wall resulted in total collapse of all roof members.

1967

61. Arthur D. Little Inc., Public Safety and Gas Distribution, Research Report prepared for the American Gas Association, Washington, D.C., December 1967.

The report defines the scope of safety prolems associated with the distribution of utility gas for the period of 1957 through 1964. It is based on a study of gas leak incidents within the gas distribution industry in which 140 companies and systems, representing 83.3 percent of all gas distribution meters in the U.S. participated. Principal findings include the number of incidents, type, location, number of fatalities and an assessment of the causes. Comparisons were made between the safety record of the gas distribution industry and that of other utility industries, railways, airlines, etc.

62. Collapse May Never Be Solved, Engineering News-Record, December 21, 1967, p. 69.

The article reviews aspects of the collapse of the three main spans of the Point Pleasant-Gallipolis Bridge on December 15, 1967. It was the first eyebar suspension bridge in the U.S. in which the eyebars formed the top chords of the stiffening trusses in both the main and anchor spans. The bridge design, the collapse sequence and the possible causes are also discussed.

63. Explosives and Demolitions, U.S. Department of the Army, Field Manual, FM 5–25, Washington, D. C., May 1967.

Information is provided on the type, characteristics, and uses of explosives and auxiliary equipment. Preparation, placement, and firing of charges is discussed. Charge calculation formulas are provided.

64. Five Die in New York Collapse, Engineering News-Record, February 2, 1967, p. 15.

Five workmen were killed when an ancient brickbearing wall building, standing on the edge of an excavation for a 40 story office tower, collapsed. Vibration caused by the power shovel work apparently caused the building to give way. The building had been a one-story blacksmith shop in the 1870's and was a four-story apartment building at the time of collapse.

65. Guide Pratique Des Installations De Gaz (Practical Guide for Gas Installations), Gas of France, et al., Paris, Joint Government decree of October 15, 1962, modified and complete March 17, 1967.

Distribution of gas and detailed requirements for installation in buildings are covered.

66. Newberry, C. W., The Response of Buildings to Sonic Boom, Sound Vibration, Vol. **6**, No. 3, Ministry of Public Building and Works, Building Research Station; England, 1967, pp. 406–418.

Some experimental observations of one excitation of building structures by sonic boom are reported. The question of coincidences between sonic boom periods (including reflections) and natural periods of building structures is particularly discussed.

67. Proposed Revision of ACI 347–63: Recommended Practice for Concrete Formwork, ACI Committee 347 (W. R. Waugh, Chairman), Journal of the American Concrete Institute, Proceedings, Vol. **64**, No. 7, July 1967, pp. 337–373.

Comprehensive recommendations for design and construction of concrete formwork covering the procedures, materials and structural types with extensive discussion of construction loading effects of reshoring multi-story structures. Indicates the need for careful consideration of design parameters such as live load to dead load ratios in deciding when to strip forms.

68. Recommandations Internationales Unifiees Pour Le Calcul Et L'Execution Des Constructions En Panneaux Assembles De Grand Format (International Recommendations for the Design and Construction of Large-Panel Structures), Comite Europeen du Beton, Bulletin No. 60, Paris, April 1967, English translation by C. V. Amerogen, Cement and Concrete Association, No. 137, London, July 1968.

A comprehensive set of design rules with commentary for large panel structures developed by CEB in 1966. Applicable to structures with floor or wall panels and with various types of joints. Specifies design rules for individual members, joints and tie beams. Promulgated prior to Ronan Point collapse, it treats provisions for prevention of progressive collapse only indirectly. It does require substantial continuity precautions which might have mitigated Ronan Point damage.

69. Robinson, J. R., Calcul Des Constructions Par Panneaux Assembles A Joints Verticaux Elastiques Plastiques (Design of Precast Panel Structures Assembled with Elasto plastic Vertical Joints), Comite Europeen du Beton Bulletin d'Information, No. 60, April 1967, pp. 173–197.

Considers the effect of elastic and plastic capacity of joints on precast panel structures. Indicates the advantages of ductility in such joints and suggests procedures for insuring reasonably ductile behavior of the joints between panels.

70. Secrecy Veils Bridge Collapse, Enginering News-Record, December 14, 1967, p. 27.

A five-span reinforced concrete beam and slab structure over a deep gorge near Mexico City collapsed, killing an estimated 30 workmen. Three central spans (72, 102, and 72 ft long) and two tall, slender piers collapsed into the gorge taking with them tons of steel tubing falsework. A commission of eight engineers is investigating the cause of the collapse. Apparently the falsework was being dismantled at the time of collapse.

71. Short, W. D., Structural Collapses During Erection or Demolition, Proceedings, Institute of Civil Engineers, London, Vol. **36**, March 1967, pp. 507–522.

The paper describes buildings and civil engineering structures which have collapsed in recent years during erection or demolition. These accidents were costly and often resulted in deaths or injuries. They could have been prevented if there had been a wider knowledge of the causes of failure.

72. Steel Span at Mid-Channel . . . Nose-Dives Into the River, Engineering News-Record, November 16, 1967, p. 19.

A $14-million, 1,600 ft long, high-level steel highway bridge collapsed during erection killing at least 20 workmen. Officials at the scene speculated that recent heavy rains had undermined one of the piers causing it to settle. As a result, the temporary cables supporting the inclined legs of the main-span frame snapped, triggering the collapse of the entire structure.

1968

73. Anatomy of Collapse, Engineering, London, November 15, 1968, p. 707.

Extracts from the official report of inquiry into the progressive collapse of a multi-story apartment building (Ronan Point) in London built entirely with industrialized (prefabricated) floors and bearing walls are included in the article.

74. Bridge Failure Triggers off Studies, Engineering News-Record, January 4, 1968, pp. 18–19.

The task of removing bridge parts, vehicles and bodies from the icy waters of the Ohio River at the site of last month's collapse of the 40 year old, eyebar suspension bridge between Point Pleasant and Gallipolis is nearly completed. Investigations into the cause of the disaster are just getting underway by a federal panel and The West Virginia Road Commission, which owns the bridge (see 62).

75. Collapse May Cause Law Change, Engineering News-Record, November 7, 1968, p. 33.

The total collapse of an almost completed four-story reinforced concrete building in Malaysia occurred while workmen were finishing jobs such as door and window adjustments, touch-up painting and hardware checking. Unofficial sources attribute the collapse to a concrete low in cement and high in sand. New building regulations may result from a governmental inquiry to determine the possible cause.

76. Concrete Pour Collapses Form, Engineering News-Record, June 13, 1968, p. 25.

The collapse of wood shores during a concrete pour for a 12-story building in Arlington, Va., killed three workers and injured 29. Workers had poured approximately 185 yd^3 of concrete on the third deck of plywood forms containing steel reinforcement bars. The deck forms for the 120×200 ft building were supported by 4×4 in wood jackposts resting on the completed second floor. When the posts gave, deck forms holding concrete for a 40×120 ft section of the building fell, collapsing the second floor to the street level.

77. Connell, K. F., and Smith R. B., Analysis of Causes and Determination of Possible Means of Prevention of External Damage to Pipelines, American Gas Association, Inc., Catalog No. L30005, New York, 1968.

An analysis of pipeline failures for the period 1950 through 1965 revealed that failures caused through the operation of mechanical equipment such as graders, bulldozers, and ditchers, appeared to be increasing slightly, while failures from all other causes were decreasing. A program was carried out to determine the causes and to develop recommendations to reduce the incidence of these "externally caused" failures.

78. Enquiry into the Accident at Canning Town, News of the Month, Concrete, London, Vol. 2, No. 6, June 1968, p. 228.

Initial news note summarizing the main effect of the accident in the Ronan Point apartment building, speculating on possible cause and announcing panel for the Ministry inquiry.

79. Feld, J., Construction Failure, John Wiley and Sons, Inc., New York, 1968.

A comprehensive treatment of causes of construction failures citing large numbers of reported construction failures and illustrating the more frequent types of failures occurring in the United States. Substantial treatment is given to failure from man-made-causes and natural disasters as well as failure of formwork and temporary structures. The book is well illustrated and contains many thoughtful recommendations for reduction of construction failures.

80. Flats Constructed with Precast Concrete Panels. Appraisal and Strengthening of Existing High Blocks: Design of New Blocks, Ministry of Housing and Local Government, Circular 62/68, London, England, November 15, 1968.

In this circular to all Local Authorities the Minister of Housing impressed most strongly on Local Authorities that all blocks over six stories built of large precast concrete panels must be appraised for resistance to progressive collapse, wind and fire and be strengthened, in accordance with the Technical Appendix. The standards set out in the appendix were ordered applied to new design. This circular applied to all existing and to new construction "pending the revision of Building Regulations and

Codes of Practice." Briefly the circular laid down two alternative methods of avoiding progressive collapse: "Method A—by providing alternative paths of support to carry the load, assuming the removal of a critical section of the load bearing wells," and "Method B—by providing a form of construction of such stiffness and continuity as to ensure the stability of the building against forces liable to damage the load supporting members." Under Method A, a series of arbitrary rules were laid down as a basis of acceptance, whereas under Method B the intent was that the Engineer should assess the members' ability to sustain the load defined (for discussion see 86).

81. Gas Turned Off, Engineering News-Record, August 22, 1968, p. 17.

The British government has told local government authorities to cut off gas supplies to some tall prefabricated apartment buildings as a result of the Ronan Point collapse. An interim report from a tribunal investigating the collapse is also discussed.

82. Godfrey, K. A., New Technology in Low-Income Housing, Civil Engineering, January 1968, pp. 43–55.

Rehabilitation of decaying urban areas has become a national goal. Part of the answer to this demand may be new technology meaning advanced production techniques. Author then describes prefabrication and the five new apartment housing systems.

83. Goffin, H., Grossformatige Wand-Und Deckentafeln Fur Den Hock-Und Industriebau (Large-sized Wall-and Ceiling Panels for Building Construction and Industrialized Construction), Betonstein-Zeitung, Weisbaden, June 1968, pp. 280–287.

This article describes, by means of examples, the problems resulting from the supervision of works and from the trend to guarantee high quality for prefabrication. Details are given of basic legal data, such as, building provisions and technical construction regulations as well as the various construction types and methods. Also being specified are volume stability, disk effects, bearing points and panel points, as well as tension-proof joints. Further physical aspects of construction, joints in sandwich-type slabs, and prefabrication in mining subsidence regions are described.

84. Griffiths, H., Pugsley, A., and Saunders, O., Report of the Inquiry into the Collapse of Flats at Ronan Point, Canning Town, Her Majesty's Stationery Office, London, England, 1968.

At about 6:00 a.m. on 16 May 1968 a gas explosion occurred in the southeast corner flat on the 18th floor of Ronan Point. The explosion blew out the concrete panels forming part of the load-bearing flank (or gable) wall. As a consequence, removal of this wall precipitated the collapse of the southeast corner above the 18th floor including both the bedrooms and living rooms. The weight of this portion of the building, as it fell, caused a progressive collapse of the remaining southeast corner flats down to the level of the cast-in-place concrete podium of the block. The report deals with the reasons for the collapse, the lessons learned from the disaster and contains recommendations for design of tall buildings.

85. Not Enough Bracing, Engineering News-Record, June 27, 1968, p. 7.

Insufficient lateral and diagonal bracing of 3×4 in wood jack posts caused the collapse of two floors of an Arlington office building during a concrete pour (see 76). Another contributing factor was that permanent steel girders to support two floors above a driveway had not been placed prior to the collapse.

86. Notes for Guidance Which May Assist in the Interpretation of Appendix 1 of the Ministry of Housing and Local Government Circular 62/68, RP/68/02, The Institution of Structural Engineers, London, December 1968.

The Institution of Structural Engineers consulted the Panel of Advisors appointed by the Ministry and the comments and explanations received on Circular 62/68 (see 80) are contained in RP/62/02.

87. Reese, L. C., and Matlock, H., Structural Damage from Tsunami at Hilo, Hawaii, Journal of the Hydraulics Division, ASCE, Vol. **94**, No. HY4, July 1968, pp. 961–982.

A study of the wave characteristics and a survey of structural damage to onshore structures due to the destructive Tsunami which stuck Hilo, Hawaii in May 1960.

88. Repercussions from the Failure of a Sub-Standard Brass-Nut. Editorial Comment, Concrete, London, Vol. **2**, No. 12, December 1968, pp. 480–481.

General comments are presented on the implications of Ronan Point disaster. The main point being one common factor in structural failures is an absence of that fundamental knowledge of how a particular structure is going to behave when it is approaching the limits of its stability and strength. The author states that such an understanding is the very quintessence of the art of the engineer, and it can never be replaced, only assisted by codes or regulations. Thus, there is need for constant

review of old codes to match new building techniques.

89. Report of British Collapse Cites Building Code Flaws, Engineering News-Record, November 21, 1968, p. 23.

This article reports that loopholes in Britain's building codes possibly contributed to the progressive collapse of all 24 floors on one corner of a 24-story London apartment house (see 94).

90. Ronan Point Inquiry, News of the Month, Concrete, London, Volume **2**, No. 9, September 1968, p. 351.

Contains verbatim copy of text of interim advisory letter from the chairman of the Ronan Point collapse inquiry panel to the Minister of Housing briefing him on the probable causes of the collapse, and suggesting that all "system" built high rise apartment buildings be examined for susceptibility to "progressive collapse." It suggests gas be turned off in any susceptible units and a strengthening program undertaken. The article also contains detailed excerpts from the Ministry letter to local governments giving advice on immediate measures to be taken.

91. The Ronan Point Inquiry and the Significance of Structural Joints, Editorial Comment, Concrete, London, Vol. **2**, No. 7, September 1968, p. 348.

Editorial commenting on the letter of the Chairman of the Panel of Inquiry to the Ministry which had stated preliminary panel findings concerning the Ronan Point collapse. The editorial points out progressive collapse is not a new phenomena having occurred during construction of Gothic cathedrals during medieval ages and that "system building" is not the only class of construction with potential for such type of collapse.

92. The Structural Behavior of Ronan Point, Concrete, London, Vol. **2**, No. 12, December 1968, pp. 488–491.

This article reports, almost verbatim, those sections of the report of the tribunal of inquiry into the partial collapse of Ronan Point that describe the design of the block, how it behaved structurally at the time of the collapse, and how it would behave under severe wind loads (see 84).

93. Structural Stability and the Prevention of Progressive Collapse, RP/68/01, The Institution of Structural Engineers, London, England, December 1968.

Recommendations concerned primarily with large residential buildings comprised of prefabricated panels which discusses basin principles, planning (of structural layout), workmanship and erection, all in general terms. It contains general recommendations on design to avoid progressive collapse.

94. Systems Built Apartments Collapse, Engineering News-Record, May 23, 1968, p. 54.

The article reports the collapse of a new, 24-story prefabricated apartment house in London (Ronan Point). The collapse is attributed to a gas explosion near the top that blew out an exterior, one-story high bearing wall, triggering a chain reaction that collapsed walls and floor slabs on all 24 stories.

1969

95. Alexander, S. J., and Hambly, E. C., Design of Domestic Buildings to Withstand Gaseous Explosions, Ove Arup and Partners, Consulting Engineers, London, England, May 1969.

Various means of reducing the consequences of gas explosions in buildings such as, complete removal of the explosive source, force ventilation, and control of the maximum flow of gas from the supply are discussed. A qualitative description of the nature of a gas explosion in terms of gas/air mixture, presence of venting, pressure rise, turbulence, and other related parameters, is presented. A method of analysis of structures subjected to these dynamic loads is provided.

96. Balcony Fails During Construction, Engineering News-Record, August 7, 1969, p. 37.

A 26×6 ft balcony at the 18th floor of a 22-story reinforced concrete apartment building collapsed in Buenos Aires. The falling balcony ripped off those on the next three lower floors.

97. Building Regulations: The Fifth Amendment and the Freedom to Design, Editorial Comment, Concrete, London, Vol. **3**, No. 9, September 1969, pp. 343–344.

A critical and thoughtul evaluation of the Report of the Panel of Inquiry on the Ronan Point collapse and the subsequent amendments to the Building Regulations. The editorial advocates placing responsibility with the design engineers and minimizing specific provisions in building regulations. The article also claims the Ronan Point design never conormed to existing building regulations.

98. Bygningsreglement for Kobstaederne Og Landet. Tillaey Nr. 3. Midlertidige Krav Til Bygningers Stabilitet. (Building regulations for urban and rural areas. Amendment No. 3 Provisional Requirements for Stability of Buildings), Denmark, February 1969.

Two minimum requirements are stated for building with more than 6 stories; either (a) or (b) must be satisfied:

(a) in every room limited by an outer wall, a floor and/or the outer wall should be able to fail without causing destruction of any floors other than those limiting the room.

(b) every normal section in a load carrying outer wall and in a floor shall be designed for a tensile force of 2 Kgf/m using allowable stresses . . . The necessary reinforcement may be placed in the elements and/or in the joints between the elements.

99. Coles, B. C., and Hamilton, W. A., Repetitive Dynamic Loading on Pretensioned Prestressed Beams, Journal of the American Concrete Institute, Proceedings, Vol. **66,** No. 9, September 1969, pp. 745–747.

A laboratory investigation of the dynamic behavior and the magnitude of the reduction in load carrying capacity of beams subjected to several repetitions of dynamic load (simulated blast-type loading) shows that the calculated ultimate static load is a satisfactory design criterion and that bond failure does not appear to be a critical factor.

100. Collins, A. R., et al., The Implications of the Report of the Inquiry into the Collapse of Flats at Ronan Point, Canning Town, The Structural Engineer, London, Vol. **47,** No. 7, July 1969.

A series of discussion are presented that deal with the implications of the Report of Inquiry into the Collapse of Flats at Ronan Point, Canning Town (see 84). The Tribunal inquired into the circumstances affecting the progressive collapse of the flats on May 16, to ascertain the cause or causes, and to consider the implications of the findings, and to make recommendations. Some of the longer-term implications of what the Tribunal had to say have hardly been discussed. There was the comment in the broadest sense that architects and engineers had been found wanting. There was the stricture that, unless British Standards and Codes of Practice were kept up to date, false standards might be set up which would lull those concerned with new forms of construction into a dangerous complacency.

101. Comments of the Institution of Structural Engineers to the Ministry of Housing and Local Government on the Proposed (Fifth) Amendments to the Building Regulations, The Structural Engineer, London, Vol. **46,** No. 9, September 1969, p. 376.

Institution of Structural Engineers' comments on the proposed (Fifth) Amendment to the Building Regulations.

102. Comparison of the Relative Safety of Gas and Electric Appliances, Shell International Gas Limited, Report No. SIG 69/9, London, October 1969.

A comparison is given of potential and existing fire hazards related to the use of gas or electric utilities in Great Britain.

103. Despeyroux, J., L'Effondrement De L'Immeuble De Ronan Point Et Ses Consequences En Matiere De Codification (The Collapse of the Ronan Point Building and its Consequences with Regard to Code Writing), Annales de l'Institut Technique du Batiment et des Travaux Publics, No. 263, November 1969, pp. 1800–1803.

The author points out that well prior to the Ronan Point collapse the CEB regulations spoke of panel structures as a "house of cards" and called for mechanically continuous networks of reinforcement to prevent progressive collapse. Many structures have been built in contempt of these regulations. He regrets that the official Ronan Point inquiry report did not specifically point out that the destroyed building violated these CEB principles and doubts that if these principles had been followed that the progressive collapse would have occurred. Commenting on the British Fifth Amendment, he indicates the 5 psi pressure as excessive and the alternate path method as being too confusing and complex.

104. Despeyroux, J., Recommandations Internationales Unifiees Pour le Calcul et L'Execution Des Structures En Panneaux Assembles De Grand Format (Unified International Recommendations for the Calculation and Construction of Large Panel Structures), Comite Europeen du Beton Commission XIII. Structure en panneaux (Panel Structures), 1969.

Contains basic design philosophy for large panel structures. Points out the basic dangers of progressive collapse and suggests proper design and detailing philosophies to minimize risk. Suggests that CEB 1964 regulations require additional factors of safety in bearing wall type structures.

105. A Failure of the Organizational System. News of the Month, Concrete, London, Vol. **3,** No. 6, June 1969, P. 215.

Summarized remarks of the President of the Institute of Structural Engineers that failure of Ronan Point was essentially a failure of an organizational system that relied too much on regulations and blurred the responsibility of the design professionals.

106. Fieldhouse Collapse, Engineering News-Record, March 6, 1969, p. 7.

Eighteen long-span steel joists partially framing a cross-shaped, 405×322 ft fieldhouse at the University of Dayton, Ohio, collapsed. The 8 ft deep, 8 ft c-c joists spanned 186 ft to jack trusses spanning 48 ft between column bays. Cause of the collapse is not yet determined.

107. Fifty-three Killed in Building Collapse, Engineering News-Record, June 19, 1969 p. 75.

A three-day old reinforced concrete restaurant near Madrid collapsed killing 53 persons and injuring 145. Construction of the two-story structure was rushed, and reports said that some of the poured concrete was not cured. The collapse began when the steel supported slate roof suddenly gave way. Seconds later, a portion of the ground floor caved in, dropping 250 persons into the basement. In a series of thundering cave-ins, the entire structure fell in.

108. Firnkas, Sepp, Book Review of Report on the Inquiry into the Collapse of Flats at Ronan Point, Canning Town, England, Civil Engineering—American-Society of Civil Engineers, November 1969, p. 96.

A reasonably comprehensive review of the report of the commission of inquiry into the Ronan Point disaster. Contains several of the key figures and photos. The author points out important differences between U.S. and European philosophy regarding joints as regards ductility and implies U.S. practice would be considerably more conservative than that found in Ronan Point (see 84).

109. Firnkas, S., Concrete Panel Building System: Progressive Collapse Analyzed, Civil Engineering—American Society of Civil Engineers, November 1969, pp. 60–62.

The collapse of a flat at Ronan Point is reviewed and an alternate path design philosophy is suggested by the author. The paper points out that Ronan Point's structural system relied on gravity and friction to develop strength in the joints. This proved inadequate and when an explosion occurred in a corner apartment, all the units above collapsed progressively to the ground. The author suggests that joints must be quasi-monolithic and be able to handle both tensile and compressive loads.

110. Glassman, A., Structural Failures, International Civil Engineering, London, No. 5, May 1969, pp. 216–223.

The causes of failure may be placed in two categories. The first category covers cases where the cause of failure is clear from the beginning. The second category covers cases of cracking or building collapse due to undetermined causes which must be clarified. The subject is discussed under the following headings: characteristics of investigations; failure due to faulty design; failure due to calculational faults; damages caused by settlement of foundations and soil action; failure due to overload; failure due to temperature influence; failure due to shrinkage and creep; and failure due to fire.

111. Guidance on the Design of Domestic Accommodation in Load-Bearing Brickwork and Blockwork to Avoid Progressive Collapse Following An Internal Explosion, RP/68/03, The Institution of Structural Engineers, London, England, May 1969.

Guidance is given for the design of load-bearing brickwork structures to withstand an appropriate nominal static pressure, representing a possible internal gas explosion, together with the additional ability to bridge over severe structural damage arising from pressure in excess of this nominal value.

112. Hanson, K. and Olesen, S. Ø., Failure Load and Failure Mechanism of Keyed Shear Joints. Test Results II, Danmarks Ingeniorakademi Bygningsafdelingen (Danish Academy of Engineering Building Department), Report No. 69/22, Copenhagen, June 1969.

The results of tests which have been made for the determination of the strength and stiffness of vertical, keyed shear joints between wall elements of pre-fabricated concrete are described. The study includes the effect of strength of joint concrete, reinforcement ratio, reinforcement in deck joint versus hairpin reinforcement in the wall joint. shrinkage in the wall joint and repeated loadings above cracking load with changing direction of the shear forces.

113. Haseltine. B. A., and Thomas. K., Load-Bearing Brickwork-Design for Accidental Forces. Clay Products Technical Bureau, Technical Note 6, Vol. 2, London, July 1969.

This Technical Note is intended to assist engineers designing load bearing brickwork structures to comply with the Institution of Structural Engineers document Guidance on the Design of Domestic Accommodation in Load-bearing Brickwork and Blockwork to Avoid Collapse Following an Internal Explosion. Only buildings containing domestic residential accommodations are covered.

114. Large Panel Structures, Editorial Comment, Concrete, London, Vol. **3**, No. 6, June 1969, p. 213.

Reports on meetings of the Institution of Structural Engineers and the Concrete Society approximately one year after the Ronan Point explosion (see 115). Editorial decries treatment of the problem in static and not dynamic terms and is critical of the alternate path of support concept.

115. Large Panel Structures, Concrete, London, Vol. **3,** No. 7, July 1969, p. 262.

A short synopsis is given on the main points brought out at a meeting held by the Concrete Society to discuss the paper Large-panel Structures—Notes on the Draft Addendum 1 to CP 116 (1965), by A. Short and J. R. Miles. One main point was almost unanimous condemnation of the arbitrary design approaches put forward in the appendix to the Ministry's circular 62/68. Further criticism was directed upon the alternative path or "fail-safe" approach and the static pressure design of 5 psi. Suggestions were that: an explosion in a building was a problem of the dynamic response of a structure and not one of statics and; there should be more emphasis on programs for test information.

116. Ligtenberg, F. K., Vailigheid En Catastrofen (Structural Safety and Catastrophic Events), TNO-Nieuws, **24,** Amsterdam, 1969.

The customary methods for calculating the strength of structures start from the assumption that a factor of safety between the strength of a structure and the given loads furnish a sufficient guarantee that abnormal loads can be sustained. Statistical considerations combining the strength of the materials, the type of the structure, the magnitude of the loads and the frequency of the occurrence of abnormal loads like fire, explosions, collisions, etc., show that this assumption is justified for small structures consisting of only a limited number of elements. A structure of greater dimensions, however, is not allowed to collapse as a whole if one of the elements fails. In this case, as well as the probability of a disaster, the magnitude of a disaster increases with the magnitude of the structure. The magnification of scale which is a marked tendency in modern buildings makes it necessary to consider these aspects seriously. It is necessary that methods be found for locating "critical" elements in a structure as well as developing design methods for a "fail-safe" design.

117. Lugez, J., Zarzvcki, A., Influence Des Joints Horizontaux Sur La Resistance Des Elements Prefabriques De Murs Porteurs (Influence of Horizontal Joints on the Resistance of Prefabricated Panel Elements of Bearing Walls), Cahiers du Centre Scientifique et Technique du Batiment, No. 103, Paris, October 1969.

The effects of horizontal joints on the strength of prefabricated elements are described. The analysis conducted for various parameters is based on observations of cracking and collapse phenomena, on a comparison of test results and, wherever possible, on simplified theoretical considerations.

118. Mast, R. F., Auxiliary Reinforcement in Concrete Connections, American Society of Civil Engineers, Journal of the Structural Division, June 1969.

A method is presented for the design of auxiliary reinforcement in concrete connections. This method is based on a physical model, which may be judiciously used to extrapolate designs into regions not covered by previous tests. Rather than attempting to predict the nature of cracking in a concrete connection, cracking in an unfavorable manner is assumed. Reinforcement is then provided, in accordance with the shear-friction hypothesis, to assure that this cracking will not lead to premature failure.

119. Mr. Hubert Bennett on Ronan Point. News of the Month, Concrete, London, Vol. **3,** No. 6, June 1969, p. 215.

Summary of a speech by a prominent British architect which indicated that Ronan Point was a unique occurrence and pointed out that application of new standards to guard against a repetition would cost millions of pounds in England alone.

120. Norme Per Il Calcolo E La Contruzione Di Structure A Grandi Panelli. Ministerio del Lavorio Pubblici, Rome, 1969.

Italian code of practice for structures manufactured from large panels.

121. Paddleford, D. F., Characteristics of Tornado Generated Missiles, Westinghouse Electric Corporation, Nuclear Energy Systems, Pittsburgh, Pennsylvania, April 1969.

To check or assess the effects of tornado-induced missiles on a plant design it is necessary to assume a spectrum of missile sizes and velocities that could accompany a tornado. The wind field of a tornado has been described

using relations appearing in the technical literature and solutions of the trajectory of a spectrum of missiles have been obtained numerically for a number of cases. The resultant size-velocity relationship for missiles generated by a 300-mph tornado is given graphically, and these results are used to obtain the velocities of typical objects that could be postulated as potential tornado missile sources.

122. Pipeline Accidents Report. Low-Pressure Natural Gas Distribution System, Gary, Indiana, National Transportation Safety Board, Washington, D.C., June 1969.

A gas line failure in Gary, Indiana is investigated and recommendations are made by the investigating Safety Board.

123. Precast Concrete Garage Collapses, Engineering News-Record, May 22, 1969, p. 51.

A majority of the precast concrete framing components for a five-story garage collapsed in Las Vegas injuring three workmen. According to a job spokesman, something apparently gave way on the level beneath the fifth level causing the slabs and girders on the fourth and fifth levels to fall on the floors below. This triggered a chain reaction to the ground.

124. Proposed Amendments to the Building Regulations 1965, Ministry of Housing and Local Government, London, England, May 30, 1969.

The proposed amendments to include provisions dealing with progressive collapse constitute the first installment of the Ministry of Housing and Local Government's proposals for amendment of the building regulations in the light of the recommendations of the Tribunal of Inquiry into the collapse of flats at Ronan Point.

125. Rapport Fra Dansk Ingeniorforenings Fragards Udvalg For Bygningers Stabilitet Ved Lokal Overpavirkning (Report of the Committee on Stability of Buildings Subject to Local Unpredictable Additional and/or Accidental Loads and Effects), Expert Council of the Danish Society of Engineers, May 1, 1969 (in Danish).

Explosions, vehicular impact and other local overloads are described.

126. Rapport Fra Dansk Ingejorforenings Fragads Udvalg For Bygningers Stabilitet Ved Lokal Overpavirkning (Report from the Danish Engineering Association Professional Committee for the Stability of Buildings under Local Overloads), Dansk Ingerjorforening, Kopenhamm, 1969.

A well illustrated report of the effects of local overloads such as explosions and vehicular impacts on stability of structures. Includes a very thorough classification of various types of local overloads.

127. Rasbash, D. J., Explosions in Domestic Structures; Part 1: The Relief of Gas and Vapour Explosions in Domestic Structures, The Structural Engineer, Vol. **47**, No. 10, October 1969, pp. 404–408.

A quantitative approach to estimating the pressures that may develop in domestic structures during gas and vapour explosions is suggested which takes account of the influence of potential explosion relief, such as external windows, doors, etc., of a structure similar to that of the London industrialized apartment building (Ronan Point), which collapsed partially due to an explosion.

128. Reporting Can Prevent Failure, Editorial, Engineering News-Record, February 6, 1969, p. 186.

Comments on the importance of reporting structural failures, which lead to advances in the practice of design and construction methods, are contained in this editorial. The Ronan Point Inquiry is mentioned as an example. The editorial states that a 1967 CEB report had specifically mentioned the danger of progressive collapse in large panel concrete construction, but had not been widely disseminated.

129. Robinson, J. R., Observation Sur Les Conclusions Du Rapport De La Commission D'Enquete De Ronan Point (Observation on the Conclusion of the Report of the Inquiry Commission on Ronan Point), Annales de l'Institut Technique du Batiment et des Travaux Publics No. 263, November 1969, pp. 1797–1799.

This article presents approximate calculations which lead the author to a conclusion that the Ronan Point apartment could not withstand pressures greater than a static equivalent of approximately 1½ psi. It points out that the risk of progressive collapse has been present in high-rise masonry bearing wall buildings for a long time, but has not generally been considered. The author feels that the "alternate path" criteria is too severe and suggests engineers have long designed statically determinate structures which have no alternate path (metal trusses, for example). He suggests simple principles for design of bearing wall structures in which venting principles would be considered.

130. Rodin, J., Statistical Design Against Progressive Collapse, The Consulting Engineer, London, August 1969.

Safety is related to both the risk and structural consequence of particular events relevant to the satisfactory behavior of structures. Absolute safety against all possible conditions and hazards can never be achieved, thus the problem is one of reducing the risk. By assessing the statistics of all foreseeable hazards in terms of risk, coupled with structural consequences, a uniform level of safety can be achieved, acceptable safety at an acceptable cost. The acceptable risk of life should be decided by politicians and representatives of the community at large, not the structural engineer. The design against progressive collapse can be done in three ways:

(a) eliminate the hazards which may lead to local failure or reduce the risk to an acceptable value.
(b) design so that the hazard does not cause any local failure.
(c) allow the local failure to take place, but design the structure against progressive collapse.

Risk of internal explosions is covered and a statistical method for evaluating the risk is presented.

131. Ronan Point, Engineering News-Record, October 30, 1969. p. 74.

The article summarizes the Ronan Point collapse and the conclusions of a special investigating board. It points out that thus far, however, more than a year after the collapse, there is more discussion than action.

132. Rozvany, G. I. N.. and Woods, J. F., Sudden Collapse of Unbonded Underprestressed Structures, Journal of the American Concrete Institute, Proceedings, Vol. **69**, No. 2, February 1969, pp. 129–135.

Expenditures and theory demonstrate that unbonded prestressed slabs and rectangular beams having a smaller average prestress than the modulus of rupture become flexually unstable at the cracking load.

133. Saillard, Y., Le Comportement De L'Immeuble De Ronan Point En Comparaison Des Principles De Base Des Recommandations Internationales 'Structures En Panneaux' du Comite Europeen du Beton (Behavior of the Ronan Point Building Compared to the Basic Principles of the International Recommendation "Panel Structures" of the Comite du Beton), Annales de l'Institut Technique du Batiment et des Travaux Publics, No. 263, November 1969, pp. 1804–1806.

Traces the development of the CEB recommendations for large panel structures and states it was published in CEB Bulletin 60 in Paris in French in July 1967. States examination of plans of Ronan Point show it did not meet the requirements of the CEB principles. Points out the Algiers building shown in the Ronan Point inquiry report did meet these requirements and survived a severe explosion. States detailed examination of the Ronan Point incident did not result in any changes to the CEB document. This paper details the authors opinions of the shortcomings of the new British recommendations and is extremely critical of the "alternate path" concept.

134. Short, A., and Miles, J. R., An Introduction to the New Code of Practice for Large Panel Construction, Concrete, London, Vol. **3**, No. 4, April 1969, pp. 121–123.

A review of the new provisions for large panel construction proposed for the British "Unified Code of Practice" related to abnormal loading conditions, origin and nature of progressive collapse and tie-forces.

135. Starr, C., Social Benefit Versus Technological Risk, What Is Our Society Willing to Pay for Safety? Science, Washington, D.C., Vol. **165**, September 1969, pp. 1232–1238.

An approach is offered for establishing a quantitative measure of benefit relative to cost for an important element in our spectrum of social values—specifically, for accidental deaths arising from technological developments in public use. The analysis is based on two assumptions. The first is that historical national accident records are adequate for revealing consistent patterns of fatalities in the public use of technology. The second assumption is that such historically revealed social preferences and costs are sufficiently enduring to permit their use for predictive purposes. In the absence of economic or sociological theory, this empirical approach provides some insights into accepted social values relative to personal risk.

136. Strengthening System-Built Blocks of Flats, Concrete, London, Vol. **3**, No. 4, April 1969, pp. 119–120.

Description of the work required to strengthen 29 blocks in inner London is given. This action was undertaken after the Ronan Point disaster and complies with method B of the Institution of Structural Engineer's Notes for Guidance which was prepared to insure the flats can withstand a recommended static pressure of 2.5 psi. The strengthening, which was carried on from inside the building, involved the bolting of steel angles to the precast concrete units of certain junctions,

thereby increasing the strength of the wall-to-floor joints. This work will provide a tensile resistance at each floor level, in both directions, of more than 1,500 lb/ft.

137. Stretch, K. L., Explosions in Domestic Structures; Part Two: The Relationship Between Containment Characteristics and Gaseous Reactions, The Structural Engineer, London, Vol. **47,** No. 10, October 1969, pp. 408–411.

Explosions caused by vapor phase reactions between common inflammable solvents or sources of energy and air and the influence of particular features of domestic buildings are examined. The inherent features of established structural systems which have obscured the necessity for special precautions in some novel systems are discussed, as well as factors such as adequate venting, that should be included in any satisfactory design code. Simplified forms of the pressure waves are described and the impact on structures of traditional brick design, of framed buildings and of concrete panel construction are analyzed.

138. Structural Safety and Progressive Collapse, Concrete, London, Vol. **3,** No. 2, February 1969, pp. 47–48.

Outlines developments in the British Institution of Structural Engineers and Comite Europeen du Beton following the Ronan Point inquiry panel report. It cites the basic documents and designs principles endorsed by both groups to limit susceptibility to progressive collapse of large panel structures.

139. The Structures of Large Panel Buildings, Calculation and Design, Project of Polish Standards PN–68/B–032531, Warsaw, 1969.

The subject of the standard is the structural design and detailing of large panel buildings. The principles presented deal with residential houses, hotels, schools, hospitals, etc., of heights not exceeding 16 stories with load bearing walls made of normal and lightweight aggregate concrete.

140. Structures to Resist the Effects of Accidental Explosions, US Department of the Army, the Navy, and the Air Force, TM 5–1300 NAVFAC P–397, AFM 88–22 technical manuals, respectively, Washington, D.C., June 1969.

The design of protective construction to limit the effects of an accidental explosion is described. Among the items covered include the basis for design, effects of explosions, and construction details. Analysis and design for both ductile and brittle mode response are discussed.

141. Systems Buildings, Engineering News-Record, Special Report, New York, Reprint from October 30, 1969.

A history of systems buildings is presented together with a discussion of current trends in U.S. construction. The efforts of European Governments to increase building construction are evaluated and several systems described.

142. The Technical Advisory Panel on Explosion Research, England, 1969.

Four major aims to follow in research on explosion hazards in buildings are identified. The first should be a survey to determine the incidence and nature of gas explosions as well as their cause and effect, to determine the degree and nature of the risk. The second, to determine whether the risk of explosion can be reduced by providing ventilation methods to disperse dangerous vapors taking account of their practicability and relation to heating cost. The third, to determine whether the pressures created by unavoidable explosions can be eliminated or controlled by venting. Finally, the last project should be the study of the effects of the pressures from explosions on structures of various kinds to establish provisions that may be required in structures to resist pressures that cannot be avoided.

143. Tests on Large Panel Construction, Bison Bulletin No. 7, Concrete Limited, 399 Strand, London, W. C. 2., England, 1969.

Tests were conducted on all aspects of the construction of the Bison Wall frame system in relation to the new criteria demanded by the Ministry of Housing Circular 62/68 (see 80). In the tests, the behavior of walls and floors, and the joints between them were checked under an assumed force being equivalent to a standard static pressure of 5 psi (720 lb/ft^2). Further tests were carried out on floors to determine their resistance to debris-loading in the event of a partial collapse of the building.

144. Wiggins, J. H., Effects of Sonic Boom, J. H. Wiggins Company, California, 1969.

Theoretical and experimental aspects of the sonic boom are discussed along with measured behavior of structural elements subjected to sonic boom. Claims for sonic boom damages are discussed from the standpoint of inspection procedures and litigation experience.

145. Wilson, C., Gabrielsen, B., Edmunds, J., and Bechtel, S., Loading and Structural Response of Wall Panels URS Research Company, Technical Report, California, November 1969.

The progress on a long-range program to investigate the loading, structural response, and debris characteristics of wall panels is presented. The objective of the study, which combines both analytical and experimental work, is the development of improved prediction methods of the mechanics of structural failure and fragmentation. During this reporting period which extends from December 1968 to August 1969, the major effort has been devoted to an analytical program which has included wall panel failure predictions to aid in the design of the experimental test program; wall panel failure theory; development of statistical failure theory for brick structures; and preliminary consideration of preloaded wall panels. Effort was also devoted to an experimental program which included loading tests, brick wall panel tests, concrete wall panel tests, interior sheetrock wall panel tests, a static test program, and a small number of tests to investigate the effect of air blast on civil defense shelter ventilating equipment.

1970

146. Accident Analysis, Nuclear Safety, Vol. **11,** No. 4, July–August 1970, pp. 298–308.

Nuclear plant safety is discussed with respect to tornado threats. Several aspects of tornados are covered, such as probability and design of vital structures. The most important aspects covered are the tornado wind forces and pressures and the possibility of tornado generated missiles which can produce a threat to the stability of buildings.

147. Alexander, S. J., and Hambly, E. C., The Design of Structures to Withstand Gaseous Explosions, (Part 1 and Part 2), Concrete, London, Vol. **4,** No. 2, February 1970, pp. 62–65, and Vol. **4,** No. 3, March 1970, pp. 107–116.

A method is developed for the design of structures to withstand the dynamic loading from gaseous explosions similar to that which caused the collapse at Ronan Point. The loading pressure pulse is described qualitatively because a precise description cannot be given because of the absence of relevant research data. The response of a structure to such dynamic loads is discussed and a method of design presented, with examples for floor slabs and load bearing walls. It is shown that relatively small amounts of reinforcement provide a substantial resistance to explosions. Proposals are given for the research that must be carried out to determine the design pressure pulse and to check the validity of the assumptions made.

148. Allgood, J. R., and Swihart, G. R., Design of Flexural Members for Static and Blast Loading, Monograph No. 5, American Concrete Institute/Iowa State University, Detroit, 1970.

The fundamentals of blast dynamics are reviewed, design criteria are established, and methods for the selection of reinforced concrete beams and slabs to resist static or blast loads are presented. A number of illustrative examples are given. References are made to experiments that verify the fundamental concepts and to sources which present more detailed discussion of specifics.

149. Apartment Building Collapses Despite Shoring, Engineering News-Record, June 25, 1970, p. 13.

A seven-year-old, 15-story reinforced concrete apartment building in Buenos Aires totally collapsed killing at least 15 persons and injuring several others. The article explains the condition of the building at the time of collapse. Severe cracking had been noted in a number of columns and the structure had been shored.

150. The Behavior of Structures When They Resist Explosions, Editorial Comment, Concrete, London, Vol. **4,** No. 3, March 1970, p. 87.

The editorial points out very little was undertaken in the two years after the Ronan Point collapse to determine true dynamic behavior and resistance of structures to gas explosions and calls attention to limited test programs which indicate dynamic response to pressure pulses far exceed static analysis and response.

151. Britain Tightens Building Standards, Moves to Stem "Progressive Collapse," Engineering News-Record, April 16, 1970, p. 12.

The article discusses the administrative regulations issued in 1968 by the British government which have now been made by Parliament. The provisions are written especially to prevent progressive collapse, like the structural failure at Ronan Point. Adoption of the law's high-rise standards brought mixed reaction within the industry and these views are presented.

152. Building Explodes as Gas Leak is Sought. Engineering News-Record, February 5, 1970, p. 25.

A gas line explosion leveled a two-story brick building in downtown Houma, La., on January 24, killing three persons and damaging several other structures. The blast occurred as a utility crew and firemen attempted to reach a reported leak.

153. The Building (Fifth Amendment) Regulations 1970 Notes for Discussion (RP/68/04), The Institution of Structural Engineers, London, England, June 1970.

The Institution has provided these notes as an interpretation of the sections of the Fifth Amendment. The notes are intended as a guide for engineers.

154. Building Regulations and Public Health and Safety, Editorial Comment, Concrete, London, Vol. 4, No. 5, May 1970, p. 165.

Editorial traces the development of the concept of "progressive collapse" and the design philosophies to limit failures to local collapse. It criticizes the Ministry of Housing for issuance of "panic document 62/68" and the "unjustified 5 psi" criteria.

155. Canadian Structural Design Manual 1970, (NCR No. 11530), Supplement No. 4 to the National Building Code of Canada, National Research Council of Canada, Ottawa, 1970.

This is an introduction to the Canadian Code of Practice provision requiring progressive collapse to be considered (see 177).

156. Collapse Blamed on Gas Blast, Engineering News-Record, March 19, 1970, p. 3.

The collapse of a block-long four-story, reinforced concrete building in Godthaab, Greenland, last week has been tentatively blamed on an explosion in a gas line that runs the length of the building in the basement. Nine persons died in the collapse, which dislodged central heat and gas main serving the six-building complex.

157. Collapse of 10 Floor Sections Kills Two Workers, Engineering News-Record, March 5, 1970, p. 15.

Sections of 10 floors of a 20-story apartment building under construction in Pittsburgh collapsed killing two men. Apparently, an overload of masonry block on the concrete plank floor of the 19th floor caused the failure. The weight of the falling block and planking then sheared off 8×20 ft sections of nine floors of the building, finally dumping an estimated 40 tons of debris onto the 10th floor.

158. Comite Europeen du Beton-Federation Internationale De La Precontrainte (International Recommendations for the Design and Construction of Concrete Structures. Principles and Recommendations), June 1970, FIP Sixth Congress, Prague, Cement and Concrete Association, London SWI, 1970.

These recommendations are the result of combining the CEB Recommendations for an International Code of Practice for Reinforced Concrete (first edition 1964) and the draft FIP-CEB Recommendations for the Design and Construction of Prestressed Concrete Structures (edition issued in June 1966). These earlier texts have been completely revised in the light of the development of knowledge of the subjects. The basic feature of these new 1970 Recommendations is that they cover the whole field of joint concrete and steel action, from reinforced to prestressed concrete, both with regards to design and construction. Similarly, structural lightweight concretes have been considered along with normal aggregate concretes.

159. Creasy, L. R., Department of Civil Engineering Technical Instruction Serial 54, Department of the Environment, London, August 1970.

The technical instruction gives design procedures and guidance on the interpretation of the Fifth Amendment to the Building Regulations to improve building structures resistance to the onset of progressive collapse should damage occur locally.

160. Creasy, L. R., Interpreting the Fifth Amendment to the Building Regulations, Concrete, London, Vol. 4, No. 6, June 1970, pp. 216–218.

Because of the uncertainty of the term structural collapse and the doubt concerning the distribution and magnitude of stress under such conditions, engineers and local authorities have been interpreting the Fifth Amendment in a variety of ways. Mr. L. R. Creasy, Chief Engineer to the U. K. Ministry of Public Building and Works, discusses his interpretation of the document speaking only as a structural engineer. A typical cast-in-place concrete building of framed construction was chosen as an illustrative example. Removal of various structural elements such as, slabs, columns, and beams, was then discussed, and the strength which the remaining members had to develop to prevent excessive structural damage was analyzed (see 163).

161. Custard, G. H., Donahue, J. D., and Thayer, J. R., Evaluation of Explosive Storage Safety Criteria, Falcon Research and Development Company, Denver, Colorado, May 1970.

Relationships have been developed to help in the understanding of the risks which are implied in the established explosive quantity-distance criteria. These relationships provide a basis for estimating the potential damage to structures exposed in a blast field which is sufficient to cause incipient structural failure. The study was implemented through the definition of ten specific structures which have been "exposed" to the blast forces from five charge sizes through analytical modeling techniques. Investigation was limited to target response to air blast forces with no consideration to ground shock, fragmentation hazards (except glass), fire hazards or other potential threats.

162. Discussion on Explosions in Domestic Structures, The Structural Engineer, London, Vol. **48,** No. 8, August 1970 pp. 319–329.

A series of discussions are presented which deal with the papers The Relief of Gas and Vapour Explosions in Domestic Structures, by D. J. Rasbash (see 127) and The Relationship between Containment Characteristics and Gaseous Reactions, by K. L. Stretch (see 137).

163. Discussions to Interpreting the Fifth Amendment to the Building Regulations, Concrete, London, Vol. **4,** No. 7, July 1970, pp. 275–276.

Discussion on Mr. Creasy's interpretation of the Fifth Amendment with respect to the example presented in his article Interpreting the Fifth Amendment to the Building Regulations (see 160).

164. Dobbs, N., and Cohen, E., Model Techniques and Response Tests of Reinforced Concrete Structures Subjected to Blast Loads, Models for Concrete Structures, 1970, ACI Publication SP–24, pp. 407–447.

Model testing of reinforced concrete protective structures subjected to blast loads in order to verify design and construction techniques required for comparative scaling indicate that damage sustained by the model and full scale structures is similar if each is tested in a similar manner, thereby establishing that model tests may be used to evaluate the structural response of full-scale reinforced concrete structures to high explosive detonations.

165. Draft Recommendations for the Choice of Design Schemes, Soviet Economic Mutual Aid, Moscow, February 1970.

Section 6, Design Requirements for Accidental Loads, gives recommendations to follow when designing a multi-story large-panel building in which there exists the possibility of an accidental explosion. The regulations give suggestions to be considered in choosing structural solutions for the building to prevent progressive collapse from a local failure.

166. The Fifth Amendment. Notes for next weeks ISE discussion, Building, June 26, 1970, pp. 101–102.

A series of notes discussing individual sections of the English Building (Fifth Amendment) Regulations 1970 prepared by a working party of the Institution of Structural Engineers to serve as a basis for a public discussion of these regulations proposed to safeguard against progressive collapse. Contains detailed, section-by-section comments on the proposed amendments.

167. Flak, H., Hellers, B. G., Holmgren, J., and Hoglund, T., Stormskador i Stockholmsomradet (Storm Damage in the Area of Stockholm), Statens Rad for Byggnadsforsking, R 44: Stockholm, 1970.

This series of three reports deal with the frequency, nature and extent of damage occurring in various parts of Sweden during the severe storms in the autumn of 1969. Most of the damage was done to roofs of structures but some buildings suffered wall damage due to progressive failure once the wall initially ruptured.

168. Full-Scale Strength Tests on Large Panel Construction, Precast Concrete, London, October 1970, pp. 283–290.

This article summarizes results of 137 static tests of individual wall, roof, floor and joint specimens of the Bison Wall Frame System undertaken to demonstrate that the system met the requirements of the Fifth Amendment to the British Code of Practice (see 143). The article describes in narrative form the purpose, general procedure and main results of the tests performed and concludes that this system meets the newly proposed element resistance criteria of the Fifth Amendment.

169. Gas Explosion Rips Subway Construction Site, Engineering News-Record, April 16, 1970, p. 11.

Gas leaking from a pipeline at a subway construction site in a heavily congested section of Osaka, Japan exploded, killing at least 76 persons, injuring 240 and setting off a series of fires that destroyed 30 buildings. The blast blew off more than 700 slab sections, each 6½ ft long, 2½ ft wide, 8 in thick and weighing 880 lb, that were covering the excavation.

170. Gas Facts—A Statistical Record of the Gas Utility Industry in 1970 Data, American Gas Association, Washington, D.C., 1970.

Presents statistical data for 1970 and summaries for earlier years for gas utility industry. Data include information on reserves, production, utilization and transmission and distribution systems.

171. Granstrom, S., Explosionsverkan—Ett Exempel Pa Katastrofpaverkan (Explosion—An Example of Overstress), Nordisk Betonkongres, Copenhagen, Denmark, 1970, pp. 159–169.

Discusses dangers of explosions in buildings. Surveys various types of potential explosions and main characteristics of each type. Among types of explosions included are high explosives, natural gas, dust, electrical, and various types of gases. The paper describes the main characteristics of the Ronan Point explosion and subsequent Scandinavian regulations for minimizing the chance of a similar accident.

172. Greenfield, F. C., Holtum, R. D., and Kalra, J. C., Large-Panel Construction in a London Borough, Concrete, London, Vol. 4, No. 12, December 1970, pp. 443–447.

A discussion of the implications on industrialized building systems employing large-panel precast concrete construction, on the requirements to strengthen structures to resist damage from explosions produced following the Ronan Point collapse of a large apartment building in London.

173. Hodgkinson, A., What the Post-Ronan Point Building Regs Mean, The Architects' Journal, London, February 25, 1970, p. 473.

A structural engineer outlines the important provisions of the Fifth Amendment to the English Building Regulations. This short article contains several very good sketches of the design conditions assumed under the alternate path criteria. The article is generally critical of the new requirements from practical application and philosophical standpoints.

174. Joints for Precast Concrete Components, Symposium at University College of Cardiff, December 1970. Organized Jointly by Wales Branches of the Concrete Society and Institution of Structural Engineers. Concrete, London, Vol. 4, No. 3, March 1970, pp. 105–106.

A brief report on a two day symposium held in Wales to disseminate information on proper design of joints between precast concrete elements. The report outlines the key factors to be considered in joint design with emphasis on meeting the new requirements imposed after the Ronan Point collapse.

175. Large-Panel Structures and Structural Connections in Precast Concrete, Addendum No. 1 (1970) to British Standard Code of Practice CP 116:1965 and CP:Part 2: 1969, British Standards Institution, London, England 1970.

The addendum relates to structures which utilize precast load-bearing wall panels of not less than a single-story height. The recommendations apply particularly where floor and roof are of concrete panel construction, but the principles should be taken to apply where other types of floor and roof construction are used. Clause 902 relates to recommendations for accommodating local or general effects arising from constructional defects such as misalignment and lack of plumb. Clause 903 to 908 inclusively, deal with the connections between units, the tying together of the structure, and the plan form of the building, aimed at enabling the structure to accommodate a limited amount of accidental loading which may occur as a result of construction loadings, differential settlement of the supports, thermal movements, explosions, and accidental impact. Clauses 909 to 916 also relate to connections in all types of precast concrete structures where connections and critical sections of panels close to joints must be designed to resist the worst combinations of shear, axial force and bending caused by vertical and horizontal loads.

176. Leggatt, A. J., Design for Accidental Damage, An open discussions meeting to be held January 14, 1971, The Structural Engineer, London, Vol. 48, No. 12, December 1970, p. 466.

An introduction by Mr. Leggatt is presented along with his definition of "accidental" damage as related to the structural engineer. Deployment of the various responsibilities in the conception and design of structures to others, instead of solely on the structural engineer is advocated. It is pointed out, although certain responsibilities may be neatly delegated to others, in practice the structural engineer often has to do it alone, especially when it comes to developing new materials or techniques. It is further suggested that by compiling a code for guiding the structural engineer in the use of new materials and techniques, partial protection may be afforded between excessive caution on the one hand and excessive boldness on the other. Several rules for guidance are given for the structural engineer to follow when using new material and techniques (for discussion see 214).

177. National Building Code of Canada, 1970, (NRCC 11246), Associate Committee on the National Building Code, National Research Council of Canada, Ottawa, 1970.

Section 4.1.1.7 covers the subject of progressive collapse (for supplement see 155).

178. Notes for Guidance, London Building (Constructional) Amending By-Laws 1970, Greater London Council, London England.

These notes have been prepared in consultation with the District Surveyor's Association

(London) for the guidance of those responsible for the design and construction of buildings in the Inner London area with a view to explaining the application of the Amending By-Laws 2.06 (1) to (9), Vehicular Impact, and Amending By-Law 3. "This explanatory document in many ways reflects the thinking of the CP.116 Addendum with regard to peripheral and internal tie forces, their development, relation to story height, and general details: It confirms the views of the Structural Document that most fully framed structures will meet the requirements."

179. Otway, H. J., Battat, M. E., Lohrding, R. K., Turner, R. D., and Cubitt, R. L., A Risk Analysis of the Omega West Reactor, University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, July 1970, pp. 4–5.

A method for estimating the risk from reactor installations is presented. The method, which considers both accident probabilities, estimates individual risk as a function of direction and distance from the reactor. Comparison of reactor risk is then compared with the numerical values of risk that are commonly accepted such as, motor vehicles, fires, lightning, etc.

180. Pipeline Accident Report. Low-Pressure Natural Gas Distribution System, Burlington, Iowa, National Transportation Safety Board, Report No. NTSB–PAR–70–1, Washington, D.C., October 1970.

During a highway construction project in Burlington, Iowa, a bulldozer drove over and partially collapsed the steel covers of a gas regulator pit, damaging the regulator. The regulator served to reduce high-pressure gas to low pressure for distribution of the Iowa Southern Utilities Company (ISU). While the pressure was partially controlled by a monitoring or safety regulator, gas, reportedly at four to five times the normal operating pressure, entered the distribution system. Gas customers in the affected area reported high gas pilots and fires to ISU and the fire department which caused major damage to the interiors of 10 houses and minor damage to kitchens and appliances in 42 others. Property damage was estimated at $80,000.

181. Poor Materials, Roof-Top Pool Blamed for Collapse, Engineering News-Record, February 26, 1970, p. 13.

A 15-story reinforced concrete apartment building scheduled for occupancy in 5 months totally collapsed in Buenos Aires. Initial findings suggest that inferior materials and excessive roof weight caused the collapse. An empty roof-top swimming pool 65 ft long by 20 ft wide contributed to the collapse.

182. Rasbash, D. J., Palmer, K. N., Rogowski, Z. W., and Ames, S., Gas Explosions in Multiple Compartments, Fire Research Station, Fire Research Note No. 847, England, November 1970.

Experimental tests were conducted to define the data needed in the mathematical modeling of gas explosions in buildings. The explosions took place in a strong chamber with partitions simulating the division of a building into rooms. Explosive mixtures of air and manufactured gas or air and natural gas were used. Pressures substantially larger were obtained than those which might be expected if no partitions were present.

183. Second Annual Report of the Secretary of Transportation on the Administration of the Natural Gas Pipeline Safety Act of 1968, Department of Transportation, Washington, D.C., April 1970.

The report is a compilation for the calendar year 1969 of gas pipeline accidents and casualties based upon failure reports received by the Office of Pipeline Safety. Classification of incidents are in terms of date, state, city, number of injuries, number of fatalities, property damage, and cause. The report lists the Federal Gas Pipeline Standards presently in effect, evaluation of the degree of observance of applicable safety standards, analysis of research activities as a result of Federal Government and private sponsorship, pending or completed judicial actions. dissemination of technical and consumer-oriented information, and recommendations for additional legislation.

184. Soviet Ekon. Wsaimopomoshtshi: Rekomendacii Po Vyboru Rastshotnych Schiem-Rabotsnyi Material, Moscow, February 1970.

Design Code for Socialistic Countries.

185. Special Study of Effects of Delay in Shutting Down Failed Pipeline Systems and Methods of Providing Rapid Shutdown, National Transportation Safety Board, Report No. MTSB–PSS–71–1, Washington, D.C., December 1970.

In recent pipeline accidents, a delay in promptly shutting down the failed pipeline systems has magnified the effects of the accident. The study points out that by reducing the time between failure and shutdown, the accident effects can be minimized or eliminated. Some of the methods and types of equipment that are presently available for use in a rapid shutdown are discussed. The

need for Federal regulations and guidelines in this area is pointed out by the fact that the current regulations would not have prevented any of the accidents referred to in the study. The study also discusses the degree of security to be provided for the public with respect to, the relative hazard of the commodity, the size of the population-at-risk at points along the pipeline, and the potentially damaging effects on property and the environment.

186. Stability of Buildings and Their Design for Prevention of Progressive Collapse Due to Local Damage. Report of Nordic Sub-Committee on Large Concrete Panels, Nordic Concrete Association Committee on Regulations, Sweden, January 29, 1970.

Guidelines are presented for recommendations on design of all buildings to prevent the possibility of progressive collapse. This report formed a basis for work on a supplement to Swedish Building Norm (SBN) taking into account the risk of accidental damage.

187. Statutory Instrument 1970 No. 109, The Building (Fifth Amendment) Regulations, Her Majesty's Stationery Office, London, England, 1970.

These regulations amend the Building Regulations 1965 by imposing additional requirements as to the structural stability of buildings of five or more stories (including any basement). Buildings must be constructed so that if any portion of any one essential structural member (other than a portion which satisfies certain specific conditions as to load) were to be removed, the consequent structural failure would be limited as specified in the Regulations. The Regulations also add to deemed-to-satisfy provision in relation to the same matters. The regulations apply to all forms of construction, cast-in-place and precast concrete, structural steel, large panel, masonry, etc.

188. Strengthening Tower Blocks of Large-Panel Construction, Concrete, London, Vol. **4**, No. 4, April 1970, pp. 142–143.

A new device is described for strengthening multistory structures built from large panels so that they will comply with the new British regulations introduced since the collapse at Ronan Point. Steel angles are positioned along the internal joints of the structure and bolted to the fall and floor slabs against which they abut.

189. Structural Design Requirements for Council Buildings, Divisional Instruction No. 5, Greater London Council, Department of Architecture and Civic Design, Structural Engineering Division, January 6, 1970.

Contains design and detailing procedures for carrying out the intent of amendments to the Building Regulations design to minimize risk of progressive collapse. Prepared for engineers designing high-rise buildings to be built in the London district. Considers many types of buildings and suggests where checks should be made in each.

190. Supplement, London Building (Constructional) Amending By-Laws, 1970, Greater London Council, London, England.

The document shall be substituted for bylaw 2.06 of Part II (General) of the London Building (Constructional) Amending By-Laws (no. 1) 1964. It has the same intent as the Building (Fifth Amendment) Regulations but with a number of modifications.

191. Tenement Hit by Car Collapses, Washington Post, Washington, D.C., August 2, 1970.

A car crashed into a five story tenement building in New York knocking out a building support and sent tenents and parts of apartments crashing into the street. The car crossed the sidewalk, knocked over a fire hydrant, side-swiped a wall and crashed into the ground floor section of the building. The removal of the building support caused the second floor to collapse and then the third, fourth and fifth in a chain reaction.

192. Twin Gym Collapse Is Double Trouble, Engineering News-Record, January 8, 1970, p. 40.

Two identical, steel-framed hexagonal school gymnasiums in Tennessee collapsed within 12 h and 12 miles of each other. Both gyms failed at precisely the same points where trusses joined a tension ring but whether or not the failures were caused by material, design or other defects has not been determined.

193. Ventilation in Dwellings to Reduce Explosion Risk, Journal of the Institution of Heating and Ventilating Engineers, London, Vol. **38**, July 1970, pp. 92–94.

This is a report on a colloquium held at the Institution of Heating and Ventilating Engineers. The meeting was prompted by Recommendation 21 of the report on the explosion at Ronan Point, "Consideration should be given to means of improving ventilation in flats and high blocks," and paragraph 172 of the report which remarked that the tendency of escaping gas to accumulate in the upper parts of rooms could be greatly reduced by ventilation.

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194. Adams, H. C., The Design of Brickwork Against Gas Explosions, British Ceramic Research Association, Proceedings, Second International Brick Masonry Conference, Stoke-on-Trent, 1971.

The paper discusses the accidental damage concept and possible causes of abnormal loading, and describes the nature of explosion damage to brickwork. Design requirements are considered in relation to the Building (Fifth Amendment) Regulations and to the possibility of providing venting relief. The "alternative path" bridging solution is the preferred design method at present.

195. Allen, D. E., Schriever, W. R., and Plewes, W. G., Structural Integrity. Commentary No. 7, Supplement No. 4 to NBC 1970, Canadian Structural Design Manual (NRCC 11530), National Research Council of Canada. Ottawa, 1971.

This commentary gives guidance to the designer by defining the term structural integrity, outlining the abnormal loads to be considered, and indicating the general design approach to be utilized to avoid progressive collapse (see 177).

196. Astbury. N. F., West, H. W. H., and Hodgkinson, H. R., Experimental Gas Explosions—Report of Further Tests at Potters Marston, Fourth Symposium on Load-Bearing Brickwork at the Mount Royal Hotel, British Ceramic Society, London, England, 1971.

Experiments involving gas explosions were carried out to investigate the effect of different layering conditions in a pair of rooms. During the tests, different layers of both gas and a gas/air mixture were used. In two of these experiments, the most explosive (stoichiometric) mixtures of manufactured gas and air were obtained and the resulting explosion caused, in one case, minor, and in the other case, major damage to the 3½-story building which was of load-bearing brick. These experiments were a repeat of earlier tests in which an attempt was made to demonstrate the effects of turbulence. Turbulence has the effect of increasing the pressures developed when an explosion proceeds from one room to another filled with gas, namely, the "cascade" effect. The test demonstrated the effectiveness of venting in limiting the maximum pressure developed in an explosion. Despite suffering extensive damage, the brick building could be safely propped and no progressive collapse occurred.

197. Astbury, N. F., West, H. W. H., Hodgkinson, H. R., Cubbage, P. A., and Clare, R., Experiments to Determine the Resistance of Brick Buildings to Gas Explosion, British Ceramic Research Association, Proceedings Second International Brick Masonry Conference, Stoke-on Trent, 1971.

A programme of experimentation has been undertaken to determine the nature and extent of the forces generated by normal domestic gas explosions, and to determine the effect of such forces on brickwork panels and on conventional loadbearing brickwork structures. The effectiveness of venting has been established and the pressures at which this occurs measured. The pressure necessary to damage a 4½ in brick wall, an 11 in cavity wall and a 9 in wall have been measured. Pressure profiles have been established for balloon and layered explosions and for natural and town gas. It has been shown that the actual pressure developed is in good agreement with that estimated from the heat content of the gases. The effect of cascade explosions proceeding from one room to another has also been examined.

198. Blast Leaves 620 ft British Tower Intact, Engineering News-Record, November 11, 1971, p. 15.

A bomb blast in London's 36-story British General Post Office Tower blew out about one-third of one upper floor's window wall, but did not cause any structural damage. About 10 lb of dynamite was responsible for the blast.

199. Bomb Data Report. California Department of Justice Criminal Intelligence Branch, California, 1971.

Statistical data on property damage, property loss, deaths and injuries, cities and targets most consistently hit, and monthly threats are analyzed for 1084 California bombing incidents reported during 1971.

200. Boston Collapse Comments, Reader Comment, Engineering News-Record, August 19, 1971, p. 7.

This letter explains some of the findings of the investigating commission and its consultants with respect to the 16-story apartment building collapse in Boston. The investigators found the construction did not conform to the design documents and the concrete strength in the roof slab was substantially below specified strength (see 204).

201. Bradshaw, R. E., and Foster, D., Two Load-Bearing Brickwork Buildings in Northern England, British Ceramic Research Association, Proceedings Second International Brick Masonry Conference, Stoke-on-Trent, 1971.

The paper describes two calculated brickwork buildings; one a completed fourteen-story block of flats at Oldham, and the other a four/five-story slender cross-wall hostel at York. Foundations, wind loading and progressive collapse are discussed in relation to the design of both blocks. Comments on the construction of the completed block are included and details of costs of structural work for both blocks are given.

202. Brondum-Nielsen, T., Prevention of Structural Collapse (3.1). Build International, London, Vol. 4, No. 5, September/October 1971.

Author maintains that the use of large concrete panel systems for multi-story buildings involves a risk of progressive collapse, which requires a new design philosophy. Local collapse is caused by abnormal situations and the risk of such situations may be reduced but cannot be eliminated. Thus, there is a need to design the structure not to resist local collapse, but to resist a progressive collapse. The best way to prevent progressive collapse is to supply alternative paths for the transfer of loads in the event of the loss of a critical member.

203. The Building Collapse at 2000 Commonwealth Avenue, Boston Massachusetts, Report of the Mayor's Investigation Commission, City of Boston, Boston Public Library, Boston, Massachusetts, June 1971.

An extremely detailed report of the Investigating Commission appointed by the Mayor of the City of Boston after collapse during construction of a 16-story reinforced concrete flat plate apartment building. The Commission concluded that a shear failure around one column propagated laterally to include an entire half of the structure at both the roof and later at the 16th floor. The structure then collapsed progressively vertically to the ground. Principal causes of failure were attributed to inadequate shoring and low concrete strength as well as numerous construction and inspection irregularities.

204. Building Collapse Blamed on Design, Construction, Engineering News-Record, July 15, 1971, p. 19.

The crucial failure in Boston which started the progressive collapse of two thirds of the building from the 16th through the first floor, occurred when the roof slab failed in shear around a column. The report noted errors in the detailing of the structural plans and probers found that rebars were missing in columns. The roof slab was subjected to a temporary construction overload by the weight of the freshly placed mechanical floor slab. The concrete strength on the roof was less than specific-substantially below 3,000 psi (see 229).

205. Building Collapse Brings Indictments, Engineering News-Record, December 23, 1971, p. 3.

Four persons are each charged with four counts of manslaughter, and six persons and one corporation are charged with conspiracy to violate the Boston Building Code in connection with the January 1971 apartment building collapse (see 206).

206. Cause of Fatal Collapse Unknown, Engineering News-Record, February 4, 1971, p. 13.

The cause of the progressive collapse from the 16th story through the first floor of the reinforced concrete apartment building in Boston is still unknown (see 229). The building is of flat plate design and three possible causes for the collapse are discussed.

207. Collapse Blamed on Deficiencies in Design, Engineering News-Record, New York, March 11, 1971, p. 15.

The collapse in Brazil of a reinforced concrete exhibition hall under construction that killed 65 workers was blamed on insufficient reinforcing steel and insufficient allowance for settlement of the building's foundation. A 278×98 ft section of roof fell after removal of the last of the shoring that supported the slab cast three months earlier. Before the collapse, one of the supporting columns reportedly sank, leaving a depression around its base (see 208).

208. Collapse of Reinforced Concrete Roof Kills 30, Engineering News-Record, February 18, 1971, p. 12.

The article reports that a government agency in Brazil is investigating the recent collapse of the newly cast roof of a reinforced concrete building. The concrete roof slab, 279×148 ft in plan crashed 41 ft to the ground almost immediately after a worker knocked out the last section of shoring supporting the completed roof. It is believed that the weight of the roof slab on its columns must have caused the ground to settle.

209. Correction. Reader Comment. Engineering News-Record, February 11, 1971, p. 7.

The January 28, 1971 report of the Boston apartment building collapse erroneously described the building as having a steel frame. The building's frame was reinforced concrete (see 229).

210. Creasy, L. R., Partial Stability, Design Circular, Directorate of Civil Engineering Development, Department of the Environment, London, England, August 1971.

Design procedures are described to insure "partial stability" of a structure for the prevention of complete disaster following the onset of a local mishap. This "stability" is based on the "catenary" and "membrane" characteristics of the components of the framework where adjacent components to the damaged ones must be capable of "bridging" or "stringing" over the area of local damage. Tests were made at Imperial College, London on beam and slab specimen to confirm the possibility of the suggested design procedures.

211. Cutler. J. F., Plewes. W. G., and Mikluchin. P. T., The Development of the Canadian Building Code for Masonry, British Ceramic Research Association, Proceedings Second International Brick Masonry Conference, Stoke-on Trent, 1971.

During the past decade a successful vigorous effort has been made in Canada towards the implementation of modern technical developments in the structural design of masonry. These efforts resulted in the codification of theoretical and experimental results in the form of a modern Building Code. In developing suitable code regulations, critical evaluation of structural research information reported by other countries has been taken into consideration. The paper explains how research information has been put to use in Canada and underlines the Canadian approach to several questions which may be considered in some way special to the overall development of engineered load-bearing masonry. Section 9 especially deals with design against progressive collapse.

212. Design To Avoid Progressive Collapse, Chapter 21 and Chapter 22 of Svensk Byggnorm 67 (SBN). Statens Planverk, Draft August 1971.

Svensk Byggnorm 67 consists partly of regulations which are compulsory both for the builders and the authorities, and partly of recommendations which are optional. The regulations shall, with certain exceptions, be applied from the 1st January, 1968. (English Translation of 345).

213. Design Was Not Cause of Collapse, Engineering News-Record, November 11, 1971, p. 16.

Excerpts from the report of the Blue Ribbon Commission, set up by the City of Boston for the purpose of enquiring into the cause of the 16-story apartment building collapse, are given to correct errors and omissions made by ENR which may have raised the erroneous inference that the collapse was caused by design faults (see 200 and 204).

214. Discussion. The Economic and Social Factors of Design for Accidental Damage, The Structural Engineer, London, Vol. **49,** No. 7, July 1971, pp. 299–305.

A series of discussions are presented which deal with economic and social aspects of design for accidental damage including relative risk of severe damage to high rise buildings as compared to both low and medium rise as well as transportation accident risks (see 174).

215. Dowding, C. H., Response of Buildings to Ground Vibrations Resulting from Construction Blasting, Doctoral Dissertation, University of Illinois at Urbana, Champaign, 1971, 219 pp., Dissertation Abstracts, Vol. **32:10(B),** University Microfilms Order No. 72–12, 143.

An assessment of the damage potential of blasting vibrations through the application of response-spectrum-analysis techniques is included in the paper.

216. Draft British Unified Code for Structural Concrete. Notes on Clauses for Preventing Progressive Collapse, CIB Commission W 23, Venice, October 1971.

Contents of the draft apply to all concrete structures. The extent of primary damage due to unpredictable loads is not defined, instead it is stated that "there should be a reasonable probability that the structure will not collapse catastrophically." A factor of safety of 1.05 is required in designing against the effects of excessive loads. Stability requirements for all concrete structures are in the form of force requirements. The principle involved in the draft is one of ensuring that the structure is adequately tied together in all directions. It is recognized that the effects of excessive loads are impossible to quantify and the magnitude of the tie forces have been chosen to give a reasonable probability against catastrophic collapse, when used with the design methods given in this Code dealing with normal loads.

217. Ferahian, R. H., Design Against Progressive Collapse, Technical Paper 332 (NRCC 11769), Ottawa, National Research Council of Canada, Division of Building Research, July 1971.

This paper presents background data and recommendations needed to help chart future action in formulating rules for codes of practice and research in the field of large panel structures with particular emphasis on all aspects of progressive collapse. All the unusual and accidental loads that can cause progressive collapse are presented and their nature and damage potential discussed. Gas explosions as a cause of progressive collapse are comprehensively treated in light of the British experience with the Ronan Point Disaster and the subsequent legislation leading to the Fifth Amendment of the Building Regulations 1970. British and European thinking and practice are compared. With this as background, the current Canadian approach for the prevention of progressive collapse, as given in the National Building Code of Canada, 1970, is appraised.

218. Field Survey of the Damage Caused by Gaseous Explosions, Construction Industry Research and Information Association, London, October 1971.

The frequency and severity of gas explosions was examined and the conclusion was reached that roughly one severe or very severe explosion occurs every two weeks. There was some evidence that the incidence of explosions is increasing.

219. Fry, J. F., Gas Explosions Attended by Fire Brigades in Dwellings, Journal of the Institute of Fuel, England, August–September 1971.

United Kingdom fire incidents involving explosions of manufactured gas in dwellings during the 13 years, 1957 to 1969, were examined. The average annual incidence was shown to be approximately 90 but appeared to be increasing as the consumption of gas increases. The average rate of incidents is about 5.0 per 10^8 therms of gas sold. Approximately 48 percent of the incidents cause some structural damage and in 40 percent of these it was considered "severe." From reports involving manufactured gas and natural gas in 1969, it appeared that natural gas was more likely to cause explosions, but that the explosions were of similar violence for the two types of gas.

220. Gas Explosion in Wohnhochhausern (Gas Explosions in Highrise Apartment Housing), Impressions from the conference entitled Niederlandischen Betontag in Utrecht. Part Two, Die Bauwirtschaft Wiesbaden, Vol. **1–2,** January 1971, pp. 10–11.

The state of interest and research into the risk and danger of gas explosions in the Netherlands is outlined. Tests were conducted with natural gas explosions in dwelling rooms to determine pressures required for building design. The two rooms were connected and various wall sizes were used with different sizes of window openings and thicknesses of glass. It was concluded that the conversion of a dynamic explosion pressure on binding elements into a static pressure for design depends upon many parameters and should be further investigated. It was further determined that window glass which is not too thick and windows which are large enough are an advantage in keeping explosion pressures in dwelling down.

221. Gas Line Explosions Draw Attention to Inadequate Laws and Enforcement, Engineering News-Record, April 15, 1971, pp. 9–10.

Contractors cause more than twice as many gas line accidents as any other single source, according to the Department of Transportation. During 11 months in 1970, the gas utility industry reported 1,019 leaks and 26 related fatalities. Damage to distribution or low-pressure gas lines accounted for 676 of the leaks, 462 of which were caused by outside forces.

222. Gifford, R. W., The Resistance of Buildings to Accidental Damage, Bison Limited, Notes of the paper presented to the Los Angeles Convention of the PCI, London, England, 1971.

The accident at Ronan Point is briefly reviewed and a discussion on its technical cause is presented. A historical summary of the various documents produced in the United Kingdom following the incident is covered, giving a background to the thinking behind the documents and a short commentary on them. Finally, a discussion on current practice and a look at possible future trends is presented.

223. Granstrom, S., Bygger Vi Korthus? Byggnadsindustrin 19, Stockholm, 1971, pp. 50–51.

Outlines several examples of progressive collapse which have occurred including Ronan Point, Godthaab New York, Auch and a gas explosion in Gubbinger. Describes model tests used to study progressive collapse in building structures and summarized current Scandinavian Building Regulations which attempt control of progressive collapse.

224. Granstrom, S., Byggnaders Stabilitet Efter Katastrofskador. Krafter i Elementfogar-Modellforsok (Stability of Buildings after Accidental Damage. Forces in Element Joints-Model

Tests), Statens Institute for Byggnadsforskning, Report R20:1971, Sweden Symposium at University College of Cardiff, December 1970. Organized Jointly by the Concrete Society and Institution of Structural Engineers. For summary of papers see Concrete, London, Vol. 4, No. 3, March 1971.

Model tests, to scale of 1:20, involving studies of joint forces and framework deformations in buildings which have sustained local damage are described. The tests relate mainly to domestic and office buildings of precast concrete. The results show that providing joint connections, even of moderate strength, can reduce dramatically the probability of collapse of buildings.

225. Granstrom, S. A., and Carlsson, M., Building Design for the Avoidance of Progressive Collapse (Byggnaders ut Formning for Undvikande av Fortskridande Ras), Library Communication No. 1670, Statens Institut for Byggforskning Projekt C653:2, Stockholm, July 1971.

Over 20 various cases of building collapse are described in fairly great detail. Illustrations and photographs of the collapsed buildings are also included. A substantial bibliography is included.

226. Guidance on the Design of Domestic Accommodation in Load-Bearing Brickwork and Blockwork to Avoid Progressive Collapse Following an Internal Explosion Institution of Civil Engineers, 4th Symposium on Load-Bearing Brickwork. British Ceramic Society, London, 1971.

A committee convened by the Institution considered the probable effects of an explosion of the severity of that which occurred at Ronan Point in domestic accommodation constructed of load-bearing brickwork or blockwork. They have considered the extent of the major structural damage which is likely to arise and have tried to provide guidelines on which the design of new construction should be developed in order to avoid progressive collapse occurring in these circumstances. They suggest solutions for strengthening buildings at both ends of the sensitivity to progressive collapse spectrum.

227. Haseltine, B. A., and Au, Y. T., Design and Construction of a Nineteen-Story Load-Bearing Building, British Ceramic Research Association, Proceedings Second International Brick Masonry Conference, Stoke-on-Trent, 1971.

The circumstances leading up to the decision to use brickwork for a large housing scheme at Portsdown, Hampshire are described. The scheme includes fifteen, seventeen and nineteen-story tower blocks, of which thirteen, fifteen and seventeen stories respectively are constructed in load-bearing brickwork. There is an associated low-rise development of four, six, and eight-story load-bearing brick buildings. The engineering design of the nineteen-story block is described and the brickwork strengths are given, together with an outline of the specification used. The early construction difficulties and techniques are indicated. Section 3.4 especially deals with progressive collapse. The paper is illustrated with diagrams, plans and photographs of the building.

228. Haseltine, B. A., and Thomas, K., Load-Bearing Brickwork Design for the Fifth Amendment (To the 1970 Building Regulations). Technical Note, Vol. 1, No. 3, Brick Development Association, England, July 1971.

This technical note summarizes the approaches that designers may take to design and detail load-bearing brick structures to safeguard against progressive collapse following removal of one or more load-bearing walls in an accident such as a gas explosion. The note includes several detailed calculation examples as well as a summary report of a test series assessing lateral load resistance of axially loaded brick walls.

229. High-Rise Fails During Construction, Engineering News-Record January 28, 1971, p. 3.

Half of a 16-story luxury apartment building under construction in Boston collapsed. The roof, which was being concreted, failed first, and a half hour later, an entire wing of the building collapsed (see 209).

230. Highway Accident Report, No. NTSB–HAR–71–6, National Transportation Safety Board, Washington, D.C., May 12, 1971.

On May 30, 1970, a tank truck partially filled with liquefied oxygen exploded, without warning, after making a delivery at the Victory Memorial Hospital in Brooklyn, New York. The force of the explosion and ensuing fire resulted in fatal injuries to the driver and a bystander, minor injuries to 30 other persons, and substantial property damages. The report contains the probable cause of the accident and contributory hazards. Of particular interest are the calculations of probable pressures present in the accident.

231. Kanoh, Y., Yamanouchi, O., and Ota, Y., Recommendations on the Structural Design of 5 Storied Apartment Houses in Precast Concrete Wall Systems; Seminar Under the

Japan-US Cooperative Science Program, Construction and Behavior of Precast Concrete Structures, Seattle, August 1971, pp. 211–222.

This report is a commentary of the proposed recommendations on the structural design of the apartment houses in wall system construction, composed of the precast concrete large panel units. The apartment houses designed to the recommendations are the most typical of the industrialized housing in Japan. Background and the design procedure of the recommendation are explained. Safety provisions are examined by the full-size test results conducted by Building Research Institute. A part of the translations of the recommendations are shown as an appendix.

232. Lewicki, B., Constructions Industrialisees en Grands Elements—Conception des Joints—Prevention Coutre la Rupture de Proche en Proche (Industrialized Construction with Large Panels—Design of Joints for Prevention of Progressive Collapse), Comite Europeen du Beton, Bulletin D'Information No. 77, April 1971, p. 89.

A very informative summary of the development of joint design in precast structures with emphasis on joints in large panel structures. Gives detailed suggestions for design of structural systems to minimize danger of progressive collapse (i.e., tension or suspended slab systems) and for practical tie beam and joint design.

233. Lewicki, B., Prevention of Progressive Collapse, Beton-En Betonconstructies 1, De Ingenieur, Netherlands, February 12, 1971, pp. 7–11.

A general discussion of the work done by different agencies including the European Concrete Committee (CEB) on progressive collapse is outlined. Broad definitions, as given by the Scandinavian Draft Stability of Buildings and Their Design for Prevention of Progressive Collapse due to Local Damage, are listed for the unpredictable loads and effects which are not taken into account in the design of buildings. Several codes or working documents are then discussed with respect to the unpredictable magnitude of local extreme loads and the extent to which local damage must be limited. Also discussed in this paper are the Scandinavian Draft, The British Addendum No. 1, The Italian Code of Practice, the Preliminary Indications for Design Recommendations for Large Panel Buildings of Socialist Countries, and The CEB-Recommendations for Large-Panel Structures.

234. Ligtenberg, F. K., Structural Safety and Fire (1.3), Build International, London, Vol. 4, No. 5, September/October 1971.

An analysis of damage caused to buildings shows that overloading and inferior materials cause trouble, but more frequently damage is caused by fire and collisions. The author concludes that fire is a loading case that must be explicitly treated in structural calculations. More data, especially on material properties under fire conditions, are needed. He states that in Netherlands there are some 4,000,000 buildings and that in 1967, 20 collapsed from local overload, 50 collapsed due to material defects or design error, around 100 were badly damaged in collisions, 200 were damaged in explosions, and in 200 cases wind caused sizable damage. In contrast, 15,000 experimental fires with 1,500 having severe fire damage indicates that assuming a 100 year life, some 5 percent of all buildings will experience fire damage in their useful life and must be considered in design.

235. Lugez, J., Influence Des Joints Horizontaux Sur Les Structures En Grands Panneaux (Influence of Horizontal Connections on Structures Made from Large Concrete Panels), Comite Europeen du Beton, Bulletin D'Information No. 77, April 1971, p. 157.

This report details the various requirements of horizontal joints in panelized construction. It considers the role of the joint in developing overall structural action, possible effects of joints on the vertical load capacity of the joints, and the role of the joints in transferring lateral shear loadings. Design formula and typical schematics of joint details are given.

236. Mainstone, R. J., The Breakage of Glass Windows by Gas Explosions, Current Paper 26/71, Building Research Station, England, October 1971.

Existing ejperimental data on the strength of glass under loads of very short duration are reviewed. The basis for graphic presentation of likely breaking pressures, under gas-explosion loading, for particular sizes and thicknesses of window panes is provided. An earlier review by Rasbash (see 127) of data on the venting of gas explosions was then used as a basis for extending the graphic presentation to cover also the possible rise in pressure after the glass is broken by explosion. The graphic presentations can be used directly for estimating the pressure reached in actual explosions from observations on the damage to glass windows. They may be used in design of glazing as an explosion vent.

237. Mattock, A. H. and Hawkins, N. M., Research on Shear Transfer in Reinforced Concrete Report SM 71–2, University of Washington, Department of Civil Engineeering, Seattle, Washington, August 1971.

Tests were conducted in a continuing investigation of the parameters affecting shear transfer strength in reinforced concrete. Some of the factors which have been studied are:

(1) the characteristics of the shear plane,
(2) the characteristics of the reinforcement,
(3) the concrete strength, and
(4) direct stresses acting parallel and transverse to the shear plane.

Shear transfer in design from the ACI Building Code, ACI, 318–71, is reviewed. Conclusions based on the test results are included.

238. Monthly Summary Reports, January through December 1971, National Bomb Data Center, International Association of Chiefs of Police, Maryland.

Bombing incidents covered by the public media as well as those incidents reported directly to the National Bomb Data Center by participating agencies are summarized. Bombing incidents are statistically broken down according to type, i.e., explosive or incendiary, number of casualties, damage, geographic region, known or suspected motive or intent, type of devices and fillers, target location and state. Also included in the report is a chronological summary of reported incidents.

239. Morton, J., Davies, S. R., and Hendry, A. W., The Stability of Load-Bearing Brickwork Structures Following Accidental Damage to a Major Bearing Wall or Pier, Proceedings Second International Brick Masonry Conference, British Ceramic Research Association, 1971, pp. 276–281.

The authors have investigated the possibility of a progressive collapse in a number of high-rise and low-rise brick structures. The assessment was made on the basis that, after local failure of one-load-bearing member, other structural members must provide an alternative path of support. This alternative path brought into play either the strength of the floor slab or the bearing support supplied by an orthogonal wall. A number of situations which could be critical and which would require investigation are outlined and methods of calculating the stability of the structure are described.

240. Morton, J. P. and Persinger, G. S., Bombing in the United States, July 1970–June 1971, The National Bomb Data Center, International Association of Chiefs of Police Inc., Gaithersburg, Maryland, 1971.

The National Bomb Data Center has reported a broad analysis of fire and explosive bombings in the US during the period July 1970 through June 1971. Bombings are classified according to state, region and population group. The report deals with property damage and the number of casualties. The frequency of incidents is analyzed in terms of target, motive and the type of explosive used.

241. Multistory Framed Buildings, Circular No. 11/71 Building Regulations 1965, Department of the Environment, London, February, 1971.

The Circular states that in general, multistory buildings having a fully framed structure in concrete or steel which comply with RP/68/05 from the Institution of Structural Engineers will be appropriate for the application of a waiver from the special provisions designed to guard against progressive collapse imposed by the Fifth Amendment.

242. Newmark, N. M., Planning and Design of Tall Buildings, State-of-of-the-Art Report No. 7, Technical Committee No. 8: Fire and Blast, University of Illinois, Urbana, September 1971.

The effects on buildings of external loadings of a transient or impulsive nature arising from the detonation of explosives, including gas or other sources, from sonic boom from aircraft, or from accidental impact are discussed. Fundamental relations for developing blast resistance design procedures are also presented based upon the work of Newmark and others.

243. Paris Suburb Blast Kills 6, Hurts 107, The New York Times, New York, December 22, 1971.

An explosion in a 12-story apartment building in Argenteuil, France blew out all the interior walls of the first six floors. Officials counted 6 dead and 107 injured, 45 seriously. Firemen in this Paris suburb said the blast was apparently due to accumulated gas.

244. PCI Design Handbook, Prestressed Concrete Institute, Chicago, 1971.

A comprehensive design guideline (with examples) of recommended procedures for design and detailing of prestressed concrete structures. The Handbook has extensive material on connections in both frame and bearing wall prestressed concrete construction for gravity and lateral loads. While progressive collapse is not specifically mentioned, many of the details suggested for ductility for earthquake design seem applicable.

245. Pipeline Accident Report. Colonial Pipeline Company Petroleum Products Pipeline, Jacksonville, Maryland, Report No. NTSB–PAR–71–2, National Transportation Safety Board, Washington, D.C., December 1971.

A pipeline leak occurred in the Colonial Pipeline System near Jacksonville, Maryland. Contractors worked continuously for 20 h to find the leak, and on the next day an explosion occurred followed by a fire. There were no fatalities, but five workmen were burned.

246. Pipeline Accident Report. Mobil Oil Corporation High-Pressure Natural Gas Pipeline, Near Houston Texas, Report No. NTSB–PAR–71–1, National Transportation Safety Board, Washington, D.C., July 1971.

A 14-in pipeline carrying natural gas at a pressure of more than 780 psig. ruptured in a residential subdivision north of Houston, Texas. All residents were evacuated, and about 8 to 10 min later, the escaping gas exploded violently. Thirteen houses, ranging from 24 feet to 250 feet from the rupture, were destroyed by the blast. The leaking gas caught fire and burned for 1½ h until valves on either side of the leak were closed by workmen. In all, 106 houses were damaged, and property damage was estimated at $500,-000.

247. Pipeline Accident Report. Phillips Pipe Line Company, Propane Gas Explosion, Report No. NTSB–PAR–72–1, National Transportation Safety Board, Washington, D.C., March 1971.

A rupture occurred in the Phillips Pipeline Company system in Franklin County, Missouri, which released 4,538 barrels of propane. An explosion, equivalent to 100.000 pounds of TNT, and a fire resulted in extensive property damage within a 2 mile radius. No fatalities occurred, but ten persons sustained injuries. The report summarizes the findings of the subsequent investigations.

248. Portion of Garage Collapses during Concrete Placement, Engineering News-Record, March 25, 1971, p. 14.

A newly placed portion of a three-story reinforced concrete parking garage collapsed in Arlington, Va. Workmen were placing concrete for a 20×20 ft slab, and when it gave way, 3,600 ft² of adjacent concrete slabs also fell.

249. Problems of Overloading, LN News (Larsen Neilsen Building System), Gotenborg, Sweden, No. 46, December 1971, pp. 4–7.

To show that overloading risks are common to traditionally built and prefabricated buildings alike, three examples of violent explosions in conventionally built structures are given. Recommendations are given concerning requirements regarding overloads and detailing to ensure capacity to withstand such overloads.

250. Recommendations Internationales Pour Le Calcul Et L'Execution Des Ouvrages En Beton (International Recommendations for the Calculation and Execution of Concrete Construction), Comite Europeen du Beton, Resistance to Accidental Actions, Venice, October 1971.

The object of this annex is to define the conditions under which it is possible to look for an improvement of safety in building construction with regards to "accidental actions." Accidental actions being defined as unpredictable loads i.e., gas explosions, accidental impact of vehicles, etc. Means for reducing or limiting the risk of such accidental actions is presented, and special recommendations are presented for large panel construction.

251. The Resistance of Buildings to Accidental Damage, RP/68/05, Institution of Structural Engineers, The Structural Engineer, Vol. **49**, No. 2, February 1971, p. 102.

The recommendations of the Institution of Structural Engineers for structural design of buildings which are presently covered by the Building (Fifth Amendment) Regulations 1970 are discussed. The recommendations stress joint continuity requirement and fear that the Fifth Amendment regulation will lead to unnecessary structural strength and cost.

252. Rivard, J. B., Risk Minimization by Optimum Allocation of Resources Available for Risk Reduction, Nuclear Safety, Vol. **12**, No. 4, July–August, 1971.

A quantitative approach to system safety has been developed. The risk from component activities are expressed as explicit functions of the resources available for their reduction, and the minimum system risk is then found by dynamic programming. Numerical examples of the method are given. The approach is explained in terms of the nuclear safety problem, but application to other fields of risk is straightforward.

253. Rodin, J., The Partial Collapse of a Prefabricated Large Panel Tall Building in London—Its Cause and Consequences, CIB Symposium on Tall Buildings, Moscow, October 12–15, 1971.

The background leading to the adoption of large panel systems for tall blocks of flats and the selection of one such system for Ronan Point, part of a major housing project in London, is reviewed. The collapse is briefly described and the findings of the Public Inquiry reviewed in relation to the major points of principle which arose. The ensuing problems, the chosen methods of dealing with them and reactions of the interested parties, are reported. The paper includes a suggested design philosophy, particularly related to tall buildings, for dealing with hazards, including gas explosions, on a probabilistic basis, in keeping with modern concepts of structural design. Its application will require more information which, hopefully, will be forthcoming from certain research projects at present in progress in the United Kingdom.

254. Sharpe, R. L., and Kost, G., Structural Response to Sonic Booms, Journal Structures Division, ASCE, Vol. **97**, No. ST4, April 1971, pp. 1157–1174.

A review of field tests with aircraft-generated sonic booms indicates that properly designed and constructed houses should not incur damage from sonic booms with nominal peak overpressures of 2 of 3 psf. Response can be predicted adequately if the characteristics of the boom and structure elements are known. Most damage incidents involve glass damage.

255. Shinawaga, T., Strength and Behavior of Vertical Joint in Precast Reinforced Concrete Wall Construction, Seminar under the Japan-US Cooperative Science Programs, Construction and Behavior of Precast Concrete Structures, Seattle, August 1971, p. 223.

The results of experiments on the strength of vertical connections and their behavior are described. A cast-in-place joint which is called a "wet joint" is used for the vertical connection with vertical shear forces between precast concrete wall panels being transmitted by shear keys in the "wet joint." The vertical connection used in the structural design of a 5-story building was based upon the results of this investigation.

256. Sinha, B. P., and Hendry, A. W., The Stability of a Five-Story Brickwork Cross-Wall Structure Following the Removal of a Section of a Main Load-Bearing Wall, The Structural Engineer, Vol. **49**, No. 10, October 1971, pp. 467–474.

Three experiments are described that had the objective of confirming that a simple five-story brick cross-wall structure could remain stable after a section of the main load bearing wall was removed at ground level to test the stability of the structure in a damage condition, as might occur following an internal explosion. Measurements were made of the applied loads, deflections and strains. The theoretical conclusion that the structure would remain stable under these conditions was confirmed and some information was obtained concerning the strength of 114 mm (4.5 in) thick wall panels subjected to lateral loadings.

257. Sinha, B. P., Maurenbrecher, A., and Hendry, A. W., Model and Full-Scale Tests on a Five-Story Cross-Wall-Structure under Lateral Loading, British Ceramic Research Association, Proceedings Second International Brick Masonry Conference, Stoke-on-Trent, 1971.

The work described is concerned with the rigidity of, and stress distribution in, a section of multi-story cross-wall structure. Tests were first carried out on one-sixth-scale model clay brickwork and deflections measured under lateral loading were compared with those obtained by existing analytical solutions. The latter did not yield accurate results, but an approximate method based on the calculation of deflections, story by story, appeared more promising. The experiments were repeated on a full-scale structure. The test site and the results of lateral loading tests are described. Comparisons are made between the one-sixth-scale test and the full-scale tests and also with the results of deflection calculations by the approximate method, by the continuum method and by a finite element analysis. On the whole the full-scale test results give substantial confirmation of the model test.

258. Slack, J. H., Explosions in Buildings—The Behavior of Reinforced Concrete Frames, Concrete, London, Vol. **5**, No. 4, April 1971, pp. 109–114.

Two instances of explosions in reinforced concrete factory buildings are discussed. The first case study is concerned with an explosion in a 4-story cast-in-place framed structure, while the second illustrates the nature of blast damage within a single-story precast concrete framed building. In the cast-in-place structure the progression of the explosion pressure wave is traced and the resulting damage to the external cladding as well as fire damage are described. The precast concrete frame building suffered column damage due to the confinement of the primary explosion. In both of the buildings, large areas of cladding, or their connections, were weaker than the main structural frame, resulting in limited overall damage to the buildings. From the first case, it appears that the framed cast-in-place structure had a greater inherent resistance to damage than would be indicated by a straightforward analysis taking account of structural continuity. In the precast frame structure, it was found that a precast frame can have a greater resistance to collapse than would seem apparent from a basic reinforced concrete design analysis. However, it is Slack's recommendation that full or partial continuity at the cast-in-place joint be provided to give individual members greater resistance to damage.

259. Special Study of Risk Concepts in Dangerous Goods Transportation Regulations, Report No. NTSB–71–1, National Transportation Safety Board, Washington, D.C., January 1971.

Examination of the salient approaches underlying the development of the existing regulations for the transportation of dangerous goods; description of the difficulties created thereby; and discussion of the needs which must be met by new approaches are covered. The study includes an example of a type of framework which might be employed for effectively guiding the risk identification, risk evaluation, and risk reduction processes addressed to the transportation of dangerous goods.

260. Stability of Modern Buildings, The Institution of Structural Engineers, London, England, September 1971.

The report is largely concerned with highrise construction in steel and concrete and with relatively new types of building structures in which members are connected by some form of virtual hinge, and the lateral stability of the structure depends generally on stiffening shear walls rather than on the stiffness of the joints in structural frame. Industrialized forms of building composed of prefabricated components are also included. The report is presented in two parts:

(1) The first part is concerned with the design of modern highrise building structures in steel and concrete. Included in this section are: criteria for stability, the box-frame and the precast box-frame.

(2) The second part deals with many types of defects and failures that commonly occur in the widest range of these forms of construction. Included in this section are: joints in precast concrete, single-story shed buildings, eccentric loading, foundations, erection precautions, and common causes of structural distress.

261. Taylor, N., and Alexander, S. J., Structural Damage by Explosions (A Pilot Survey), Technical Note 22, Construction Industry Research and Information Association, London, England, June, 1971.

A pilot survey was initiated to establish the procedures for future and wider surveys on the frequency of gas explosions and the structural damage they cause. Newspapers were used to obtain reports of explosions in residences and, where appropriate, visits were made to damaged properties and comprehensive investigation of the circumstances carried out. Findings show that gaseous explosions in domestic buildings in Great Britain causing significant structural damage occur at the rate of less than one per week.

262. Thomas, K., Structural Brickwork—Materials and Performance, The Structural Engineer, London, Vol. **49,** No. 10, October 1971, pp. 441–450.

Calculated loadbearing brickwork is discussed and the basic requirements are specified. Materials and their effects on strength and performance are considered and recommendations made. The mechanism of brickwork failure under vertical and lateral loading is covered and the results of current research in this field are included. Factors affecting strength are discussed and information is provided on composite action with concrete beams, also quality control.

263. Third Annual Report of the Secretary of Transportation on the Administration of the Natural Gas Pipeline Safety Act of 1968, Department of Transportation, Washington, D.C., July 1971.

Refer to annotation for the Second Annual Report; April 1970 (25). This report is the yearly compilation for the calendar year 1970.

264. Two Killed and 26 Injured in New Rochelle Explosion, The New York Times, New York, December 30, 1971.

An explosion and fire leveled a two-story auto sales and service building and destroyed an adjoining structure on the main thoroughfare of New Rochelle, New York. It was reported that at least two men were killed and 26 others were injured. The cause of the fire has not yet been determined, but fire officials said that a boiler in the building might have exploded.

265. U.S. Capitol Survives Bombing with Light Damage, Engineering News-Record, March 11, 1971, p. 11.

Fifteen to 20 lb of dynamite detonated in the U.S. Capitol building did only minor damage. Heavy masonry interior walls absorbed the force to cushion the blast. The bombing disproved earlier reports that the west wall was in imminent danger of collapse.

266. Viaduct Falls on Busy Intersection, Engineering News-Record, November 25, 1971, p. 12.

A 402-ft three-span section of concrete viaduct under construction fell on busy streets in downtown Rio de Janeiro, killing at least 24 persons. At the time of the accident, a 2.5 ton transit mixer carrying about 8 tons of concrete was rolling out on the 161-ft center span. The span split near the middle, right under the truck and collapsed in a V-shape. Two adjacent spans followed, falling almost intact as columns gave way (for additional details see 275, 308, and 360).

267. West, H. W. H., A Note on the Resistance of Glass Windows to Pressures Generated by Gaseous Explosions, Fourth Symposium on Load-Bearing Brickwork at the Mount Royal Hotel, British Ceramic Society, London, 1971.

Tests were carried out involving the effect of gas explosions on windows of various details in order to study their effectiveness in providing venting. Specimens included single-glazed windows of 32 oz glass and double-glazed units of the same thickness of glass. Because of their higher strength, the double-glazed windows provided ineffective venting. Further, the resistance of glass to short-term loads (defined as lasting 3 s) is more than twice that under sustained loadings. Repeated explosions that do not break glass may be the cause of eventual failure at a lower pressure. The strength of glass decreases with time. For example, glass 18 months old failed at loads some 20 percent less than those obtained with newly-manufactured glass. Finally, while the failure of glass may give an indication of the pressure developed in a real incident, care is necessary in interpreting test results since a distortion of the frame can cause the glass to break at a pressure less than its actual breaking strength.

268. Wilton, C., Gabrielsen, B., and Morris, P., Structural Response and Loading of Wall Panels, URS Report 709–11, URS Research Company, California, July 1971.

This report is a continuation of a comprehensive investigation of the response to blast loading of full scale wall panels fabricated from brittle materials, notably nonreinforced brickwork. Information such as element failure times, energy or impulse transmitted to a building frame, and the influence of support conditions and other geometric factors were obtained from the tests.

269. Alexander, S. J., and Taylor, N., Field Observations of Gaseous Explosions in Buildings (a report based on the CIRIA survey), Notes Reference No. 356/72, Building Research Station Symposium-Buildings and the Hazard of Explosion, Garston, England, October 18, 1972.

The Construction Industry Research and Information Association (CIRIA) began a survey in April, 1971 covering damage to buildings from all accidental causes, covering the whole of Great Britain. This paper concentrates on gaseous explosions since they accounted for the majority of the more severe incidents. It deals with the frequency of incidents, an evaluation of the severity of incidents, and descriptions of several incidents.

270. Allen, D. E., and Schriever, W. R., Progressive Collapse, Abnormal Loads, and Building Codes, Structural Failures: Modes, Causes, Responsibilities, ASCE National Meeting on Structural Engineering, Cleveland, Ohio, April 1972, pp. 21–47.

A brief discussion and 19 dramatic photographs of progressive collapses of various types of structures that were initiated by local failure due to abnormal loads. Some statistics are also included based on a study of news reports, and building code provisions on progressive collapse are reviewed briefly.

271. Armer, G. S. T., and Kumar, S., Tests on Assemblies of Large Precast Concrete Panels, Precast Concrete, Vol. **3**, No. 8, September 1972, pp. 541–546.

This paper describes an investigation comprising tests on twenty-eight half-scale assemblies of precast concrete large panels. The object of this investigation was to study the behavior of such assemblies after the notional removal of certain load-bearing elements. The paper concludes with a brief discussion of the problem of designing this form of construction with the aim of reducing the danger of progressive collapse.

272. Beck, H., Stability in the Design of Tall Concrete Buildings, Theme Report, Technical Committee 23, ASCE-IABSE International Conference on Tall Buildings, Preprints: Reports Vol. **III–23,** August 1972, pp. 1–16.

The fundamentals of stability are reviewed with emphasis on the special effects of reinforced concrete behavior. A survey of methods for calculating the stability of columns, shear walls, and precast systems is presented. Some design recommendations and research needs are also discussed.

273. Bomb Summary, Uniform Crime Reports, Federal Bureau of Investigation, National Bomb Data Center, 1972.

The data concerning bombing incidents are divided into sections and charts, including bombing incidents by target, by region, geographic division and stage, and by apparent motive. Also included are selected in-incidents involving bombing attacks directed against the law enforcement community.

274. Brakel, J., List of Limit States, State-of-the-Art Report 2, Technical Committee 26, ASCE–IABSE International Conference on Tall Buildings, Preprints: Reports Vol. **III–26**, August 1972, pp. 21–59.

A comprehensive list of the various limit states of reinforced concrete structures is presented. An example would be rupture of critical sections of a structure (progressive collapse). Each of the limit states is discussed in detail and information is given on pertinent literature reference.

275. Builder Punished Before Collapse Probe Ends, Engineering News-Record, March 9, 1972, p. 13.

Punitive action was taken against the contractor in the recent Brazilian bridge collapse. The firm was prohibited from all state sponsored construction work. Investigation indicates the box girder was not yet post-tensioned at the time of the collapse. In addition, the government charged many unauthorized openings were cast in the slab (see 266).

276. Creasy, L. R., Stability of Modern Buildings, The Structural Engineer, London, Vol. **50**, No. 1, January 1972, pp. 3–6.

The first part of the "Stability" report deals with the basic "anatomy of stability" of tall buildings and traces the application of this principle to many types of concrete and steel construction. This appraisal is also extended to some other types of buildings to illustrate the application of this basic concept of stability in this fundamental way. The second part of the report reviews a number of fundamental aspects of sound design which are common to most types of building structures and often overlooked. Many of these are concerned with the relative movement of the different parts of the foundation and superstructure. Suggestions are made on the provisions which should be incorporated into the original design so that these movements can be safely accepted by the structure in service. An appendix treats the subject of "Partial Stability" in which a building suffers local damage with probable restriction in use, but without complete collapse. The basic principles of a design procedure for "partial stability" based on catenary and membrane action are outlined (for discussion see 279).

277. Despeyroux, J., Commentary on Structural Standards for Concrete Structures, Theme Report, Technical Committee No. 20, ASCE-IABSE International Conference on Tall Buildings, Preprints: Report Vol. **III–20**, August, 1972, pp. 7–27.

Though based upon modern safety concepts and recent advances in the field of concrete construction, the existing codes for concrete structures do not generally take into account the specific problems brought up by the tallness of buildings. Current design and execution practices make up for this lack of specifications. They prove to be very likely to result in a consistent base for future standardization. Modern safety concepts are reviewed, special attention being paid to the problem of the resistance of tall buildings to accidental loadings and progressive collapse. As what concerns designs problems, tall structures differ from the lower ones by the fact that the loadings due to such actions as wind, or earthquakes have to be determined taking into account the dynamic properties of the structures, and that new types of loadings, ordinarily neglected, due to elastic shortening, shrinkage, creep and temperature, may appear. Second order effects become of primary importance. Repetition of alternating loadings may have an unfavorable influence on the behavior of the structures. Execution of works also needs specific standardization, mainly in the field of tolerances and quality control. Some special techniques present points that are worth considering for Codes of Practice.

278. Detailed Findings on Fatal Steam Pipe Blast Withheld, Engineering News-Record, New York, July 13, 1972, p. 11.

A 16 in diameter steam pipe burst in the 36th floor offices of the General Utilities Corporation in New York City on May 4, 1972. It was reported that seven office workers died in the blast. Initial reports suggest that failure occurred at bellows-type expansion joint and that the steam inside, used to power air conditioning compressors located on the building roof was at 155 psi and about 500°F.

279. Discussion on the Stability of Modern Buildings, The Structural Engineer, London, Vol. **50**, No. 7, July 1972, pp. 275–288.

A series of discussions are presented which deal with the paper Stability of Modern Buildings by L. R. Creasy (see 276).

280. Dragosavic, M., Research on Gas Explosions in Buildings in the Netherlands, Notes Reference No. 354/72, Symposium on Buildings and the Hazards of Explosion, Building Research Station, Garston, England, 1972.

Summarizes research programs conducted in the Netherlands to determine the level of pressure to be expected in explosions due to pockets of gas in typical buildings. Points out that the danger of progressive collapse is one due to the overall structural design rather than the design of single members.

281. Dragosavic, M., Structural Measures to Prevent Explosions of Natural Gas in Multi-Story Domestic Structures, Scientific Institute for Building Materials and Structures (In collaboration with Committee B16a of Stichting Bouwresearch), Delft, Netherlands, February 1972.

Part A of this report summarizes the possible measures to take in order to prevent the collapse of a building after a natural gas explosion. The execution and results of tests involving natural gas explosions in buildings are described in Part B (see 338).

282. The Dust Clears at Clarkston, Concrete, London, Vol. **6**, No. 1, January 1972, p. 37.

A gas explosion destroyed a row of twenty-two single story terraced shops in Clarkston, Glasgow. Below the shops were a series of basement voids where gas from a nearby broken main seeped and concentrated until it was ignited. The maximum damage occurred about halfway along the terrace below some three or four of the shops. At the location of the explosion, floor slabs were lifted and the collapse of the front row of columns implied the failure of 12 in$\times$18 in reinforced concrete beams and cross beams at ground level.

283. Excavator Hits Gap Pipe, Six Die, Engineering News-Record, November 9, 1972, p. 21.

A gas explosion in a store in Lake City, Minnesota killed six persons and injured three. Gas leaked into the store's basement after an excavator operator, working on a building project adjacent to the store, ruptured a medium-pressure gas line.

284. Excavator Hits Gas Pipeline; Explosion Rips Nearby House, Engineering News-Record, November 16, 1972.

An excavator uprooted a gas line in a Minneapolis suburb, causing an explosion that destroyed a home and injured 13 persons. It was not clear whether the contractor had been informed of the location of the gas line.

285. Ferahian, R. H., Buildings: Design for Progressive Collapse, Civil Engineering, ASCE, February 1972, pp. 66–69.

Unusual loads, with some emphasis on gas explosions and the danger of progressive collapse in tall buildings made of precast concrete elements, are discussed, and design rules used in Great Britain, France and Canada are reviewed.

286. Fourth Annual Report of the Secretary of Transportation on the Administration of the Natural Gas Pipeline Safety Act of 1968, United States Department of Transportation, Office of Pipeline Safety, Washington, D.C., 1972.

Refer to the annotation for the Second Annual Report, April 1970 (see 183). This report is the yearly compilation for the calendar year 1971.

287. Gas Leak Probes Set, Engineering News-Record, March 30, 1972, p. 3.

A recent natural gas explosion which destroyed two homes in Fairfax County, Virginia, is prompting new investigations into gas leaks by the National Transportation Safety Board.

288. Graaf, S., Stabilization of IB at Aldershot, Concrete, London, Vol. **6**, No. 4, April 1972, pp. 30–32.

Details of the strengthening of British Army precast housing buildings to withstand explosive forces. Continuity between floors and load bearing walls was achieved by drilled-in diagonal anchor pin joints. Vertical tie rods were added to anchor strengthened partition walls against uplift.

289. Granstrom, S. A., The Scandinavian Approach to Structural Safety, Notes Reference No. 358/72, Building Research Station Symposium-Buildings and the Hazard of Explosion, Garston England, October 18, 1972.

This is a discussion on the draft Swedish Regulation on design for progressive collapse; its history and a comparison of the draft with British regulations.

290. Greider, W., The Economics of Death or, Your Life May Not Be Worth Saving, Washington Post, Washington, D.C., April 9, 1972.

Author describes the rationale behind the cost-benefit analysis of putting a price tag on human worth, or the price of life and death.

Also covered are some of the problems evaluators encounter in trying to determine a standard means for comparison of all lives.

291. Illingworth, J. R., Formwork, Civil Engineering and Public Works Review, June 1972, pp. 581–592.

A review of current practice in the design and use of formwork and associated equipment is presented and accompanied by a bibliography of 39 references to the more important published works of recent years. The article points out that where formwork failures occur, the most frequent are those involving falsework. In most falsework failures, inadequate consideration of falsework design usually results in a progressive collapse of the falsework itself with catastrophic results.

292. The IRA and the Structural Engineer, European Scientific Notes, Office of Naval Research, London, March 1972, pp. 71–72.

The bombing of an Army Officer's building in Aldershot near London in February 1972 is described. The Irish Republican Army claimed to have carried out the bombing using 280 pounds of gelignite. The building did not collapse. The walls of one-half of the building were blow away completely, but the structural frame of reinforced concrete remained intact.

293. IRA Bomb Kills 8, Including Bombers, Washington Post, Washington, D.C. August 23, 1972.

A 100 lb bomb, which apparently exploded prematurely, destroyed a customs station in Newry, Northern Ireland on August 22, 1972. The bomb killed eight persons, including the two Republican guerrillas who planted it.

294. Konstruktieve Maatregelen Tegen Aardgasexplosies In Hoge Woongebouwen (Structural Measures Against Explosions of Natural Gas in Multistory Residential Buildings), Rapport NR:BI–72–6/04.3.02.520, Institut TNO Voor Bouwmaterialen En Bouwconstructies, Delft, February 1972.

Research was undertaken to determine the possibilities of preventing explosions of natural gas in multi-story residential buildings or of limiting the effects of explosions. The structural measures whereby this can be achieved comprise:

(a) the prevention of gas leakage;

(b) ensuring that a wall or floor which fails as a result of pressure due to an explosion will not cause progressive collapse;

(c) if the requirement in (b) is not economically feasible; so designing the essential structural elements of a building that they can withstand the pressure developed in the event of a gas explosion.

Part B of the report presents an account of 34 tests with explosions of natural gas under extreme conditions such as may occur in a dwelling. Presents pressure measurements and design recommendations.

295. Leach, S. J., and Bloomfield, D. P., Gas Accumulation and Ventilation, Notes Reference No. 357/72, Building Research Station Symposium-Buildings and the Hazard of Explosion, Garston, England, October 18, 1972.

The influence of buoyancy on the dilution by ventilating air of accidental leaks of toxic and flammable gas is discussed and the limiting cases, where buoyancy effects are negligible and where they dominate, are theoretically investigated. Theoretical results are tabulated and presented on design charts for controlling gas hazards in buildings by ventilation for a wide range of practical situations.

296. Lewicki, B., and Pauw, A., Joints. Precast Panel Buildings, ASCE-IABSE International Conference on Tall Buildings, Lehigh University, 1972, Proceedings, Vol. **III**, pp. 171–189.

This discussion of design considerations for joints and connections in precast concrete structures stresses the importance of tensile continuity and joint ductility in large precast panel buildings. The importance of tie and peripheral bond beams in developing floor and wall diaphram action is emphasized. Design recommendations for floor and wall joints and for minimum reinforcement requirements in tie beams and tensile continuity connections are included.

297. MacGregor, J. G., Stability of Reinforced Concrete Building Frames, State-of-Art-Report 1, Technical Committee 23, ASCE-IABSE International Conference on Tall Buildings, Preprints: Report Vol. **III–23**, August 1972, pp. 19–35.

The behavior of reinforced concrete frames is reviewed, followed by a review of theoretical analysis of the stability of elastic, elastoplastic, and reinforced concrete frames. Approximate methods and design recommendations are presented concerning frame stability.

298. Mainstone, R. J., Internal Blast, State-of-the-Art Report 6, Technical Committee 8, ASCE-IABSE International Conference on Tall Buildings, Preprint: Reports Vol. **1b-8**, August 1972, pp. 127–141.

Recent studies of the nature and structural effects of internal blast are reviewed. High-explosive blast is distinguished from that due to a gaseous deflagration, and the main emphasis is on the latter since this has been the most widespread cause of local and sometimes more widespread structural damage under peacetime conditions in recent years. Both the possibility of limiting the peak pressures reached by means of venting and the design of structural elements and complete structures to resist the blast are considered. A final comment is made on codes of practice and regulations.

299. Mainstone, R. J., The Effects of Explosion on Buildings, Notes Reference No. 352/72, Building Research Station Symposium. Buildings and the Hazard of Explosion, Garston, England, October 18, 1972.

The report covers the following: sources, characteristics and incidence of internal blast, control of peak pressures, and design of structural elements and the structure as a whole to withstand internal explosion and resist progressive collapse.

300. Marosszeky, M., Construction Loads Imposed in Multi-Story Structures, Civil Engineering Transactions, Australia, Vol. **CE14**, No. 1. April 1972, pp. 91–93.

A simple analysis is presented for evaluating the severity of construction loads in a multistory structure built of in situ concrete. Where the upper floors are supported by the lower floors, the construction loads can be reduced sufficiently to make them less critical than the service loads when floors are released an dallowed to carry their self weight before the next floor is poured.

301. Nissen, Henrik, Industrialized Building and Modular Design, Cement and Concrete Association, London, 1972.

The book deals with general subjects in the field of industrialized building and modular designs and shows how the principles have been applied to actual projects in Denmark. The whole range of prefabricated construction is covered; the design examples include four apartment buildings, one terraced house, three one-family houses. two schools, one office and one factory. The building systems discussed include those using brickwork, concrete, wood and steel. Extensive treatment of force transmitting connections including typical details and test results for connection and tie systems for precast and load bearing units are included.

302. Odgaard, A., and Olesen, S. O., Local Failure in Panel Buildings. A Discussion Illustrated by a Model Test. Byggeteknisk Konstruktions-forsknings Central, Report No. 017/B47, Denmark, September 1972.

The report contains the description and the results of a project which consisted in the construction and testing of a 4-story concrete large panel building in the model scale 1:4. Questions concerned with the concepts of local failure and progressive collapse have been examined. Generalizations are made to extend the test results into design recommendations.

303. Palmer, K. N., Explosions Research at the Fire Research Station, Notes Reference No. 353/72, Building Research Station Symposium-Buildings and the Hazard of Explosion, Garston, England, October 8, 1972.

The paper outlines research pertaining to the problem of explosions in buildings and the design requirements that should be laid down.

304. Popoff, A. Jr., Designing Against Progressive Collapse, PCI Design Seminar, October 1972.

The paper includes a survey of the Regulations adopted by Britain, France, Canada and the United States following the Ronan Point failure. In Appendix C, Designing Against Progressive Collapse, the author describes the minimum reinforcement and the minimum connections which he feels every precast building should have.

305. Popoff, A. Jr., Stability of Precast Concrete Systems Buildings, ASCE-IABSE International Conference on Tall Buildings, Lehigh University, 1972, Proceedings, Vol. **III**, pp. 571–583.

A review of existing and emerging regulations for preventing progressive collapse in a precast concrete systems building points out the need for continuous wall and slab reinforcement, and indicates that this can be provided at nominal cost. It suggests the adoption of design principles similar to those used for earthquake design. For precast systems, the design of joints is of prime importance. Eighteen references and excerpts from British Regulations to prevent progressive collapse.

306. Possible Hazard. Engineering News-Record, May 25, 1972, p. 13.

The author of Building Construction for the Fire Service warned officials of fire departments that formwork fire in a post-tensioned concrete building under construction

could result in a "catastrophic total collapse" that would bring "terrible casualties to fire-fighting forces." He cites possibility of a progressive collapse engulfing firemen fighting a form fire on an upper story.

307. Remainder of Collapsed Building Demolished, Engineering News-Record, July 27, 1972, p. 11.

The remaining one-third of the 16-story reinforced concrete apartment building that collapsed while under construction in Boston in January, 1971 was demolished because it was "structurally unsound and unsafe" and the structure contained "questionable concrete." The $5-million building, of flat plate design, incurred a progressive collapse of two-thirds of its slabs and columns when a shear failure occurred around a column at the roof slab and the roof slab fell.

308. Report Blames Viaduct Collapse on Sloppy Work. Engineering News-Record, January 27, 1972, p. 10.

An investigating committee reported that the collapse of a 402-ft three-span section of concrete viaduct under construction in Rio de Janeiro resulted from mistakes and omissions in design and construction (see 266).

309. Sanders, P. H., Evaluation of the Risk of Vehicle Impact on Structures, Structural Failures: Modes, Causes, Responsibilities, ASCE National Meeting on Structural Engineering, Cleveland, Ohio, April 1972. pp. 87–98.

A method of statistical analysis is proposed for determining the probability that an exterior ground-floor column in a multi-story building will be struck by a motor vehicle straying from its normal traffic path.

310. Section of Building Collapses During Razing, Engineering News-Record, March 30, 1972, p. 3.

The center section of a V-shaped, eight-story department store in downtown Kansas City, Missouri collapsed during razing of the structure. The collapse occurred while workers were using acetylene torches on the first floor of the steel framed structure. The City charged demolition contractor violated city codes which call for buildings to be razed from the top down.

311. Spanish Explosion, Washington Post, Washington, D.C., March 7, 1972.

A 10-story apartment building in Barcelona, Spain was reported to have suffered a violent explosion on the fourth floor. All floors of one corner of the building collapsed.

312. Special Study of Systematic Approach to Pipeline Safety, Report Number: NTSB–72–1, National Transportation Safety Board, Washington, D.C. May 1972.

This study describes what system safety is, what its potential benefits are, and some of the methods by which it may be applied to safety in the pipeline field. For example, by using the systematic approach to safety, pipeline accidents can be predicted and analyzed before they occur. Accidents can then be prevented by taking the action necessary to eliminate or control the hazards which lead to the incidents.

313. Strehlow, R. A., Unconfined Vapor Cloud Explosions—An Overview, Report AAE TR 72–1, UILU-ENG. 72 0501, Aeronautical and Astronautical Engineering Department, University of Illinois, Urbana, Illinois, February 1972.

The explosion of unconfined vapor clouds produced by the dispersion of flammable liquid or vapor spills is becoming a serious problem, mainly due to the increased size of the spills in recent years. This paper surveys accidental explosions that have occurred over the past 40 years and also evaluates recent research efforts which pertain to the dispersion and explosion of large vapor clouds.

314. Structural Safety—A Literature Review. Journal Structural Division, ASCE, Vol. **98,** No. ST4, April 1972, pp. 845–884.

A literature review and bibliography containing 351 references is provided as a guide for structural engineers interested in studying the problem of a structural safety. The review is divided into five sections treating load analysis, strength analysis, dynamic structural analysis, structural reliability analysis, and design aspects.

315. Summary of Liquid Pipeline Accidents Reported on Dot Form 7000–1 from January 1, 1971, through December 31, 1971. Office of Pipeline Safety, Department of Transportation, Washington, D.C., March, 1972.

Liquid Pipeline accidents reported to the Department of Transportation are summarized. Data include the location, number and percentage of accidents which occurred, commodities involved, deaths, injuries, and value of property damage sustained, cause of accident, and location of accident by state.

316. Sutherland, R. J. M., Structural Design of Masonry Buildings, ASCE-IABSE International Conference on Tall Buildings, Lehigh University, 1972, Proceedings, Vol. **III,** pp. 1035–1055.

While the advantage of masonry is economy without visual or planning monotony, the most obvious limitation is structural performance. Only if all conditions are favorable, is it possible to build 25 to 30 stories high in unreinforced load bearing masonry. The use of masonry is discussed in relation to national codes from the viewpoints of stability, earthquakes, explosions and other accidental damage. Future developments are noted.

317. Swinnerton, H. A., An Ancient Form of Energy Adapted to Modern Practice, Civil Engineering and Public Works Review, April 1972, pp. 387–389.

This article reviews several aspects of the demolition industry, including advantages obtained by the explosives in the past and the future.

318. Tall Building Criteria and Loading: Fire and Blast, Technical Committee 8, ASCE-IABSE International Conference on Tall Buildings, Lehigh University, 1972, Proceedings, Vol. **Ib**, pp. 463–746.

A series of reports and discussions presenting the state of the art of designing and construction tall buildings so they can safely resist fire and blast loadings.

319. Wakabayashi, M., Frames Under Strong Impulsive, Wind or Seismic Loading, State-of-the-Art Report 6, Technical Committee 15, ASCE-IABSE International Conference on Tall Buildings, Reports Vol. **II–15,** August 1972, pp. 95–115.

A general review is given on the behavior and design of structural frames and their components under strong impulsive loadings, such as an internal or external explosion, and wind or seismic loadings. The main characteristics of these loads are first discussed in relation to structural behavior, emphasizing the problems of ductility, energy absorption capacity, P-delta effect and progressive plastic deformation. As the second step of the discussion, the behavior of beams, columns, beam-columns, braces, connections and frames under monotonic loading is discussed by introducing theoretical and experimental studies. The dynamic plasticity problems of the structure due to impulsive load and the behavior of frames and their components under repeated loading are discussed. Several examples of the application of hysteretic characteristics to dynamic analysis are shown, and finally a reference is made to the problem of progressive plastic deformation in the plastic design to tall buildings.

320. West, H. W. H., Load-Bearing Brickwork Under Explosion Loading, Notes Reference No. 355/72, Symposium on Buildings and the Hazards of Explosion, Building Research Station, Garston, England, 1972.

This paper describes gas explosion experiments undertaken by the British Ceramic Research Association from 1969 to 1972. Simulating conditions in typical upper stories of a cross-bearing wall apartment building, typical concentrations of natural and town gas were ignited. Maximum measured pressures were around $3\frac{1}{2}$ psi in almost all realistic cases although one test in an unvented room induced pressures of 5 psi. This was felt to be nontypical.

321. Wilton, C., and Gabrielson, B., Shock Tunnel Tests of Wall Panels, Technical Report, URS 70 30–7, Vol. **1,** Test Information and Analysis, URS Research Company, San Mateo, California, January 1972.

Test information and analytical results for a variety of reinforced brick, concrete block and clay tile wall geometries subjected to blast loads, and for short statically loaded beams are presented in Volume 1. Non-preloaded solid walls tested stronger than predicted. Preloading with the equivalent of one or two stories added only 10 to 20 percent to wall strength. Walls with doorways and with windows behaved as predicted, with concrete block walls being very weak comparatively. Interior walls of hollow clay tile and concrete block failed at very low overpressures.

322. Wing of Completed Apartment Building Collapses, Engineering News-Record, November 2, 1972, p. 12.

One wing of an eight-story reinforced concrete building collapsed in Buenos Aires. Preliminary investigation indicates that concrete quality and placement of reinforcing bars may have fallen short of requirements. An eyewitness said the building "slid down like a ball of cream," destroying some ground floor stores and an automobile service station. Some settlement and cracking of columns in the structure had been noted.

323. Witteveen, J., Philosophy of Risks and Acceptable Damage and Indications for Design, Technical Committee 8: Fire and Blast, ASCE-IABSE Joint Committee-Planning and Design of Tall Buildings, Proceedings of the 6th Regional Conference, Delft, The Netherlands, May 15, 1972, pp. 35–38.

Accounts of building failures in the Netherlands for one year showed that, in most cases, structural damage was caused by extreme situations as fire and blast and that in many cases failure of a relatively minor structural part, or a fire in a relatively unimportant room, initiated a catastrophe that led to considerable consequential structural damage. To answer the question "Is there a 'limit of growth' of tall buildings due to these problems?" it is necessary to establish a logical philosophy on the risks and the acceptable damage and to develop a more adequate calculation method to evaluate these factors. These are elaborated in the article.

324. Aged Hotel Falls After Structural Defect Cited, Engineering News-Record, August 9, 1973, p. 12.

One-third of an 8-story, 105 year old hotel collapsed in New York City, four weeks after the hotel had been cited for unrepaired structural work. The structure is of brick and wood construction.

325. Allen, D. E., and Schriever, W. R., Progressive Collapse, Abnormal Loads, and Building Codes, Structural Failures: Modes, Causes, Responsibilities—a compilation of papers printed at the ASCE National Meeting on Structural Engineering, Cleveland, Ohio, April 1972, published by ASCE, New York, 1973.

Examples of progressive collapse that have occurred in the past and of abnormal loads which can initiate progressive collapse are given. Statistics are also included based on a study of news reports, giving a rough measure of existing situations susceptible to progressive collapse. Building Code provisions on progressive collapse are reviewed briefly.

326. Armer, G. S. T., Current Research at BRS on the Stability of Precast Concrete Panel Structures, Reference No. 388/73, DOE/CIRIA Seminar The Stability of Precast Concrete Structures, London, March 27, 1973.

This paper describes the program of tests being carried out at the Building Research Station (England) aimed at discovering modes of failure of a three-story, four-bay panel structure under uniform loading with variations in the support conditions which simulate loss of panels due to explosion.

327. Baker, A., and Yu, C., Research to Investigate the Strength of Floor-to-Outside-Wall Joints in Precast Concrete, Reference No. B387/73, DOE/CIRIA Seminar, The Stability of Precast Concrete Structures, London, March 27, 1973.

The purpose of the research was to provide test data for the design of floor-to-wall joints so that they hold under certain specified accidental loads, or load damage, and prevent progressive collapse. Test results lead to preliminary expressions for determining joint strength and adequacy for reducing risk of progressive collapse.

328. The Behavior of Large Panel Structures, Construction Industry Research and Information Association, London, Report 45, March 1973.

The report gives the findings of a two-part study which examined the local behavior of shear transfer and compression transfer joints, and which also determined the most efficient means of analyzing walls composed of large panels. As a result of the experimental study, empirical formulae, for more efficient design, have been proposed, while computer programs have been produced for elastic and elasto-plastic analysis of panel shear walls taking into account the slip between panels.

329. Blast Rips a Sears Tower Neighbor, Engineering News-Record, September 6, 1973, p. 16.

A gas explosion that ripped through a 19-story reinforced concrete building in Chicago also smashed 65 to 70 glass panels in the 1,450 ft high Sears Tower across the street from the explosion scene. The explosion buckled 6 to 10 in walls and floors in the building, and also collapsed stairwells. However, the building was still structurally sound and did not have to be razed.

330. Blast Strikes Skyscraper, Engineering News-Record, November 15, 1973, p. 16.

One worker was killed and 19 others injured last week when a short circuit triggered a fire and explosion in the 31-story Northern Trust Company Building under construction in Chicago.

331. Bombers Harass Building Sites, Engineering News-Record, August 16, 1973, p. 3.

Police last week removed three homemade pipe bombs from widely separated construction sites in New York City. Nine bombs have been found or have exploded at city building sites since January 1.

332. Burnett, E. F. P., Abnormal Loadings and the Safety of Buildings, Report Prepared for: Structures Section, National Bureaus of Standards, Washington, D.C., August 1973.

The objective of this report is to attempt to identify and classify all forms of loading that can influence a building. In particular, those forms of loading that by current design standards may be presumed to be abnormal, will be categorized and their significance considered. Types of loading treated in detail include: explosive bombing; natural gas explosions; aircraft accidents; and sonic boom effects.

333. Burnett, E. F. P., Somes, N. F., and Leyendecker, E. V., Residential Buildings and Gas-Related Explosions, NBSIR 73–208, (June 1973).

The findings of an analysis of available USA statistics concerning the frequency of gas-related explosions in residential buildings are presented. The study was confined to incidents involving piped gas systems as they affect residential and commercial buildings. Though due regard has to be taken of the limitations inherent in the available statistics, it is concluded that in the USA the probability of occurrence of an explosion capable of causing significant structural damage could be 2.2 per million housing units per year.

334. Collapse Kills Five and Destroys Large Portion of 26-Story Building Under Way, Engineering News-Record, March 8, 1973, p. 12.

A form failure, a structural failure or a climbing crane collapse killed at least five workers and destroyed a large section of a 26-story cast-in-place reinforced concrete apartment building under construction in Bailey's Crossroads, Virginia. The weight of the falling climbing crane, the green concrete and the cured 8 in thick floor slabs, ripped an 80 ft wide top-to-bottom gap in the building. Two completed decks of an adjacent parking garage also collapsed. (For more details see 335, 374, 349, 350, 347, 361, 362.)

335. Collapse Blamed on Premature Shoring Removal, Engineering News-Record, April 19, 1973, p. 11.

The possible premature removal of shoring between the 22nd and 23rd floors of the 26-story building in Bailey's Crossroad apparently caused the progressive collapse of a portion of the cast-in-place reinforced concrete structure. The finding was contained in a consultant's report to be presented to a grand jury.

336. Colman, D. G., An Investigation of Joints in Frameworks, Reference No. B389/73, DOE/CIRIA Seminar, The Stability of Precast Concrete Structures, London, March 27, 1973.

This paper covers the precast concrete part of a pilot study commissioned to look at a limited range of joints, both in precast concrete and in structural steel construction. Eight different forms of steel insert joints for precast concrete construction have been studied to try to obtain some general impressions of the current state of practice, and some detailed impressions of the specific form of joint studied.

337. Cracknell, C. J., and Jarman, D. A., Effect of Heavy Impact Loads on Structural Members, Concrete, London, Vol. **7,** No. 8, September 1973, pp. 49–50.

A design procedure is outlined (with worked examples) for the impact loading that occurs on a reinforced concrete beam when a load fails under gravity from a medium height that the damage caused to the structural member is similar to that of a very heavy static load.

338. Dragosavic, M., Structural Measures Against Natural-Gas Explosions in High-Rise Blocks of Flats, Heron, Vol. **19,** No. 4, 1973, 51 pp.

English translation of entry 281.

339. Excessive Horsepower Drops Former Stable, Engineering News-Record, September 27, 1973, p. 13.

A possible overload and unauthorized alterations may have been responsible for the collapse of a four-story brick and timber building in New York City that was converted in 1918 from a stable to a garage.

340. Explosions Take Heavy Toll, Engineering News-Record, March 1, 1973, p. 3.

Report of three explosions involving gas leaks or pipeline ruptures including an apartment building.

341. Explosives Complete a Partial Collapse, Engineering News-Record, December 13, 1973, p. 12.

Explosives knocked down the rest of the partially collapsed concrete shell roof of a bulk materials storage building 464 ft long, by 105 ft wide by 100 ft high. Two panels collapsed at one end of the building and explosives were needed to drop the roof in a way that would not destroy or damage the columns and concrete walls, which rise only about half the building's height.

342. Failures at Two Schools Spur Concern for 100 Others of Similar Design, Engineering News-Record, July 5, 1973, p. 10.

Bearing failures at end of a precast joist triggered a progressive collapse of the entire roof according to investigating officials. Bearing surfaces were very narrow (1.5 in) and typical of details used in a large number of structures.

343. Fatal Pipe Installation Engineering News-Record, November 8, 1973, p. 3.

The collapse of a portion of a 105 year old hotel in New York City (see 324) was attributed to an apparently unauthorized installation about 30 years ago of a drain pipe in a bearing wall. A crack in the pipe resulted in a leak that weakened the mortar of the brickwork.

344. Fribush, S. L., Bowser, D., and Chapman, R., Estimates of Vehicular Collisions with Multistory Residential Buildings, NBSIR 73–175, (April 1973).

Through analysis of data from Oklahoma and Illinois along with national statistics, estimates are made of the number of vehicular collisions with buildings on an annual, nation wide basis. The best estimate is on the order of tens of thousands. However, since the impetus for the study was on multistory buildings and the likelihood of their being subject to progressive collapse, the calculations have been refined to apply to substantial damage to multistory residential buildings. In 1970, such accidents were only on the order of 40, hence the probability of a given building being so affected in a single year is approximately one in ten thousand. Some discussion is provided on improvement for data collection for the future.

345. Fortskridande ras (Design to Avoid Progressive Collapse), The National Swedish Board of Urban Planning, Publication No. 63, July 1, 1973.

The National Swedish Board of Urban Planning has worked out regulations regarding the stability of buildings in order to reduce the risk of progressive collapse due to local damage. The regulations are divided into mandatory requirements and recommendations with solutions deemed to satisfy the requirements. In connection with the regulations, some commentary is published. The regulations are supplements to Chapter 21 (section:93) and Chapter 22 (section:35) in Svensk Byggnorm (SBN).

346. Granstrom, S., Stability After Local Damage, Report of research in Sweden, CIB W23A, Copenhagen, September 4, 1973.

Summarizes current Swedish philosophy regarding acceptable risks in multi-story construction. Summarizes principal causes of three progressive collapses in Sweden (propane explosions, solvent explosions, fire). Discussed social effects of risk analysis and compares to statistics regarding death by fire, drowning, and suicide.

347. Guilty in Collapse, Engineering News-Record, July 19, 1973, p. 16.

A Virginia state court found a concrete subcontractor guilty of misdemeanor charges stemming from the March collapse of a 26-story apartment building under construction in a Washington, D.C. suburb (see 334).

348. Hughes, B. P., Limit States of Impact and CP110, Concrete, London, Vol. 7, No. 8, August 1973, pp. 37–40.

Relative to the recent Fifth Amendment of the British Standard CP110, an examination is made of the essential requirements and assumptions which can be made to facilitate simple design for exceptional events, especially limit states of impact. It is demonstrated that for all normal designs where the simplified stability clauses are followed, a satisfactory resistance to accidental damage is assured. Includes 2 examples of calculation of recommended tie forces to satisfy CP110.

349. Indicted Subcontractor also Faces OSHA Action, Engineering News-Record, May 21, 1973, p. 13.

The concrete subcontractor for the apartment building that collapsed at Bailey's Crossroads, has been charged with willful violation of the Occupational Safety and Health Act (OSHA). Charges alleged that the contractor was responsible for the premature removal of forms, failure to properly conduct tests to insure concrete strength was sufficient for form removal, and use of damaged shoring materials (see 334).

350. Indictment Against GC on Collapsed Building Dismissed, Engineering News-Record, June 14, 1973. p. 15.

The general contractor for the 26-story apartment building that collapsed in March while under construction in a Washington, D.C., suburb has been cleared of charges made by a grand jury. The judge determined the contract made the concrete subcontractor responsible. A consultant hired by the county says the collapse was caused by the premature removal of shoring (see 334).

351. Inexperience Hurts. Engineering News-Record, November 15, 1973. p. 3.

Collapse of a three-story garage in New York City (see 324) was caused by an $80,000 alteration job performed by an inexperienced contractor who did not consult with an architect or engineer. Alterations included replacement of 500 wood floor beams, installation of a new roof of corrugated metal decking and 4 in. of reinforced concrete topped by 1.5 in of asphaltic concrete.

352. Insurance Facts 1973, Insurance Information Institute, New York, 1973.

The booklet includes a ten year U.S. property insurance catastrophe record and indicates type of catastrophe and magnitude of loss.

353. Janney, J. R., Structural Failures, Structural Failures: Modes, Causes, Responsibilities, ASCE National Meeting on Structural Engineering, Cleveland, Ohio, April 1972, pp. 11–20.

A brief discussion of several case histories where failures have occurred due to gravity loads. The discussion is divided into failures caused by ponding, bearing problems, shear and stability. A plea is made that more documentation on such failures should be published.

354. Lewicki, B., Deuar, K., and Zieleniewski, S., Interaction of Floor and Wall for Prevention of Progressive Collapse in Large Panel Buildings, International Council for Building Research Studies and Documentation—Working Commission 2A, Meeting at Copenhagen, September 1973, printed by Centre for Building Systems Research and Development, Warsaw.

The interaction of bearing walls and floors in large panel buildings can reduce to a large extent the risk of a progressive collapse. An initial theoretical study on this problem is presented suggesting a method of calculation for panel structures with elements removed. Authors outline needed testing program on panels and joints.

355. Leyendecker, E. V., and Fattal, S. G., Investigation of the Skyline Plaza Collapse in Fairfax County, Virginia, NBSIR 73–222, (June 1973).

The progressive collapse of the Skyline Plaza apartment building A–4 at Bailey's Crossroads, Virginia (see 333) has been studied by using information contained in case records of the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor and obtained from on-site inspections by investigators from the National Bureau of Standards. Non-compliance with OSHA construction standards has been identified with regard to formwork, field-cured concrete specimens and crane installation.

356. Life Span of Structures, Report of Observations of Attendees at the Engineering Foundation Conference, New England College, Henniker, N.H., July 22–27, 1973.

The life span of structures is determined by design, construction, functional serviceability or environment as natural causes of demise. This paper deals with such topics as the life cycle of structures, structural design, fire, insurance and rehabilitation of bridges.

357. Litle, W. A., Boston Collapse (a summary paper), Structural Failures: Modes, Causes, Responsibilities—a compilation of papers printed at the ASCE National Meeting on Structural Engineering, Cleveland, Ohio, April 1972, published by ASCE, New York, 1973.

The paper outlines the conditions and details of the January 25, 1971 collapse of a 16-story reinforced concrete apartment building under construction. Also included is a summary of a report by the five-man investigating commission appointed by the mayor to probe the collapse.

358. Mainstone, R. J., The Hazard of Internal Blast in Buildings, Building Research Establishment Current Paper, CP 11/73, England, April 1973.

Recent studies of the nature and structural effects of internal blast are reviewed. High explosive blast is distinguished from that due to a gaseous deflagration, and the main emphasis is on the latter since this has been the most widespread cause of local and sometimes more extensive structural damage under peacetime conditions in recent years. Both the possibility of limiting the peak pressures reached by means of venting and the design of structural elements and complete structures to resist the blast are considered. A final comment is made on codes of practice and regulations.

359. Morton, Jane P., Bombing Incident Target Analysis, July 1970—December 1971, International Association of Chiefs of Police, Gaithersburg, Maryland, 1973.

During the period July, 1970, through December, 1971 a total of 2,889 bombing incidents were recorded by the IACP based on data gathered from field reports and the regular screening of 11,000 daily and weekly news publications. The incidents in this publication have been placed into fourteen major categories with various sub-categories and analyzed to evaluate the significance of the targets being attacked. The analysis includes the frequency of incidents directed against each target, the kind of bomb employed, the motive or intent of the bomber, and the geographical and regional location of targets. In addition, a chronological summary listing of bomb incidents for each target category is presented.

360. Not Guilty, Engineering News-Record, September 13, 1973, p. 16.

The court of justice of Guamabara, Brazil, has absolved the president of Sobrenco Construction Company, five engineers and five state inspectors of criminal responsibility in connection with the collapse of a 402 ft section of concrete viaduct under construction in Rio de Janeiro on November 20, 1971 (see 266).

361. Not Guilty, Engineering News-Record, October 4, 1973, p. 32.

A job superintendent was acquitted of involuntary manslaughter in the building collapse that killed 14 construction workers. The judge ruled that the prosecution did not conclusively prove that the defendant prematurely ordered removal of shoring from beneath the 23rd floor of a planned 26-story reinforced concrete building in Bailey's Crossroads, Virginia (see 334).

362. OSHA Makes a Deal, Engineering News-Record, November 22, 1973, p. 15.

The concrete subcontractor for the Bailey's Crossroads building agreed to pay $13,000 in federal penalties without admitting guilt in OSHA violations (see 334).

363. Partially Collapsed Building Repaired, Engineering News-Record, January 25, 1973, p. 26.

Repairs have been completed on Ronan Point, a 24-story London apartment building that partially collapsed in 1968. The article mentions that this failure possibly reduced enthusiasm for systems building in England. The article notes that subsequent to the Ronan Point collapse, the government checked 2,000 high-rise buildings of more than six stories and of these, 700 required strengthening.

364. Peterson, Hans, Analysis of Building Structures, Chalmers University of Technology, Department of Building Construction, Report 1973: 11, Goteborg, 1973.

The work summarized in this paper deals with the structural analysis of multi-story buildings. Two methods, the finite element method and the stringer method, are used. The finite element technique is applied to the bending and in-plane analysis of plates. The analysis is further extended to the evaluation of the response of multi-story buildings to static loads. Experimental results for slabs and wall joints are also presented.

365. Richtlinien und Bestimmungen der neuen DIN 1045 fur GroBtalelbauten (Directives and specifications of the new German standard DIN 1045 for large-sized constructions), Betonwerk and Fertigteil-Technik, Vol. 1, 1973. (In German, with English and French summary pp. 5–14.)

DIN 1045 contains no summarized section of specifications for large-sized slab construction. Although the new specifications for precast reinforced-concrete constructions are summarized in section 19—previously DIN 4225—the specifications for large-panel slab constructions have to be compiled from various further sections. This article compiles and explains, based on the specifications of the new DIN 1045 for large-sized slab constructions, the completed "Tentative specifications for constructions of large sized wall and floor panels."

366. Rules and Regulations Relating to Resistance to Progressive Collapse under Extreme Local Loads, Housing and Development Administration, Department of Buildings, The City Record, New York, August 2, 1973.

Amendment of the City of New York Building Code to require resistance to progressive collapse by either the alternate path method or the specific local resistance to 720 psf method.

367. Sahlin. S., and Runesson. K., Nagra Berakningar Av Kraftomlagring MMI Cellstruktur, Chalmers University of Technology. Institute for Building, Report 73:12, July 1973.

Report presents results of a detailed finite element type analysis of a three story bearing wall structure with typical door and window openings. Various structural configurations are assumed based on loss of key panel and corner elements. Results are presented in terms of forces and deformations with key elements removed.

368. Sanders, P. H., Evaluation of the Risk of Vehicle Impact on Structures, Structural Failures: Modes, Causes, Responsibilities—a compilation of papers printed at the ASCE National Meeting on Structural Engineering, Cleveland, Ohio, April 1972, published by ASCE, New York, 1973.

The failure of an exterior ground-floor column in a multi-story building would cause collapse at every level of those floor areas that depend upon the failed column for support. This paper deals with the probability of a motor vehicle striking an object located near a traffic path. This probability is shown to be a function of the distance of the object from the traffic path and the volume of traffic.

369. School Roof Collapse Blamed on Short Ledge, Cross Ties. Engineering News-Record, August 23, 1973, p. 14.

The British Building Research Establishment cited several reasons for the collapse last June of a school's assembly hall roof in London. These include insufficient bearing area, insufficient cross ties, corroded reinforcement, strength loss due to use of high alumina cement (conversion) and lack of continuity.

370. Somes, N. F., Abnormal Loading on Building and Progressive Collapse, NBSIR 73–221, (May 1973).

This report attempts to define the parameters of the problem of progressive collapse, to classify and discuss the various sources of abnormal loading and to quantify their frequency insofar as the currently available U.S. data permits. The implication of these findings for the USA are then discussed. The response of buildings and building elements to abnormal loading is then reviewed, including cases of progressive collapse. Several alternative approaches for the introductions of criteria are presented and, finally, conclusions are given with respect to the problem posed in the USA.

371. Steele, W. A. Bowser, D., and Chapman, R. E., The Incidence of Hazardous Material Accidents During Transportation and Storage, NBSIR 73–412 (November 1973).

This report is one of a series describing background research concerning the incidence of abnormal loading. The report is organized in terms of modes of hazardous material transportation and storage. These modes—pipeline, water, motor vehicle, and railroad transportation systems—are addressed in four sections with Storage Systems discussed in a fifth. The sections depend on the amount of available data, rather than the risk involved in an accident. A summary of the results is presented in the last section. On the whole, there is little empirical evidence to substantiate a threat to buildings from hazardous materials transport. However, trends in volumes shipped in proximity to structures of interest raises the prospect of future incidents.

372. Structural Design Requirements to Increase Resistance of Buildings to Progressive Collapse, Proposed HUD Handbook by the HUD Staff, U.S. Department of Housing and Urban Development, November 1973.

This draft document reflects the state-of-the-art for methods to increase the resistance of buildings to progressive collapse, and proposed mandatory requirements for the structural design of high-rise buildings to be constructed under HUD programs.

373. Structural Failures: Modes, Causes, Responsibilities, A compilation of papers presented at the ASCE National Meeting on Structural Engineering, Cleveland, Ohio, April 1972 and published by ASCE, New York, 1973.

The book contains seven papers which relate directly to structural failures.

374. Two Firms, Individual, Indicted as Result of Fatal Collapse, Engineering News-Record, May 3, 1973, p. 16.

Indictments have been returned against the general contractor, the concrete subcontractor and the subcontractor's job superintendent in connection with the accident at Bailey's Crossroads (see 334).

375. Weeks, G. A., Tests on the Public Building Frame at BRS, Reference No. B390/73, DOE/CIRIA Seminar, The Stability of Precast Concrete Structures, London, March 27, 1973.

The Department of the Environment has adopted a standard system for precast concrete frame construction for use within the Public Sector. Previous structural experimentation associated with this development has been limited to tests on individual components and isolated joints. This paper describes some aspects of an experimental program, including tests to failure, carried out in the Structures Laboratory at the Building Research Station on a full-scale two-story assembly built in this way and should be treated as an interim document. Test results indicated substantial geometric effects which influenced stability which would not have been noted in isolated joint tests.

376. Wilford, M. J., and Yu, C. W., Catenary Action in Damaged Structures, Reference No. B391/73, DOE/CIRIA Seminar, The Stability of Precast Concrete Structures, London, March 27, 1973.

The Structural Engineer is now required to design a structure against the possibility of complete disaster following local damage. Many of our current forms of construction have this capacity, but there is no recognized design data on which to calculate for this possibility. This paper attempts to establish and prove a design procedure based on "catenary" and "membrane" action of the structural members, to produce a state of "partial stability." The report summarizes tests on beam and slab specimens with supports removed to determine collapse state

load capacity. Results indicated special detailing is generally required to ensure catenary action.

377. Wilhelmsen, A. M., and Larsson, B. Sonic Booms and Structural Damage, D3/1973 (Statens institut for byggnadsforskning), Stockholm, May 1973.

The study of the effects of sonic booms was performed in three stages. The first stage comprised a survey of the available literature on the effect of sonic booms on buildings and contact with research workers in other countries working in this field, but is not included in the English edition. The second stage consisted of a survey of claims for damage in Sweden in an attempt to clarify the extent to which it was possible to judge whether damage could be caused by sonic booms. The third stage comprised a test series of overflights over test units. Data and conclusions are presented which indicate sonic boom is not a threat to primary structural members if planes are flying above 1000 m.

3. Author Index

Numbers refer to references, which are numbered consecutively.

4. Subject Index

Numbers refer to references, which are numbered consecutively.

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This bibliography on the subjects of abnormal loading and progressive collapse is an annotated listing of articles that have appeared in the technical literature from 1948 through 1973. The entries have been arranged chronologically by year and alphabetically within years. Both subject and author indexes have been included. The references listed have been selected as most representative of the historical background and best representing the origin and present state-of-the-art of current practice without undue repetition of data.

References pertaining to characteristics, frequencies, incidents, tests, design procedures, and regulations for many types of abnormal loadings are included. Among these are various types of accidental impacts, construction loads, explosions, faulty practices, and extreme atmospheric loads. Heavy emphasis was placed on referencing applicable building codes and regulations pertaining to the subjects of progressive collapse and abnormal loadings. This bibliography also contains numerous references to contemporary professional opinion as expressed in editorials and discussions of the subject and, particularly, on the various regulations proposed. A large number of proposed analysis and design procedures, as well as applicable test results, are referenced. In addition to the general reference material, a careful search was made of the ten most recent years (1964-1973) of Engineering News Record to identify and annotate possible progressive collapse examples from building failures reported by that publication.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Abnormal loading; alternate path; annotated bibliography; bibliography; building code; building regulations; collapse; failures; progressive collapse; specific resistance

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