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THE TIME FOR REEVALUATION

Presidential Address by Robert H. Culver

(Presented at the Annual Meeting of the Boston Society of Civil Engineers, March 25, 1970)

The Boston Society of Civil Engineers was founded 122 years ago when six engineers met in the United States Hotel to form a society to promote "social intercourse and professional improvement". Later that same year, a celebration was held on Boston Common to inaugurate a modern water supply for Boston. The latter event was a striking testimonial to the growing technical ingenuity of the engineers.

This same ingenuity through the intervening years since 1848 has enabled the engineer to continuously increase the physical ease, improve the health and lengthen the life of mankind. Pure water supplies were developed. Sewage was collected and carried away. New devices without number were conceived and produced. Life became more exciting and less arduous with each passing year.

People flourished with these improvements in their lives. The population of the United States increased ten fold, from 23 millions to over 200 millions during these 122 years. The population of the world grew at a slower pace increasing from about 1.2 billions to about 3.5 billions. The use of machinery on the farms eliminated the need for large numbers of manual laborers. The result is that today there are fewer people on American farms than at the turn of the century, yet food is produced for three times as many people. In America today, less than 35 percent of the population live in non-metropolitan areas. We are truly an urban society. Never have the vast majority lived such a good life.

The mind of the engineer, as he looks down from his ivory tower of accomplishments, is troubled. Things don't seem to be right. We are in a war in the Far East. War threatens us with involvement in the Middle East. Large numbers of people are dependent on the government for welfare. We are told that our water, air and land are polluted, that we have a drug problem and a generation gap with our children. The engineer is puzzled. Why, with all of these luxuries unknown to previous generations, are people dissatisfied? The question that nags at his conscience is "Was it my wonderful work which brought us to this condition?" The answer to this question is not readily apparent.

Let us examine some of the evidence. At a recent meeting of our Society, a spokesman for the electric power industry described the advances that his organization was making in reducing the amounts of pollution discharged from the stacks of fossil fuel generating stations. He assured his listeners that great strides were being made in the design of new plants so that only a fraction of the present discharge of pollutants would occur in the future for each ton of fuel burned. However, he went on to say that due to increased power demands, it was necessary for the industry to construct larger and larger plants at an ever increasing rate. Therefore, in spite of the improvement in the effluents, there would be more pollution discharged into the atmosphere in the future than is now the case. However, he reassured the audience that the stacks would be built higher and the plants would be more widely dispersed so that, at ground level, there would be less pollution. For someone who grew up with the idea that everything that goes up must come down, this reasoning is a little hard to understand. Furthermore, there is some fear that excessive carbon-dioxide in the air is causing unforeseen climatic changes.

I believe that the above example applies to many sectors of the environment. It stands to reason that an increased population will need more shoes, more textile products, will burn more fuel to heat their homes and move their automobiles. Our growing country will produce more sewage, more trash, and in general put more and more stress upon the physical environment. I likewise believe that more and more people, living in close proximity, will create stresses on each other. I think this is especially true in a nation to which these conditions are relatively new, a nation which does not yet fully realize that these stresses even exist.

It is unrealistic to expect that engineers will be able to reverse the population trend to which their ingenuity has contributed. We must leave this to the social scientist. Therefore, what should engineers be doing? Is it possible that engineers could turn their ingenuity to the creation of an environment which would tend to relieve, at least in part, the stresses in modern society? Could they create an environment in which many people can live lives of satisfaction and fulfillment? I think that they can if they realize the importance of doing so.

What are some of the stresses to which we are all subjected? In a modern city, why should pedestrians be exposed to the elements — the rain, snow and blazing sun? Why should the pedestrian in the city compete with automobiles and trucks for space on the streets? How many pedestrians have been irritated by being splashed with mud from a passing car, or from stepping into a puddle of cold water which goes above their overshoes? Why should our nostrils and lungs be assailed with the effluvium from automobile and diesel truck exhaust? Is it necessary for the wheels of the subways and the streetcars to screech with an ear-deafening noise as they pass around the curves?

Cities which were in use in 1848 with their relatively small populations are obviously no longer suitable for modern living. They must be reconstructed. How are we going about this reconstruction? We are building super-highways, parking garages and apparently doing everything we can to give the automobile an even greater advantage over the pedestrian. Have we done anything for the pedestrian? In a few locations, we have built some steep steps by means of which he can climb to an overhead walkway, usually windy, which he can then use to cross over the traffic. Can such devices be considered an encouragement to walking? How much has this neglect of the pedestrian contributed to the recently noted decline in the life expectancy of Americans? It seems to be a backward step in two ways: more pollution and less exercise. Perhaps we should stop looking exclusively at machines and more at people.

Beyond the minor irritations of daily life, what consideration will need to be given to the means for providing people with housing, working space and entertainment in an ever more crowded space? This will undoubtedly mean higher and larger buildings. What kind of planning will be necessary for a city comprised of great buildings to function in a manner which will provide not only a bearable life to its inhabitants but a life which is truly worth living? Consideration will have to be given to the relationship of each building to its neighbor. Consideration will have to be given to the view from each window of each apartment. Each series of buildings will have to function as a working unit and reduce the need for people to travel great distances to obtain the necessities of an amenable life. They must be designed to encourage a change in present living habits which are rooted in rural life.

As the urban sprawl continues to spread its tentacles across the countryside, many people are becoming concerned that irreversible, at least within the foreseeable future, damage to the environment is occurring. The alarm of these citizens is well founded. Furthermore, they have raised their voices to sound a warning. All engineers should heed this warning.

The rising tide of people who are becoming conscious of the loss of values which cannot be expressed in terms of dollars, provides both a challenge and an opportunity to the engineer. The challenge concerns the ability of the engineer to continue and to expand the facilities and services needed to protect the health and comfort of a growing population and to do this in a manner which will enhance the environment from both a physical and an esthetic point of view. The opportunity presented to the engineer is equally as great as the challenge. Those who are concerned with our future are to a large extent ignorant of the means available for the preservation and enhancement of the values they feel we are losing. The engineer with his technical knowledge, his understanding of the fundamental factors involved, and his ability to develop new techniques, is in a unique position to provide the leadership which is vital to the success of our future environment. However, before the engineer can provide this leadership, he must recognize the problem.

If the engineer is not convinced that the problem exists, and if the engineer fails to exercise the leadership of which he is capable, there are others less qualified, ready and willing to furnish leadership. In general, engineers have been negligent of their duty in this area. Unless they wake up and assume the responsibilities which are rightfully theirs, they will have only themselves to blame for the conditions which will be the inevitable result.

What is it that each of you can do individually and collectively to provide leadership in the battle to maintain and improve our environment against the encroaching needs of the expanding population? The initial decision of any group of people to carry out a concerted policy is a political decision. Hence, if engineers are going to be leaders, they must enter the political arena. How can this be done? One of the first things that I think each of us can do to a greater extent than most of us are presently doing is to become members of, and lend our support and our specialized knowledge to those groups which are trying to attack these problems. Almost every town in the Commonwealth has a conservation commission. How many of these conservation commissions have an engineering member or an engineering advisor? Almost every town has a planning board. How many engineers are serving these planning boards either as members or advisors? How many of you have volunteered to serve on or advise a committee concerned with revisions of the building code in your city or town? Many of you are concerned that you cannot afford the time to serve in these positions. It takes too many evenings of the week. Perhaps the time has come when you cannot not afford the time. In my opinion, when a man applies for an receives a license to practice engineering, he has accepted a public responsibility as well as a license for personal profit. This responsibility is to serve the public with the best of his talents. The same applies to our engineering societies. They must give more attention to their social responsibilities, even at the cost of loss of tax-free status. We do not live alone. Like it or not, we are the people. The time is now. The future will not be built tomorrow; it is being built today.

In summary, the problems with which engineers are faced today may resemble on the surface those that were faced by the engineers who founded our society in 1848, that is, to supply people with pure water, adequate housing, collection and disposal of sewage and refuse, and adequate transportation. However, the resemblance between the problems of 1848 and 1970 is superficial. Just as the technology has changed in 120 years, so have the real needs of the public whom the engineer has agreed to serve. It is time that the engineers closed the philosophical generation gap between the founding engineers of 1848 and the basic needs of 1970 and the years immediately in the future.

ANALYSIS OF SHEAR WALL-FRAME SYSTEMS

by STEPHEN CHRISS*

ABSTRACT: Methods of analysis of interconnected shear and shear wall-frame system subjected to horizontal static loading, are reviewed and summarized. All of the reviewed methods consider structures whose shear walls and frames form rectangular grid plans, are subjected to horizontal loading parallel to the grid, and undergo uniaxial displacements, also parallel to the grid.

A method based on the theorem of minimum total potential, is proposed, resulting in a system of simultaneous linear equations containing displacements as unknowns. The method employing matrix formulation, can be applied in the "general case" to structures undergoing biaxial and rotational displacements (u, v, ϕ). Only horizontal components of external static loads are considered, but need not be parallel. Shear walls and frames need not occupy a rectangular grid plan.

KEY WORDS: analysis; biaxial displacements; frames; interaction; minimum total potential; review; rotational displacements; shear walls.

INTRODUCTION

In present building terminology, the term "shear wall" signifies a structural system in the form of walls or cores capable of withstanding lateral forces. Walls may be flat or curved, while cores may be of the open or closed box type. Cores are becoming increasingly important in contemporary multistory technology because of their twofold function, namely: stiffening of the building against lateral loading, and providing vertical passages for services, stairwells and elevators. When shear walls act in conjunction with beam-column frames, the resulting building behavior under lateral wind or seismic loading constitutes generally an improvement over the behavior resulting from either frames or shear walls acting alone.

Therefore, incorporation of both structural components into the system appears advantageous. However, the difference in deflection characteristics between shear walls and frames generates an interaction affecting the system response to direct as well as torsional loading. The latter loading can be generated due to nonsymmetrical loading or nonsymmetrical building configuration. In fact shear wall arrangements resulting in building torsion have been incorporated into several actual buildings,[1,2,3] and further hypothetical but possible situations have also been shown.[1]

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As the effects of torsion on buildings subjected to dynamic loading become apparent,[4,5] and building codes recognize eccentricities, the ability to predict such torsional effects is becoming increasingly important. Accordingly, an investigation into the torsional analysis seems appropriate; and it is mainly due to this consideration that this paper was undertaken.

The present paper is divided into three main parts. In the first, the work of various investigators is reviewed, and the analysis steps are summarized for the purpose of providing the fundamental information needed from a design engineer's point of view. Only a small number of papers sufficiently representing the analysis spectrum of systems subjected to lateral loading is included in this review. Since most of the published literature deals with static loading, only static loading papers were considered. A considerably more extensive bibliography of the papers published up to 1966 is given elsewhere.[6] All of the papers reviewed herein treat cases in which structural components form rectangular grid plans, and loading and displacements are parallel to the grid.

In the second part of the paper, an energy method is developed applicable to building systems that are non-rectangular in plan or irregular in elevation; are subjected to horizontal static but otherwise irregular loading; and are free to undergo biaxial and rotational (torsional) displacements. A method is also developed for analysis for uniaxial displacements.

In the third part, a numerical example is presented employing a Y shaped (in plan) low building of average complexity, acted upon by earthquake loading.

PART I
REVIEW OF METHODS OF ANALYSIS

1. Review Objectives*

Reviews are carried out from the point of view of providing basic information for design purposes. Thus, the implied assumptions are revealed in addition to the stated ones, the analysis steps are summarized, and a broad view of the applicability range of the particular method is given whenever possible. Comments pertaining to a particular analysis method are stated with the method, but comments common to two or more methods are presented at the end of this review part.

*Doubly spaced headings correspond to italics headings of the Journal of the Structural Division, ASCE.

2. General Considerations

A. *Nature of Systems Analyzed*

Analyses have been formulated for systems consisting of (a) perforated shear walls constituting in fact wide column-wide beam bents, (b) two or more shear walls, interconnected through floor slabs or shallow beams, (c) shear walls interconnected with frames.

The various methods of analysis may be classified either according to the type of mathematical treatment, or according to the sssigned physical system behavior. Classification according to the type of mathematical treatment generates four principal categories as follows: (a) portal method, (b) differential equation methods, (c) iteration methods, and (d) simultaneous linear equations and digital computer methods. Classification according to the assigned physical system behavior produces the groups of (a) continuous system methods, and (b) discrete system methods, depending on whether the stress resultants of the system are treated as continuous or point variables. The first classification system, i.e. that pertaining to the type of mathematical treatment, is used in the subsequent sections of this review part.

B. *Assumptions Common to All Methods*

The methods to be described are all based on a number of common assumptions as follows:

1. The system to be analyzed is linearly elastic or can be reduced into constituent linearly elastic systems.
2. The principle of superposition holds.
3. The system consists of frame and shear wall configurations lying totally on vertical planes and forming in plan a rectangular grid pattern.
4. Frames and shear walls are interconnected at floor levels by means of rigid floor diaphragms, except for the treatment by Goldberg[23] in which deformable floor media are considered.
5. The external static loads acting on the system are horizontal, parallel to the grid, and they are applied at floor levels.
6. The system undergoes lateral displacements in the direction of the externally applied loads only.

The additional particular assumptions, stated or implied that are applicable to each method, are presented with the method description in the following sections of this part.

3. Portal Method

Green[7] developed an analysis method applicable to shear wall systems consisting of wide column-wide beam multiple-bay bents. The method, constituting one of the earliest analysis attempts, is a modification of the classical portal method taking into account the effects of finite dimensions of column-beam joints.

The additional particular assumptions used in the analysis are:

a. Axial deformations of beams and columns are negligible.
b. The column-beam joints are rigid rectangles of finite dimensions.
c. Shears delivered from the beams and columns into joints are acting at the center of the joints.
d. Points of inflection occur in the middle of the clear height and the clear span in columns and beams respectively.

The analysis includes the effect of shear deformations of the columns and of course the effect of flexural deformations of columns and beams. The method considers a free body separated from the bent by two slicing planes, positioned at column midheights above and below the floor considered; and the analysis is carried out on a trial basis. The method as presented by Green[7] is limited to systems whose physical dimensions conform to the mechanics of analysis. Furthermore, in the analysis, the horizontal external load acting on the floor of the free body under consideration is neglected. Inclusion of this load would result in shearing stress resultants different for the top and bottom halves of the columns, yielding in turn, different opening spacing requirements from floor to floor. In addition, the assumption of negligible column axial deformations should be treated with caution as explained in the discussion later in this part. The applicability of this method is, therefore, severely limited.

4. Differential Equation Methods

A. *Interconnected Shear Walls*

Interconnected shear wall systems have been analyzed by Beck,[8] by Frischmann, Prabhu and Toppler,[9] and by Rosman.[10, 11, 12, 13]

The systems considered by the first two investigators[8, 9] consisted of two identical shear walls acting as parallel vertical cantilevers interconnected at floor levels by means of horizontal beams. The additional particular assumptions used by the investigators[8, 9] are:

a. The externally applied horizontal loading is uniformly distributed throughout the height of the building.
b. Interconnecting horizontal beams are fixed at each end to the shear wall.
c. Shear walls and tying beams possess constant elastic characteristics, and the story height is constant.

d. There are sufficient stories permitting localized effects to be neglected.
e. Shear deformations of the shear walls are negligible.
f. The horizontal tying beams possess negligible flexural stiffness as compared to the flexural story stiffness of shear walls; this assumption permits absence of inflection points in shear walls.
g. The midspan of the tying beams coincides with their inflection point.
h. Shear walls are fixed to a rigid foundation.

Beck[8] considered a free body obtained by bisecting the two shear wall system by means of a vertical plane passing through the midspan of the horizontal tying beams. The free body is considered under the influence of (a) half the external horizontal loading which tends to deflect it, and (b) vertical shearing forces acting on a hypothetical medium consisting of equivalent laminae replacing the finite tying beams, which tend to restore it.

The analysis takes into account the effects of (a) axial deformations of the shear walls, (b) shear deformations of the interconnection beams, and (c) flexural deformations of all components. As a starting point in the analysis, Beck[8] used compatibility of deflections of the hypothetical laminae in the free body, and thus obtained a second order differential equation relating vertical shears of the laminae to the moment of the shear wall due to external loading. Solution of the differential equation yields values for the vertical shears in the interconnected beams, from which stress resultants in the shear walls and system deflections may be determined.

Frischmann *et al.*[9] lumped together the two shear walls into one vertical member whose rigidity is equal to the sum of the rigidities of the component members. This vertical member, termed the "equivalent column", is considered under the influence of the deflecting total externally applied load, and restoring bending moments induced due to distortions of the interconnecting beams. The analysis takes into account only the effect of flexural deformations of vertical and horizontal members.

Frischmann *et al.*[9] through consideration of a moment-slope relationship arrived at a second order differential equation relating the total moment of the equivalent column to the externally applied load. Solution of the differential equation yields values for the total bending moments of the equivalent column, from which system deflections and bending moments in the interconnecting beams may be calculated. The approach used by the authors[9] allows extension of the method to cases of three or more interconnected shear walls of different rigidities.

Rosman[10, 11, 12, 13] developed solutions for two nonsymmetrical wall, and three symmetrical wall configurations, subjected to uniformly distributed, top concentrated, and trapezoidal loads. He also considered a variety of shear wall support conditions. The additional particular assumptions are essentially similar to those used by Beck.[8] Through considerations similar to those used by Beck, but of more general character, Rosman arrived at a second order differential equation relating the integral of vertical shears in the hypothetical laminae to the physical characteristics of the system and the external loading. It is worth noting that the above-mentioned governing differential equation can be established independently of support conditions, whose characteristics are only affecting the integration constants.

Rosman[14] also discussed the possibility of solutions to systems consisting of four or more interconnected shear walls, by consideration of equality of vertical shears in the hypothetical laminae (plastic hinge formation) and application of the Ritz method.

B. *Shear Walls Interconnected with Frames*

Shear wall-frame systems have been analyzed by Rosenblueth and Holtz,[15] by Cardan,[16] and by Rosman.[17] All of the above authors are basing their analyses on the following additional particular assumptions:

a. Shear walls and frames possess constant elastic characteristics and the story height is constant.
b. There are sufficient stories to permit localized effects to be neglected.
c. Shear walls and frames terminate at the same floor level.
d. Behavior of the frame under lateral loading is analogous to the behavior of a discrete spring-type system, the particulars of which are discussed in the section "Discussion of Assumptions", further on in the paper.

In the analysis by Rosenblueth and Holtz[15] and by Cardan,[16] the shear walls are considered as cantilevers subjected to (a) the deflecting total external horizontal loading, and (b) restoring bending moments and horizontal forces induced due to deformation of the interconnected girders and frames. The analysis takes into account the effect of shear and flexural deformations of shear walls. The authors,[15, 16] by consideration of flexural and shearing deformation relationships, arrived at a second order differential equation relating the total slope of the shear wall to the known external lateral loading. From the solution of the differential equation, slopes and subsequently stress resultants may be determined. Cardan,[16] in addition to external uniformly distributed loading, considered the possibilities of triangularly distributed load, top point load, and foundation rotation.

Rosman's[17] analysis takes into account the effects of flexural deformations of shear walls and of rotation of their foundation. The frames and shear walls are considered interconnected by means of a hypothetical medium consisting of equivalent laminae replacing the finite hinging inextensible links. An expression of the total strain energy of the system is formulated and, through the application of calculus of variation, a differential equation is established relating the bending moment in the shear wall to system characteristics. Uniformly and triangularly distributed lateral loadings are considered.

5. Iteration Methods

Iteration analyses have been applied to shear wall-frame systems by Rosenblueth and Holtz,[15] by Khan and Sbarounis,[18] and by Khan.[19]

In the analysis of Rosenblueth and Holtz[15] the shear walls are considered as cantilevers subjected to external deflecting and internal restoring loading. The authors'[15] analysis is based on the following additional particular assumptions:

a. Shear walls and frames possess constant elastic characteristics.

b. The behavior of the frame under lateral loading is analogous to the behavior of a discrete spring type system.

c. The frame columns exhibit negligible axial deformation.

The analysis of the authors[15] takes into account the effects of (a) shear and flexural deformations of the shear walls, and (b) variations of story height. The iterative process consists of the following operations:

1. Initially, a trial slope distribution is assumed.
2. On the basis of the above slope distribution, the shear taken by the frame is calculated and subtracted from the known external lateral shear to give the shear taken by the shear wall.
3. The wall shear is integrated and the resultant moment is combined with the bending moments induced due to deformation of the interconnecting girders, thus yielding the resultant bending moment on the shear wall.
4. The resultant bending moment is divided by the flexural rigidity E1 of the shear wall, and integrated to give the calculated slope distribution which is compared to the slope distribution assumed at the beginning of the cycle.
5. Subsequent iteration cycles are then performed until the assumed and calculated slope distribution are within acceptable bounds.

From the finally established slope distribution, deflections can be evaluated by intergration, while stress resultants of shear walls and frames will be those pertaining to the last cycle of iteration.

F. Khan and J. Sbarounis[18] followed a different and more generalized approach. The analysis of the authors[18] is based only on the common assumptions cited at the beginning of this part. The analysis takes into account the effects of (a) shear deformations of shear walls and axial deformations of the frame column, (b) flexural deformations of all components, (c) plastic hinge formation in the shear walls, (d) foundation rotation, and (e) variation of story height and system characteristics from story to story.

The iterative process is carried out as follows:

1. Initially the known external horizontal loading is applied to the shear wall and its deflected shape computed.
2. The forces required to hold the frame in a deflected configuration conforming to that of the shear wall are calculated and applied to the shear wall.
3. The horizontal deflections of the shear wall due to the above set of forces are then determined and combined with those determined in step 1, yielding resultant deflections.
4. The above operations constitute the first cycle of iteration.

Initial deflection values to be used in subsequent iteration cycles are given by forced convergence formulas.

According to the authors[18] the iterative process requires three to twelve cycles depending on the frame to wall stiffness ratio. Deflections and stress resultants of the system are those pertaining to the last cycle.

The authors[18] presented a large number of graphs from which a quick evaluation of shear wall and frame shears and deflections can be made for preliminary designs. The method appears to be of sufficiently broad character to cover a variety of actual building configurations.

Khan[19] carried out an analysis pertaining to the interaction of shear walls rigidly interconnected to perpendicular frames, with the system being subjected to lateral loading acting on the plane of the shear wall. An iteration is performed on principles similar to those used by Khan and Sbarounis[18] in order to determine the effective column area to be considered as the flange of an I beam whose web is simulated by the shear wall. The method takes into account the effect of axial deformations of the columns, and flexural and shear deformations of the spandrel beams. Naturally the flange contribution is significant for relatively stiff spandrel beams, and in those cases its effect should definitely be included in the analysis.

6. Simultaneous Linear Equations and Digital Computer Methods

Analysis methods in this category have been presented by Gould,[20] Clough, King and Wilson,[21] and Goldberg.[23]

Gould [20]considered the shear walls as cantilevers subjected to the forcing loading of the external forces, and to the restoring loading of the interconnected frames. The author's [20]analysis is based on the following additional particular assumptions:

a. The shear deformations of the shear walls and axial deformations of the frame columns are negligible.
b. The behavior of the frame under lateral loading is analogous to that of a discrete spring type system.
c. There are sufficient stories to permit application of the finite difference method.

The analysis takes into account the effect of (a) flexural deformations of the system, and (b) variation of story height and system characteristics from story to story. In the analysis, either a fourth order differential equation, or a second order differential equation relating deflections to loading or moment, are employed, depending on their adaptability to the particular structural system.

The differential equations are modified to contain only horizontal deflections as unknowns. One differential equation can be written for every floor level resulting in a system of linear equations. A computer solution of the linear system appears to be advantageous, and from the determined deflections stress resultants of the system may be computed.

Clough et al[21] presented a digital computer analysis applicable to large multistory buildings containing shear walls and frames, interconnected in planar arrays, and subjected simultaneously to lateral and gravity loads. The authors'[21] method constitutes an extension of a previous presentation[22] in which no shear walls were included. The analysis is only subject to the common assumptions cited at the beginning of this part, and it takes into account the effects of (a) axial and shear deformations of sheer walls and frame columns, (b) shear deformations of the frame beams, and (c) flexural deformations of all components.

The analysis consists of the following operations:

1. The building is sliced vertically down into parallel planar arrays and the stiffness of each array to lateral loading is determined.
2. The arrays are reassembled into the original building form, giving by superposition the total lateral stiffness of the building.

3. From the known lateral loads and building lateral stiffness, the lateral displacements and stress resultants in the members are determined.

The lateral stiffness of the array outlined in step 1 above is determined as follows:

1. A loading-displacement relationship is established for the array resulting in a matrix equation relating gravity and lateral forces to rotational, vertical, and translational displacements.
2. The rotational and translational displacements are eliminated from the array loading-displacement relationship, yielding the lateral frame stiffness and the lateral forces necessary to keep the frame unswayed while subjected to gravity loading.

The method appears to be advantageous for cases in which sidesway effects resulting from gravity loads are not negligible. The method can be improved to take into account the eccentric effect of girder shears acting on the face of finite width shear walls, by introducing the concept or rigid gusset extensions as proposed by MacLeod.[24] Interconnected shear wall systems can then be treated on the same basis as above.

Goldberg[23] considered long narrow multistory buildings containing shear walls and frames and subjected to lateral loading. The analysis is subjected to the common assumptions cited at the beginning of this part with the exception of the rigid floor diaphragm. Thus, the analysis takes into account the effects of (a) flexural and shear deformations of floor slabs and shear walls whether in the form of flat or ribbed plates, and (b) flexural deformations of frame columns and beams. Essentially, the following operations are performed:

1. Moment and shear balancing equations are established for every shear wall-floor slab and frame-floor slab intersection.
2. The unknown moments and shears are then replaced by equivalent slope deflection expressions containing rotational and extensional displacements as unknowns. A system of matrix equations is thus obtained.
3. The system is solved through elimination by substitution, yielding rotational and extensional displacements.

Stress resultants may be obtained by substitution of displacements into the appropriate slope deflection equations. The method is capable of being extended to include secondary effects as well as treatment of nonsymmetrical buildings and loadings.

7. Further Analysis Considerations

Barnard and Schwaighofer[27] undertook model studies to determine the coupling effectiveness of a system consisting of two shear walls interconnected solely through a floor slab. For the particular configuration studied it was concluded that for a continuous system analysis of the Beck or Rosman type, the total slab width is effective as an interconnecting beam, although criticism has been raised.[28, 29]

Michael[30] showed that in systems consisting of wide shear walls interconnected through "non-shallow" beams, the effective beam span to be used in the analysis is equal to the physical clear span plus the beam depth. Such span increase, due to wall-beam interaction, appears to be mostly significant for cases of small beam span to depth ratios.

8. Discussion of Assumptions

A. *Common Assumptions*

All of the common assumptions presented in section 2.B of the present part appear realistic and attainable. In particular, the assumption of rigid floor diaphragms appears realistic for square, or nearly square, floor plans. For floor plans in the form of a rectangle (ratio of sides of 3 or over) it has been shown[23, 25] that neglect of a floor plate deformations leads to considerably underestimated horizontal deflections and causes upsetting of the distribution of horizontal shears between frames and shear walls. Such discrepancies between the results based on a rigid or non-rigid floor plate naturally become smaller for the most favorable shear wall-frame relative positions, and vice versa.

B. *Particular Assumptions*

The particular assumptions that have been most commonly encountered in the preceding analysis methods are discussed briefly.

B. 1 *Assumption of Constant Characteristics*

In most medium height buildings (eight to fifteen stories), and almost all tall buildings (over twenty stories), the rigidity of the columns and bearing shear walls is decreased with increasing floor level, due to reduction in member load carrying capacity. In addition, there are variations in story heights between the first few and the typical stories, dictated by architectural and utilitarian considerations. Moreover, special structural features, although predominant in typical floors, are absent in the floors at or near ground level. It, therefore, appears that the assumptions of constant characteristics and constant story height must be introduced with caution.

B. 2 *Assumption of Discrete Spring System Frame*

A discrete spring type system is, for the purpose of this investigation, considered to consist of the assembly shown in Fig. 1, originally introduced by Gould.[20] To test the validity of this assumption, the frame section shown in Fig. 2 was used to determine the load-displacement relationship.

The frame pertains to a building with a spandrel beam to column stiffness ratio of 3. Relative reaction values as determined by analysis as well as those pertaining to the discrete spring type system are shown in Fig. 2.

It is seen that a sizeable difference exists between the two sets of forces. It, therefore, appears that the analogy of a discrete spring type system is only justified for high spandrel beam to column stiffness ratios.

B. 3 *Assumption of Negligible Axial Deformations*

MacLeod[24] has shown that for stiff interconnecting beams, neglect of axial deformations of the shear walls leads to significantly underestimated horizontal deflections and moderately overestimated shears in the connecting beams. Rosman[12] has also emphasized that neglect of axial deformations especially in high, interconnected shear walls, leads to erroneous results. Bandel[26] has shown that neglect of axial deformation, in the columns of narrow tall frames leads to considerably underestimated deflections. Therefore, it appears that the assumption of negligible axial deformations becomes unreliable under certain conditions; however, no general criteria regarding the range of applicability of this assumption have been established.

9 Method Evaluation

Differential equation methods are relatively easy to manipulate, in general do not require computer facilities, and inherently yield results in a formulated manner. However, they require imposition of limiting assumptions which may result in misrepresentation of the state of stress and deformation of the system. Their use is recommended only for cases of multistory buildings in which variations of system characteristics are kept at a minimum.

Iteration methods allow complete freedom in variation of system characteristics and loading, but they are also subject to judicious assumptions regarding the grouping together of frames and shear walls for easier manipulation. The possibility of arithmetical errors is kept at a minimum through step by step comparisons. However, methods in this category are laborious and unless quick convergence is obtained, manual manipulation of the operations appears to be of little merit. Digital computer methods inherently

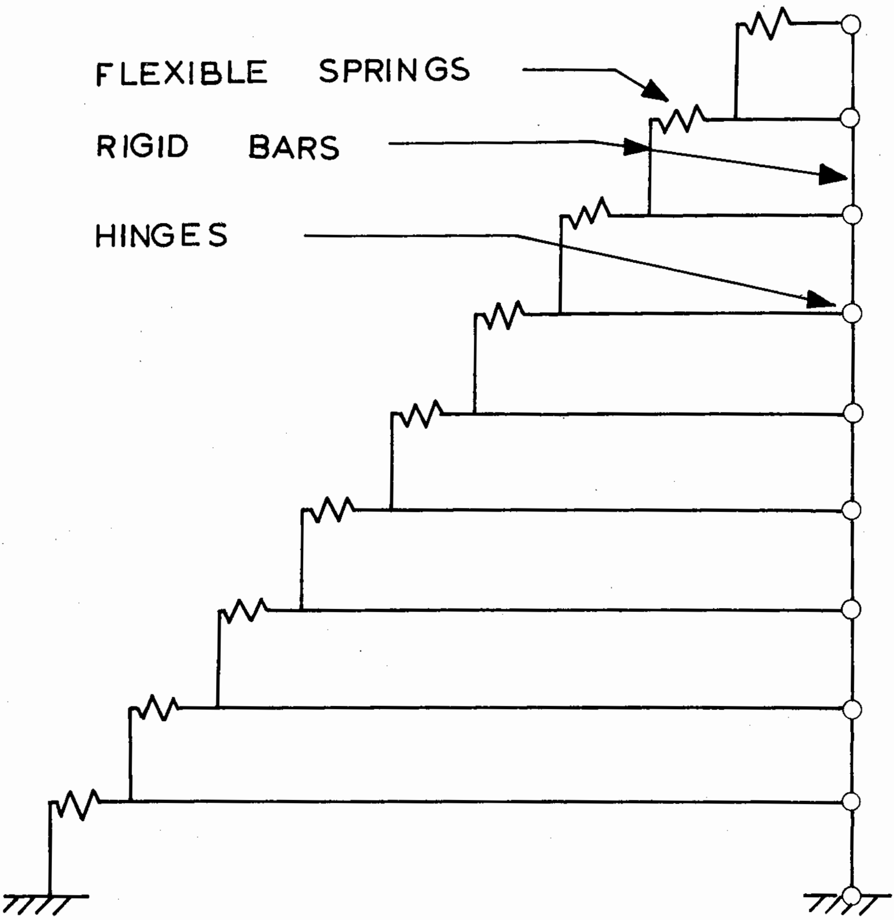

Fig. 1 — Discrete Spring Type System

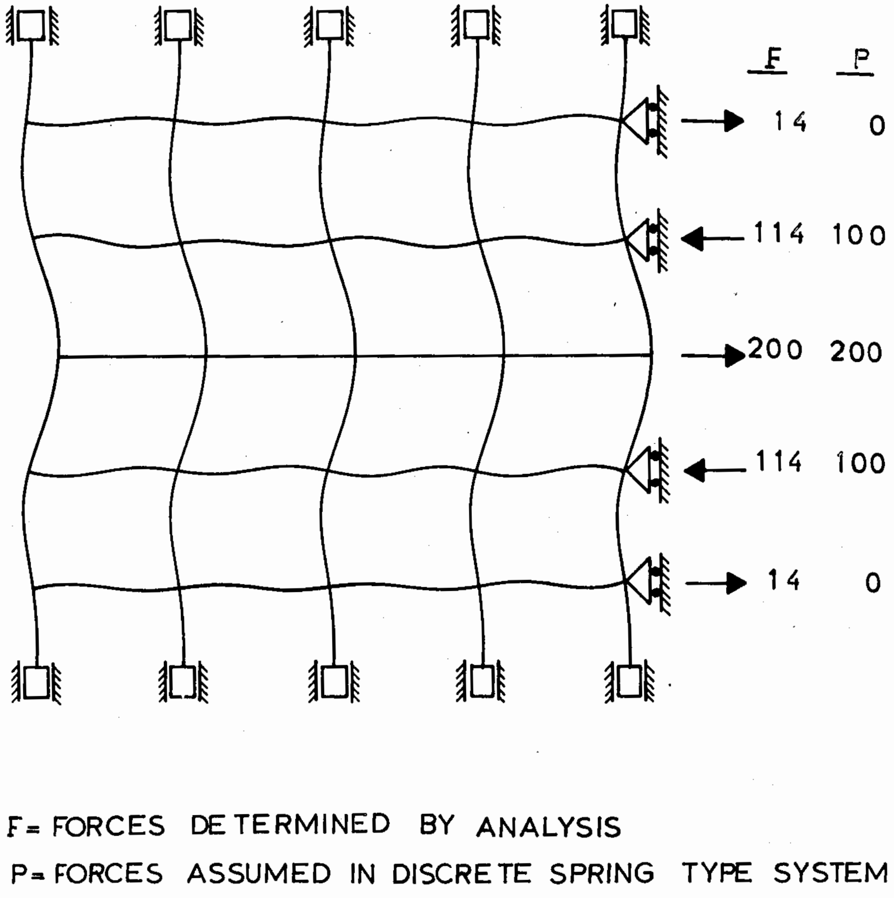

Fig. 2 — Determined and Assumed Forces in Typical Frame Action

allow extensive flexibility in system characteristics. However, one may be faced with the lack of a suitable program, excessive programming and processing costs, or even limited computer capacity.

PART 2
METHOD OF ANALYSIS FOR BIAXIAL AND ROTATIONAL DISPLACEMENTS

1 General Considerations

The method of analysis presented in this paper is based on the theorem of minimum total potential,[31, 32] and it results in a system of simultaneous linear equations for displacements. Computational work at various stages of the analysis may be carried out by means of a slide rule, desk calculator or digital computer, depending on the size of the work and the accuracy required.

2 Assumptions and Limitations

The proposed method is based on the following assumptions and limitations:

1. The structure may contain any number of shear walls and frames which remain linearly elastic during deformation. Formation of plastic hinges may be taken into account by reducing the original structure to constituent linearly elastic systems.
2. Foundations of the structure may rotate in a linearly elastic manner.
3. Frames and shear walls are interconnected by means of floor diaphragms which are extensionally rigid in their own horizontal plane, but flexurally or torsionally flexible about horizontal axes lying in their plane.
4. External loads acting on the system are horizontal and are applied only at floor levels.

3 System Characteristics

A building containing several shear walls and frames arranged in a nonrectangular grid is shown in Fig. 3. For purposes of identification, frames and shear walls are assigned characteristics f1, f2 etc. and w1, w2 etc., in a prescribed order. In formulating one class of energy equations, columns are considered as isolated elements regardless of whether or not they belong to frames, and thus they are also assigned characteristics c1, c2 etc.

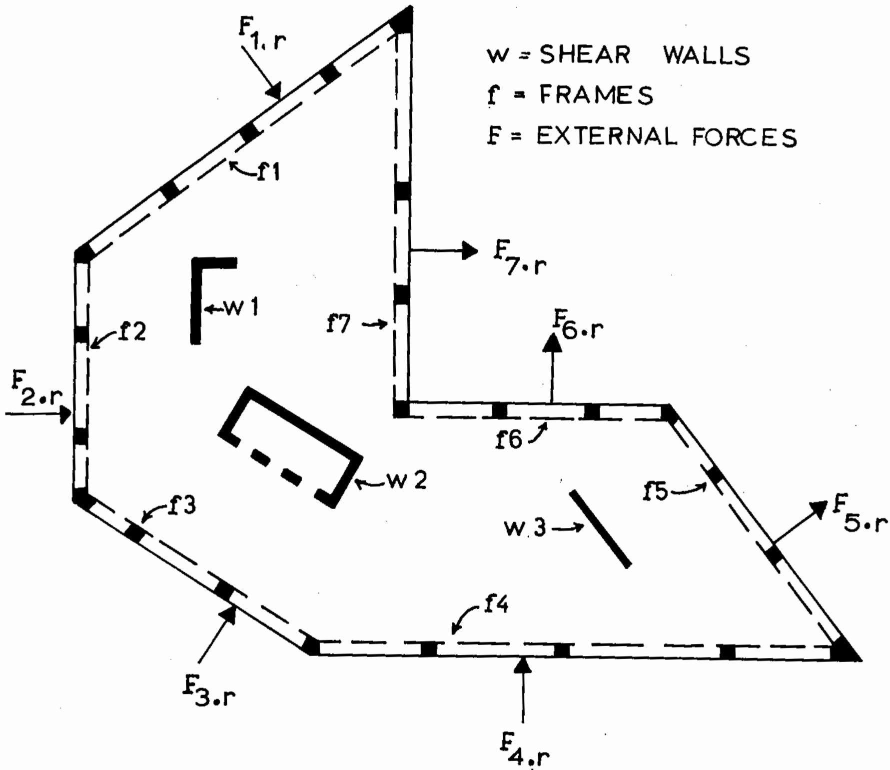

Fig. 3 — Shear Walls and Frames in Nonrectangular Grid

The building is subjected to external horizontal loads F, which for the case of wind loading will act perpendicularly on its faces. The resultant wind force on each face may be located at a position other than the center of the face, and the resultants pertaining to each floor level on the same face do not have to lie on the same vertical line.

For purposes of analysis, the building is assumed to undergo successive displacements; the position of each of the building floors can then be specified as shown in Fig. 4 in terms of (a) rotational displacements about a specific point C in the plane of the floor, and (b) translational displacements u and v with respect to a fixed coordinate system XOY. Points C for the various floors lie on the same vertical line.

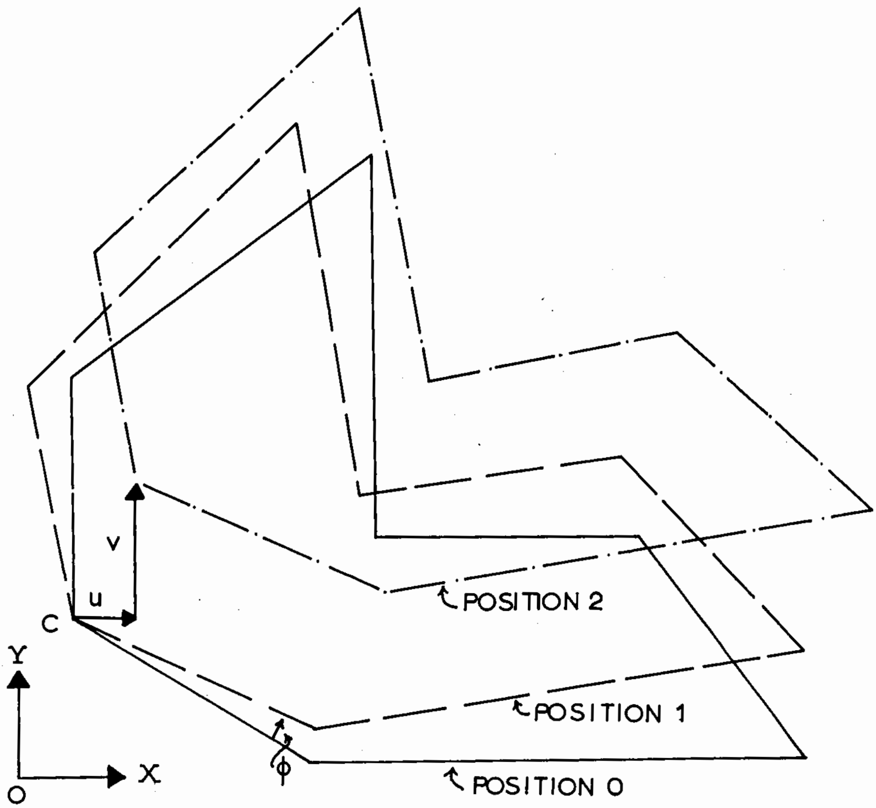

Fig. 4 — Successive Floor Displacements

4 Considerations for Shear Walls

A. *Kinematic Relationships*

The displacement of shear wall w2 shown in Fig.3 is considered in detail. It is assumed for simplicity that the shear center and center of rotation of the wall cross-section coincide with its centroid.

Rotation of the wall centroid about point C, as shown in Fig. 5, and subsequent translation from position 1 to position 2 as shown in Figs. 4 and 6, will cause displacements given by

$$u' = (r \sin \theta)\, \phi + u \quad \text{(1a)}$$

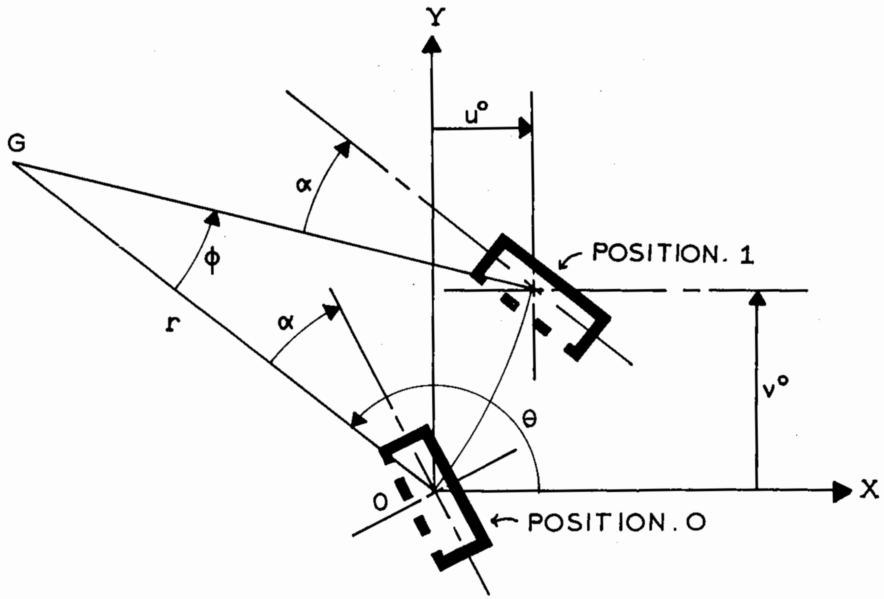

Fig. 5 — Shear Wall Displacements Due to Rotation

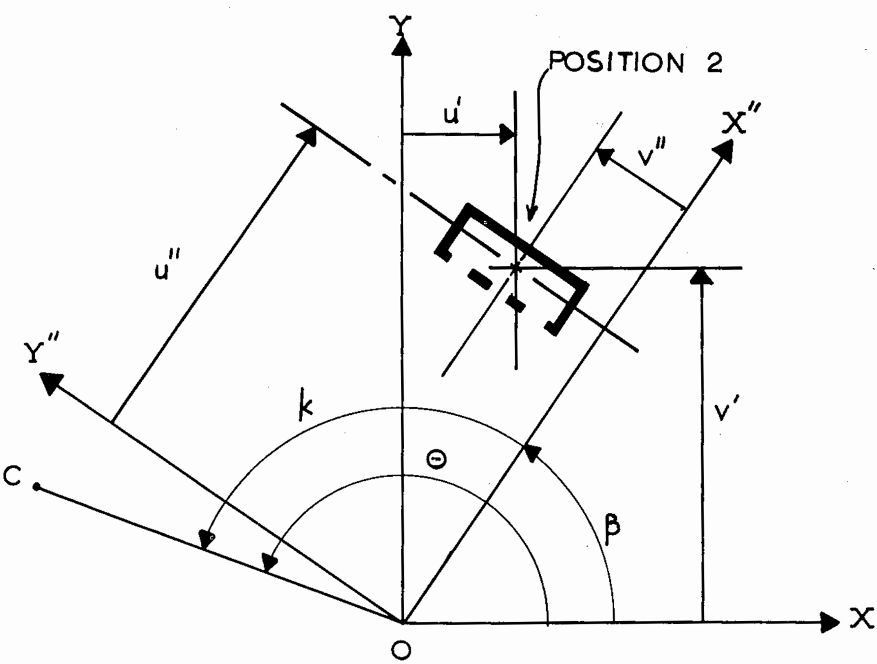

Fig. 6 — Shear Wall Coordinate Transformation

$$v' = -(r \cos \theta)\,\phi + v \quad \text{(1b)}$$

$$\phi' = \phi \quad \text{(1c)}$$

in which r is the distance from point C to the centroid of the wall; θ is the angle between r and OX axis.

Transforming displacements u', v', ϕ' into displacements u'', v'', ϕ'' pertaining to the principal axes of the wall as shown in Fig. 6, gives

$$u'' = au + bv + c\phi \quad \text{(2a)}$$

$$v'' = -bu + av - d\phi \quad \text{(2b)}$$

$$\phi'' = -\phi \quad \text{(2c)}$$

in which a, b, c, d designate the quantities $\cos\beta$, $\sin\beta$, r sink, r cosk respectively; β is the angle between coordinate systems XOY and X″OY″; k is the difference between angles θ and β.

Since the quantities r are identical, and the quantities β and k are practically identical for all floors, the constants in Eqs. 2 are practically identical for all floors.

B. *Energy Relationships*

The strain energy stored in the shear wall is due to biaxial translational and rotational displacements.

The stiffness equation for a cantilever structure is given by

$$\{P^W\} = [A^W]\,\{u^W\} \quad \text{(3)}$$

in which $\{P^W\}$ and $\{u^W\}$ denote the column matrices of load and displacement respectively; $[A^W]$ denotes the stiffness square matrix. Coefficients of the stiffness matrix include the effect of shear as shown in Appendix I. The strain energy $\{U^W\}$ of the structure is given by

$$\{U^W\} = \frac{1}{2}\,[u_r^W]\,\{P^W\} \quad \text{(4)}$$

in which $\{U^W\}$ is the strain energy in the form of a lxl matrix; $[u_r^W]$ is the row vector of displacements.

Combining Eqs. 3 and 4, considering that the stiffness matrix is symmetric,[33] and differentiation of both sides of the resultant equation, the following is obtained.

$$\left\{\begin{matrix} \dfrac{\partial U^w}{\partial U_1^w} \\ \dfrac{\partial U^w}{\partial u_2^w} \\ \cdot \\ \cdot \\ \dfrac{\partial U^w}{\partial u_n^w} \end{matrix}\right\} = \left\{\frac{\partial U^w}{\partial u^w}\right\} = [A^w] \quad \{u^w\} \quad \ldots\ldots\ldots\ldots \quad (5)$$

The implication of the above equation is noteworthy: the first derivative of the strain energy matrix for a cantilever structure, is equal to the stiffness matrix postmultiplied by the displacement column matrix. Applying Eq. 5 to the particular case of the shear wall, undergoing biaxial and rotational displacements gives

$$\left\{\frac{\partial U_a^w}{\partial u''}\right\} = [A^w] \quad \{u''\} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5a)$$

$$\left\{\frac{\partial U_b^w}{\partial v''}\right\} = [B^w] \quad \{v''\} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5b)$$

$$\left\{\frac{\partial U_\phi^w}{\partial \phi''}\right\} = [C^w] \quad \{\phi''\} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5c)$$

in which $\left\{U_{\phi}^{W}\right\}$, $\left\{U_{a}^{W}\right\}$, $\left\{U_{b}^{W}\right\}$ are the strain energy column matrices of shear wall due to rotational displacements and translational displacements parallel to OX″ and OY″ axes respectively; $[C^W]$, $[A^W]$, $[B^W]$ denote the respective stiffness matrices.

The total strain energy stored in the shear wall is given by

$$\left\{U_{T}^{W}\right\} = \left\{U_{a}^{W}\right\} + \left\{U_{b}^{W}\right\} + \left\{U_{\phi}^{W}\right\} \quad \ldots\ldots\ldots\ldots (6)$$

Differentiating $\left\{U_{T}^{W}\right\}$ with respect to u, v and ϕ gives

$$\left\{\frac{\partial U_{T}^{W}}{\partial u}\right\} = \left\{\frac{\partial U_{a}^{W}}{\partial u''}\right\}\left\{\frac{\partial u''}{\partial u}\right\} + \left\{\frac{\partial U_{b}^{W}}{\partial v''}\right\}\left\{\frac{\partial v''}{\partial u}\right\} \ldots\ldots\ldots (7a)$$

$$\left\{\frac{\partial U_{T}^{W}}{\partial v}\right\} = \left\{\frac{\partial U_{a}^{W}}{\partial u''}\right\}\left\{\frac{\partial u''}{\partial v}\right\} + \left\{\frac{\partial U_{b}^{W}}{\partial v''}\right\}\left\{\frac{\partial v''}{\partial v}\right\} \ldots\ldots\ldots (7b)$$

$$\left\{\frac{\partial U_{T}^{W}}{\partial \phi}\right\} = \left\{\frac{\partial U_{a}^{W}}{\partial \phi''}\right\} + \left\{\frac{\partial U_{b}^{W}}{\partial \phi''}\right\} + \left\{\frac{\partial U_{\phi}^{W}}{\partial \phi''}\right\} \ldots\ldots\ldots (7c)$$

Combining Eqs. 7a, 5a, 5b, 2a and 2b

$$\left\{\frac{\partial U_{T}^{W}}{\partial u}\right\} = a[A^W]\left\{u''\right\} - b[B^W]\left\{v''\right\} \ldots\ldots\ldots\ldots (8a)$$

Introducing Eqs. 2a and 2b into Eq. 8a rearranging, and abbreviating the resulting matrix sums by.

$$a^2[A^W] + b^2[B^W] = [K_1^W] \quad \ldots\ldots\ldots\ldots\ldots\ldots (8b)$$

$$ab[A^W] - ab[B^W] = [L_1^W] \quad \ldots\ldots\ldots\ldots\ldots\ldots (8c)$$

$$ac[A^W] + bd[B^W] = [M_1^W] \quad \ldots\ldots\ldots\ldots\ldots\ldots (8d)$$

The following is obtained

$$\left\{\frac{\partial U_T^W}{\partial u}\right\} = [K_1^W]\{u\} + [L_1^W]\{v\} + [M_1^W]\{\phi\} \ldots (9)$$

Combining Eqs. 7b, 5a, 5b, 2a and 2b

$$\left\{\frac{\partial U_T^W}{\partial v}\right\} = b[A^W]\{u\} + a[B^W]\{v''\} \ldots\ldots\ldots\ldots (10)$$

Introducing Eqs. 2a, 2b into Eq. 1o, rearranging and then introducing the abbreviations

$$ab[A^W] - ab[B^W] = [K_2^W] \ldots\ldots\ldots\ldots (11a)$$

$$b^2[A^W] + a^2[B^W] = [L_2^W] \ldots\ldots\ldots\ldots (11b)$$

$$bc[A^W] - ad[B^W] = [M_2^W] \ldots\ldots\ldots\ldots (11c)$$

Eq. 10 becomes

$$\left\{\frac{\partial U_T^W}{\partial v}\right\} = [K_2^W]\{u\} + [L_2^W]\{v\} + [M_2^W]\{\phi\} \ldots\ldots\ldots (12)$$

By analogous procedures

$$\left\{\frac{\partial U_T^W}{\partial \phi}\right\} = [K_3^W]\{u\} + [L_3^W]\{v\} + [M_3^W]\{\phi\} \ldots\ldots\ldots (13)$$

in which

$$ca[A^W] + bd[B^W] = [K_3^W] \ldots\ldots\ldots\ldots (14a)$$

$$bc[A^W] - ad[B^W] = [L_3^W] \ldots\ldots\ldots\ldots (14b)$$

$$c^2[A^W] + d^2[B^W] + [C^W] = [M_3^W] \ldots\ldots\ldots\ldots (14c)$$

Eqs. 9, 12 and 13 have been derived for only one shear wall; they can be, however, considered as including all shear walls of the building, if the combined stiffness matrices [K], [L], [M] are extended to include stiffness matrices for all shear walls.

5 Considerations for Frames

A. Kinematic Considerations

The displacement of frame f1 shown in Fig. 3 is considered in detail. Firstly the frame centroid at a floor level is rotated about point C, moving from position 0 to position 1 as shown in Fig. 7. This movement will cause rotational and translational displacements of the frame centroid. The frame is then translated from position 1 to position 2 in accordance with the translations of the rigid floor diaphragm shown in Fig. 4. Position 2 of the frame is shown in Fig. 8, in which also are shown the displacements u'' and v'' pertaining to longitudinal and transverse axes of the frame. Consideration of the total movement of the frame would indicate that the frame undergoes two types of displacement: (a) a displacement in which the frame moves in the direction of its horizontal longitudinal axis, (b) a displacement in which each column of the frame moves in the direction perpendicular to the frame horizontal longitudinal axis.

The first type of displacement being similar to that encountered in the previous section, is termed frame action displacement.

In the second type of displacement the columns behave as individual elements coupled to each other by means of spandrel beams. If the torsional stiffness of the spandrel beams is negligible, the columns can be treated in a manner analogous to that used for individual shear walls. This type of displacement is termed cantilever action displacement.

B. *Frame Action Energy Relationships*

The component of displacement parallel to the frame longitudinal axis is given by Eq. 2a and is designated by u'' in Fig. 8. Energy relationships for the frame can be established from the previously established relationships for the shear wall. Thus the following relationships can be set up analogous to Eq. 9 by setting $[B^W]' = 0$

$$\left\{\frac{\partial U_T^f}{\partial v}\right\} = [K_1^f]\left\{u\right\} + [L_1^f]\left\{v\right\} + [M_1^f]\left\{\phi\right\} \quad \ldots\ldots\ldots\ldots \quad (15)$$

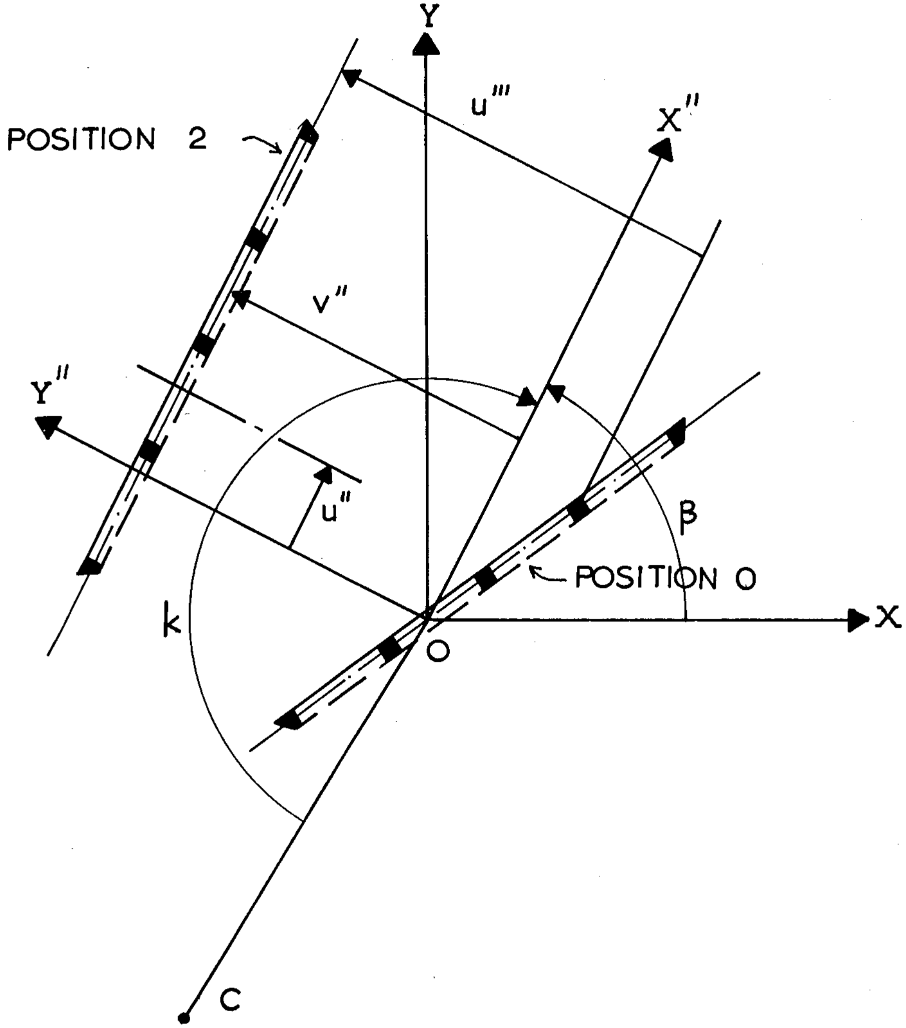

Fig. 7 — Frame Displacements Due to Rotation

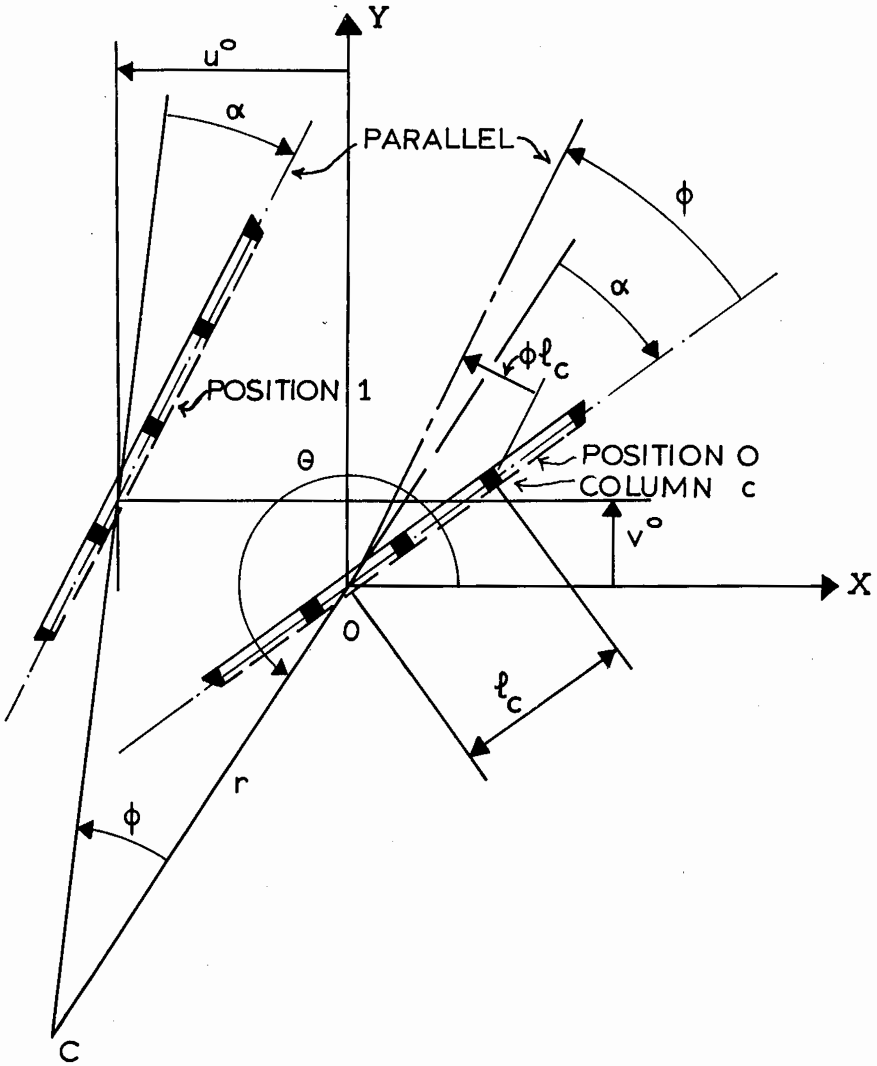

Fig. 8 — Frame Coordinate Transformation

Similarly from Eq. 12 by setting $[B^W] = 0$

$$\left\{\frac{\partial U_T^f}{\partial v}\right\} = [K_2^f]\left\{u\right\} + [L_2^f]\left\{v\right\} + [M_2^f]\left\{\phi\right\} \quad \ldots\ldots\ldots\ldots \quad (16)$$

And from Eq. 13 by setting $[\overset{w}{B}] = [\overset{w}{C}] = 0.$

$$\left\{\frac{\partial U_T^f}{\partial \phi}\right\} = [K_3^f]\left\{u\right\} + [L_3^f]\left\{v\right\} + [M_3^f]\left\{\phi\right\} \quad \ldots\ldots\ldots\ldots \quad (17)$$

Eqs. 15, 16, and 17 have been derived for only one frame; they can however be considered as including all frames of the building, if the combined stiffness matrices [K], [L], [M] are extended to include stiffness matrices for all frames.

C. *Cantilever Action Energy Relationships*

The strain energy stored in the column is due to translational displacements in the direction of the transverse frame axis shown in position 2 in Fig. 8. The strain energy due to column torsion is neglected in the present analysis.

Column c shown in Fig. 7 is chosen in exemplifying the energy relationships. By reference to Figs. 7 and 8, and by analogy to Eq. 2a, the displacement in the direction of the transverse frame axis is given by

$$u^{III} = (\sin\beta)u + (\cos\beta)v - r(\cos k)\phi + \ell_c\phi \quad \ldots\ldots\ldots\ldots\ldots \quad (18)$$

in which ℓ_c is the distance from the frame centroid to the column centroid. The above relationship is of the form

$$u^{III} = au + bv + c\phi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (19)$$

Since the total strain energy in the column is due to uniaxial translations, energy relationships can be obtained from the corresponding relationships for a shear wall by setting $[B] = [C] = 0$.

Thus, by analogy to Eqs. 9, 12 and 13

$$\left\{\frac{\partial U_T^c}{\partial u}\right\} = [K_1^c]\left\{u\right\} + [L_1^c]\left\{v\right\} + [M_1^c]\left\{\phi\right\} \quad \ldots\ldots\ldots\ldots \quad (20)$$

$$\left\{\frac{\partial U_T^c}{\partial v}\right\} = [K_2^c]\left\{u\right\} + [L_2^c]\left\{v\right\} + [M_2^c]\left\{\phi\right\} \ldots\ldots\ldots\ldots \quad (21)$$

$$\left\{\frac{\partial U_T^c}{\partial \phi}\right\} = [K_3^c]\left\{u\right\} + [L_3^c]\left\{v\right\} + [M_3^c]\left\{\phi\right\} \ldots\ldots\ldots\ldots \quad (22)$$

in which $\left\{U_T^c\right\}$ denotes the total strain energy stored in the column. Eqs. 20, 21 and 22 have been derived for only one column; they can however be considered as including all columns of the building if the combined stiffness matrices [K], [L], [M] are extended to include stiffness matrices for all columns.

6 Potential of External Loads

Load $F_{1.n}$ acting on face 1 at the n^{th} floor of the building, as shown in Fig. 3, is chosen to exemplify the pertinent relationships. For the above particular building face and floor level, the potential is given by

$$V_{1.n} = - u''_{1.n} F_{1.n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

in which $u''_{1.n}$ is the displacement of the point of application of the load in the direction of the load. Since the displacement $u''_{1.n}$ can be expressed as a function of the type of Eq. 2a, Eq. 23 becomes

$$V_{1.n} = -(a_{1.n} u_n + b_{1.n} v_n + c_{1.n} \phi_n) F_{1.n} \ldots\ldots\ldots \quad (24)$$

in which the constants $a_{1.n}$, $b_{1.n}$, $c_{1.n}$ refer to the coordinate transformation XOY X″OY″ such that the positive direction of the OX″ axis coincides with the direction of the load as shown in Fig. 9.

Differentiating Eq. 24 with respect to u_n

$$\frac{\partial V_{1.n}}{\partial u_n} = - a_{1.n} F_{1.n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (25)$$

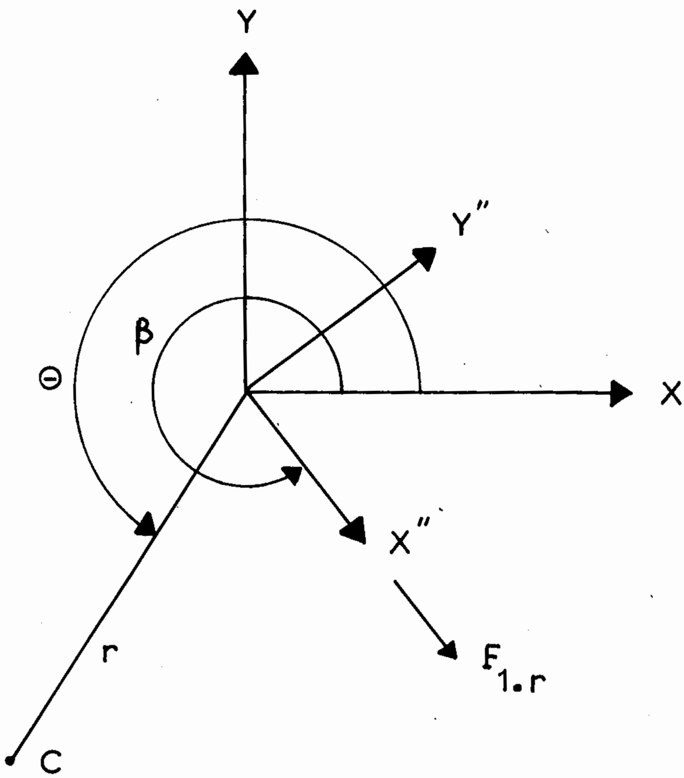

Fig. 9 — Force Coordinate Transformation

Considering expressions similar to Eq. 25 for all floors of the building at face 1

$$\begin{Bmatrix} \dfrac{\partial V_{1.1}}{\partial u_1} \\ \dfrac{\partial V_{1.2}}{\partial u_2} \\ \cdot \\ \cdot \\ \dfrac{\partial V_{1.p}}{\partial u_p} \end{Bmatrix} = - \begin{Bmatrix} a_{1.1} F_{1.1} \\ a_{1.2} F_{1.2} \\ \cdot \\ \cdot \\ a_{1.p} F_{1.p} \end{Bmatrix} \quad \ldots\ldots\ldots\ldots\ldots \quad (26)$$

Setting Eq. 26 in matrix form

$$\begin{Bmatrix} \dfrac{\partial V_{1.}}{\partial u} \end{Bmatrix} = - \begin{Bmatrix} a_{1.} F_{1.} \end{Bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (27)$$

Considering potential relationships similar to Eq. 27 for all faces, 1 to 7, of the building, grouping together and replacing the matrix sums by equivalent matrices

$$\begin{Bmatrix} \dfrac{\partial V_T}{\partial u} \end{Bmatrix} = - \begin{Bmatrix} aF \end{Bmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (28)$$

in which V_T is the potential due to all loads acting on the building. Establishing relationships similar to Eq. 28 for displacements v and ϕ

$$\begin{Bmatrix} \dfrac{\partial V_T}{\partial v} \end{Bmatrix} = - \begin{Bmatrix} bF \end{Bmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (29)$$

$$\begin{Bmatrix} \dfrac{\partial V_T}{\partial \phi} \end{Bmatrix} = - \begin{Bmatrix} cF \end{Bmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (30)$$

7 Application of Minimum Total Potential Theorem

According to the minimum total potential theorem, at equilibrium

$$\left\{\frac{\partial U_T}{\partial u}\right\} + \left\{\frac{\partial V_T}{\partial u}\right\} = 0 \quad \text{(31a)}$$

$$\left\{\frac{\partial U_T}{\partial v}\right\} + \left\{\frac{\partial V_T}{\partial v}\right\} = 0 \quad \text{(31b)}$$

$$\left\{\frac{\partial U_T}{\partial \phi}\right\} + \left\{\frac{\partial V_T}{\partial \phi}\right\} = 0 \quad \text{(31c)}$$

Since U_T and V_T in the above equations refer to the entire sustem, the following relationships exist

$$\left\{\frac{\partial U_T}{\partial u}\right\} = \left\{\frac{\partial U_T^w}{\partial u}\right\} + \left\{\frac{\partial U_T^f}{\partial u}\right\} + \left\{\frac{\partial U_T^c}{\partial u}\right\} \quad \text{(32a)}$$

$$\left\{\frac{\partial U_T}{\partial v}\right\} = \left\{\frac{\partial U_T^w}{\partial v}\right\} + \left\{\frac{\partial U_T^f}{\partial v}\right\} + \left\{\frac{\partial U_T^c}{\partial v}\right\} \quad \text{(32b)}$$

$$\left\{\frac{\partial U_T}{\partial \phi}\right\} = \left\{\frac{\partial U_T^w}{\partial \phi}\right\} + \left\{\frac{\partial U_T^f}{\partial \phi}\right\} + \left\{\frac{\partial U_T^c}{\partial \phi}\right\} \quad \text{(32c)}$$

Combining Eqs. 9, 15, 20, 28, 31a and 32a

$$([K_1^w] + [K_1^f] + [K_1^c])\{u\} + ([L_1^w] + [L_1^f] + [L_1^c])\{v\} +$$

$$([M_1^w] + [M_1^f] + [M_1^c])\{\phi\} = \{aF\} \quad \text{(33)}$$

Abbreviating the matrix sums in Eq. 33

$$[K_1^T] \{u\} + [L_1^T] \{v\} + [M_1^T] \{\phi\} = \{aF\} \qquad (34)$$

By an analogous process combining Eqs. 12, 16, 31b, 32b, 29 and 21

$$[K_2^T] \{u\} + [L_2^T] \{v\} + [M_2^T] \{\phi\} = \{bF\} \qquad (35)$$

Similarly, combining Eqs. 13, 17, 22, 30, 31c, 32c and 22

$$[K_3^T] \{u\} + [L_3^T] \{v\} + [M_3^T] \{\phi\} = \{cF\} \qquad (36)$$

Solution of the system of Eqs. 34, 35 and 36 will yield values for the displacements u, v and ϕ.

The forces necessary to keep the structural systems of the building in the known deflected configuration can then be computed from the pertinent stiffness equations. Stress resultants can then be determined by conventional means from either the known displacements or computed forces.

METHOD OF ANALYSIS FOR UNIAXIAL DISPLACEMENTS

A structure is considered that consists of planar arrays of shear walls and frames as shown in Fig. 10 and incorporating the following characteristics: (a) interconnecting links may be omitted from several floor levels, (b) external loading may be applied on each shear wall and frame individually. Frames are characterized by f1, f2 etc., and shear walls by w1, w2 etc. Floors are numbered as follows:

The floor levels of the first system proceeding from left to right are assigned Arabic numerals increasing from bottom to top, and all floor levels of system 1 are included in this operation. Then, system 2 is inspected starting from the lowest floor and proceeding upward. The floor levels of system 2 that are interconnected with system 1 are assigned the same numerals as those for system 1 while each encountered level which is not interconnected to system 1 is assigned the next numeral in the series. System 3 is treated relative to system 2 in the same manner that system 2 was treated relative to system 1.

Externally applied forces are then assigned the superscript pertaining to the system, and the subscript pertaining to the floor level. Floor level displacements are assigned the subscript pertaining to the level in question. The complete column matrices of externally applied forces and displacements for the system combination 1 + 2 + 3 are given by

$$\left\{ \bar{F} \right\} = \left\{ \begin{array}{l} F_1^{f1} \\ F_2^{f1} + F_2^{w1} + F_2^{f2} \\ F_3^{f1} + F_3^{w1} + F_3^{f2} \\ F_4^{f1} \\ F_5^{f1} \\ \qquad F_6^{w1} + F_6^{f2} \\ \qquad F_7^{w1} + F_7^{f2} \end{array} \right\} \quad \text{(37a)}$$

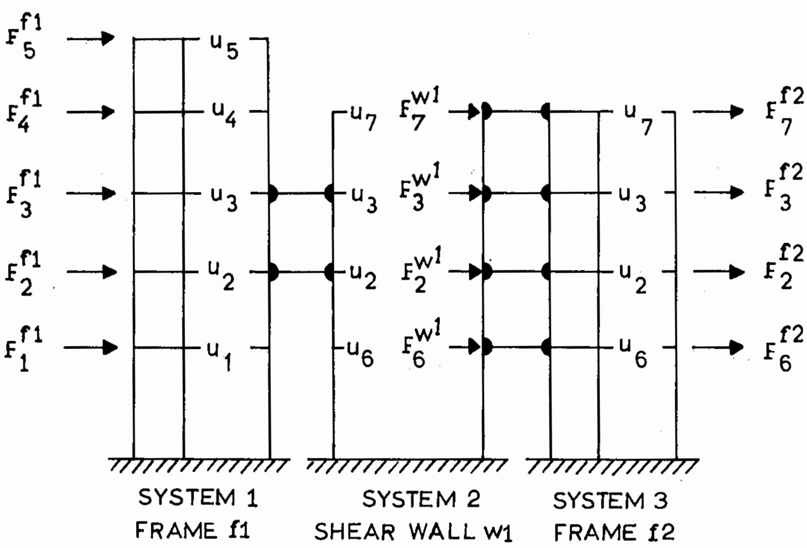

Fig. 10 — Generalized Planar Arrays

$$\left\{\bar{u}\right\} = \left\{\begin{matrix} u_1 \\ u_2 \\ u_3 \\ u_4 \\ u_5 \\ u_6 \\ u_7 \end{matrix}\right\} \quad \text{.................................} \quad (37b)$$

Establishing an equation for frame f1 analogous to Eq. 5

$$\left\{\frac{\partial U^{f1}}{\partial u^{f1}}\right\} = [A^{f1}] \left\{u^{f1}\right\} \quad \text{.........................} \quad (38)$$

in which $\left\{u^{f1}\right\}$ is the column matrix of displacements for frame f1 only. Eq. 38 can be modified to

$$\left\{\frac{\partial U^{f1}}{\partial \bar{u}}\right\} = [\bar{A}^{f1}] \left\{\bar{u}\right\} \quad \text{.............................} \quad (39)$$

in which $[\bar{A}^{f1}]$, resulting from $[A^{f1}]$ by the introduction of appropriate zero elements, corresponds to the complete displacement column matrix $\left\{\bar{u}\right\}$. Establishing expressions similar to Eq. 39 for shear wall w1 and frame f2 and combining them with Eq. 39 gives

$$\left\{\frac{\partial U}{\partial \bar{u}}\right\} = [\bar{A}] \left\{\bar{u}\right\} \quad \text{..............................} \quad (40)$$

in which U is the total strain energy for the combined system 1 + 2 + 3 and

$$[\bar{A}] = [\bar{A}^{f1}] + [\bar{A}^{w1}] + [\bar{A}^{f2}]$$

Applying Eq. 27 to frame f1

$$\left\{\frac{\partial V^{f1}}{\partial u^{f1}}\right\} = -\left\{F^{f1}\right\} \quad \ldots\ldots\ldots\ldots \quad (41)$$

Eq. 41 can be modified as

$$\left\{\frac{\partial V^{f1}}{\partial \bar{u}}\right\} = -\left\{\bar{F}^{f1}\right\} \quad \ldots\ldots\ldots\ldots \quad (42)$$

in which $\left\{\bar{F}^{f1}\right\}$, resulting from $\left\{F^{f1}\right\}$ by the introduction of appropriate zero elements, corresponds to the complete displacement column matrix given by Eq. 37b. Establishing expressions similar to Eq. 42 for shear wall w1 and frame f2 and combining them with Eq. 42

$$\left\{\frac{\partial V}{\partial \bar{u}}\right\} = -\left\{\bar{F}\right\} \quad \ldots\ldots\ldots\ldots \quad (43)$$

in which V is the potential for the combined system 1+2+3, and $\left\{\bar{F}\right\}$ is given by Eq. 37a.

Applying the theorem of minimum total potential to Eqs. 40 and 43

$$[\bar{A}]\left\{\bar{u}\right\} = \left\{\bar{F}\right\} \quad \ldots\ldots\ldots\ldots \quad (44)$$

Solution of Eq. 44 will give the complete set of horizontal displacements, from which the forces necessary to keep the system in the known deflected configuration and stress resultants can be computed. The method can be applied to any structure regardless of number of systems and floors.

The effect of foundation rotation rotation may be treated by the introduction of a member of equivalent stiffness, as is outlined in Reference 18.

The effect of plastic hinge formation may be taken into account by resolving the structure into two or more constituent systems. In the first, the structure is assumed to consist of the original material behaving in a linearly elastic manner up to the point of the first plastic hinge formation. In the second constituent system, the plastic hinge is replaced by an equivalent hypothetical linearly elastic material. Determination of the stiffness matrix of both systems must be carried out. Resultant action of the original structure can be obtained by superposition of the results of the two constituent systems.

Formation of more than one plastic hinge can be treated in a similar manner.

PART 3
NUMERICAL APPLICATION

1. System Characteristics

A four story building, having a plan configuration as shown in Fig. 11, was analyzed for earthquake loading acting in the OX direction. The number of stories was chosen deliberately small in order to keep the computa-

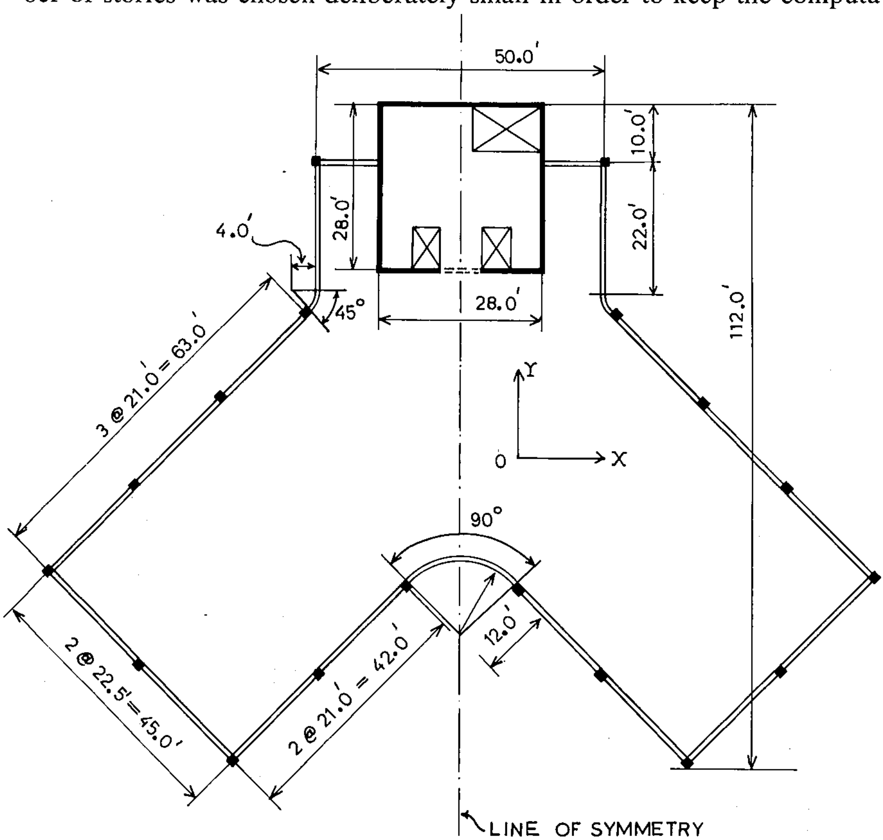

Fig. 11 — Example Building — Floor Plan

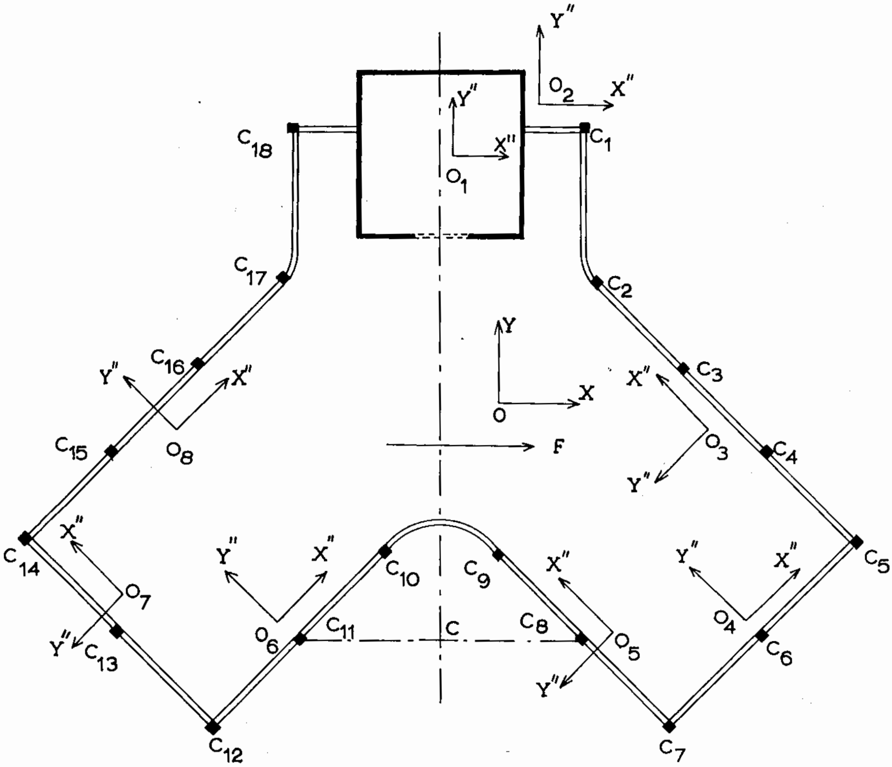

Fig. 12 — Example Building — Reference Systems

tions in a manageable space. The building is of reinforced concrete, waffle slab construction. The core is 10 in. thick and the columns 15 in. square.

The perimetric spandrel supporting the floor is 6.0 ft. deep and 12 in. wide, yielding (I/L) spandrel/ (I/L) column $\cong$ 25, and therefore justifying the assumption of discrete spring type systems for the perimetric frames. The first story is 13.3 ft. high and the remaining stories are 11.3 ft. high. Core and perimetric frames are resting on a rigid diaphragm at the first floor level.

The total lateral force was calculated as 560 kips, which is 0.057 of the total building weight. In applying the lateral loading, the center of stiffness was arbitrarily assumed at the center of the core and the center of mass was located by calculations at 50.0 feet from it. This is the point at which lateral forces F are applied as shown in Fig. 12. This apparent eccentricity thus exceeds 25% of the 112.0 ft. lateral building dimension; the effects of torsion were therefore doubled (according to recommendation of the current National Building Code of Canada) by doubling the total lateral force to 1,120 kips. The individual lateral forces were calculated according to a formula of the above Code and are shown in Table 2 below.

The flexural rigidity EI of the core and columns was calculated as $1.5(10^9)$ kip-ft.^{2} and $1.3(10^5)$ kip-ft.^{2} respectively.

The following assumptions were made in the analysis:

1. Floor plates are extensionally rigid in their own plane, but flexurally or torsionally flexible about horizontal axes lying in their plane.
2. Lateral forces are horizontal and are applied at floor levels.
3. The torsional rigidity of the core and the torsional and transverse rigidities of the columns are negligible. All axial deformations are negligible.
4. Shear deformations are effective for the core but negligible for the columns.
5. The effective height for flexure in the columns is the story height minus the spandrel depth.

The structural system is sectionalized into eight stiffness elements consisting of the core and column groups. Each element is given a characteristic number, as shown in Table 1, which is used as an identifying subscript in subsequent development. Individual coordinate axes systems $X'' O_n Y''$ (subscript n denotes the element characteristic number) are assigned one to a stiffness element as shown in Fig. 12 in which also is shown the center of rotation C for each floor plate.

TABLE 1. IDENTIFICATION OF STIFFNESS ELEMENTS

Stiffness Element	Characteristic Number
Core	1
FCC* C_1, C_{18}	2
FCC C_2, C_3, C_4, C_5	3
FCC C_5, C_6, C_7	4
FCC C_7, C_8, C_9	5
FCC C_{10}, C_{11}, C_{12}	6
FCC C_{12}, C_{13}, C_{14}	7
FCC C_{14}, C_{15}, C_{16}, C_{17}	8

*FCC = Frame comprising columns
**Columns are shown in Fig. 12

Stiffness matrices bearing the stiffness element characteristic number as subscript are shown below. Stiffness matrices for the core incorporate the effect of shear and were computed by the "STRESS" computer program.

$$[A_1] = [B_1] = \begin{bmatrix} 1.588 & -1.253 & 0.161 & 0.090 \\ -1.253 & 2.229 & -1.380 & 0.270 \\ 0.161 & -1.380 & 2.097 & -0.913 \\ 0.090 & 0.271 & -0.913 & 0.532 \end{bmatrix} \quad \ldots (45)$$

$$[A_2] = \begin{bmatrix} 0.023 & -0.020 & 0 & 0 \\ -0.020 & 0.040 & -0.020 & 0 \\ 0 & -0.020 & 0.040 & -0.020 \\ 0 & 0 & -0.020 & 0.020 \end{bmatrix} \quad \ldots (46)$$

$$[A_3] = [A_8] = \begin{bmatrix} 0.047 & -0.-41 & 0 & 0 \\ -0.041 & 0.082 & -0.041 & 0 \\ 0 & -0.041 & 0.082 & -0.041 \\ 0 & 0 & -0.041 & 0.041 \end{bmatrix} \quad \ldots (47)$$

$$\begin{matrix} [A_4] = [A_5] = \\ [A_6] = [A_7] = \end{matrix} \begin{bmatrix} 0.035 & -0.031 & 0 & 0 \\ -0.031 & 0.062 & -0.031 & 0 \\ 0 & -0.031 & 0.062 & -0.031 \\ 0 & 0 & -0.031 & 0.031 \end{bmatrix} \quad \ldots (48)$$

Measured quantities β, r, k and calculated quantities a, b, c, d are shown in Tables 2 and 3.

TABLE 2. CONSTANTS OF FORCE SYSTEM

Floor Level	Force (kips)	β (degrees)	k (degrees)	r (ft.x10^{-6})	a	b	c (ft.x10^{-6})
2	112.0						
3	224.0						
4	336.0	0	270	34.(10^6)	1	0	−34.(10^6)
Roof	448.0						

TABLE 3. CONSTANTS OF STIFFNESS ELEMENTS

Stiffness Element Characteristic Number	ß (degrees)	k (degrees)	r (ft.x10−6	a	b	c (ft.x10^{-6})	d (ft.x10^{-6})
1	0	270	83.(10^6)	1	0	−83.(10^6)	0
2	0	270	87.(10^6)	1	0	−87.(10^6)	0
3	135	82.5	62.5(10^6)	−0.707	0.707	62.(10^6)	8.(10^6)
4	45	135	54.5(10^6)	0.707	0.707	38.5(10^6)	−38.5(10^6)
5	135	45	24.(10^6)	−0.707	0.707	17.(10^6)	17.(10^6)
6	45	315	24.(10^6)	0.707	0.707	−17.(10^6)	−17.(10^6)
7	135	225	54.5(10^6)	−0.707	0.707	−38.5(10^6)	−38.5(10^6)
8	45	277.5	62.5(10^6)	0.707	0.707	−62.(10^6)	8.(10^6)

2. Calculations

Calculation of the matrices of coefficients of Eqs. 34, 35 and 36 is performed in two stages. In the first stage, equations are developed in terms of symbols. Subscripts appearing in the right hand side of this class of equations denote the stiffness element characteristic number, Symbols [A], [B], a, b, c, d are those pertaining to Eqs. 45 to 48 Table 3. In the second stage of development numerical substitutions are made into the expressions developed in the first stage.

First Stage

$$[K_1^W] = a_1^2 \ [A_1] + b_1^2 \ [B_1] \quad \ldots\ldots\ldots\ldots \quad (49a)$$

$$\left[K_1^f\right] = \sum_{n=2}^{8} a_n^2 \left[A_n\right] \quad \ldots\ldots\ldots\ldots \quad (49b)$$

$$\left[L_1^w\right] = a_1 \; b_1 \; \left[A_1\right] - a_1 \; b_1 \; \left[B_1\right] \qquad (50a)$$

$$\left[L_1^f\right] = \sum_{n=2}^{8} a_n \; b_n \; \left[A_n\right] \qquad (50b)$$

$$\left[M_1^w\right] = a_1 \; c_1 \; \left[A_1\right] + b_1 \; d_1 \; \left[B_1\right] \qquad (51a)$$

$$\left[M_1^f\right] = \sum_{n=2}^{8} a_n \; c_n \; \left[A_n\right] \qquad (51b)$$

$$\left[K_2^w\right] = a_1 \; b_1 \; \left[A_1\right] - a_1 \; b_1 \; \left[B_1\right] \qquad (52a)$$

$$\left[K_2^f\right] = \sum_{n=2}^{8} a_n \; b_n \; \left[A_n\right] \qquad (52b)$$

$$\left[L_2^w\right] = b_1^2 \; \left[A_1\right] + a_1^2 \; \left[B_1\right] \qquad (53a)$$

$$\left[L_2^f\right] = \sum_{n=2}^{8} b_n^2 \; \left[A_n\right] \qquad (53b)$$

$$\left[M_2^w\right] = b_1 \; c_1 \; \left[A_1\right] - a_1 \; d_1 \; \left[B_1\right] \qquad (54a)$$

$$\left[M_2^f\right] = \sum_{n=2}^{8} b_n\ c_n \left[A_n\right] \qquad (54b)$$

$$\left[K_3^w\right] = c_1\ a_1 \left[A_1\right] + b_1\ d_1 \left[B_1\right] \qquad (55a)$$

$$\left[K_3^f\right] = \sum_{n=2}^{8} a_n\ c_n \left[A_n\right] \qquad (55b)$$

$$\left[L_3^w\right] = b_1\ c_1 \left[A_1\right] - a_1\ d_1 \left[B_1\right] \qquad (56a)$$

$$\left[L_3^f\right] = \sum_{n=2}^{8} b_n\ c_n \left[A_n\right] \qquad (56b)$$

$$\left[M_3^w\right] = c_1^2 \left[A_1\right] + d_1^2 \left[B_1\right] \qquad (57a)$$

$$\left[M_3^f\right] = \sum_{n=2}^{8} c_n^2 \left[A_n\right] \qquad (57b)$$

Second Stage

$$\left[K_1^t\right] = \left[K^w\right] + \left[K_1^f\right] = \begin{bmatrix} 0.1728 & 0.1376 & 0.0161 & 0.0090 \\ 0.1376 & 0.2476 & 0.1503 & 0.0271 \\ 0.0161 & 0.1503 & 0.2344 & 0.1036 \\ 0.0090 & 0.0271 & 0.1030 & 0.0655 \end{bmatrix} (10) \quad \ldots\ldots\ldots\ldots\ldots \quad (58)$$

$$\left[L_1^t\right] = \left[L_1^w\right] + \left[L_1^f\right] = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (59)$$

$$\left[M_1^t\right] = \begin{bmatrix} 0.136891 & 0.10841 & 0.013363 & 0.007470 \\ 0.108417 & 0.193843 & 0.118958 & 0.22493 \\ 0.013363 & 0.118958 & 0.182887 & 0.080197 \\ 0.007470 & 0.022493 & 0.080197 & 0.049574 \end{bmatrix} (10^9) \ldots\ldots \quad (60)$$

$$\left[K_2^t\right] = \left[K_2^w\right] + \left[K_2^f\right] = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (61)$$

$$\left[L_2^t\right] = \left[L_2^w\right] + \left[L_2^f\right] = \begin{bmatrix} 0.1705 & 0.1356 & 0.0161 & 0.0090 \\ 0.1356 & 0.2435 & 0.1483 & 0.0270 \\ 0.0161 & 0.1483 & 0.2303 & 0.1016 \\ 0.0090 & 0.0270 & 0.1016 & 0.0635 \end{bmatrix} (10) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (62)$$

$$\left[M_2^t\right] = \left[M_2^w\right] + \left[M_2^f\right] = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (63)$$

$$\left[K_3^t\right] = \left[K_3^w\right] + \left[K_3^f\right] = \begin{bmatrix} 0.136891 & 0.10841 & 0.013363 & 0.007470 \\ 0.108417 & 0.193843 & 0.118958 & 0.022493 \\ 0.013363 & 0.118958 & 0.182887 & 0.080197 \\ 0.007470 & 0.022493 & 0.080197 & 0.049574 \end{bmatrix} (10^9) \ldots\ldots\ldots (64)$$

$$\left[L_3^t\right] = \left[L_3^w\right] + \left[L_3^f\right] = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (65)$$

$$\left[M_3^t\right] = \left[M_3^w\right] + \left[M_3^f\right] = \begin{bmatrix} 0.117752 & 0.093472 & 0.011270 & 0.006300 \\ 0.093472 & 0.167554 & 0.102362 & 0.018970 \\ 0.011270 & 0.102362 & 0.158284 & 0.069672 \\ 0.006300 & 0.018970 & 0.069672 & 0.043002 \end{bmatrix} (10^{17}) \ldots\ldots\ldots \quad (66)$$

Also with values taken from Table 3

$$\left\{ {}_a F \right\} = \left\{ \begin{matrix} 0.112 \\ 0.224 \\ 0.336 \\ 0.448 \end{matrix} \right\} (10^3) \quad \ldots\ldots (67)$$

$$\left\{ {}_b F \right\} = \left\{ \begin{matrix} 0 \\ 0 \\ 0 \\ 0 \end{matrix} \right\} \quad \ldots\ldots (68)$$

$$\left\{ {}_c F \right\} = \left\{ \begin{matrix} -0.038 \\ -0.076 \\ -0.114 \\ -0.152 \end{matrix} \right\} (10^{11}) \quad \ldots\ldots (69)$$

A system of twelve equations with twelve unknown is assembled from the determined values:

$$\begin{bmatrix} [K_1^t] & [L_1^t] & [M_1^t] \\ [K_2^t] & [L_2^t] & [M_2^t] \\ [K_3^t] & [L_3^t] & [M_3^t] \end{bmatrix} \left\{ \begin{matrix} \{u\} \\ \{v\} \\ \{\phi\} \end{matrix} \right\} = \left\{ \begin{matrix} \{{}_a F\} \\ \{{}_b F\} \\ \{{}_c F\} \end{matrix} \right\} \quad \ldots\ldots (70)$$

Solution of the above system through a computer program, gives the values shown in Table 4.

TABLE 4. DETERMINED VALUES OF DEFLECTIONS AND ROTATIONS

Floor Level	u (ft.)	v (ft.)	ϕ Radians
Roof	0.0490	0	0.000447
4	0.0453	0	0.000436
3	0.0399	0	0.000405
2	0.0330	0	0.000358

It is seen that v deflections are zero; this is expected since the stiffness elements comprise a system symmetrical about the OY axis and all external forces are perpendicular to that axis. On the basis of the figures of Table 4, the roof plate is shown in the displaced and original position in Fig. 13; displacements are shown magnified 200 times.

In plane displacements u'', for each stiffness element, can be computed from Eq. 2a, and the force system necessary to keep the element in the known deflected configuration may be computed from the stiffness equation incorporating the appropriate stiffness matrix. Stress resultants in the frames can then be computed from the known lateral forces by a conventional method.

CONCLUSIONS

Several methods of analysis of interconnected shear walls and shear wall-frame systems, subjected to horizontal static loading, have been reviewed and summarized. All of the reviewed methods consider structures subjected to the following restrictions: (1) shear walls and frames form rectangular grid plans, (2) the horizontal loading acting on the structure is parallel to the grid, and (3) the structure undergoes uniaxial displacements parallel to the grid.

A method of analysis, free of the above restrictions, and intended to supplement rather than replace the existing methods, has been presented herein. The method, based on the theorem of minimum total potential, is employing stiffness matrices of the constituent stiffness elements of the structure analyzed, as the basic input information. Stiffness matrices may in-

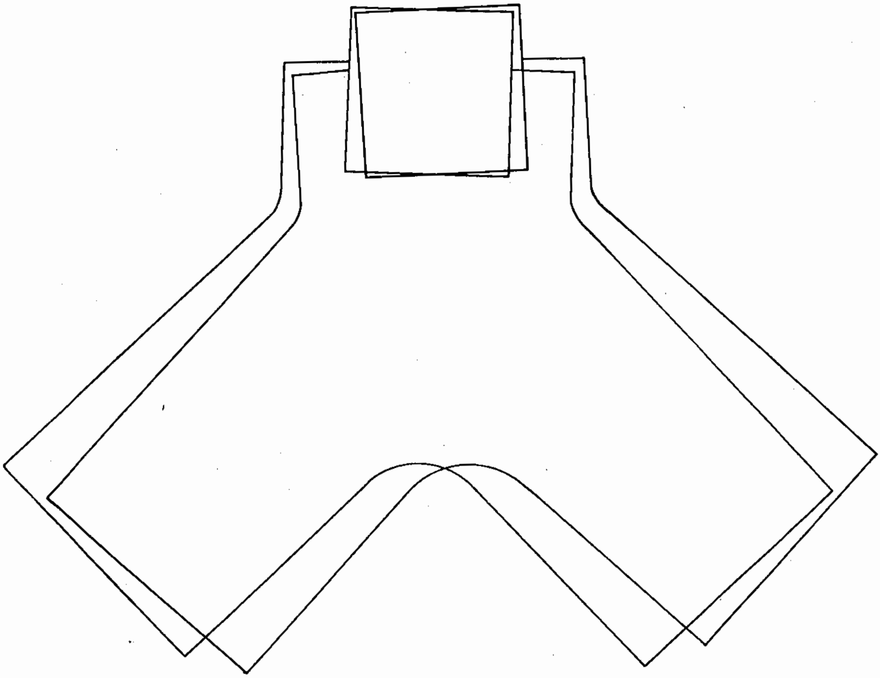

Fig. 13 — Example Building — Roof Displacements

clude the effect of shearing, torsional and axial deformations. The "general case" has been developed first, in which the structure to be analyzed consists of shear walls and frames interconnected through rigid floor diaphragms undergoing biaxial and rotational displacements. Then, the method was applied to the special case of planar arrays of shear walls and frames of arbitrary characteristics, and connected through inextensible links, undergoing uniaxial displacements only. The unknown displacement quantities form algebraic systems of linear equations, which can be solved by means of a digital computer.

In order to exhibit the workability of the method, a numerical example has been presented employing a Y shaped in plan building. In order to keep the numerically developed matrices within a manageable space, the number of stories was limited to four, without, however, impairing the general character of the method. Increasing the number of stories of this example building would have only the effect of increasing the size of computational matrices with all other steps remaining the same.

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APPENDIX I

Determination of Stiffness Coefficients

1. *Shear Walls*

The stiffness coefficients for a shear wall taking into consideration the effect of bending and shear, can be determined directly or indirectly. The direct method would consist of deflecting, by a unit displacement, the cantilever structure, one point at a time, while locking all other points against translational displacements only. Thus, the stiffness coefficient A_{kj} is equal to the reaction required to keep point k locked against displacement, while a load applied at joint j is producing a unit displacement at j.

Reactions can be determined from a moment distribution. Fixed end moments, stiffness and carry over factors can be determined from the relationships in Reference 22, as follows:

$$\text{FEM} = \frac{6(EI)}{L^2} \left\{\frac{1}{1-2\beta}\right\} \delta \quad \text{(47)}$$

$$\text{ST} = \frac{M_1}{\theta} = \frac{2(EI)}{L} \left\{\frac{2+\beta}{1+2\beta}\right\} \quad \text{(48)}$$

$$COF = \frac{M_2}{M_1} = \frac{1-\beta}{2+\beta} \quad \text{.............................} \quad (49)$$

in which FEM, ST, COF signify fixed end moment, stiffness, and carry over factor respectively; subscripts 1 and 2 refer to the near and far end of the member respectively; θ denotes the angle of rotation of end 1 while end 2 is fixed; β is a parameter given by

$$\beta = \frac{6(EI)}{L^2(AG)}$$

In the above relationships a constant shear distribution has been assumed through the depth of the member. A parabolic distribution, taking into account the effect of intervening ribs[23], can be effected by a suitable modification of the parameter β.

The indirect method of determining the stiffness coefficients, would involve determining and inverting the flexibility matrix.

In inspecting the stiffness matrix for correctness, it must be borne in mind that it must be symmetric about the main diagonal, and that the sum of the coefficients of any column, including the base shear coefficient if any, must be zero for equilibrium of the system.

2. *Frames*

Stiffness coefficients for beam-column frames due to primary effects (bending plus shear) can be determined according to the direct method outlined previously for shear walls. Axial deformations of columns generated in the deflection operation will induce secondary bending moments which in turn will cause additional deflections and reactions. The combined stiffness coefficients will then be equal to the ratio of the sum of primary and secondary reactions to the sum of primary and secondary deflections.

APPENDIX II — NOTATION

The following symbols have been adopted for use in this paper:

a, b, c = constants;

A = stiffness coefficients;

[A] = square stiffness matrix due to displacements parallel to OX axis;

[$\bar{A}$] = square stiffness matrix defined by Eq. 39;

AG = shearing rigidity;
[B] = square stiffness matrix due to displacements parallel to OY axis;
[C] = square stiffness matrix due to tortional displacements;
EI = flexural rigidity;
{F} = column matrix of external loads;
$\{\bar{F}\}$ = column matrix of external loads defined by Eq. 42;
[K], [L], [M] = combined stiffness matrices defined by Eqs. 8, 11, 14;
M = bending moment;
OX, OY, OZ = cartesian coordinate system whose OZ axis is parallel to the vertical axis of the building;
OX″, OY″, OZ = cartesian coordinate system whose OX″, OY″ axes are parallel to the principal axes of the shear wall cross section, or frame plan projection;
P = force acting on shear wall or frame at floor level;
{P} = load column matrix;
r = radius of rotation of shear wall or frame centroid;
u, v = displacements of the rigid floor diaphragm with respect to XOY system;

displacements of the shear wall or frame centroid in moving from position 1 to position 2;

uo, vo = displacements of the shear wall or frame centroid (with respect to XOY system) in moving from position 0 to position 1;
u′, v′ = displacements of the shear wall or frame centroid (with respect to XOY system) in moving from position 0 to position 2;
{u} = displacement column matrix;
$\{\bar{u}\}$ = displacement column matrix defined by Eq. 37b;
U = strain energy;
V = potential of external loads;

GREEK SYMBOLS

β = angle between XOY and X″OY″ systems;
θ = angle between axis OX and the line drawn from the center of rotaions C to centroid of shear wall or frame;
ϕ = horizontal rotation of floor diaphragm;

SUPERSCRIPTS

c signifies column;

w denotes shear wall;

f signifies frame;

″ denotes quantities pertaining to X″OY″ system;

SUBSCRIPTS

a signifies quantities pertaining to displacements parallel to OX axis;

b denotes quantities pertaining to displacements parallel to OY axis:

n denotes quantities pertaining to nth floor;

ℓ signifies matrix quantities applicable to ℓth face and including all floors;

ℓ.n denotes quantities pertaining to ℓth face and nth floor of the building;

ϕ signifies quantities pertaining to rotational displacements;

IN MEMORIAM

GORDON M. FAIR

President Boston Society of Civil Engineers 1939-1940

His Legacy To The Engineering Profession

Some fifteen years ago a highly regarded journal of the civil engineering profession published a personality profile titled: "Master of the House - and Much of What He Surveys."

This story in the ENGINEERING NEWS-RECORD opened with the declaration that few, if any, contemporary Americans have exerted a greater influence on engineering than Gordon Maskew Fair. However, it went on to say, evidence of his accomplishments were not to be found in monumental structures. He did not work with steel or concrete. His work had to do with moulding the minds of men.

Included with this account was a roster of distinguished leaders in the practice and teaching of environmental engineering. This list presented only a cross section of the more than 700 graduate students whose professional careers and contributions to society were shaped by Professor Fair.

Far greater in number — and far beyond the halls of Harvard — are those who have been influenced by this eloquent advocate of environmental harmony and the application of engineering skills for its attainment. His writings on these matters have been translated into many languages. And with small regard for personal travail he carried his teachings to lands around the globe.

One of his colleagues in the Rockefeller Foundation — which he served as a member of the board of scientific directors and, incidentally, was the first engineer to achieve such distinction — had this to say: Whether it be in the swamps of Sardinia, in the jungles of Brazil, in the lecture rooms of the Ecole Polytechnique in Paris or in the laboratories of the London School of Hygiene, the presence of Gordon Fair inspired all those with whom he came in contact.

In probing the genius of this man who was affectionately known as the "high priest" of sanitary engineering, one discovers two outstanding characteristics — a great depth of perspective and an uncanny sense of revelation.

On the one hand he was the interpreter of history, reminding us, in the words of George Santayana, that "those who cannot remember the past are condemned to repeat it." No matter what aspect of sanitary engineering doctrine or technology was brought forth for discussion Professor Fair was always prepared to document its origins, merits and limitations, and from this extract lessons appropriate to solution of the problem at hand. Once he told me: "My students probably regard me as an incorrigible antiquarian; but I am simply seeking to demonstrate how one may profit from a knowledge of past labors."

On the other hand, Gordon Fair was the clairvoyant whose intuitive capabilities led to the identification of emerging problems before they were recognized as matters of concern to the profession at large. Thus he was able to delineate areas for research and engineering investigation, the importance of which now assumes dramatic dimensions as the nation mounts an intensified campaign to curb the pollution of water, air and land resources.

Earlier I alluded to the conviction of Professor Fair that constant vigilance must be exercised and safeguards devised to counter the destructive impacts of man on his environment. Dedicated to this proposition, he chose engineering as the fulcrum, and teaching as the lever, for moving the minds of men to cope with scientific and technological change.

That today the sanitary-engineering profession is uniquely prepared to respond to rising social initiative for protecting the environment in no small measure can be credited to Gordon Fair and those hundreds of disciples who came under his tutelage during the past half century. With assurance it can be said that the arsenal of technology is amply stocked and engineering talent already mobilized to advance this new crusade for pollution abatement.

This, then, is the professional legacy of the man in whose memory we have gathered to pay tribute. His endowment of knowledge and vision will continue to enrich all those who aspire to apply engineering skills for improving the welfare of mankind.

(Comments of Edward J. Cleary at a memorial service on February 20, 1970)

PROCEEDINGS OF THE SOCIETY

Minutes of Meeting

Boston Society of Civil Engineers

January 28, 1970 — The regular monthly meeting of the Boston Society of Civil Engineers was held jointly with the Hydraulics Section in the Adams Room, United Community Services Building, 14 Somerset Street, Boston, Massachusetts. This meeting is designated the John R. Freeman Memorial Lecture.

A catered roast beef dinner was served before the meeting and it was enjoyed by fifty (50) members and guests.

After the dinner, Vice President Spencer called the meeting to order at 7:00 P.M.

Vice President Spencer stated that unless there was objection, the reading of the Minutes of the previous meeting held on December 10, 1969 would be omitted as they would be published in a forthcoming issue of the Journal.

The Secretary announced that at the Board of Government meeting held earlier in the day the following had been elected to membership:-

Grade of Member - Joel P. Bilodeau, Milton M. Cameron, Ching Chang Fang, Wayne T. Fisher, Thomas F. X. Flynn, Melvin W. Morgan, Michael E. Rafferty, Richard G. Sherman

Grade of Junior Member - Charyl W. Butterworth, Richard W. Check, Max S. Clark, 3rd., David F. Doyle, Leslie T. Hatch

The Secretary also announced that applications for membership had been received from the following:—

Richard N. Altieri, Watertown, Mass.
Richard J. Prudente, Everett, Mass.
James O. Olson, Essex Jct., Vermont *
Conrad C. Fagone, Arlington, Mass. *
M. Anthony Lally, No. Andover, Mass.*

*Transfer from Junior

The Secretary moved and it was seconded and VOTED "that the Board of Government be authorized to transfer an amount not to exceed $8000.00 from the Principal of the Permanent Fund to the Current Fund for Current Expenditures. Vice President Spencer announced that this was the final action on this matter.

Vice President Spencer then turned the meeting over to Ronald T. McLaughlin, Chairman of the Hydraulics Section to conduct any business of that section.

Chairman Ronald T. McLaughlin stated that this meeting was sponsored by the John R. Freeman Fund Committee as "A John R. Freeman Memorial Lecture" and turned the meeting over to Prof. Leslie J. Hooper, Chairman of the John R. Freeman Fund Committee. Prof. Hooper described the John R. Freeman Fund and read to those present some of Mr. Freeman's thoughts as expressed in the Deed of Gift. Prof. Hooper invited suggestions from the Society as to how these funds might be appropriately expended. Prof. Hooper then introduced the guest speaker for the evening as the fifth John R. Freeman Lecturer. The speaker, Mr. Klas Cederwall gave a very interesting and informative illustrated lecture on "Dispersion Phenomena in Coastal Environments". This paper is already in the hands of the editor and will be published in a forthcoming issue of the Journal. Prof. Hooper announced that since the hour was late, there would be no formal discussion period, but that those who wished to could meet with the speaker following the close of business. Prof. Hooper then presented the speaker with a suitably inscribed certificate and an honorarium.

Sixty one (61) members and guest attended the lecture.

The meeting adjourned at 8:35 P.M.

Respectfully submitted,
Paul A. Dunkerley
Secretary

February 18, 1970 — A Joint Meeting of the Massachusetts Section of the American Society of Civil Engineers and the Boston Society of Civil Engineers was held as a luncheon meeting at the Red Coach Grill, on Stanhope Street, Boston, Massachusetts. Luncheon was served at 12:15 P.M.

President Francis T. Sendker of the Massachusetts Section of the ASCE called the meeting to order at 1:00 P.M. After introducing the guests at the head table, President Sendker turned the meeting over to President Robert H. Culver of the BSCE to conduct any business.

President Culver announced the death of Past President and Honorary Member Gordon M. Fair on February 11, 1970. A moment of silence was observed in memory of Prof. Fair.

President Culver then called upon the Secretary for any announcements. The Secretary announced that applications for membership had been received from the following:-

Derek A. DeSouza, Somerville, Mass.
Alfred M. Corneliuson, Jamaica Plain, Mass.
Glen E. Mitchell, Medford, Mass.
Kenneth A. Goff, Acton, Mass. *
Anthony H. Slocum, Marblehead, Mass.
Samuel A. Wigon, Brookline, Mass.

*Transfer from Junior

President Culver then returned the chairmanship of the meeting to President Sendker.

At the conclusion of the business affairs of the Massachusetts Section of the ASCE, Mr. Edward Newton introduced the speaker of the afternoon, Mr. T. Richard Guinan, Vice President of the State Street Bank and Trust Company.

Mr. Guinan gave an interesting and factual summation of the problems associated with "Financing Municipal Construction Projects". In his talk, Mr. Guinan emphasized the recent spiral of interest charges on municipal bonds, so that late in 1969 these interest charges had reached an all-time high of more than 7%. Following Mr. Guinan's talk, there was a lively question and answer period.

The meeting was adjourned at 2:00 P.M.

One hundred and five guests were present during the program.

Respectfully submitted,
Paul A. Dunkerley
Secretary

March 25, 1970 — President Robert H. Culver convened the 122nd Annual Meeting of the Boston Society of Civil Engineers at 4:10 P.M., in the Morse Auditorium, Museum of Science, Science Park, Boston, Massachusetts.

President Culver stated that the minutes of the November and December 1969, and January and February 1970 meetings would be published in a forthcoming issue of the Journal. He declared that the minutes of the April, May, July, September and October 1969 meetings had been published in the Journal.

President Culver called upon the Secretary for announcements. The Secretary announced that at the Board of Government meeting held on March 23, 1970, the following had been elected to membership:

Grade of Member - Alfred M. Corneliuson, Derek A. DeSouza, Kenneth A. Goff*, Glenn E. Mitchell, Anthony M. Slocum, Samuel E. Wigon

* Transfer from Junior

The Secretary further announced that applications for membership had been received from the following :—

Thomas S. Baron, Worcester, Mass.
Duncan M. Brown, Waltham, Mass.
Harold T. Benoit, Jr., East Derry, N.H.*
Daniel S. King, Arlington, Mass. *
Paul A. Nason, Manchester, N. H.
Robert A. Navias, Bridgewater, Mass.
Walter H. Weidner, Jr., Arlington, Mass.
Birger Schmidt, Cambridge, Mass.
Herbert Storch, Boston, Mass.

The Annual Reports of the Board of Government, the Treasurer, the Secretary and the Auditors were presented.

Reports from the following Committees were also presented:— Publication Committee, Hospitality Committee, Library Committee, John R. Freeman Fund Committee, Ralph W. Horne Fund Committee, Subsoils of Boston Committee, Membership Committee, Joint Legislative Affairs Committee, Committee on Professional Conduct, Public Relations Committee, Quarters Committee, B.S.C.E.-A.S.C.E. Relations Committee, and the Organizational Contact Committee. The B.S.C.E. Representative to the Ad Hoc Committee on Massachusetts Registration Laws also reported.

It was moved and VOTED "that these Reports be placed on file and published in a forthcoming issue of the Journal."

The Annual Reports of the Executive Committees of the Sections were presented and the President declared that these reports would be published in a forthcoming issue of the Journal.

The Tellers of Election, Mr. Samuel E. Rice and Michael A. Donnelly made their report on the results of the Election. President Culver declared that the following officers had been elected for the ensuing year:

President - Ernest L. Spencer
V-President - James P. Archibald
Secretary - Paul A. Dunkerley
Treasurer - Robert T. Colburn
Directors - Donald T. Goldberg, Peter S. Eagleson

Elected to the Nominating Committee were, Charles A. Parthum, Frank E. Perkins and Albert B. Rich.

President Culver then made a few announcements concerning the dinner meeting.

Following a 5-minute recess, President Culver delivered his Presidential Address entitled "The Time for Reevaluation".

Forty-two members and guests attended the business meeting.

The meeting adjourned at 5:50 P.M., to reconvene following the social hour and dinner.

President Culver called the adjourned meeting to order again at 8:30 P.M. Following general remarks and the introduction of the guests at the head table, President Culver turned the affairs of the meeting to the awarding of prizes.

The Secretary stated that the Ralph W. Horne Fund was established in 1964 by a gift from the Directors of Fay, Spofford & Thorndike, Inc., the income from which would be devoted to a prize or certificate to be awarded annually to a member designated by the Board of Government as having been outstanding in unpaid public service in municipal, state, or federal elective or appointive posts; or in philanthropic activity in the public interest. The Secretary stated that the recipient of the award this year was Wilfred MacGregor Hall, and asked the recipient to step forward. President Culver presented Mr. Hall the Ralph W. Horne Award which was a certificate reading as follows:

RALPH W. HORNE FUND AWARD
PRESENTED BY THE
BOSTON SOCIETY OF
CIVIL ENGINEERS
TO
WILFRED MacGREGOR HALL

Recognized a capable engineer and industrious businessman, and who, in addition, has given liberally of himself and his time to numerous philanthropic and educational activities. In recognition of this generosity and public service, the Boston Society of Civil Engineers by unanimous vote of the Board of Government has elected him to be the

SIXTH RECIPIENT
OF THE
RALPH W. HORNE FUND AWARD
AND THIS CERTIFICATE IS PROUDLY PRESENTED TO HIM
MARCH 25, 1970

Robert H. Culver
President

The Secretary announced the endowment conditions for the prizes which would be awarded, and called upon each of the recipients to step forward to receive his prize as follows:

Award	*Recipient*	*Paper*
Desmond FitzGerald Medal	Peter A. Larsen	"Head Losses Caused by an Ice Cover on Open Channels"
Clemens Herschel Award	Thomas R. Camp	"Hydraulics of Mixing Tanks"
Desmond FitzGerald Scholarship	Dennis A. Mahoney	
William P. Morse Scholarship	Winslow Hawkes	

President Culver then introduced the guest speaker of the evening, Reverend Robert F. Drinan, S.J., Vice President of Boston College and Dean of the Law School. Father Drinan gave an interesting and thought-provoking talk on the subject "A New Foreign Policy for America in the 1970's." Following Father Drinan's talk, President Culver turned the gavel over to newly-elected President Ernest L. Spencer.

President Spencer then presented the retiring President Culver with a certificate of appreciation for services rendered. Following this, President Spencer gave a brief talk on his plans for the ensuing year, in which he solicited from the membership suggestions concerning the conduct of the business of the Society.

One hundred and sixty-two members and guests attended the dinner and the meeting following the dinner.

The meeting adjourned at 9:25 P.M.

Respectfully submitted,
Paul A. Dunkerley
Secretary

COMPUTER SECTIONS

April 1, 1970:—The Computer Section of the Boston Society of Civil Engineers met at Patten's Restaurant, 173 Milk Street, Boston. Total attendance was 76, of whom 60 attended the dinner. The following announcements were made:

- The next meeting will be held jointly with the Hydraulics Section at 7:30 p.m., Wednesday, May 6th, at the Corps of Engineers Reservoir Control Center, 424 Trapelo Road, Waltham. The meeting will be preceded by a social hour and dinner at the Cottage Crest Restaurant, 610 Trapelo Road, Waltham.
- The Executive Committee will meet on April 16th to plan next year's program. Program topics will be welcomed.
- Anyone wishing to have his name added to the section mailing list should contact the section clerk.
- The Society has agreed to endorse the semi-annual meeting of the ICES Users Group to be held at MIT on June 18th and 19th. A workshop will be held on June 17th. Those interested should contact Don Cucinotti, program chairman, at Stone and Webster.
- The chairman expressed his appreciation to those who had brought in samples of computer graphic prints for display.

Prof. Saul Namyet introduced the first speaker, Mr. Paul DeNapoli, Chief Engineer, Harding and Buchanan, Boston. Mr. DeNapoli described his experiences with the use of computers and computer graphics using time-sharing and remote terminal hardware. Three major classes of programs were used covering geometric, structural and hydraulic problems. Structure problems, as exemplified by bridge abutments, were executed by batch processing, but all design data were saved on files so that separate programs could be used to list materials for drawing tables and for plotting. Sanitary and hydraulic programs were written in the conversational mode permitting the engineer to "talk" to the computer while developing a design. Mr. DeNapoli said that sanitary engineers found this mode to be best suited to their needs. Typical of the programs available were those for designing the components of sewage treatment plants, pump selection, and drainage pipelines. Mr. DeNapoli concluded his talk by showing a series of slides illustrating graphical output from a variety of programs.

The second speaker of the evening was Mr. Joseph Fornataro, Northeastern Regional Manager for California Computer Products, Inc. Mr. Fornataro reviewed the evolution of automatic plotters which had their origin in analog devices. Today's plotters are generally driven by digital computers and have speeds up to 1000 inches per second on microfilm and resolutions in the order of a thousandth of an inch. Remote plotting, however, is constrained by the transmission speed over voice grade lines. Mr. Fornataro described several of the software programs which his company has developed, including packages for plotting contours, subdivision plots, PERT diagrams, perspectives including piping isometrics, financial trend charts, and FORTRAN flow charts. In his conclusion Mr. Fornataro suggested that the Society form a standards committee to evaluate plotting programs.

The meeting was next opened to questions from the floor addressed to either of the speakers. A good discussion ensued which indicated that those present had both experience in the use of computer graphics or were seriously interested in the technique.

Respectfully submitted,
David I. Hellstrom, Clerk

ANNUAL REPORTS

REPORT OF THE BOARD OF GOVERNMENT FOR YEAR 1969 - 1970

To the Boston Society of Civil Engineers:

Pursuant to the requirements of the By-Laws the Board of Government presents its report for the year ending March 25, 1970.

The following is a statement of the status of membership in the Society:-

Honorary	12
Members	1113
Associates	3
Juniors	55
Students	3
Total	1186
Applications pending on March 25, 1970	12
Student Chapters	2

Summary of Additions

New Members	109
New Juniors	14

Reinstatements

Members	1

Summary of Transfers

Juniors to Members	8

Summary of Loss of Members

Deaths	10
Resignations	20
Dropped for non-payment of dues	20
Dropped for failure to transfer	2

Life Membership

Life Members	128
Members becoming eligible today for Life Membership	5

Honorary Membership is as follows:-

John B. Babcock, 3rd, elected, January 2, 1969
Charles O. Baird, Jr., elected January 2, 1969
Harry P. Burden, elected, February 1, 1965
Thomas R. Camp, elected, February 3, 1964
Arthur Casagrande, elected, February 1, 1965
Frank M. Gunby, elected, February 15, 1950

Ralph W. Horne, elected, February 1, 1965
Karl R. Kennison, elected, February 7, 1951
Frank A. Marston, elected, February 15, 1960
Howard M. Turner, elected, February 18, 1952
Frederic N. Weaver, elected, February 1, 1965
John A. Volpe, elected, January 29, 1968

The following members have been lost through death:

Charles M. Anderson, October 14, 1969
E. Sherman Chase, July 8, 1969
Gordon M. Fair, January 11, 1970
Kimball R. Garland, June 28, 1969
George E. Harkness, September, 1969
Francis H. Kingsbury, August 11, 1969
Robert W. Mawney, July 31, 1969
Frank J. McCann, February 10, 1969
Russell J. Rice, May 7, 1969
George G. Rommer, March 26, 1969

MEETINGS OF THE SOCIETY

March 24, 1969	Address of retiring President Harl P. Aldrich, Jr. "Back Bay Boston"
April 16, 1969	Joint Meeting with BSCE Transportation Section. Senator James R. McIntyre, Massachusetts Senator and Mayor of Quincy. "Proposed Massachusetts Department of Transportation".
May 21, 1969	Joint Meeting with BSCE Construction Section. Mr. John B. Davis, Deputy Chief Engineer, Massachusetts Port Authority. "General Logan Airport — Past and Future".
June 4, 1969	Joint Outing with BSCE Sanitary Section. Mr. Richard A. Smith, Engineer for the Boston Edison Company. "Environmental Radiation Surveillance at Pilgrim Station, Plymouth, Mass".
July 9, 1969	Special Meeting. "Revision of Boston Building Code" Richard Thuma, Commissioner.
September 24, 1969	Joint Meeting with BSCE Transportation Section. Mr. John Hanson, U.S. Dept. of Transportation, Federal Highway Administration for Region 1. "A Broad Overview of our Nation's Highway Transportation Program, Concepts and Goals — and a Look Ahead".
October 15, 1969	Joint Meeting with Mass. Section American Society of Civil Engineers (Student Night) Dr. Ruth Terzaghi, Research Fellow in Engineering at Harvard University. "The Civil Engineer in a Troubled World".
November 12, 1969	Joint Meeting with BSCE Structural Section. Mr. Leslie Robertson, Partner of Skillings, Helle, Christansen & Robertson. "The Design and Construction of High Rise Buildings including the World Trade Center at New York".
December 10, 1969	Joint Meeting with BSCE Geotechnical Section. Mr. William S. Swiger, Consulting Engineer, Stone & Webster Engrg. Corp. "Pile Driving Specifications".

January 28, 1970	Joint Meeting with the BSCE Hydraulics Section. John R. Freeman Memorial Lecture. Klas Cederwall, Consulting Engineer. "Dispersion Phenomena in Coastal Environments".
February 18, 1970	Joint Meeting with Mass. Section, American Society of Civil Engineers. Mr. T. Richard Guinan, Vice President, State Street Bank and Trust Company. "Financing Municipal Construction Projects".

ATTENDANCE AT MEETINGS

Date	Place	Meeting	Dinner
March 24, 1969	M.I.T. Faculty Club	52	229
April 16, 1969	Purcell's Restaurant	46	46
May 21, 1969	Nick's Restaurant	48	48
June 4, 1969	Bert's Restaurant Plymouth, Mass.	24	24
July 9, 1969	Fanueil Hall, Boston	17	
September 24, 1969	Purcell's Restaurant	55	55
October 15, 1969	Tufts University	235	235
November 12, 1969	Purcell's Restaurant	48	48
December 10, 1969	Bristol Bay Room, Kevin's Wharf, Boston	51	51
January 28, 1970	United Community Services Building, Boston	61	50
February 18, 1970	Red Coach Grill	105	105

Meetings of the Sections of the Society were held during the year. These meetings of the Sections offering opportunity for more detailed discussions continue to demonstrate their value to their members and to the Society. A wide variety of subjects were presented. The Annual Reports of the various Sections will be presented at the Annual Meeting of the Society and will be published in the Journal.

*FUNDS OF THE SOCIETY**

Permanent Fund. The Permanent Fund of the Society has a present value of $75,-533.76. The Board of Government authorized the use of as much as necessary of the current income of this fund for payment of current expenses. By vote of the Society, as prescribed by the By-Laws, at the December 10, 1969 and January 28, 1970 meetings the Board of Government was authorized to transfer an amount not to exceed $8000 from the Principal of the Permanent Fund for current expenditures. The amount necessary to transfer from the Principal of the Permanent Fund for current expenditures was $8,000.00.

John R. Freeman Fund. In 1925 the late John R. Freeman, a Past President and Honorary Member of the Society, made a gift to the Society of Securities which was established as the John R. Freeman Fund. The income from this fund is to be particularly devoted to the encouragement of young engineers. Mr. Freeman suggested several uses, such as, the payment of expenses for experiments and compilations to be reported before the Society; for underwriting meritorious books or publications pertaining to hydraulic science or art; or a portion be devoted to a yearly prize for the most useful paper relating to hydraulics contributed to the Society; or establishing a traveling scholarship every third year open to members of the Society for visiting engineering works, a

*Details regarding the value and income of these funds are given in the Treasurer's report.

report of which would be presented to the Society. This year a John R. Freeman Memorial Lecture was given by Klas Cederwall, Consulting Engineer, on "Dispersion Phenomena in Coastal Environments". The expenditure from this fund during the year was $3,139.14.

Edmund K. Turner Fund. In 1916 the Society received a bequest of $1,000 from Edmund K. Turner, a former member of the Society, the income of which is to be used for Library purposes. The Board voted to use $300 of the income of this fund for the purchase of books for the Library.

Alexis H. French Fund. The Alexis H. French Fund, a bequest of $1,000 was received in 1931, from the late Alexis H. French, a Past President of the Society. The income of this fund is "to be devoted to the Library of the Society". The Board voted to use $300 of the income of this fund for the purchase of books for the Library.

Tinkham Memorial Fund. The Samuel E. Tinkham Fund, established in 1921 at Massachusetts Institute of Technology, by the Society "to assist some worthy student of high standing to continue his studies in Civil Engineering" had a value of $3,507.24 on June 30, 1969. Jay M. Pollach, a student in Civil Engineering class of 1972 was awarded this scholarship of $250 for the year 1969-1970.

Clemens Herschel Fund. This fund was established in 1931 by a bequest of $1000 from the late Clemens Herschel, a Past President and Honorary Member of the Society. The income from this fund is "to be used for presentation of prizes for papers which have been particularly useful and commendable and worthy of grateful acknowledgment". The expenditure from this fund during the year was $26.68.

Desmond FitzGerald Fund. The Desmond FitzGerald Fund extablished in 1910 by a bequest of $2,000 from the late Desmond FitzGerald, a Past President and Honorary Member of the Society, provided that the income from this fund shall "be used for charitable and educational purposes." The Board voted on April 13, 1964 to use the income of this fund to establish a Boston Society of Civil Engineer's Scholarship in Memory of Desmond FitzGerald, and that it be given to a student in Civil Engineering at Northeastern University. It was voted on January 28,1970 to accept the recommendation of the Committee at Northeastern University, namely, that a Scholarship of $150 be given to Dennis A. Mahony, presentation to be made at the Annual Meeting of the Society on March 25, 1970.

Edward W. Howe Fund. This Fund, a bequest of $1,000 was received in 1933 from the late Edward W. Howe, a Past President of the Society. No restrictions were placed on the use of this bequest, but the recommendation of the Board of Government was "that the fund be kept intact and that the income be used for the benefit of the Society or its members."

William P. Morse Fund. This Fund, a bequest of $2,000 was received in 1949 from the late William P. Morse, a former member of the Society. No restrictions were placed on the use of this bequest, but the recommendation of the Board of Government was "that this fund be kept intact and that the income be used for the benefit of the Society or its members." Upon recommendation of the Committee appointed by the President, the Board voted on April 5, 1954 to appropriate from the income of this fund a Scholarship to be known as the "Boston Society of Civil Engineer's Scholarship in Memory of William P. Morse," and that it be given to a Civil Engineering Student at Tufts University." It was voted on January 28, 1970 to adopt the recommendation of the Committee at Tufts University, namely, that a $150 Scholarship be given to Winslow Hawkes, presentation to be made at the Annual Meeting of the Society on March 25, 1970.

Frank B. Walker Fund. This Fund, a bequest of $1,000 was received in 1961 from Mary H. Walker, wife of Frank B. Walker, a Past President of the Society. No restrictions were placed on the use of this bequest but the recommendation of the Board of

Government was "that this fund be kept intact and that the income be used for the benefit of the Society or its members."

Ralph W. Horne Fund. This Fund, a gift of $3,000 was received June 29, 1964 from the Directors of Fay, Spofford & Thorndike Inc., the income from which shall be devoted to a prize or certificate to be awarded annually to a member designated by the Board of Government as having been outstanding in unpaid public service in municipal, state, or federal elective or appointive posts; or in philanthropic activity in the public interest. Members of B.S.C.E. only are eligible for the Award. The Board of Government voted unanimously January 28, 1970 to approve the recommendation of the Ralph W. Horne Fund Award Committee, namely, that Wilfred M. Hall be the recipient to receive the Ralph W. Horne Fund Award for the year 1969-1970, presentation to be made at the Annual Meeting of the Society on March 25, 1970.

PRIZES

AWARD	*RECIPIENT*	*PAPER*
Desmond FitzGerald Medal	Peter A. Larson	"Head Losses Caused by an Ice Cover on Open Channels"
Clemens Herschel Award	Thomas R. Camp	"Hydraulics of Mixing Tanks"
Ralph W. Horne Award	Wilfred M. Hall	
Desmond FitzGerald Scholarship	Dennis A. Mahony	
William P. Morse Scholarship	Winslow Hawkes	

LIBRARY

The Report of the Library Committee contains a complete account of the Library Committee's activities during the past year.

COMMITTEES

The usual special committees dealing with the activities and conduct of the Society were appointed. The membership of these committees is published in the Journal and the reports of the committees will be presented at the Annual Meeting March 25, 1970.

Your Board in conclusion wishes to express its appreciation of the excellent work done by the officers of the Sections and by the committees of the Society.

Robert H. Culver President

REPORT OF THE SECRETARY

Boston, Mass., March 25, 1970

To the Boston Society of Civil Engineers:

The following is a statement of cash received by the Secretary and of the expenditures approved by the President in accordance with the budget adopted by the Board of Government.

FOR THE YEAR ENDING MARCH 25, 1970

	EXPENDITURES	*RECEIPTS*
OFFICE		
Secretary's Salary & Expense	$1,416.80	
Treasurer's Honorarium	910.80	
Stationary, Printing & Postage	1,332.72	
Incidentals & Petty Cash	127.23	
Insurance & Treasurer's Bond	51.00	
Quarters, Rent. Tel. & Light	6,251.93	
Office Secretary	6,847.60	
Soil Mechanics	2,275.71	$981.00
Social Security	564.82	
MEETINGS		
Rent of Halls	80.00	
Hospitality Committee	1,461.79	1,217.93
Reporting & Projection	16.88	
Annual Meeting March, 1969	1,266.78	984.00
Special Fund for Speakers	150.00	
SECTIONS		
Sanitary Section	36.50	
Structural Section	193.90	
Transportation Section	38.22	
Hydraulics Section	41.14	
Construction Section	55.45	
Geotechnical Section	8.40	
Computer Section	60.95	
JOURNAL		
Editor's Salary & Expense	985.05	
Printing & Postage	13,187.08	
Advertisements		2,566.79
Sale of Journals		2,391.90
Reprints	1,026.94	888.00
Copyright	18.00	
Newsletter	738.15	
	$39,143.84	*$9,029.62*
LIBRARY		
Periodicals	74.00	
Binding	60.67	
MISCELLANEOUS		
Binding Journals for Members	10.27	10.27
Badges	335.90	5.00
Bank Charges	1.25	
Miscellaneous	315.95	114.80
Engineering Societies Dues	1,150.25	
Public Relations Committee	100.88	
Sales Tax	.55	
Dues from B.S.C.E. Members		19,274.00
Trans. Income Perm Fund		4,596.96
Trans. Prin.		8,000.00
Current Fund		162.91
	$41,193.56	*$41,193.56*

109 New Members; 14 New Junior Members; 8 Junior Members transferred to Member.

The above receipts have been paid to the Treasurer who's receipt the Secretary holds. The Secretary holds cash amounting to $30 to be used as a fixed fund or cash on hand. $46.75 withholding Tax is payable to State of Massachusetts in April.

Respectfully submitted,
Paul A. Dunkerley
Secretary

REPORT OF THE TREASURER

March 25,1970
Fiscal year March 1, 1969 - February 28, 1970

FINANCIAL STANDING

The financial standing of the Society is summarized in the following four tables which accompany this report. The tables represent conditions as they existed at the close of business on February 28, 1970.

TABLE I	Condensed Statement of Condition — Assets and Liabilities
TABLE II	Condensed Statement of Income and Expenditures Distribution to Funds
TABLE III	Portfolio of Investments
TABLE IV	Income and Yield from Investments

SOCIETY INVESTMENTS

The Boston Safe Deposit and Trust Company continues to serve as financial advisor and custodian of the securities owned by the Society. The Custodian Bank has furnished us a certified audit of the Income and Principal Accounts.

Twice this year the Investments Division of the Boston Safe Deposit and Trust Company has reviewed our portfolio of securities and recommended changes to the Society. The Investment Committee of the Society considered these changes and presented its findings to the Board of Government. In each case the Board voted to authorize the recommended changes and directed the Custodian to proceed with the transactions. The general policy which dictates the handling of the portfolio is the maintenance of reasonable income consistent with a reasonable growth rate as a hedge against inflation.

The following changes were made in the Portfolio during the year.

Sold	
So. Pac. Co. Series A 4½%, 77 Bonds	$3,277.92
150 Shares General Electric Co.	12,831.10
110 Shares Monsanto Chemical Co.	5,466.58
Total	$21,575.60
Bought	
50 Shares Illinois Power Co.	$1,905.06
300 Shares McGraw Edison Co.	10,421.07
260 Shares Wilson & Co., Inc.	7,865.88
3 Shares International Business Mach. Corp.	1,068.75
Total	$21,260.76

Received as result of stock split
300 Shares Newmont Mining Corp.
236 Shares Texaco, Inc.

The percentage of common stocks in the portfolio based on current market value is now 77.4% compared to 73% a year ago. The yield from the securities in the portfolio based on current market value is approximately 4.9%.

AUDIT

The Auditing Committee has reviewed the Treasurer's account book, the bills paid by the Treasurer, the receipts from the Secretary, the savings bank passbook, the check-book, and the certified audit of the income and principal accounts. The information contained in this report has been verified.

INVESTMENT FUNDS-INCOME ACCOUNT (Bos. Safe Dep. & Tr. Co. Custodian)

Balance in account March 1,1969	$ 5,006.60	
Dividends received	6,740.54	
Interest received	2,826.25	
Sub Total		$14,573.39
Service charges	$ 910.87	
Transfer to savings	6,500.00	
Transfer to checking	6,000.00	
Sub Total		$13,410.87
Balance in account February 28, 1970		$1,162.52

INVESTMENT FUNDS-PRINCIPAL ACCOUNT (Bos. Safe Dep. & Tr. Co. Custodian)

Balance in account March 1, 1969	$ -162.69	
Bonds Sold	3,277.92	
Stocks Sold	18,297.68	
Sub Total		$21,412.91
Stocks Bought	$21,260.76	
Sub Total		$21,260.76
Balance in account February 28, 1970		$ 152.15

SAVINGS ACCOUNT (First Fed. Sav. & Loan Assoc. of Boston)

This savings account is used as a temporary investment for money available for investment and for excess balance in the check book, thus providing additional income to the funds, until there is a need to transfer it to the checkbook to meet expenditures.

Balance March 1, 1970	$ 3,015.56	
Transfer from Income Account	6,500.00	
Transfer from Checking Account	4,000.00	
Interest Received	419.62	
Sub Total		$13,935.18
Transfer to Checking Account		$11,000.00
Sub Total		$11,000.00
Balance February 28, 1970		$ 2,935.18

CURRENT FUND ACCOUNT

This fund is set up for payment of operating expenses of the Society and for receiving income allocated for that purpose. To provide money for operation in March before regular income is received, the fund is provided with a balance of approximately $1,500.00 on March first.

Total Expenditures	$41,193.56
Total Income and Receipts	28,433.69
Excess of Income over Expenditures	($-12,759.87)
Transfer from Permanent Fund Income	$ 4,596.96
Transfer from Permanent Fund Principal	8,000.00
Balance in Fund March 1, 1969	1,500.00
Sub Total Available to cover deficiency	$14,096.96
Balance February 28, 1970	$ 1,337.09

By vote of the Board of Government $4,596.96 was transferred from the Income of the Permanent Fund to the Current Fund. By vote of the Board of Government and two votes taken at regular monthly meetings of the Society $8,000.00 was transferred from the Principal of the Permanent Fund to the Current Fund.

The membership and other interested persons are referred to the report of the Secretary published elsewhere in the Journal for a detailed breakdown of the income and expenditures of the Current Fund.

PERMANENT FUND

The Permanent Fund receives income from its prorated portion of interest and dividends from investments and pays its portion of service charges of the Custodian Bank.

Receipts from entrance fees are credited to the principal of this fund. These amounted to $1,140.00 this year.

Income from Interest and Dividends	$ 5,059.13
Prorated portion of Custodian service charges	462.17
Net Income	$ 4,596.96

As explained above, the total net income of $4,596.96 plus $8,000.00 from principal was transferred from the Permanent Fund to the Current Fund.

JOHN R. FREEMAN FUND

Payments from this fund were made this year for a scholarship to Mr. Michael Collins, a graduate student at M.I.T., and for expenses of the annual Freeman Lecture. The lecturer, Mr. Klås Cederwall, received an honorarium of $300.00.

Scholarship to Mr. Michael Collins	$ 2,120.00
Expenses of Freeman Lecture	439.64
Lecturers honorarium	300.00
Prorated portion of Custodian service charges	279.50
Total Expenditures	$ 3,139.14

Received from prorated portion of income from investment	$ 3,074.79
Excess of Income over Expenditures	($ -64.35)

LECTURES FUND

This fund was newly created at the beginning of this year by combining the Transportation Lectures Fund, the Structural Lectures Fund, and the Lectures Fund into a single Lectures Fund.

This fund received its prorated portion of income from investments this year and paid its portion of the Custodian service charges. No other payments were made from this fund. The balance in this fund on February 28, 1970 was *$6,853.40.*

BORING DATA FUND

The Committee on Subsoils of Boston has been actively engaged in revising and adding to the Boring Data Book. Mr. Clarence Seagrave (retired) has continued his work of sifting and collating the information into a publishable form, and has been assisted by Mr. E. M. Battle and Mr. N. P. Kenis.

No solicitations of outside funds were made this year. However, at the February 1970, meeting, the Board requested the Treasurer to apply for permission from the Office of the Attorney General of Massachusetts to solicit funds in accordance with Chapter 68, Acts of 1964. This permission has been requested and received. Solicitations may now be made.

The only income to this fund this year was a donation of $10.00. However, the fund has been augmented by transfer of $1,000.00 from the Frank B. Walker Fund by vote of the Board of Government on May 21,1969, in order to insure continuation of this work.

Balance in Fund March 1, 1969	$ 3,423.28
Received donation	10.00
Transfer from Frank B. Walker Fund	1,000.00
Total Receipts	$ 4,433.28
Paid for sorting and collating information for publication	$ 3,705.57
Paid Printer	6.08
Total Expenses	$ 3,711.65
Balance in Fund February 28,1970	$ 721.63

KARL R. KENNISON FUND

On March 3, 1970, Mr. Charles Flaherty of the Massachusetts Company reported to the Treasurer of the Society on the status of the irrevocable trusts established on behalf of the Society by Mr. Karl R. Kennison. As of February 28,1970, the two trusts involving shares in the Massachusetts Fund were as follows.

	No. Shares	*Market Value*
Trust #4315	356,650 shares	$ 3,791.19
Trust #4444	466,464 shares	4,958.51
Total	823,114 shares	$ 8,749.70

A year ago there were 787,909 shares which had a market value of $9,842.20.

OTHER FUNDS

The membership and other interested persons are referred to the Report of the Board of Government published elsewhere in this issue of the Journal for information concerning the remaining funds, the reasons for existence, and the disbursements made from each.

WITHHELD TAXES

The item of $46.75 for taxes withheld listed under Liabilities in Table I is for unpaid Massachusetts State Income Taxes withheld. This is due and payable in April.

ACKNOWLEDGEMENTS

This is the first year your present Treasurer has served in this office. I should like to thank Prof. Paul A. Dunkerley, the former Treasurer, for his valued assistance in helping me to become acquainted with the accounting procedures and the operation of the various funds. I should like to express my appreciation for the help and indulgence of all members of the Board during the period of my indoctrination.

Respectfully submitted,
Robert T. Colburn
Treasurer

TABLE I

CONDENSED STATEMENT OF CONDITION

ASSETS AND LIABILITIES

February 28, 1970

Assets	*Book Value*		*Market Value*	
	2-28-70	*3-1-69*	*2-28-70*	*3-1-69*
1st Nat. Bank Bos. (Check. Acct.)	$ 1,662.31	$ 7,253.50	$ 1,662	$ 7,253
Boston Safe Dep. & Tr. Co.				
(Custodian Acct.)				
Bonds	55,628.84	59,820.14	40,151	48,531
Common Stocks	99,210.51	87,580.73	157,222	170,135
Balance in acct.	1,314.67	4,843.91	1,315	4,844
1st Fed. Sav. & Loan Assoc. (Savings)	2,935.18	3,015.56	2,935	3,016
Cash held by Secretary	30.00	30.00	30	30
TOTAL ASSETS	$160,781.51	$162,543.84	$203,315	$233,809

Liabilities and Funds				
Permanent Fund	$ 75,533.76	$ 78,555.27	$ 95,684	$114,079
John R. Freeman Fund	52,023.92	49,622.40	65,933	72,063
Edmund K. Turner Fund	2,463.60	2,225.71	3,136	3,232
Desmond Fitzgerald Fund	4,988.17	4,646.25	6,292	6,747
Alexis H. French Fund	2,439.68	2,203.48	3,096	3,200
Clemens Herschel Fund	1,681.16	1,543.11	2,111	2,241
Edward W. Howe Fund	2,743.41	2,478.43	3,498	3,599
William P. Morse Fund	4,729.89	4,411.00	5,990	6,406
Frank B. Walker Fund	1,239.07	2,028.35	1,568	2,946
Ralph W. Horne Fund	3,949.98	3,686.23	5,005	5,353
Lectures Fund	6,853.40	6,190.33	8,703	8,990
Sub Total Investments Funds	$158,646.04	$157,590.56	$201,016	$228,856
Boring Data Fund	721.63	3,423.28	722	3,423
Current Fund	1,337.09	1,500.00	1,500	1,500
Secretary's Change Fund	30.00	30.00	30	30
Reserve for Taxes Withheld	46.75	*	47	*
TOTAL LIABILITIES	$160,781.51	$162,543.84	$203,315	$233,809

* $308.25 is included in the Current Fund for taxes withheld.

TABLE II

CONDENSED STATEMENT OF INCOME AND EXPENDITURES — DISTRIBUTION TO FUNDS

Fiscal Year March 1, 1969 through February 28, 1970

FUND	*Book Value* Mar. 1, '69	*Income* Interest and Dividends	*Gain* from sale of securities	*Receipts* & Transfers to funds	*Expenditures* and Transfers from funds	*Book Value* Feb. 28,'70
Permanent	$78,555.27	$5,059.13	$3,838.49	$1,140.00	$462.17	$75,533.76
Transfer to Current					12,596.96	
John R. Freeman	49,622.40	3,074.79	2,465.87		3,139.14	52,023.92
Edmund K. Turner	2,225.71	142.13	108.77		13.01	2,463.60
Desmond Fitzgerald	4,646.25	289.83	230.38		178.29	4,988.17
Alexis H. French	2,203.48	140.79	108.27		12.86	2,439.68
Clemens Herschel	1,543.11	97.35	76.22		35.52	1,681.16
Edward W. Howe	2,478.43	158.27	121.19		14.48	2,743.41
William P. Morse	4,411.00	275.10	218.74		174.95	4,729.89
Frank B. Walker	2,028.35	123.88	98.70		11.86	1,239.07
Transfer to Boring Data					1,000.00	
Ralph W. Horne	3,686.23	229.56	183.07		148.88	3,949.98
Lectures	6,190.33	395.58	303.62		36.13	6,853.40
SUB TOTAL Invest. Funds	$157,590.56	$9,986.41	$7,753.32	$1,140.00	$17,824.25	$158,646.04
Boring Data Fund	3,423.28			10.00	3,711.65)	721.63
Transfer from Walker				1,000.00	)	
Current Fund	1,500.00			28,433.69	41,193.56)	1,337.09
Transfer from Permanent				12,596.96	)	
Secretaries Change Fund	30.00					30.00
Reserve for taxes withheld	*					46.75
TOTALS	$162,543.84	$9,986.41	$7,753.32	$43,180.65	$62,729.46	$160,781.51

*$308.25 is included in Current Fund for taxes withheld.

TABLE III

BOSTON SOCIETY OF CIVIL ENGINEERS

PORTFOLIO OF INVESTMENTS

		Book Value		Market Value	
BONDS 19.7%		*2-28-70*	*3-1-69*	*2-28-70*	*3-1-69*
6,000	Assoc. Invest. Co. 5 1/2 -79. Deb.	$ 6,000	$ 6,000	$ 4,320	$ 4,800
10,000	Flintkote Co. 4 5/8 - 81. Deb.	10,450	10,450	7,300	8,000
1,000	Florida Po. Corp. 3 1/8 - 84. 1st Mort.	1,018	1,018	604	654
5,000	Florida Po. Corp. 3 7/8 - 86. 1st Mort.	5,038	5,038	3,219	3,525
5,000	Georgia Po. Co. 3 3/8 - 77. 1st Mort.	5,162	5,162	3,669	3,825
5,000	Marine Mid. Corp. 4 1/2 - 89. Deb.	5,000	5,000	3,275	3,650
10,000	Montreal Quebec Imp. 6% - 87. Deb.	10,075	10,075	6,900	8,850
10,000	Orange & Rockland 6 1/2 - 97.1st Mort.	9,950	9,950	8,262	9,350
3,000	Ontario 3 1/4 - 72. Deb.	2,936	2,936	2,602	2,602
4,000	So. Pac. Co. 4 1/2 - 77. 1st Mort.	--	4,191	--	3,275
	TOTAL BONDS	$55,629	$59,820	$40,151	$48,531

(Continued next page)

TABLE III — (Continued)

COMMON STOCKS 77.4%					
250	Amer. Tel. & Tel. Co.	$ 4,506	$ 4,506	$12,812	$12,970
400	Clark Equipment Co.	12,287	12,287	13,600	12,800
150	General Electric Co.	--	2,341	--	12,975
170	General Motors Corp.	9,131	9,131	11,794	13,196
214	Hartford Insurance Co.	1,534	1,534	10,700	11,609
250	Illinois Power Co.	11,591	9,686	8,500	7,375
35	Inter. Business Mach. Corp.	6,400	5,332	11,909	9,388
110	Monsanto Chemical Co.	--	7,290	--	5,404
200	Nat. Dairy Prod. Co.	1,155	1,155	7,800	8,150
308	New England Elec. System	6,216	6,216	6,699	8,585
500	Newmont Mining Corp.	12,548	12,548	16,000	14,950
177	So. Cal. Edison Co.	1,933	1,933	5,332	6,571
200	Std. Oil N.J.	2,013	2,013	10,868	15,575
472	Texaco Corp.	1,516	1,516	13,157	19,352
200	Warner Lambert Pharm. Co.	9,937	9,937	14,400	11,075
4	W. R. Grace & Co.	156	156	93	160
300	McGraw Edison Co.	10,421	--	8,813	--
260	Wilson & Co. Corp.	7,866	--	4,745	--
	TOTAL COMMON STOCKS	$99,210	$87,581	$157,222	$170,135
SAVINGS BANK 1.4%					
	1st Fed. Sav. & Loan Assoc.	$ 2,935	$ 3,016	$ 2,935	$ 3,016
CASH ACCOUNTS 1.5%					
	1st Nat. Bank of Bos. Check Acct.	$ 1,662	$7,253	$1,662	$7,253
	Bos. Safe Dep. & Tr. Co. Custodian Ac.	1,315	4,844	1,315	4,844
	Cash	30	30	30	30
	TOTAL SAVINGS & CASH	$5,942	$15,143	$5,942	$15,143
	GRAND TOTAL	$160,781	$162,544	$203,315	$233,809

TABLE IV

INCOME AND YIELD FROM INVESTMENTS

Fiscal Year March 1, 1969, to February 28, 1970

		Income	*Yield On Current Market Value*
BONDS			
6,000	Assoc. Invest. Co. 5 1/8 - 79. Deb.	$ 307.50	7.1%
10,000	Flintkote Co. 4 5/8 - 81. Deb.	462.50	6.3
1,000	Florida Po. Corp. 3 1/8 - 84. 1st Mort.	31.25	4.8
5,000	Florida Po. Corp. 3 7/8 - 86. 1st Mort.	193.75	6.0
5,000	Georgia Po. Co. 3 3/8 - 77. 1st Mort.	168.75	4.6
5,000	Marine Midland 4 1/2 - 89. Deb.	225.00	6.9
10,000	Montreal Quebec Imp. 6% - 87. Deb.	600.00	8.7
10,000	Orange & Rockland 6½ - 97. 1st Mort.	650.00	7.8
3,000	Ontario 3 1/4 - 72. Deb.	97.50	3.7
4,000	So. Pac. Co. 4 1/2 - 77. 1st Mort.	90.00	5.3
	Total Bonds	$2,826.25	6.8%
COMMON STOCKS			
250	Amer. Tel. & Tel.	$ 612.50	4.8%
400	Clark Equipment Co.	560.00	4.1
150	General Electric Co.	97.50	3.6
170	General Motors Corp.	731.00	6.2
214	Hartford Insurance Co.	299.60	2.8
250	Illinois Power Co.	475.00	6.6
35	Inter. Business Mach. Corp.	115.20	1.0
110	Monsanto Chemical Co.	99.00	5.3
200	Nat. Dairy Products Co.	335.00	4.5
308	New England Electric Co.	455.84	6.8
500	Newmont Mining Corp.	520.00	3.2
177	So. Cal. Edison Co.	247.80	4.7
200	Std. Oil N. J.	750.00	6.9
472	Texaco Corp.	731.60	5.6
200	Warner Lambert Pharm. Co.	220.00	1.5
4	W. R. Grace & Co.	—	—
300	McGraw Edison Co.	315.00	4.7
260	Wilson & Co. Corp.	175.50	7.4
	Total Common Stocks	$6,740.54	4.5%
	TOTAL	$9,566.79	4.9%

REPORT OF THE AUDITING COMMITTEE

Boston, Mass., March 25, 1970

To the Boston Society of Civil Engineers:

We have reviewed the records and accounts of the Secretary and Treasurer of the Boston Society of Civil Engineers, and we have compared the bank statement of securities held by the Boston Safe Deposit and Trust Company with the enumeration submitted by the Treasurer.

We have found them to be in order and to account accurately for the Society's Funds.

Respectfully submitted,
James P. Archibald
Max D. Sorota

REPORT OF JOURNAL EDITOR

Boston, Mass., March 25, 1970

To the Boston Society of Civil Engineers:

During the last fiscal year, the Journal issues for January 1969, April 1969, and July-October 1969 were published. The last-mentioned was published as a double issue so that the Boring Data for the Boston Peninsula could be available under one cover.

Volume 56 for the year 1969 contained four technical papers and the Boring Data for the Boston Peninsula, plus Society reports, in 297 pages of text. This is ten more pages of text than in 1968.

The boring data published are for Section 1 of Greater Boston. Data for other sections of the Greater Boston area are in the process of preparation by the Subsoils of Boston Committee, and will be published in later Journal issues, by section, as they become available. The publication of the boring data increases the Journal expense since it involves extra composition costs. The Society should benefit, however, when all the boring data are eventually published in a single hard-cover volume, since the composed copy is being retained for future use.

The continuing purpose of the Journal is to provide the Society members and our subscribers with a publication of high standards as a medium for top quality technical papers, high grade professional advertising, and Society reports. The availability of top quality professional papers, suitable for a recognized medium of technical literature and with an international circulation, is the key to its continued success.

Respectfully submitted,
H. H. Holly, Editor

REPORT OF PUBLICATION COMMITTEE
March 25,1970

To the Boston Society of Civil Engineers:

During the period March 1969 — February 1970 the publication committee received and distributed for review nine papers.

Of these nine, three were rejected, one was published three have been accepted for publication and two have been returned to the authors for modification and conditional acceptance.

We have been working towards developing an inventory of papers and at a subsequent date plan to submit an outline of proposed procedural improvements we consider to be feasible.

Respectfully submitted,
Ernest A. Herzog, Chairman
Publication Committee

REPORT OF THE LIBRARY COMMITTEE

March 25, 1970

To the Boston Society of Civil Engineers:

No significant change in the use of the Library has been apparent during the past year. Even reference works have been used to only a limited extent.

No expenditures have been made for new books, and no books have been donated to the Library.

Lack of sufficient shelf space and of storeroom space for Journals kept in stock for sale is a continuing and increasing problem.

After due investigation, the committee recommends that the Clemens Herschel special library be donated to Tufts University Library, which has indicated an interest in receiving it. The Herschel Library consists of very old books of only historical value, many being concerned with England.

In a similar vein, the committee recommends the disposal of the bound volumes of The Canadian Engineer and The Engineering Journal, together covering the period 1912 to 1963. Preferably these should be given to one of the Boston area educational institutions if one would like to have them, otherwise, they should be discarded. Mrs. Boudia reports that she has never seen anyone refer to any of these volumes. More recent issues of The Engineering Journal received by the Library are kept unbound.

The books and bound periodicals referred to above together occupy some 42 feet of shelf space, which could thus be made available for better usage.

It is further recommended that arrangements be made for the part-time employment of a student or students to work under Mrs. Boudia's supervision in rearranging the storeroom stock in more orderly fashion and in assisting her in such rearrangement of books on the library shelves as may be found desirable. This work might be done during the summer, if not convenient earlier. Such assistance should be furnished from time to time as the need arises.

Further action is needed in culling out additional library material that is no longer of sufficient value to BSCE members to warrant its retention. The assistance of officers of the appropriate sections should be enlisted in determining which books or periodicals should be offered to other libraries or discarded.

Respectfully submitted,
John M. Biggs
Joseph Capone
George W. Hankinson
William H. Parker, III
Nathaniel N. Wentworth, Jr.
Harry L. Kinsel, Chairman

REPORT OF THE HOSPITALITY COMMITTEE

Boston, Massachusetts, March 5, 1970

To the Boston Society of Civil Engineers:

The Hospitality Committee submits the following report for the year 1969-1970:

A total of eleven meetings of the Society were held during the past year. This was three meetings more than the previous year. Included in this total were the 121st Annual Meeting, two joint meetings with the American Society of Civil Engineers, one of which was a Student's Night Meeting, a discussion meeting of the City of Boston Building Code, and seven regular meetings of the Society.

Catered dinners were served prior to five meetions

The average attendance of members and guests for all eleven meetings or dinners (using the larger attendance figure) was 84 as compared to last year's average of 92.

DATE	*PLACE*	*MEETING*	*DINNER*
March 24, 1969	M.I.T. Faculty	52	229
April 16,1969	Purcell's Restaurant	46	46
May 21, 1969	Nick's Restaurant	48	48
June 4, 1969	Bert's Restaurant Plymouth, Mass.	24	24
July 9, 1969	Fanueil Hall, Boston	17	-
September 24, 1969	Purcell's Restaurant	55	55
October 15, 1969	Tufts University	235	235
November 12, 1969	Purcell's Restaurant	48	48
December 10, 1969	Bristol Bay Room Kevin's Wharf, Boston	51	51
January 28, 1970	United Community Services Building	61	50
February 18, 1970	Red Coach Grill, Boston	105	105

Respectfully Submitted
Conrad C. Fagone
Chairman

REPORT OF THE MEMBERSHIP COMMITTEE

Boston, Mass., March 25, 1970

To the Boston Society of Civil Engineers:

In the past year the Committee held two formal meetings. Each member covered his own firm and some of the larger firms not represented on the Committee.

During the year, the Society elected 109 new members and 14 new Junior Members. Twelve applications are pending. Total membership as of this date — 1186.

Respectfully submitted,
Charles H. Flavin
Chairman

REPORT OF THE PUBLIC RELATIONS COMMITTEE

Boston, Mass.

To the Boston Society of Civil Engineers:

No formal meetings were held during the year by this Committee although discussions were held by telephone. Of the three members on the committee, one was transferred to Washington, and a second could not be contacted.

First, one could argue that with BSCE's considerable recent increase in membership, public relations perhaps is not needed. However, from the viewpoint of speakers, publicity is important.

Secondly, for overall Society publicity, a suitable brochure could be prepared for use in future membership drives and to acquaint prospective speakers with BSCE.

The following two suggestions are offered for consideration by the Board of Government:

1. A standard form be prepared similar to those of national societies on which speakers may indicate pertinent background information. This form could then be mailed to Boston and local newspapers from the BSCE office.
2. If an overall BSCE brochure is desired, this could be a project for a future Public Relations Committee.

Respectfully submitted,
Charles A. Parthum, Chairman

COMMITTEE ON SUBSOILS OF BOSTON

March 25, 1970

To the Boston Society of Civil Engineers:

The Committee on Subsoils of Boston met on May 8 and October 2, 1969.

The Committee completed collection and compilation of boring information for the Boston Peninsula in June 1969. The data for this first area were published in the July-October special issue of the Journal of the Boston Society of Civil Engineers.

During the last months of 1969, collection and compilation of boring data for two additional sub-areas from Greater Boston, namely Roxbury and South Boston were also completed. It is contemplated to present this information in another special issue of the Journal by mid-summer 1970.

The total receipts collected from our first fund raising campaign ($6,390.00) proved to be insufficient to cover the expenses connected with the work in progress. The Board of Government rescued the project twice by appropriating a total sum of $1,500.00 to complete the work connected with the last two sub-areas. We wish to take this opportunity to express our thanks to the members of the Board of Government for their generous support.

Due to lack of funds, no further work is being carried out currently. In order to finance the project, the Committee requested the Board for permission to solicit additional funds from potential users of the information. The success or failure of this second fund raising campaign will determine whether or not the project of collecting boring information from Greater Boston can be brought to completion.

Respectfully submitted,
Horst Borbereky, Chairman
Subsoils of Boston Committee

REPORT OF COMMITTEE ON PROFESSIONAL CONDUCT

Boston, Mass., March 25,1970

To the Boston Society of Civil Engineers:

During the past year the Society has received no complaints of violations of ethical practice, and the Committee has held no meetings.

Respectfully submitted,
George G. Bogren
Francis S. Harvey
George M. Reece
William L. Hyland, Chairman

REPORT OF QUARTERS COMMITTEE

Boston, Mass., March 25, 1970

To the Boston Society of Civil Engineers:

In February 1969, the Quarters Committee contacted several real estate companies with a request to locate suitable new quarters for the Society, and at the same time to find a tenant to sub-let our present quarters at 47 Winter Street until the termination of our lease on 30 June 1972. The response was not rewarding , especially to finding a subtenant. It now appears that we should stay in our present quarters until the lease terminates.

Accordingly, we recommend that the Society rooms be cleaned and painted between 1 June and 1 September 1970. The building owner, Mr. Hornstein, had agreed to paint the quarters at the time the new 5-year lease was negotiated. We postponed that work pending a review of possible major renovations.

In the meantime, the Quarters Committee will begin a search for from 600 to 900 sq. ft. of modern space suitable for an office, library and meeting room for the Board of Government, to be occupied in 1972.

Respectfully submitted,
Paul A. Dunkerley
Frank L. Heaney
Walter M. Newman
Harl P. Aldrich, Jr., Chairman

REPORT OF THE ORGANIZATIONAL CONTACT COMMITTEE

March 25, 1970

To the Boston Society of Civil Engineers:

The Organizational Contact Committee reviewed the previously prepared list of contact men at various local firms and organizations in order to make corrections and to keep up to date. There are 129 individuals from 109 organizations presently on this list. The Committee recommends that the list be updated each September by sending questionnaires for confirmation or changes of the names of the contact men, firms, organizations, addresses, telephones, comments, etc.

The Committee also recommends the following:

1. The format of the bulletin board notices be changed as follows:
   a. Use different color paper for each successive notice.
   b. Notices should describe the details of a particular meeting with an abstract of the talk and should list the dates and titles of 2 or 3 future meetings.
   c. Provide space on the notice for persons to indicate their intention of attending the particular meeting so that others may be moved to attend.

2. A letter be sent by the President of the Society to all the heads and principal engineers of the various firms and organizations to encourage their attendance and to suggest that they make it known within their organization whenever they plan to attend a meeting.
3. The Committee be informed of any program changes so that it may contact the various organizations by telephone whenever there is insufficient time to send notices by mail.
4. Designated contact men be encouraged to discuss with members of the Organizational Contact Committee any matters related to the function of the Society.

Respectfully submitted,
ORGANIZATIONAL CONTACT COMMITTEE
Athanasios A. Vulgaropulos, Chairman
Leland F. Carter
Howard Simpson
Stephen E. Dore
Charles C. Ladd
A. Paul LaRosa
Peter K. Taylor

REPORT OF BSCE-ASCE RELATIONSHIP COMMITTEE

Boston, Mass., March 25, 1970

To the Boston Society of Civil Engineers:

The activities of this Committee are directed towards a more beneficial professional environment for the civil engineer in the Boston area through greater co-operative activities between the Boston Society of Civil Engineers and the Massachusetts Section of the American Society of Civil Engineers. The Committee has coordinated its work very closely with a like committee of the Massachusetts Section of the American Society of Civil Engineers chairmanned by Professor Saul Namyet. A study made by the ASCE Committee reveals the following approximate memberships in the Societies:

BSCE only	706
ASCE only	1,152
Members of Both	393
BSCE Total	1,098
ASCE Total	1,545
(943 are subscribing members)	

At the present time 21 of the 35 BSCE Technical Section officers are members of ASCE.

Cooperative activity can be separated into a long-range program and a short-range program. The Committee feels that it is advisable to make this separation in order that short-range goals may be achieved without being dependent upon the outcome of long-range goals.

Long-range goals could include the ultimate consolidation of both societies into one society. This accomplishment would involve a great deal of study in regard to legal entanglements, endowments and other considerations. During this period the Committee feels that appropriate short-range goals could be finalized to include;

(1) Joint technical meetings. The ASCE is in accord with this proposal and would form technical sections to jointly sponsor technical meetings with BSCE. It was noted that any involvement of the expenditure of large sums of money in these activities would require the approval of both parent Societies. It was noted that joint technical section meetings might induce more papers for the Journal if it were possible for a speaker to have his papers published also in the ASCE Journals. It should also promote larger attendance at the section meetings.

(2) All meetings of the parent societies would be joint with the exception of the annual meetings of each Society.

(3) The newsletters of both societies would be combined to form a BSCE-ASCE newsletter. A joint newsletter should realize economies for both societies.

(4) The BSCE Board of Government should invite the ASCE to form a Quarters Committee to work jointly with the BSCE Quarters Committee.

It is hoped that these short-range suggestions could be implemented in the fall of 1970.

The Committee members expressed their willingness to continue to serve on this Committee in the forthcoming year.

Respectfully submitted,
William A. Henderson
Edward C. Keane
Robert J. Van Epps
James P. Archibald, Chairman

REPORT OF THE JOHN R. FREEMAN FUND COMMITTEE

Boston, Mass. March 25, 1970

To the Boston Society of Civil Engineers:

On January 28th, 1970, Dr. Klas Cederwall presented the fifth John R. Freeman Memorial Lecture at a Joint Meeting of the Hydraulics Section and the Main Society. His subject was "Dispersion Phenomena in Coastal Environments".

The program is being reviewed and plans are underway for the coming year.

Respectfully submitted,
George R. Rich
Clyde W. Hubbard
Lee M. G. Wolman
David Campbell
Leslie J. Hooper, Chairman

REPORT OF THE RALPH W. HORNE FUND COMMITTEE

Boston, Mass., March 25, 1970

To the Boston Society of Civil Engineers:

This is the Fourth Annual Report of the Ralph W. Horne Fund Committee.

At its 1969 Annual Meeting, the Society, acting upon recommendation of the Committee, named Edward Wright as the recipient of the Ralph W. Horne Award and presented him a scroll in recognition of unpaid public service which he has rendered throughout his professional career.

Prior recipients of the award were Dr. Carl Stephen Ell in 1968, Llewellyn T. Schofield in 1967, Miles N. Clair in 1966, and Charles O. Baird, Jr. in 1965.

Respectfully submitted,
Miles N. Clair
George G. Bogren
William L. Hyland, Chairman

REPORT OF BSCE REPRESENTATIVE

on Ad-Hoc Committee "Joint Committee on Revisions to Massachusetts Professional Engineers and Land Surveyors Registration Laws"

To the Boston Society of Civil Engineers:

The writer was BSCE's representative on this committee, which included 20 representatives of 14 engineering societies active in the Commonwealth. Over a fourteen-month period, revisions to the Massachusetts Registration laws were formulated, unanimously endorsed by the Board of Registration of Professional Engineers and of Land Surveyors and submitted to the General Court as House No. 1341, entitled "An Act Relative to Membership of the Board of Registration of Professional Engineers and of Land Surveyors, and Regulation the Practice of Engineering and of Land Surveying".

A hearing was held on February 25, 1970, before the Committee on State Administration, and no opposition was heard.

Successful enactment of this bill will strengthen our registration laws, bring us into agreement with the majority of other states, and allow reciprocal recognition.

Respectfully submitted,
Charles A. Parthum
BSCE Representative

SANITARY SECTION

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE

To the Boston Society of Civil Engineers:

The Sanitary Section held four meetings during the year. A brief account of these meetings follows:

1 — March 5, 1969 Annual Meeting held in the Society rooms.

The Nominating Committee presented the following proposed slate of officers and members of the Executive Committee:

David A. Duncan — Chairman
Leland F. Carter — Vice Chairman
Cornelius J. O'Leary — Clerk
William Parker — Executive Committee
Jack Cochran — Executive Committee
Paul Guertin — Executive Committee

There being no additional candidates the Chairman directed the Clerk to cast one vote for the slate.

After the election Professor Perry L. McCarty talked on Nitrogen Removal from Agricultural Wastewater in California.

2 — June 4, 1969 Annual Outing and Joint Meeting with Main Society in Plymouth, Massachusetts. Members toured the site of Pilgrim Nuclear Power Plant of Boston Edison Company under construction and scheduled for operation in 1971.

The evening meeting was held at Bert's Restaurant where Mr. Richard Smith of Boston Edison Company presented a detailed presentation of the Environmental Surveillance program set up to provide fundamental protection from the surrounding environs.

3 — October 1, 1969 meeting held in the Society rooms. About twenty-four members and guests attended.

The meeting was opened by Chairman Dave Duncan who notified the members that the Executive Committee had voted to notify the Board of Government of the inadequacy of the present quarters. The Chairman asked for discussion of the matter. It was the consensus that such a letter be sent to the Board of Government. It was voted that the Chairman forward such a letter.

Mr. David Jenkins, Associate Professor of Sanitary Engineering and Chief Chemist of the Sanitary Engineering Laboratory at the University of California presented a paper on Phosphorus Removal in Waste Treatment Processes.

Thirty-five members were in attendance.

4 — December 3, 1969 meeting held in the Society rooms.

Chairman David Duncan opened the meeting and notified the members that a nominating committee consisting of Mr. Charles Parthum, Chairman, Mr. Walter Newman and Professor Robert L. Meserve was appointed to submit a slate of officers for the coming year.

Mr. Duncan introduced Mr. Robert Culver, President of the Society who spoke briefly to the Section on the increased desire of young people to protect and enhance the environment. He stressed that he welcomed this interest because it will require professional engineers to be more astute in their endeavors.

Mr. Duncan introduced Mr. Joseph C. Lawler, Partner -- Camp, Dresser, and McKee who presented a very interesting talk on "The 840 mgd Water Treatment Plant for Sydney, Australia".

About forty members were in attendance.

The Executive Committee met on August 4, 1969, October 1, 1969, and December 3, 1969.

Major subjects discussed included:

1. The Section's dissatisfaction with the present quarters and that action be taken to notify the Board of Government.
2. Expansion of the Section's programs to include topics on air pollution control, solid waste disposal and other environmental problem areas.
3. Having a least one luncheon meeting during the year.

The committee took the following action on these subjects:

1. Notified the Board of Government of the inadequacy of the quarters on October 10, 1969.
2. The March 4, 1970 meeting was on air pollution control.
3. No action was taken relative to the luncheon meeting since scheduled speakers were not available. The possibility of such a meeting during next year, will be considered further.

Respectfully Submitted
Cornelius J. O'Leary
Clerk

REPORT OF THE EXECUTIVE COMMITTEE OF THE STRUCTURAL SECTION

March 16, 1970

To the Boston Society of Civil Engineers:

The following meetings were held during the past year:

March 12, 1969 — Mr. Grady J. Taylor of Howard, Needles, Tammen and Bergendoff, spoke on the "Rio de Janeiro-Niterol Bridge". Attendance was 26.

April 1, 1969 — Mr. Lanier C. Greer of the Boston Redevelopment Authority spoke on "Boston's Plan for the 1976 World Exposition". Attendance was 22.

May 14, 1969 — Mr. Edward Cohen, Partner, Amman and Whitney, spoke on "Forthcoming Revisions to the A.C.E. Code (318-63)". Attendance was 38.

October 8, 1969 — Mr. Frank W. Stockwell, Jr., of the American Institute of Steel Construction, spoke on the 1969 A.I.S.C. Specification. Attendance was 44.

November 12, 1969 — Mr. Leslie Robertson, Partner, Skilling, Helle, Christiansen and Robertson, spoke on the "Design and Construction of High Rise Buildings".This was a joint meeting with the Main Society. Attendance was 48.

January 14, 1970 — Dr. Eliahu E. Traum, Professor of Construction, Graduate School of Design, Harvard University and, Visiting Professor of Structure at M.I.T., with Dr. Waclaw P. Zalewski, Professor of Structures, Department of Architecture, M.I.T. spoke on "A Conceptual Model for Shear Wall-Frame Systems". Attendance was 28.

February 11, 1970 — Mr. Logan L. Donnel of Simpson, Gumpertz & Heger spoke on how "A Structural Engineer Looks at Brick Masonry Problems" and Mr. Hans William Hagen of William LeMessurier Associates spoke on "The Phillips Exeter Academy Space Trusses". Attendance was 36.

Respectfully submitted,
Sepp Firnkas
Clerk

TRANSPORTATION SECTION

March 25, 1970

To the Boston Society of Civil Engineers:

The Executive Committee for the year 1969 — 1970 consisted of the following:

Charles D. Shaker — Chairman
A. Paul La Rosa — Vice Chairman
A. Russell Barnes — Clerk
Charles H. Flavin
Maurice Freedman
Robert T. Tierney

The Transportation Section held three meetings during the past year, as follows:

September 24, 1969 — Joint Meeting with Main Society

John A. Hanson, Federal Highway Administrator of Region 1 of the United States Department of Transportation, spoke on "A Broad Overview of Our Nation's Proposed Highway Transportation Program — Concepts and Goals and a Look Ahead". Attending the meeting with Mr. Hanson was John G. Bestgen, Acting Division Engineer of the Boston office of the Federal Highway Division.

Attendance — 55

This dinner meeting was held in the Harvard Room of Purcell's Restaurant, School Street, Boston.

November 19, 1969 — Joint Meeting with Computer Section, B.S.C.E.

David Carter, Engineer-Programmer for the State of New Hampshire Department of Public Works and Highways, delivered an interesting and informative talk on the subject of "Computer Applications in the Highway Engineering Field".

Attendance — 55

This dinner meeting was held in the Harvard Room of Purcell's Restaurant, School Street, Boston.

February 25, 1970

Mr. H. Alfred Pontier, Partner in the consulting engineering firm of Edwards and Kelcey, Inc., presented an illustrated lecture on "Interstate Route 93 through Franconia Notch State Park". He presented three solutions for a highly complex and controversial project which has attracted nationwide attention. The study weighs the traditional use of this mountain pass for the efficient and safe movement of people and goods versus the equally important values of recreation, conservation and aesthetics.

The following were nominated and elected to the Executive Committee of the Transportation Section for the year 1970 — 1971:

A. Paul La Rosa — Chairman
A. Russell Barnes — Vice Chairman
Robert Tierney — Clerk
Maurice Freedman
Richard K. Guzowski
Charles D. Shaker

Attendance — 78

This dinner meeting was held in the Harvard Room of Purcell's Restaurant, School Street, Boston.

Plans are well along for the first meeting of the Transportation Section for the 1970 — 1971 season. It will be a joint meeting with the Boston Chapter of the Institute of Traffic Engineers and will be held on Wednesday evening, May 20, 1970, at Purcell's Restaurant. The subject will be "The Federal Aid TOPICS Program".

"TOPICS" stands for "Traffic Operations Program for the Improvement of Capacity and Safety". This program is a federally aided action type which is designed to encourage short-range improvements in capacity and safety on urban arterial streets. These improvements include traffic control devices, traffic signal systems, channelizations, etc. All aspects of the program will be discussed, including its impact on cities and towns in Massachusetts.

The Transportation Section has been designated by the Board of Government to handle all arrangements on its behalf for B.S.C.E.'s participation in the A.S.C.E. 1970 National Transportation Engineering Convention. The convention will be held in Boston at the Statler Hilton Hotel between July 13 — 17, 1970. B.S.C.E.'s participation will be in the form of sponsoring a dinner meeting on Monday evening, July 13. It is expected that a nationally known speaker will be booked for this meeting.

Respectfully submitted,
Charles D. Shaker
Chairman

EXECUTIVE COMMITTEE REPORT
HYDRAULICS SECTION

March 10, 1970

To the Boston Society of Civil Engineers:

The following meetings were held during the past year:

April 23, 1969 — Professor Henry M. Paynter of MIT and Professor Lawrence C. Neale of the Alden Reasearch Laboratories spoke on the "Surge Tank for the Northfield Pumped Storage Project".

Design, model tests and interpretations of model results were presented.

Attendance: 28

November 5, 1969 — Mr. Nicholas Lally of the Water Resources Division, Metropolitan Development HUD gave an illustrated talk on the non-structural aspects of "Flood Plain Management".

Attendance: 19

January 28, 1970 — The Annual Meeting was held jointly with the Main Society of the Boston Society of Civil Engineers in the Adams Room of the United Community Services Building, 14 Somerset Street, Boston, Massachusetts. In the absence of President Robert H. Culver, Mr. Ernest L. Spencer presided.

Mr. Spencer called upon Professor Leslie J. Hooper, Chairman of the John R. Freeman Memorial Fund Committee to introduce the speaker, Dr. Klas Cederwall, Consulting Engineer, who gave the Fifth Annual John R. Freeman Memorial Lecture on "Dispersion Phenomena in Coastal Environments". Dr. Cederwall was presented with a framed certificate for the lecture and an honorarium on behalf of the John R. Freeman Memorial Fund.

Attendance: 50 at dinner and 61 at the meeting.

March 9, 1970 — Chairman Ronald T. McLaughlin presented the report of the Nominating Committee of the Hydraulic Section consisting of Mr. Athanasios A. Vulgaropulos, Chairman, Mr. Peter S. Eagleson and Mr. Allan Grieve, Jr.

The following slate of officers of the Hydraulic Section for the year 1970-1971 was elected unanimously by voice vote:

Chairman	Stephen E. Dore, Jr.
Vice Chairman	Albert G. Ferron
Clerk	Jerome Degen
Executive Committee	Frank E. Perkins
	Robert S. Restall
	Saul Cooper

The chairman then called upon Mr. Robert S. Restall, Senior Staff Associate, New England River Basin Commission, who spoke on "Environmental Considerations of Electirc Power Plant Siting".

Attendance: 16

Respectfully submitted
Albert G. Ferron
Clerk

CONSTRUCTION SECTION

To the Boston Society of Civil Engineers:

The following meetings have been held during the year:

May 15, 1969 — Executive Committee Meeting, attended by F. J. Killilea, Chairman; H. M. Priluck, Vice Chairman;A. H. Mosher; W. E. Wiley. Discussed program for year and developed tentative list of speakers.

May 21, 1969 — Joint Meeting of Construction Section and Main Society. John R. Davis, Deputy Chief Engineer, Mass. Port Authority presented a talk entitled "General Airport Construction — Past and Future". Forty-eight members and guests were present.

Sept. 17, 1969 — Joint Meeting of Construction and Computer Sections, presenting a panel discussion entitled "Computer Applications for Construction Management". The panel comprised:

Benjamin Clark, President, Clark & Slater, Inc.

Leonard Walsh, Program Controller, Construction Department, MBTA

Robert Daniels, President, Project Software and Development, Inc.

Herbert M. Priluck, Consulting Engineer, acted as moderator. Fifty members and guests were present.

January 21, 1970 — Section meeting, on the subject: Construction Specifications Institute, Boston Architectural Center, BSCE, and Producers' Council: Who, What and Why are these organizations, and How are they inter-related? Each of our guest speakers presented information on his organization, as follows:

Emil Hervol, President, Boston Chapter, C.S.I.

Sanford R. Greenfield, AIA, Director of Education, BAC

Prof. Ernest L. Spencer, Vice President, BSCE

Allen R. Davis, President, Boston Chapter, P.C.

Preceding this presentation, A. H. Mosher, Chairman of the Nominating Committee, presented the following slate of officers to serve for the coming year:

Chairman:	Charles F. Sullivan
V.C.:	James A. Fife
Clerk:	Morse H. Klubock
At-Large:	William E. Wiley
	Arthur H. Mosher
	Frank J. Killilea, Jr.

Thirty-three members and quests were present.

Respectfully submitted,
J. A. Fife
Clerk

REPORT OF THE EXECUTIVE COMMITTEE OF THE GEOTECHNICAL SECTION

Boston, Mass., March 23, 1970

To the Boston Society of Civil Engineers:

The Geotechnical Section held the following meetings during the past year:

March 20, 1969 — Organizational Meeting. The following officers and members of the Executive Committee were elected:

Donald T. Goldberg	Chairman
Charles C. Ladd	Vice-Chairman
Philip A. Wild	Clerk
Edmund G. Johnson	Executive Committee
Vincent J. Murphy	Executive Committee
Steve J. Poulos	Executive Committee

The meeting was held at the MIT Faculty Club with 70 attending.

October 29, 1969 — Dr. Arthur Casagrande, Gordon McKay Professor of Soil Mechanics and Foundation Engineering, Harvard University, spoke on Liquification of Sands. The meeting was held at the Harvard Faculty Club with 78 attending.

November 20, 1969 — Joint meeting with the American Society of Civil Engineers. Dr. Leopold Muller, Professor of Rock Mechanics, University of Karlsruhe, West Germany, spoke on Rock Mechanics and Tunneling. The meeting was held at the Charter House Motor Hotel in Cambridge with 51 attending.

December 10, 1969 — Joint meeting with the Main Society. Mr. William F. Swiger, Consulting Engineer, Stone & Webster Engineering Corporation spoke on Pile Specifications. The meeting was held at Kevin's Wharf in Boston with 51 attending.

March 18, 1970 — Annual Meeting of the Section. The following were nominated and elected to the Executive Committee of the Geotechnical Section for the year 1970-1971:

Charles C. Ladd	Chairman
Philip A. Wild	Vice-Chairman
Edmund G. Johnson	Clerk
Vincent J. Murphy	Executive Committee
Steve J. Poulos	Executive Committee
Stiles F. Stevens	Executive Committee

Mr. J. Barry Cooke, Consulting Engineer, Kentfield, California, spoke on Rockfill Dams. The meeting was held at the Red Coach Grill, Boston, with 63 attending.

January 13, 1970 — Geotechnical Section Forum. Special meetings held separately from the regular Section meetings, the Forum is intended to provide a means for discussion of geotechnical topics and problems on an informal basis. The topic for this first meeting was Problems with Pier Foundations in the Cambridge Formation. Mr. Allen Gass of Golder, Gass Associates made the presentation. The meeting was held at the Tech Square House Restaurant with 71 attending.

Respectfully submitted,
Philip A. Wild, Clerk

REPORT OF THE EXECUTIVE COMMITTEE OF THE COMPUTER SECTION
Boston, Mass., March 13, 1970

To the Boston Society of Civil Engineers:

During its first year of operation the Computer Section conducted or participated jointly with other sections in six meetings. These are summarized as follows:

April 22, 1969 — Meeting at the Society Rooms; Attendance 30.

This was the first meeting of the newly formed section. Its purpose was to organize the Section, elect officers, establish objectives, and discuss topics for future meetings. The following officers of the Section were elected:

Frank E. Perkins	Chairman
Gerald L. Woodland	Vice Chairman
Alan E. Rimer	Clerk
Richard F. Dutting	Executive Committee
David I. Hellstrom	" "
Saul Namyet	" "

May 27, 1969 — Meeting at Purcell's Restaurant: Attendance 28.

The film, "Computer Generated Movies" was shown in order to illustrate the extent to which computer graphics has progressed in some fields, and to show how such techniques can compress and clarify voluminous computer outputs. However, the principal function of this meeting was social, providing the members of the new section with an opportunity to meet informally.

September 17, 1969 — Meeting at Purcell's Restaurant; Attendance 50.

This meeting was held jointly with the Construction Section and consisted of a panel discussion on computer use in project management. See Construction Section report for details.

October 22, 1969 — Meeting at Purcell's Restaurant. Attendance 40.

The Computer and Structural Sections met jointly to hear Fr. John T. Christian, Assistant Professor of Civil Engineering at M.I.T. speak on "Finite Element Methods in Civil Engineering". Dr. Christian gave a clear, physical picture of the nature of finite element methods and then described a number of interesting applications which covered several branches of civil engineering.

November 19, 1969 — Meeting at Prucell's Restaurant. Attendance 55.

This meeting was held jointly with the Transportation Section. Mr. David Carter spoke on Computer Applications in the New Hampshire Highway Department. See Transportation Section report for details.

January 7, 1970 — Meeting at Purcell's Restaurant. Attendance 70.

A panel discussion on the topic, "Who Pays for the Computer". highlighted the annual meeting of the Section. The panel was comprised of:

Mr. Charles D. Shaker;	Fay, Spofford & Thorndike, Inc.
Prof. Daniel Roos:	M.I.T.
Mr. James P. Collins:	Collins & Associates, Inc.

Moderator for the panel was Mr. Alan E. Rimer of Camp, Dresser and McKee. Each of the panelists described various methods of accounting and charging for computer use, and the pros and cons of each. A very lively and informative discussion period followed:

Elected as Officers for the year 1970-71 were:

Gerald L. Woodland	Chairman
Alan E. Rimer	Vice Chairman
David I. Hellstrom	Clerk
Saul Namyet Robert D. Logcher Frank E. Perkins	Executive Committee

This first year of its existence has demonstrated that the Computer Section does have an important role to play in the Society. To date we have concentrated on working with other sections to stimulate programs related to computer applications. In addition, the meeting of January 7, 1970 was of general interest and apparently was of considerable value to those in attendance. In order to fulfill our role of service to the Society the record of that meeting is being edited and will be published in the BSCE Journal.

Respectfully submitted,
Frank E. Perkins
Chairman

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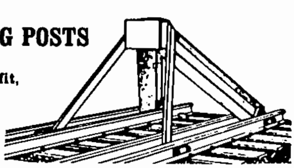

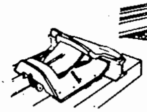

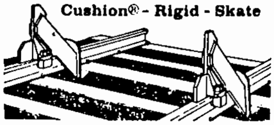

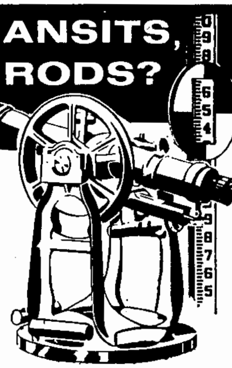

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