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JOHN F. FLAHERTY

President

Boston Society of Civil Engineers 1963-64

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Volume 50 APRIL, 1963 Number 2

THE PUBLIC IMAGE OF THE ENGINEER

PRESIDENTIAL ADDRESS BY GEORGE G. BOGREN

(Boston Society of Civil Engineers, March 21, 1963)

MOST presidential addresses in recent years have been on the subject of engineering practice and education, depending on whether the President was a practicing engineer or an educator. This year, the subject has been suggested by recent events; it can be disposed of in few words.

First, we engineers were concerned with the decreasing number of students graduating from our engineering schools, from the standpoint of national defense. Then we were concerned with the decreasing attendance at engineering society meetings; this has been seemingly remedied by decreasing the number of meetings by having more joint meetings of the main society with its sections. More recently, we have been concerned with the bad press which civil engineering has suffered because of alleged improper practice of a few professional engineers. All the above symptoms have a common effect—a poor public image of the engineer. What are the causes?

During the past year, this Society's members on the Joint Committee on Professional Conduct of the Massachusetts Section of the American Society of Civil Engineers, the Massachusetts Society of Professional Engineers, and the Boston Society of Civil Engineers, have on more than one occasion requested approval of your Board of Government of a statement of purpose, or scope of procedure, to govern the activity of the Committee in improving the public image of the professional engineer, by publicity and by available legal procedure. The Board was obliged to deny approval of more than one of these requests, by advice of legal counsel. The Board sympathized with the requests—the members of the Joint Committee from this Society were its elite, men of stature and seniority in the profession—and yet the Board was obliged to deny support to them because your Society possesses financial assets which are vulnerable to suits for defamation of character. Eventually, this Society's members on the Joint Committee and our legal counsel agreed upon a revised statement of purpose for the Committee which met the approval of our legal counsel. In other words, we are vulnerable to libel suits because we have substantial financial assets, and must therefore proceed cautiously in statement or action against those persons charged with practicing engineering illegally.

A "Committee to Uphold Principles of Engineering Registration Laws, Inc." has been formed to take legal action against those practicing professional engineering illegally, without exposing the Societies to which its members belong to suits for defamation of character. Your Society is ably represented thereon.

It would appear, then, that if the State Board of Registration of Engineers takes legal action on improper practice of professional engineering, and if engineering societies police their own members through their codes of ethics, the public image of the engineer should improve. Unfortunately, there are other complications—the attitude of the public, the attitude of engineering students, and the attitude of professional engineers themselves.

The public takes for granted the palatable and safe water it drinks, the majestic bridges and superhighways on which it rides, and the airports upon which its planes land—all designed by civil engineers. The public thinks in terms of what it sees—construction. It does not see the drafting boards, the studies, the reports, the conferences, the decisions.

And the students who will replace us—why do they not enter the field of civil engineering? The January 1963 Bulletin of the Harvard Engineering Society reports the change of name of the society to "Society of Harvard Engineers and Scientists" because graduate engineers "do not like the title of engineer. The title has been greatly abused, and they prefer to be called scientists." Another society, the Society of Automotive Engineers, is said to be considering changing its name. Will a rose smell sweeter by another name? Or would it be better to popularize the smell?

Another indication of the deterioration of the public image of the engineer is the attitude of municipal and industrial clients, which I have observed over the past forty years. Clients engage professional engineers on the basis of their professional reputation, and then some of them proceed to treat the engineers as vendors of simple commodities, demanding adherence to standards set up by the client's personnel, ignorant of the broad professional engineering problem. All is justified, in their mind, by the conservation of the taxpayers' or the corporations' dollar. They overlook the simple fact that the engineer was engaged to provide talent that was not available locally. In these cases, the engineer should stand his ground professionally, challenging the demands of well-meaning but professionally incompetent clients.

Articles in the technical literature by eminent engineers on the subject of relations between engineers and clients often recommend the taking of the client into the engineer's confidence more, and explaining in detail all the phases of design and construction as they occur. It is also recommended that the relationship of the engineer and client be spelled out in more detail in the contract for engineering services. In some types of engineering work this may be possible and desirable—in others, such as policy-making studies and reports, it may not be so.

Fortunately, we engineers have well established guides to methods for improving our public image—namely, the experience of the legal, medical and architectural professions in maintaining public respect for their professional status. The general public may grumble about the fees charged by lawyers, or about the difficulties of getting appointments with doctors or dentists, but there is no doubt in its mind of the place in society occupied by members of these professions, nor of society's debt to them.

The engineering profession has no opportunity to develop the very personal relationship of doctor and patient as in the medical profession, nor does it operate in the exclusive atmosphere of the Courts, as in the case of lawyers. But, like the architect, the engineer provides indispensable parts of man's environment, and he must somehow attach a certain dignity to the process, which it deserves.

As to the desirability of changing the name "engineer" to "scientist" in order to attract the younger generation to our profession, I have my doubts, particularly in the case of a society as venerable as ours.

I do believe, however, that we must be willing to entertain a reasonable risk of our society assets in legal procedure against those who are guilty of unprofessional conduct. Courts of law are run by professional men, before whom the truly professional engineer is in sympathetic company.

It seems trite, and it has been said in better words before, but the public image of the professional engineer is what we want to make it, individually, one by one, in our dealings with the public. In the light of recent events, we cannot afford to be careless or apathetic.

THE USE OF MODELS IN STRUCTURAL DESIGN

By William A. Litle,* and Robert J. Hansen,** *Member*

(Presented at a joint meeting of the Boston Society of Civil Engineers and Structural Section, B.S.C.E., held on February 13, 1963.)

Summary

Reasons for, the basis of, and techniques used in structural model analysis as currently practiced in the Laboratory for Structural Models, Department of Civil Engineering, M.I.T., are described. Several examples of recent model projects are cited.

I. Introduction

Civil engineering structures are most often one of a kind. Consequently, it usually is not economically feasible to construct trial prototype structures—as the airplane industry may—in order to determine whether a proposed design possesses sufficient stiffness and strength. In fact the client demands of the structural engineer that a satisfactory design be produced prior to the start of construction of the prototype for an economic remuneration on the order of 1% of the final construction cost. In addition the time available for the preparation of this design is often short. The possibility of studying a reduced scale model, perhaps constructed of a material different from that of the prototype, has obvious and widespread consequences. It is felt that if structural designers were to better understand the basis upon which model investigations are carried out, they would better appreciate the fact that the structural model can be a very powerful design tool.

The present paper presents a brief review of the structural modelling problem and cites some examples from recent experience in the Laboratory for Structural Models, Department of Civil Engineering, at the Massachusetts Institute of Technology.

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II. The Experimental Design Process

2.1 *The Model Problem.* The total process of a model study might be broken down into five steps, namely: (1) planning the study; (2) fabricating the model; (3) constructing a loading system; (4) instrumenting the model and measuring the structural response; and (5) interpreting the results and extrapolating them to the prototype. After the objective of the model study has been established it is imperative that the engineer consider precisely how each phase of the investigation is to be carried out and satisfy himself that the methods of fabrication, loading and measuring will be compatible with each other and will allow useful results to be obtained. For example, the loading of a structural model depends intimately upon the proposed means of recording the desired information, the size of the model, the model material, etc. Thus if electric resistance strain gages were to be used one might wish that minimum strains of 0.000050 in./in. be induced in order that inherent errors in the measuring system be negligible. If $E_{steel} = 30,000,000$ psi, $E_{brass} = 16,000,000$ psi, $E_{aluminum} = 11,000,000$ psi, $E_{mortar} = 3,000,000$ psi, $E_{rigid\ plastic} = 400,000$ psi and $E_{foamed\ plastic} = 3000$ psi, then the size of the loads required would be directly proportional to the modulus of elasticity of the model material. It might appear that very low modulus materials were always to be preferred, however, the ease of loading would have to be balanced against the fact that a metallic sensing element may yield erroneous strain information when attached to low modulus materials. In this example, the material to be used in Step (2), the size and cost of the loading system in Step (3) and the interpretation of results in Step (5) are heavily dependent upon one another. Other similar examples could be cited.

In the following sections, the various steps involved in the total model process will be treated. First the theory of models will be presented. This theory stands by itself. It forms the base for planning the study and supplies the information for extrapolating the model results to the prototype. The steps of fabrication, loading, and instrumentation are mostly technological in nature but the means of carrying them out will influence the outcome of the experiment in a most significant way and hence should be thoroughly considered in the planning stage.

2.2 *Planning—The Theory of Models.* In order to be able to deduce quantitative results regarding some phase of the structural response of the prototype from an investigation of a small scale model there must exist some relations which relate the behavior of the small scale model to that of the full scale structure. The theory underlying such relationships is really a mathematical theory of dimensions and in regard to the small scale model the governing relationships are often described as the principles of similitude. The theory of models consists of two essential facts. These facts will be stated very concisely and afterwards will be discussed more fully.

1. *Any mathematical description (i.e., equation) which describes some aspect of nature must be in a dimensionally homogeneous form.* That is, the governing equation must be valid regardless of the choice of units in which the physical variables are measured. Thus the equation $f = Mc/I$ is correct regardless of whether force and length are measured in pounds and feet, pounds and inches, or grams and furlongs.
2. As a consequence of the fact that all of the governing equations must be dimensionally homogeneous it is a fact that any governing equation of the form $F(X_1, X_2, X_3, \ldots X_n) = 0$ must also be expressible in the form $G(\pi_1, \pi_2, \ldots \pi_m) = 0$, where the π's are dimensionless products of the physical variables $X_1, X_2, \ldots X_n$ and $n - m = r$ where r is the maximum number of the physical variables X_1, X_2, X_n which are dimensionally independent. This fact was proved by Buckingham in 1914.

Without entering into the realm of philosophy and a discussion of how it came about that man established the concepts which we know today as dimensions, very little can be said regarding the first statement. It may be of interest to note that there are only 6 fundamental dimensions which have come to be established in the history of scientific development, namely:

(1) length (L)
(2) force or mass (F) or (M)
(3) time (T)
(4) temperature (K)
(5) heat (X)
(6) electric charge (Q)

In structural engineering problems involving static response only the first two will usually be involved whereas dynamic response problems will usually involve the first three dimensions. As examples of dimensionally homogeneous equations consider the deflection of a simple prismatic elastic beam loaded as shown in Fig. 1a.

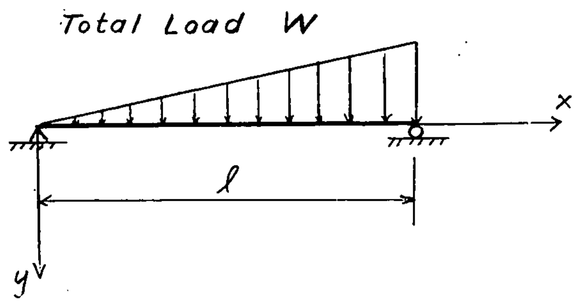

FIG. 1a

$$y = \frac{Wx}{180\,EI\,l^2}\,(3x^4 - 10\,l^2x^2 + 7\,l^4)$$

dimensionally

$$L = \frac{FL}{\frac{F}{L^2}L^4L^2}\,(L^4 - L^2L^2 + L^4)$$

Or consider the partial differential equation which governs the small deflections of the laterally loaded plate. (See Fig. 1b).

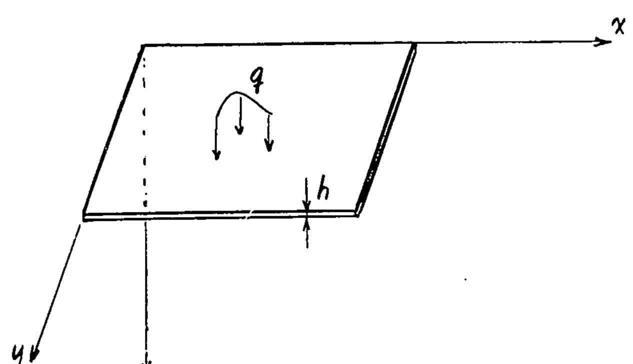

FIG. 1b

$$\frac{\partial^4 w}{\partial x^4} + 2\frac{\partial^4 w}{\partial x^2 \partial y^2} + \frac{\partial^4 w}{\partial y^4} = \frac{12(1-\nu^2)}{Eh^3} q$$

dimensionally

$$\frac{L}{L^4} + \frac{L}{L^4} + \frac{L}{L^4} = \frac{1}{\frac{F}{L^2}L^3}\frac{F}{L^2}$$

It is with regard to the second essential fact that some further explanation may be required. In order to formulate the problem as suggested in fact 2, it is necessary to understand the concept of the dimensional dependence or independence between a set of physical quantities. Table 1 presents a sample of physical quantities which might be involved in problems of structural response.

TABLE 1. Typical Quantities in Structural Problems

	Quantity	Dimensions
l	Length	L
t	Time	T
F	Force	F
V	Velocity	LT^{-1}
σ	Stress	FL^{-2}
ε	Strain	1
a	Acceleration	LT^{-2}
q	Surface force	FL^{-2}
ν	Poisson's Ratio	1
ρ	Specific weight	FL^{-3}
w	Displacement	L

From such a set of quantities it is possible *dimensionally* to form certain quantities in the set by combining others in the form of products. Thus the dimensions of length divided by the dimensions of time yield the dimensions of velocity. Also, the dimensions of stress divided by the product of the dimensions of acceleration and the dimensions of time squared yield the dimensions of specific weight. Consequently, it is seen that the products $\frac{vt}{l}$ and $\frac{\rho a t^2}{\sigma}$ are dimensionless. In any such set of quantities there is a limiting number of quantities which cannot themselves be combined to form a dimensionless product but which can be combined with each other quantity in the set to yield a dimensionless product. The quantities involved in the limited set are said to be dimensionally independent while the other quantities are dimensionally dependent on the special limited set.

The theory involved in establishing the basis of the concept of dimensional dependence and independence can be rigorously deduced either through the use of the calculus of implicit functions or through a consideration of the possible solutions of a certain set of linear algebraic equations which arise when the continuous product of the given set of quantities, each raised to an arbitrary power, is made to be dimensionless. The most important results of this theory insofar as the structural engineer is concerned can be set down as follows:

1. There are three relevant dimensions in dynamic problems—force, length, and time, while only two are involved in static problems—force and length. Correspondingly, there are three and only three dimensionally independent physical quantities in a set of quantities involved in a dynamic problem while there are two and only two such quantities in a static problem.
2. The dimensionally independent quantities in any given set are by no means unique. For the dynamic problem they may, with the following exceptions, be any three which include force, length and time among their dimensions. *Exception No. 1.* None of the three quantities may have the same dimensions. *Exception No. 2.* A dimensionless quantity (such as strain or Poisson's Ratio) may not be included. Subject to the same exceptions the static problem admits any two quantities which include both force and length among their dimensions.
3. The dimensionally dependent relationships may be determined by forming, with the previously determined dimensionally independent quantities, a dimensionless product for each of the remaining variables in the given set. Clearly, there will be $n - 3$ such relationships for the dynamic problem and $n - 2$ such for the static problem.

Returning again to the second essential fact relating to the theory of models it is seen that if one can identify the variables which are relevant in a particular structural response problem then the solution of the problem must be expressible in the form $F(X_1, X_2, X_3, \ldots X_n)$

$= 0$ where the X's are the relevant physical variables. Of course, in a complicated problem the nature of the function F is unknown. However, Buckingham's theorem says that $F(X_1, X_2, \ldots X_n) = 0$ can alternatively be written in the form $G(\pi_1, \pi_2, \ldots \pi_{n-3}) = 0$ and $G_1(\pi_1, \pi_2, \ldots \pi_{n-2}) = 0$ for the dynamic and static problems respectively. The π's are in fact the dimensionally dependent relationships. Of course, the G equations could be solved explicitly for any one of the dimensionless products—say π_2 as $\pi_2 = \phi_1(\pi_1, \pi_3, \ldots \pi_{n-3})$ and $\pi_2 = \phi_2(\pi_1, \pi_3, \ldots \pi_{n-2})$ for the dynamic and static problems respectively.

At this point it may not be clear just how all this can be of use in model analysis. The idea has been stated very succinctly by Bridgman (1) in 1922 which with revision of notation reads "There are in engineering practice a large number of problems so complicated that the exact solution is not attainable. Under these conditions dimensional analysis enables us to obtain certain information about the form of the result which could be obtained in practice only by experiments with an impossibly wide variation of the arguments of the unknown function. In order to apply dimensional analysis we merely have to know what kind of a physical system it is that we are dealing with, and what the variables are which enter the equation; we do not even have to write the equations down explicitly, much less solve them.

"Suppose that the variables of the problem are denoted by X_1, X_2, etc., and that the dimensionless products are found, and that the result is thrown into the form $\pi_2 = \phi(\pi_1, \pi_3, \ldots)$ where the arguments of the ϕ function and the factor outside embrace all the dimensionless products, so that the result as shown is general. Now in passing from one physical system to another the arbitrary function will in general change in an unknown way, so that little if any useful information could be obtained by indiscriminate model experiments. But if the models are chosen in such a restricted way that all the arguments of the unknown functions have the same value for the model as for the full scale example, then the only variable in passing from model to full scale is in the factors outside the functional sign, and the manner of variation of these factors is known from the dimensional analysis." Thus one can write

$$\frac{\pi_2 \text{ prototype}}{\pi_2 \text{ model}} = \frac{\phi(\pi_1 \text{ prototype}, \pi_3 \text{ prototype}, \ldots)}{\phi(\pi_1 \text{ model}, \pi_3 \text{ model}, \ldots)} \tag{1}$$

and if

$$\pi_1 \text{ model} = \pi_1 \text{ prototype}$$
$$\pi_3 \text{ model} = \pi_3 \text{ prototype} \qquad (2)$$
$$\text{etc.}$$

then it is true that model results can be extrapolated to the prototype by

$$\pi_2 \text{ prototype} = \pi_2 \text{ model} \qquad (3)$$

Equations (1), (2), and (3) constitute the results of the theory of models insofar as the dimensional analysis is concerned. It should be pointed out now that the difficulties which the model engineer faces are first to identify the relevant physical variables and second to satisfy the set of Eqs. (2). Clearly, if a relevant physical variable is omitted in the analysis and no provison is made for it in the model then useful results cannot be obtained. On the other hand to include irrelevant variables unnecessarily increases the number of Eqs. (2) which must be satisfied. The technological difficulties involved in such satisfaction generally become more and more troublesome as the number of Eqs. (2) increases.

2.2.1 *Example.* Suppose that one were considering a prototype structure which was a simple span prismatic beam, the material of which was linearly elastic. (See Fig. 1c). The beam is subjected to a mid-span load P and it is of interest to determine the tensile stress in the bottom fibers of the mid-span cross-section.

If one were to adopt an experimental investigation on a small scale structural model as a means of determining the stress in the prototype beam, one usually measures the strain in the model. Then with determined knowledge of the elastic properties of the model material the strain measurements are transformed to stress. Thus as far as the dimensional analysis is concerned we have the relevant physical quantities given in Table 2.

TABLE 2. RELEVANT QUANTITIES IN EXAMPLE 2.2.1

	Quantity	Dimensions
the desired quantity	f stress	FL^{-2}
	l span length	L
	b width	L
	d depth	L
	P concentrated load	F

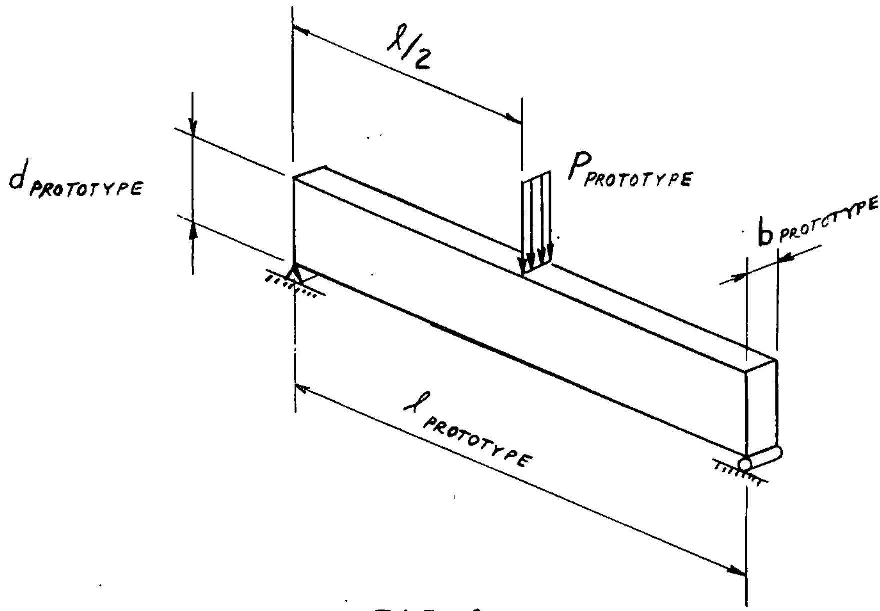

FIG. 1c

The quantities l and P can be taken as dimensionally independent and as such we will be free to choose their model magnitudes arbitrarily. The dimensionless products then are seen to be $\frac{fl^2}{P}$, $\frac{l}{b}$, and $\frac{l}{d}$. According to Buckingham's theorem

$$F(f, l, b, d, P) = 0 \tag{4}$$

can be written in the form

$$G\left(\frac{fl^2}{P}, \frac{l}{b}, \frac{l}{d}\right) = 0$$

or in the solved form

$$f = \frac{P}{l^2} \phi \left(\frac{l}{b}, \frac{l}{d}\right) \tag{5}$$

Of course in this simple problem it is known that

$$\phi\left(\frac{l}{b}, \frac{l}{d}\right) = \frac{3}{2}\frac{l}{b}\left(\frac{l}{d}\right)^2 = \frac{3\,l^3}{2bd^2}$$

but such information cannot be obtained from the dimensional analysis. Thus the model restrictions and model to prototype extrapolation as given by Eqs. (2) and (3) are

$$\left(\frac{l}{b}\right)_{\text{model}} = \left(\frac{l}{d}\right)_{\text{prototype}} \text{ and } \left(\frac{l}{d}\right)_{m} = \left(\frac{l}{d}\right)_{p} \tag{6}$$

$$f_{\text{prototype}} = f_{\text{model}} \frac{P_p \, l_m^2}{P_m \, l_p^2} \tag{7}$$

2.3 *Materials.* A prototype structure may be constructed of one or more materials. Steel and concrete are most commonly used although some use is also made of aluminum, plastics and other materials. Each of these materials will possess certain properties which will cause them to respond in a certain way when they are subjected to environmental conditions. The response may depend upon the magnitude of an applied force system, the atmospheric conditions with respect to temperature and relative humidity, the age of the material since molecular or chemical changes may have taken place, and other factors. To further complicate matters it is not even sufficient to specify all the aforementioned factors at the so-called "time of interest." The response at any particular time may very well depend upon the time history of the aforementioned factors as well as their present state. Scientists and engineers have for years been struggling to qualify the behavior of materials under the action of environmental conditions. Much remains to be done in this area. In spite of the lack of understanding with respect to the behavior of materials, the structural engineer who desires to study a model of a prototype must determine which prototype material characteristics are to be modelled. At the present time model engineers consider two categories: 1) elastic conditions and 2) the complete response up to and including failure. For the elastic case the modulus of elasticity and Poisson's Ratio are considered. For the response up to and including failure it is generally required that the uniaxial tension and compression stress-strain curves be considered in addition to insisting that the proposed model materials possess the same rheological characteristics as the prototype materials.

2.3.1 *Static Response in Elastic Range.* In the static problem it was seen that there are only two physical quantities which are dimensionally independent. Correspondingly, the magnitudes of only two of the relevant physical quantities can be chosen arbitrarily when establishing the model. It is often most convenient to select the length scale ratio and the modulus of elasticity ratios. With regard to all other relevant physical variables the model magnitudes would have to be in accordance with the dictates of the Eqs. (2). (Note that in the example in Section 2.2.1, it happened to be most convenient to select the span length ratio and the concentrated load ratio arbitrarily.)

For such static problems the use of a rigid plastic model material such as polyvinyl chloride or Plexiglas is often most advantageous. The outstanding characteristics of plastics as potential model materials are their ease of fabrication, low stiffness, and reasonable cost. Their principal disadvantages are creep characteristics and sensitivity to temperature. Fig. 2a depicts some properties of rigid polyvinyl chloride and Fig. 2b presents its most important characteristics as far as structural modelling is concerned.

It should be mentioned that special consideration must usually be taken to model dead weight conditions. For example, if the length scale and modulus of elasticity ratios between prototype and model are

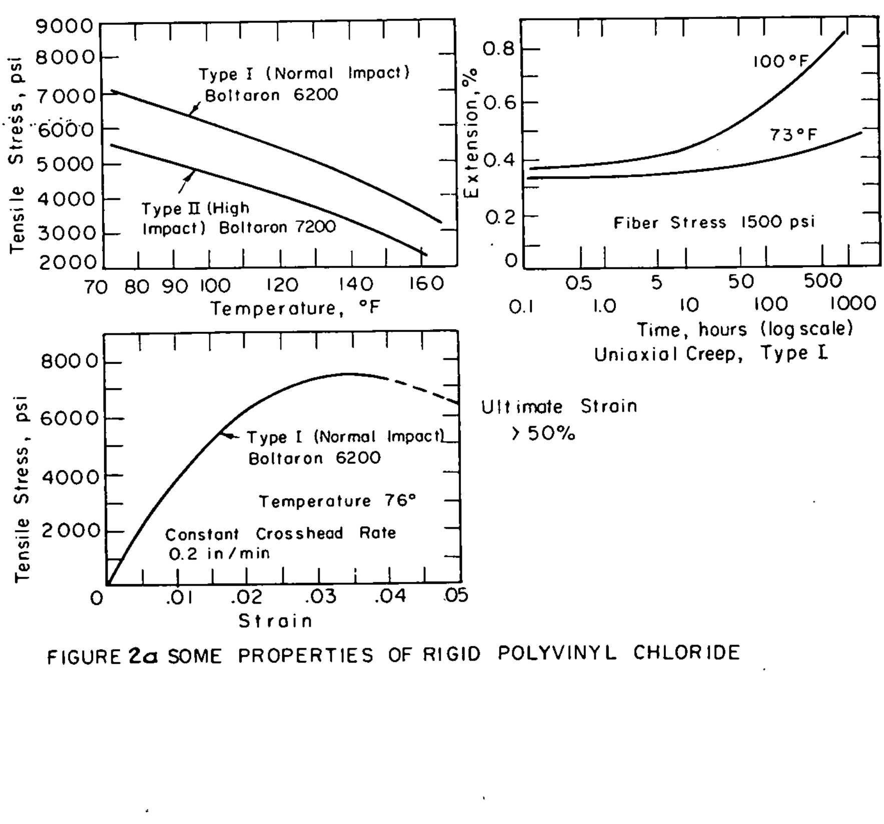

FIGURE 2a SOME PROPERTIES OF RIGID POLYVINYL CHLORIDE

chosen to suit the conditions of the model engineer, then one of the dimensionless products will be $\frac{\rho l}{E}$, where ρ is the specific weight of the

		UNPLASTICIZED POLYVINYL CHORIDE NORMAL IMPACT (BOLTARON 6200)
GENERAL	NATURE	THERMO PLASTIC
	COLOR	BASIC RESIN IS TRANSPARENT (MANY COLOR ADDITIVES)
	SPECIFIC GRAVITY	1.43
	AVAILABLE SHAPES	CALENDERED SHEETS $\left(\frac{1}{32}, \frac{1}{16}, \frac{3}{32}, \frac{1}{8}, \frac{1}{4}, \frac{1''}{2}\right)$, RODS, TUBES
	THICKNESS VARIATION IN PREFORMED SHEETS	± 10%
	COST	$\frac{1''}{32}$ – $0.55/ft^2 $\frac{1}{16}$ – 0.70 $\frac{1}{8}$ – 1.00
	JOINTING CHARACTERISTICS	CAN BE WELDED USING PVC RODS AND HEATED INERT GAS
	SHRINKAGE	7% @ 270 °F (ASTM D551-41)
	WATER ABSORPTION (ASTM D570)	0.15% IN 24 HOURS
MECHANICAL	ORDER OF MAGNITUDE TENSILE PROPERTIES (ASTM D638) 73 °F	7500 PSI @ UPPER YIELD STRAIN @ UPPER YIELD = 3% ULTIMATE ELONGATION = 55%
	ORDER OF MAGNITUDE COMPRESSION PROPERTIES (ASTM D695) 73 °F	10,000 PSI @ UPPER YIELD STRAIN @ UPPER YIELD = 5%
	UNIAXIAL CREEP (ASTM D621)	045%-4000 PSI @ 75°F, 24 HRS
	MODULUS OF ELASTICITY (ASTM D638, D695, D790)	460,000 ± 30,000 PSI
	POISSON'S RATIO	~0.4
THERMAL	VACUUM FORMING TEMPERATURE	185 – 260 °F
	THERMAL CONDUCTIVITY	$1.16 \frac{\text{BTU (IN)}}{\text{(HOUR) (FT}^2\text{) (°F)}}$
	COEFFICIENT OF EXPANSION	3.7×10^{-5} IN/IN/°F @ 70°F
OPTICAL	REFRACTIVE INDEX	1.55
	LUMINOUS TRANSMITTANCE	DEPENDENT ON COMPOSITION

FIGURE 2b SOME PROPERTIES OF RIGID POLYVINYL CHLORIDE

material. Therefore

$$\left(\frac{\rho l}{E}\right)_{\text{model}} = \left(\frac{\rho l}{E}\right)_{\text{prototype}}$$

and

$$\rho_{\text{model}} = \rho_{\text{prototype}} \frac{l_p}{l_m} \frac{E_m}{E_p} \tag{8}$$

As a typical illustration consider a prototype of concrete, a model of polyvinyl chloride, and a length scale is 1/10. Then

$$\rho_{\text{model}} = 90\ \#/\text{ft.}^3 \neq 150\ (10)\left(\frac{450{,}000}{3{,}000{,}000}\right) = 225\ \#/\text{ft.}^3$$

and Eq. (8) is not satisfied. To model dead weight one usually takes recourse to hanging additional mass to make up for the lack of mass in the model material.

2.3.2 *Static Response at Failure Loads.* When it is desired to model the response up to and including failure it is still generally most convenient to select the length scale and stress ratios. As opposed to the elastic case, however, the stress-strain curves of prototype and model materials must be similar over the entire range up to failure. This is shown in Figure 3. For prototype materials of steel or concrete there are no other materials presently available which exactly satisfy the stipulation on the model material which Figure 3 demands. For

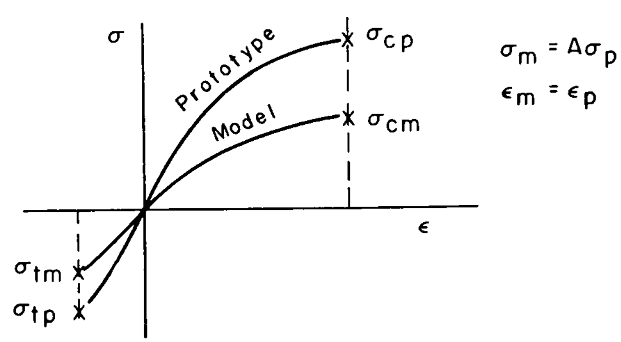

FIGURE 3 NECESSARY CONDITIONS FOR COMPLETE SIMILARITY OF MATERIALS

this reason steel and concrete are often used as their own model materials. When this is attempted, however, fabrication conditions often require large models. As substitute materials it has been found at M.I.T. that a phosphor bronze will satisfactorily simulate steel even though its yield range is not as large as that of the constructional steels. Figure 4 indicates the degree to which various non-ferrous metals

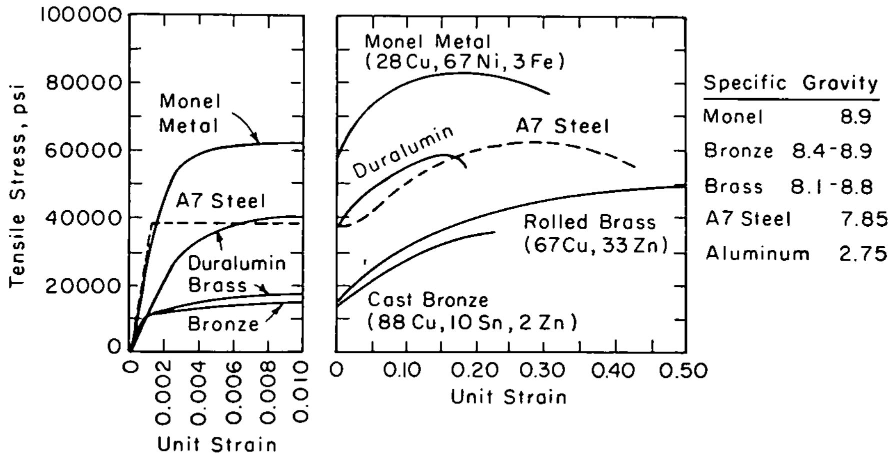

FIGURE 4. A7 STEEL COMPARED TO A GROUP OF NON-FERROUS METAL ALLOYS.

simulate steel. Considerable developmental work has been done at various laboratories and has led to the use of cement mortars to simulate concrete. Figure 5 indicates typical stress-strain curves for mortars used in M.I.T. model programs. As might be expected one of the most troublesome problems with mortars is their variability which depends upon mixing, curing and other factors.

2.3.3 *Dynamic Response.* It was shown that in the case of static response, small scale models would ordinarily not simulate prototype gravity forces. The fact that the magnitude of one additional model variable may be selected arbitrarily in the dynamic problem should not lead one to believe that the specific weight could be that variable—and hence eliminate the difficulty of modelling the dead weight stresses. Clearly, length, stress and specific weight are not dimensionally independent physical quantities. Thus it is seen that the matter of dead weight stresses is a static phenomenon in any case so that artificial means must ordinarily be used to provide the simulation if the dead weight stresses are significant with regard to the overall response.

Insofar as material properties are concerned the change from a static to a dynamic problem requires that one consider the effect of

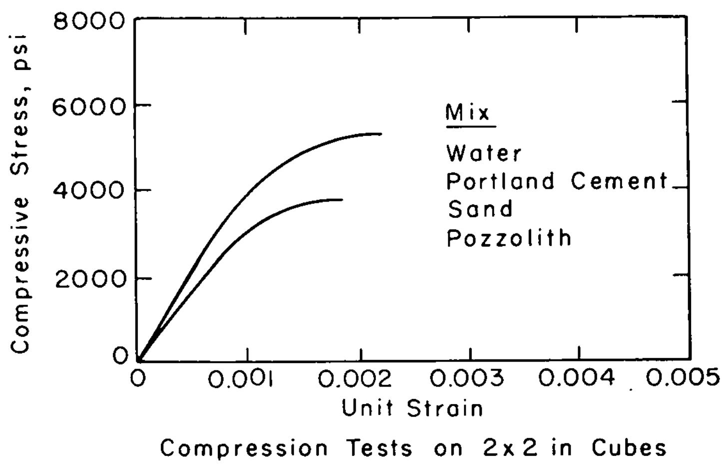

FIGURE 5. TYPICAL COMPRESSION STRESS-STRAIN CURVES FOR MORTARS.

strain rate upon the stress-strain curves. In theory this strain-rate effect can be modelled by choosing an appropriate time scale ratio. In practice, however, so little is known with regard to the dynamic behavior of materials that such correlation is difficult except in the case where the model and prototype material are identical.

2.4 *Model Fabrication.* It is impossible to present a general discussion of fabrication techniques since they would vary depending upon the nature of the model to be fabricated, the materials to be used, and the equipment and personnel which are available. In the following, a brief resume of some of the common techniques used with plastics, mortars, and metals will be presented.

2.4.1 *Fabrication of Plastic Models.* In recent years architects and engineers alike have shown increasing interest in thin shell forms. It happens that analytical techniques for analyzing these forms are quite weak, so it is natural that those responsible for the construction of such forms have turned to experimental methods of design. For those problems involving elastic response, in particular the elastic stability problem, the use of plastic model materials offers many advantages.

The family of plastic materials can broadly be divided into two groups, *thermoplastic* and *thermosetting*. Thermoplastic resins are those which undergo no permanent change on heating. On continued heating above room temperatures their tensile strength decreases and at temperatures of the order of 150-300°F they become quite rubbery. At even higher temperatures they melt. This situation is shown qualitatively in Figure 6. At the elevated temperatures they can easily

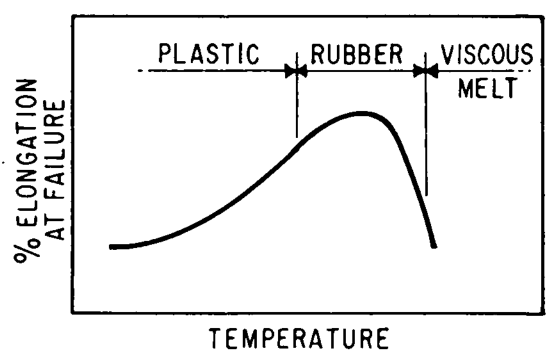

FIGURE 6. % ELONGATION VS. TEMPERATURE FOR THERMOPLASTICS

be formed into a variety of shapes which they retain on cooling. Of course, the process can be repeated and the plastic can be remolded into some new shape. By distinction, a thermosetting resin is one which does not possess this property of being able to be reformed at will under elevated temperatures. Once the thermoset has achieved its rigid form it maintains that shape.

The experimenter is usually interested in fabricating only one or at most a few models. This fact is responsible for his rejection of what in one sense are the most powerful molding techniques available. Commercially, millions of pounds of plastic resins are compression, transfer, and injection molded into every conceivable shape and, within limits, size. These three general techniques employ very high pressures and temperatures in conjunction with very elaborate molds (pressures reach 4000 psi in compression molds and 25,000 pounds per square inch of plunger area in injection molds, temperatures reach 600°F, and molds may cost $10,000 apiece). Clearly then, these commercial operations are not suited to the fabrication of a single or even a few items.

For shells of constant thickness the process of vacuum forming *thermoplastic* sheet materials is quite feasible. This technique consists of heating the plastic sheet until it is in the rubbery state and then allowing a vacuum pressure to force the sheet against a prepared mold. The pressing operation might derive from a number of systems, one that is satisfactory for most forms being a combination of mechanical draping and suction as diagramed in Figure 7a. As can be seen, the

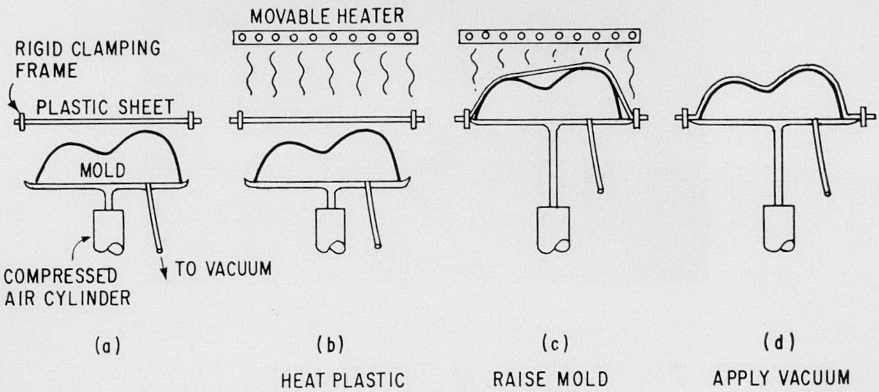

FIGURE 7a. SCHEMATIC VACUUM DRAPE FORMING SEQUENCE

essential components of such a system are: (1) a clamping device; (2) a heater; (3) compressed air; and (4) a vacuum system. Model scale is not limited by the nature of the process, however, it can be seen that as size increases, the heating, air and vacuum requirements can lead to considerable expense. Commercially manufactured laboratory machines are available with up to 20 $\times$ 20 inches forming areas for between \$500 and \$1000. For larger sizes it would be advisable to construct one's own machine since the commercially available ones are intended for production runs, and hence include considerable automatic features not needed by the model engineer. Figure 7b shows

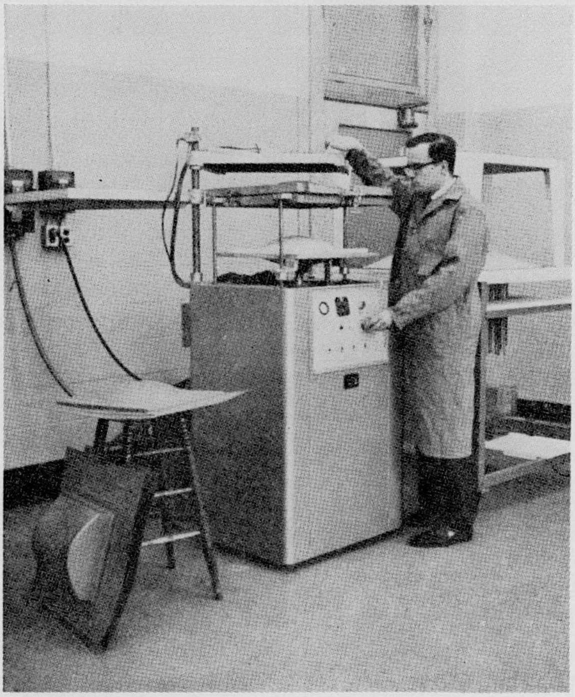

FIGURE 7b. VACUUM FORMING MACHINE

the machine which is used at M.I.T. For structures with single curvature, pressing is not needed. One merely inserts a prepared mold into an oven, lays the rigid sheet of thermoplastic over the mold, and heats the sheet until the action of gravity alone is sufficient to force the plastic against the mold.

A natural question that might be asked is whether the thickness changes that must be a consequence of the vacuum pressing operation are tolerable? This is a two-sided question. First, what sort of thickness variations result from such pressing and second, how do shell thickness variations affect the structural behavior that is to be investigated? Commercially available plastic sheets have inherent thickness variations on the order of 10%. The further thickness variations induced in forming would depend upon mold shape, mold type, and sequence used in the forming operation so that no certain values may be stated. As examples, the skewed hyperbolic paraboloid and dome shown in Figure 8 were formed on male molds from 20 × 20 × .028 inch sheets

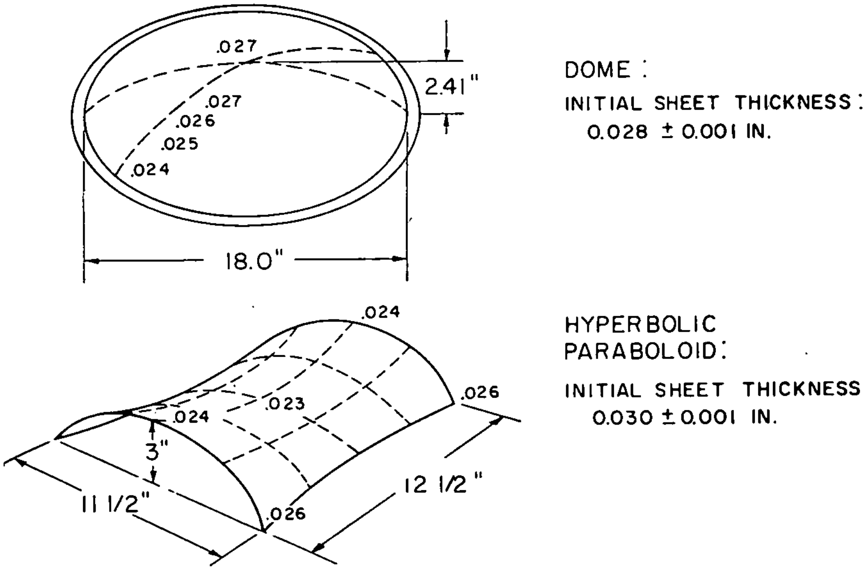

FIGURE 8. TYPICAL THICKNESS CHANGES IN VACUUM PRESSED PLASTIC MODELS

of polyvinyl chloride. Other civil engineering shapes could be expected to show similar variation; however, it must be noted that steep slopes will lead to substantial thickness reductions and variations. The second question regarding how these thickness variations affect the structural behavior of the model and, in turn, predictions of prototype behavior has not yet been sufficiently investigated.

Seldom would one want more than 5 or 10 models; therefore wood, plaster, thermosetting plastics, and even certain foamed plastics would be satisfactory mold materials.

The vacuum process would not be feasible for forming variable thickness shells. The technique which has been used for variable thickness models involves casting a thermosetting resin against a prepared mold. Certain resins can be cured at room temperatures and atmospheric pressure without liberating noxious gases, examples being some epoxy compounds, polyesters, and the phenolics. Shrinkage is not excessive, being on the order of 0.5 to 1%.

Of course, the greatest portion of model construction in the past and even today has been and is accomplished by hand assembly of pieces fabricated from commercially available stock such as sheets, rods, tubes, etc. Even in the fabrication of shell type structures by one of the two means noted above, there may be considerable hand work involved in attaching diaphragms, stiffeners, edge members, etc. The separate operations involved may be sawing, grinding, sanding, welding, cementing, and drilling. Since the techniques of performing these operations vary from one plastic to another, a discussion will not be given here. In general, however, the family of plastics are easily fabricated.

2.4.2 *Fabrication of Reinforced Mortar Models.* Insofar as fabrication is concerned the use of mortar and reinforced mortar models in place of concrete and reinforced concrete prototype structures does not lead to entirely different fabrication processes but rather to techniques of miniaturization. For model reinforced mortar elements of beams, columns, slabs, etc. the first step is the assembly of the reinforcement cages. The cages for beam and column elements are assembled over a metal form block. The form block is machined to the proper cross-section and grooves are placed where longitudinal reinforcing wires are desired. Small scale deformed wires have not been used at M.I.T. and recourse has been taken to the use of a commercially available smooth annealed steel wire for the main steel and then copper stirrup or tie elements are wrapped around the longitudinal steel and soldered to it. The cages are allowed to rust in a moist room in order to improve bond strength (if bond strength is likely to be a governing criterion insofar as the prototype is concerned then the model approach may not be at all useful since model bond failures are not controllable) after which casting of the models takes place in prepared formwork. The mortar mix must be weighed very carefully and mixing is generally acomplished in a commercial or home electric mixer. Special mortar electric mixers are also available. Care must be taken during the casting operation in order to insure a dense uniform specimen. Small vibrators aid in reducing honeycombing but tend to segregate the aggregate from the water-cement paste.

Slabs and curved panels incorporating 4 layers of reinforcement can be fabricated to 1/4″ thickness. The process is the same as for beam and column elements except that some sort of flat or curved form is substituted for the metal form block in the fabrication of the reinforcement mesh. Figures 9 and 10 illustrate the fabrication of the steel reinforcement.

2.4.3 *Fabrication of Metal Models.* Steel and aluminum are the most common metallic prototype materials. To model such materials the engineer may want to choose steel, aluminum or one of the copper based alloys as a model material. While the techniques for welding, bolting and riveting prototype structures are well developed,

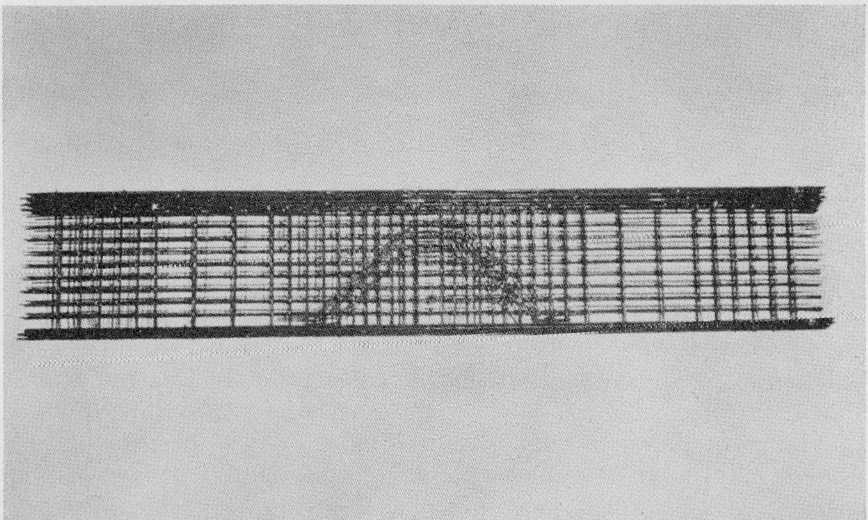

FIGURE 9. REINFORCEMENT CAGE FOR BEAM 16" LONG

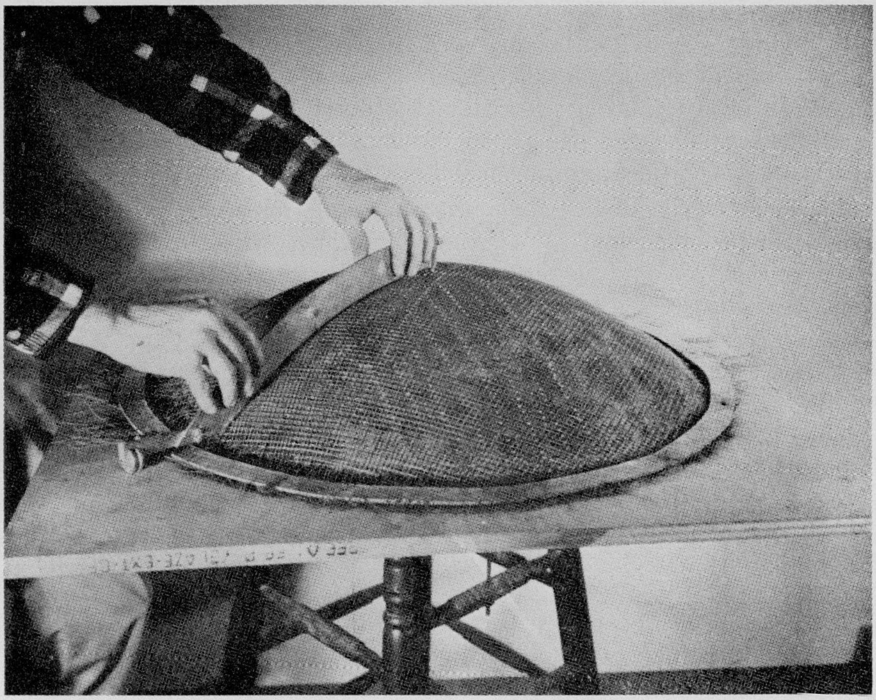

FIGURE 10. WIRE MESH OF A DOME READY FOR CASTING

the reproduction of such construction in a small scale model is most difficult.

Thus when a 5/16″ fillet weld is scaled at the moderate ratio of 1/15, it becomes necessary to make a 1/48″ fillet weld in the model. The problems involved with heating and the resultant distortion of the material properties are indeed difficult to overcome. In England special techniques for welding small steel parts have been developed. Aluminum, of course, is difficult to weld at any scale. The brasses and bronzes may be welded at temperatures considerably below that of steel. At M.I.T., it has been found that a "free cutting" phosphor bronze (88 Cu, 4 Sn, 4 Fe, 4 Pb) can be brazed with a silver brazing alloy and connections made which will transmit the full plastic bending moment. One half inch deep wide flange sections were machined, then annealed at 1280°F and finally the joints were brazed with a grade 4 silver brazing alloy which has a flow temperature of 1175°F. This process, which can be carried out by students after some initial instruction does not alter the annealed mechanical properties of the base metal.

Aluminum has sometimes been used in the fabrication of thin-shell roof structures where the geometric form is cylindric or is a surface of revolution. Cold rolled aluminum sheet has been used in a study of the buckling characteristics of parabolic cylinders. Surfaces of revolution can be formed by a spinning process whereby a blank of aluminum alloy is clamped to a wooden or metal die. The die is rotated at a high speed and the metal is forced against the die. Thickness tolerances of around 0.005 inches can be maintained, but it must be remembered that by definition the material is strain-hardened by the cold working.

2.5 *Loading and Instrumenting Structural Models.* Generally speaking there are two types of structural model tests, the direct test and the indirect test. In the direct test, prototype loads are reproduced directly on the model. In the indirect test one determines influence lines and then after assuming linearly elastic behavior and the associated principle of superposition, one builds up the response due to the actual loading system by utilizing the unit solutions.

In the direct tests, loads are currently applied by weights hung from discrete points, by weight-lever systems, by loading frames (one or a few concentrated loads), or by air pressure. Unit strains are measured using either electrical or mechanical gages or photoelastic coatings. Deflections are measured with dial gages; however, an investigation at M.I.T. has shown that photogrammetric techniques may be more satisfactory than the standard dial gages—particularly when there are a large number of points involved.

In the indirect tests, one introduces into the model some certain known deformation (deflection, rotation, etc.) and measures at all other points in the model the corresponding deformations. Muller-Brelau's Principle is then used to obtain the ordinates for the influence line corresponding to the particular restraint. This technique is most useful when applied to indeterminate frameworks, the members of which have variable moments of inertia. The Beggs Deformeter may be used to obtain moment, thrust or shear influence lines but requires one to cut the model at the point in question. The M.I.T. Moment Deformeter provides only for moment influence lines but does not require cutting the model, thus enabling one to obtain several influence lines from one model.

2.6 *Interpretation of Measurements.* The usual result of a model investigation consists of a set of experimental data related to some aspect of the model behavior. Perhaps the most crucial step in the entire experimental design procedure is the interpretation of this data both as regards the behavior of the model and more importantly the anticipated behavior of the prototype structure. It has been noted that the structural model analysis can be considered as incorporating a sequence of five steps, namely: (1) planning, (2) fabrication, (3) loading, (4) instrumentation and recording of data, and (5) interpretation of the results. Errors may enter in each of these five steps and the following list of possible error sources is given not with the intention of being exhaustive but merely illustrative:

Planning

1. Mistake in dimensional analysis
2. Failure to recognize a relevant variable
3. Insufficient definition of the problem

Fabrication

1. Geometry: thickness, length, etc.
2. Material properties
   a. Poisson's Ratios eg. plastics = 0.3 — 0.5 whereas concrete = 0.2
   b. Modulus of Elasticity
   c. Coefficient of thermal expansion
   d. Density
   e. Microscopic and macroscopic structure
   f. Creep characteristics
   g. Failure strain
   h. Ultimate strength
   i. Residual or initial stresses
3. Boundary conditions

Loading

1. Magnitude
2. Direction

3. Distribution
4. Time history
5. Errors associated with hanging weights at discrete points to make up gravity load deficiency
6. Errors associated with reproducing both scaled overpressure level and time duration in nuclear blast wave loadings.

Instrumentation

1. Electric resistance strain gages
   a. Incomplete bonding of adhesive
   b. Chemical attack on plastic by bonding adhesive
   c. Temperature compensation
   d. Calibration errors
   e. Inherent recording instrument error
   f. Gage factor error
   g. Transverse sensitivity
   h. Heating effect on plastic materials by gage current
   i. Gage stiffening of plastic materials
2. Photoelasticity
   a. Possible non-homogeneity
   b. Creep strains
   c. Loading beyond linear range
   d. Judgment errors in precise location of isochromatic and isoclinic lines
3. Displacements
   a. Judgment errors in smallest division of instrument
   b. Support system of recording device not compatible with magnitude of displacements
   c. Ditto circuitry, calibration, etc., errors listed under resistance strain gages
4. Pressure
   a. Meniscus corrections in a liquid manometer

Interpretation

1. One generally measures surface strain and then after making some assumption such as plane stress, plane strain, etc., interprets the surface strains in a three dimensional way
2. Slide rule error in reduction of data

This listing includes a wide variety of errors, some integration of which determines what we commonly refer to as experimental error. In a more specific sense, however, each of the errors listed above may be considered to fall into one of three general error categories: (1) blunders; (2) random errors; and (3) systematic errors. Blunders are outright mistakes and should be eliminated by care and repetition of measurements. It is impossible to give a rigorous operational definition of random; however, for purposes here it is sufficient to say that a random phenomenon is one whose observation leads to different outcomes for a given set of circumstances. We may consider a random error as the difference between a single measured value and the "best" value of a set of measurements whose variation is random. It should be noted that the algebraic sign of a random error is just as likely to be positive as negative. Random errors may arise in two rather different contexts. First, there are random phenomena associated with the statistical nature of the physical model. These have to do with such things as thickness variations or material property variations. Second, random errors may be introduced directly as a part of the measuring process. Examples of these would be the variation inherent in estimating the smallest division on some recording instrument. A systematic error is one which tends to have the same algebraic sign. If the error is always of constant magnitude then it merely shifts the entire range of values either up or down the scale. If it changes in magnitude during the course of the experiment, the relation of the measurements one to another are altered and little can be said. In the limit as the changes become more and more chaotic, systematic error may be considered random. Examples of systematic error would be: (1) improper bonding of electric resistance strain gage; (2) support that offers moment restraint when a hinge is desired; (3) incorrect calibration of a measuring instrument; (4) use of radial pressure in place of vertical loading; and (5) effect of unknown residual stresses in buckling of a compression element.

2.6.1 *Statistics of Measurements.* A rather extensive mathematical theory has been formulated which enables the engineer to make logical quantitative statements concerning the behavior of a structural system which is influenced by random fluctuations. *It has already been stated that many of the errors involved in an experimental small scale model study are of a systematic nature and hence are not amenable to statistical argument. In fact it is felt that systematic errors* *are generally the most important ones. Every effort should be made to discover and eliminate them—perhaps by means of internal static checks of the observed results, recalibration of measuring instruments or repeating the experiment.* Nevertheless, there are many experimental phenomena which are random and the model engineer should certainly be aware of the basic techniques for the statistical treatment of random phenomenon.

It is not the intent of this paper to develop the elementary concepts of probability theory and the propagation of errors and yet it will be necessary to use some of these facts. The following simply is a statement of certain results. The reader is referred to the literature (2, 3, 4, 5) for the development of these and many further results.

1. The mean value of any series of measurements is defined as

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n} \tag{9}$$

2. The standard deviation of any series of measurements is defined as

$$S = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \overline{X}_i)^2}{n}} \tag{10}$$

3. The experimental design engineer makes a limited number of observations of any particular quantity. From these observations he can compute a mean value and a standard deviation but he would still be interested in knowing from what parent probability density function the observations have been drawn. Many times it may satisfactorily be assumed that the measurements came from a normal (Gaussian) probability density function:

$$p(X) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(X-\mu)^2}{2\sigma^2}} \tag{11}$$

where μ and σ are the mean and standard deviation of the universe of measurements as opposed to the sample from which $\overline{X}$ and S were computed.

4. If one is not willing to make an assumption regarding the parent density function one can use Chebyshev's Inequality which is valid regardless of the governing probability density function. It states

$$\text{Probability}\left[|X-\mu|>h\sigma\right]<\frac{1}{h^2} \qquad (12)$$

where h is any positive constant. The use of Eqs. (11) or (12) enable one to make probabalistic statements regarding the outcome of an additional, as yet unmeasured, event.

5. In many cases, it is not enough merely to know something about the measured phenomenon. For example, one does not usually measure stress, but rather strain and modulus of elasticity. Stress is then computed as the product of the two. This leads to the idea of propagation of random errors. If $X_1, X_2, \ldots X_n$ are measured independent random variables and it is true that $V = f(X_1, X_2, \ldots X_n)$, then

$$\overline{V} = f(\overline{X}_1, \overline{X}_2, \ldots \overline{X}_n) \qquad (13)$$

$$S_v = \sqrt{\sum_{i=1}^{n}\left(\frac{\partial V}{\partial X_i}\right)^2 S_{Xi}^2} \qquad (14)$$

where it is noted that the partial derivatives in Eq. (14) are to be evaluated at the mean values $\overline{X}_i$, and consequently are constants. It should be noted that Eqs. (13) and (14) do not require a specification of the probability density functions of the independent random variables X. However, having the knowledge of the mean and standard deviation of the derived variables does not imply knowledge of the probability density function of the derived variable even when the density functions of the X_i's are known. On the other hand it is always possible to fall back on Chebyshev's Inequality.

2.6.2 *Example.* Using the simple beam example of Section 2.2.1, it is known that

$$f = \frac{Mc}{I} = \frac{3}{2}\frac{Pl}{bd^2} \qquad (15)$$

Eqs. (13) and (14) lead to the correct expressions

$$\bar{f} = \frac{3}{2} \frac{\bar{P}\bar{l}}{\bar{b}\bar{d}^2} \tag{16}$$

$$\sigma_f = \sqrt{\left(\frac{3}{2}\frac{\bar{l}}{\bar{b}\bar{d}^2}\right)^2 \sigma_P^2 + \left(\frac{3}{2}\frac{\bar{P}}{\bar{b}\bar{d}^2}\right)^2 \sigma_l^2 + \left(\frac{3}{2}\frac{\bar{P}\bar{l}}{\bar{b}^2\bar{d}^2}\right)^2 \sigma_b^2 + \left(\frac{3\bar{P}\bar{l}}{\bar{b}\bar{d}^3}\right)^2 \sigma_d^2} \tag{17}$$

In the experimental solution of this problem the model restrictions and model to prototype extrapolation are given by Eqs. (6) and (7).

$$\left(\frac{l}{b}\right)_m = \left(\frac{l}{b}\right)_p \quad \text{and} \quad \left(\frac{l}{d}\right)_m = \left(\frac{l}{d}\right)_p \tag{6}$$

$$f_{\text{prototype}} = f_{\text{model}} \frac{P_p\, l_m^2}{P_m\, l_p^2} \tag{7}$$

It should be noted that Eq. (7) is certainly not a unique extrapolation equation. In light of Eq. (6) it could be written in several ways, for example,

$$f_p = f_m \frac{P_p\, l_m^2}{P_m\, l_p^2} = f_m \frac{P_p\, b_m^2}{P_m\, b_p^2} = f_m \frac{P_p\, l_m^{.25}\, d_p^{.23}}{P_m\, l_p^{.25}\, d_m^{.23}} = f_m \frac{P_p\, l_p\, b_m\, d_m^2}{P_m\, l_m\, b_p\, d_p^2} = \text{etc.} \tag{18}$$

Now it should be clear that all of the terms in the various right hand sides of Eq. (18) are in fact random variables. It must be assumed that the relevant information regarding the prototype variables P_p, l_p, b_p and d_p has been known since the start. With regard to the model variables P_m, l_m, b_m and d_m, it is seen that the scaling factors for P and l have been chosen freely while the other two length variables are constrained by Eq. (6). If it is realized that the corresponding prototype quantities must necessarily be variable in themselves, one can ask what particular value or magnitude of P_p or b_p, etc., is to be scaled? Should one attempt to scale the mean value of the prototype quantity, the most probable value, the value which is exceeded 99% of the time, etc.? At this time it must be admitted that further study is needed in this area. However, several things can be said.

It should be noted that if the scaling laws are applied to the mean values of the prototype and model quantities then Eq. (6) becomes

$$\left(\frac{\bar{l}}{\bar{b}}\right)_m = \left(\frac{\bar{l}}{\bar{b}}\right)_p \quad \text{and} \quad \left(\frac{\bar{l}}{\bar{d}}\right)_m = \left(\frac{\bar{l}}{\bar{d}}\right)_p \tag{19}$$

The dispersions about the resulting model means would in general bear little relation to the dispersions about the prototype means since fabrication techniques, etc., would be entirely different. Of course, measurements on a series of models would furnish an indication of the dispersions present in the model quantities, and the measured means and standard deviations of f_m, P_m, l_m, b_m and d_m could be obtained by following the procedures of Section 2.6.1. Thus if a single value of the mean and standard deviation of P_p, l_p, b_p, d_p, P_m, l_m, b_m, d_m and f_m were all known, it is clear that when Eq. (19) is satisfied then all of the possible extrapolation equations given by Eq. (18) will yield the same result for the mean value of f_p.

As far as obtaining a measure of the dispersion of the prototype stress about its mean value there is no uncertainty. In fact it can be seen that even if the exact probability density functions of P_p, l_p, . . . l_m, b_m, d_m, and f_m were known, the various right hand sides of Eq. (18) would lead to differing values for the standard deviation of f_p. Further, none of these values would agree with Eq. (17) which is known to be correct.

Thus we have seen that *while experimental results obtained from structural models can be used to predict something about the average or mean value of a particular physical quantity in a prototype structure, it is in general not possible to determine anything regarding the possible dispersion about this derived mean value.* Two further points are worthy of mention.

First, in the simple beam problem which has just been discussed, there is no ambiguity regarding what is meant by the depth d. As it related to this problem it was clearly the depth at the cross-section under investigation. Similarly, there was no indefiniteness involved in the definition of P, l, or b. It should be realized, however, that as soon as one enters into the field of statically indeterminate structures, real problems of definition arise. For example, where should the depth d be measured in a two-span beam—since the internal moment acting at the cross-section of interest is some function of the depth existing along the entire beam? Or, going one step further into the woods, what is meant by the thickness of a small scale thin-shell model when that thickness varies in an irregular manner over the entire shell surface?

Finally it would be the rare occasion when many separate models would be fabricated and tested. It has been shown that the only advantage of fabricating and testing more than one model is to obtain a better approximation to the true model means. If the means are taken to be the results obtained from a single model then it is particularly important that the investigator be convinced of the absence of blunders and major systematic errors in that single model study.

III. Examples of Model Projects

The M.I.T. Laboratory for Structural Models has undertaken a few projects related to actual designs. In comparison to the National Civil Engineering Laboratory of Portugal, or the Experimental Institute for Models and Structures of Bergamo, Italy, it is in its infancy. However, major effort has been devoted to improving techniques of model analysis, to reduce their cost and time, and to understand and determine the errors associated with a model project. Earlier portions of this paper reflect some of this background or fundamental effort. This portion of the paper will present a description, but not analysis, of two of the several projects undertaken in the laboratory.

3.1 *Design of Providence Post Office Shell Roof.* The structural design of the shell roof system of the Providence Post Office (Figure 11) was accomplished by Hansen, Holley, and Biggs acting as consultants to Chas. A. Maguire and Associates, Architect-Engineers of the project. A previous paper (6) has been presented on the overall aspects of this design, and this paper will only consider very briefly the model program which was undertaken in the M.I.T. Laboratory.

Since the stability of the groined vault type, thin shell roof is not amenable to theoretical analysis, a series of model experiments were undertaken. Since only the stability problem was to be considered the model needed only simulate the elastic behavior of the prototype. Further, it was not necessary that stress distributions be determined, since analytic techniques, although approximate, were adequate for this task. This introduced certain simplifications in the model problem, making it feasible to use polyvinyl chloride as a modeling material.

This particular material was selected from many considered, and it was the first time it had been used in our laboratory. Further, we had no knowledge of its previous use in any laboratory for a structural model analysis. It was selected for (1) its ease of molding, (2) its consistency in thickness, (3) its similarity to concrete in its stress-strain characteristics, (4) its low modulus of elasticity, (5) its low creep properties, and (6) the ease with which ribs or other elements could be fastened to the shell proper by epoxy adhesives.

FIGURE 11. PROVIDENCE POST OFFICE

The structural system and geometry of the shell roof had been established by architectural considerations. Thus, the structural design task consisted of determining the appropriate shell thickness, rib locations and dimensions and the reinforcement needed for shears, thrusts, and bending moments. To determine the appropriate shell thickness a series of 1/80 scale models of the shell were pressed out of flat sheets of polyvinyl chloride. Thicknesses were selected that simulated prototype shell thicknesses of 4½, 6, 7½ and 9 inches. A sample model as mounted in its test jig is shown in Figure 12. The first model tested simulated a 4½ inch prototype thickness. It was subjected to uniformly distributed loads applied by weights hung at discrete points.

With ribs located at selected positions as shown in Figure 12, the model was unable to carry the desired load level (a load level based on an appropriate multiple of the design dead plus live load). Accordingly the second shell thickness model was selected. This model

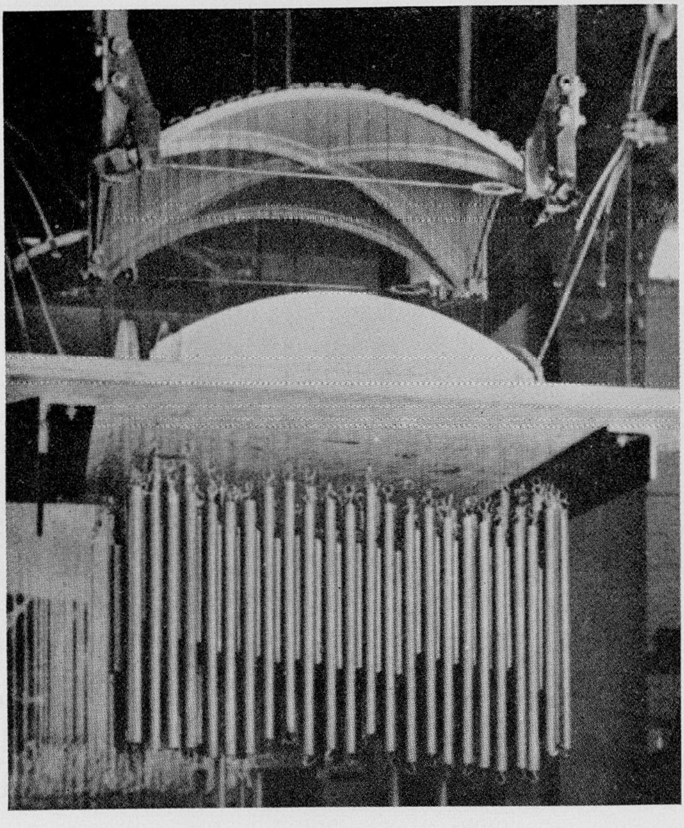

FIGURE 12 BUCKLING MODEL-PROVIDENCE POST OFFICE

proved to be adequate to carry the desired load level—both uniformly and non-uniformly distributed, and the shell dimensions were uniquely determined.

The interesting aspect of this study was that the model served to determine directly the necessary shell thickness. Further each model could be tested several times, and even modified between tests. This proved to be a powerful, rapid, and inexpensive computer.

3.2 *Air Blast Loaded-Reinforced Concrete Domes.* A considerable effort has been expended in the M.I.T. Laboratory developing and proving the technique of producing micro-concrete reinforced with fine wires. Such concrete is made of a sand-cement mortar, while the reinforcing consists of annealed wires of various diameters, which are cleaned of oil and other surface effects in a hydrochloric acid bath, and rusted in a moist room to improve the bonding characteristics. This or similar techniques are used at various laboratories, such as the Cement and Concrete Association Laboratory in England.

The M.I.T. development has been centered on evolving the technique of producing reinforced micro-concrete which has the same cracking, deflection and ultimate strength characteristics of full scale concrete. The development of such a capability would, of course, prove of material benefit to the structural engineering design and research profession, permitting the rapid, relatively inexpensive evaluation of complex or hitherto unstudied reinforced concrete elements.

Many tests of micro-concrete structural elements, columns, beams, and shear walls under both static and dynamic loading conditions have been made in the M.I.T. Laboratory. In general, it is possible to produce very small scale elements as small as ¼ inch thick by larger dimensions, in shell structures or slabs, and columns with a cross-sectional dimension of ½ inch by ½ inch. These very small elements behave in a similar manner to large scale elements subjected to similar loading and restraint conditions.

To demonstrate the reliability of this miniaturization technique the M.I.T. group undertook to model at 1/25 scale some reinforced concrete dome structures which had been tested in a nuclear weapons experiment in Nevada. The Nevada experiment included several reinforced concrete domes of six inch thickness, of span of 50 feet and rise of 11.5 feet. Domes were in air blast regions where they survived without damage, were partially destroyed, and essentially completely destroyed.

The models were of 2 foot span, the appropriate rise, and ¼ inch thick. Further, they were reinforced with 4 layers of reinforcing. A typical reinforcing mat prior to casting is shown in the fabrication process in Figure 10.

The models were shipped to the field some 2500 miles from M.I.T.

where they were subjected to the air blast produced by a very large charge of TNT. They were placed at such distances that they experienced the same overpressures that the prototype domes experienced in the Nevada tests. Appropriately and to our satisfaction they suffered complete collapse, partial collapse and complete survival at the same pressure levels as did the prototype domes. Figure 13 illustrates one of 12 domes placed in the experiment in its pre-shot condition while Figure 14 illustrates the same dome after the blast.

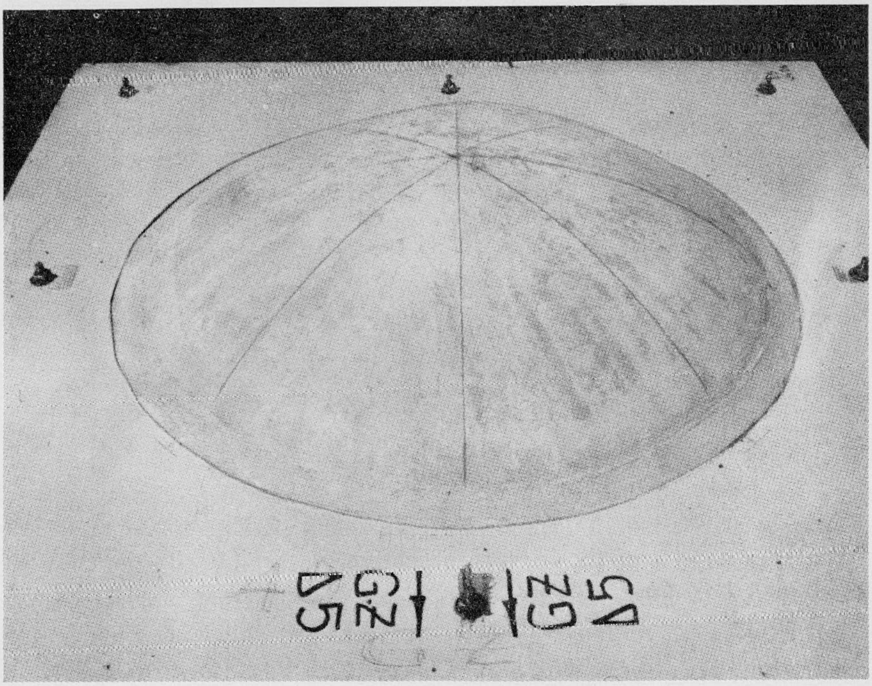

FIGURE 13. MODEL DOME: PRE-SHOT

IV. Conclusions

The model technique can be extremely useful in the teaching, research, and design process. At the present time models are not used as extensively and as effectively as they might, because of a lack of appreciation of their advantages and disadvantages by the profession, but perhaps more importantly by their excessive cost and by the time

FIGURE 14. MODEL DOME: POST-SHOT

needed for an adequate model program. The M.I.T. model development program has as its primary objective the further devleopment of the model technique so that it can be used extensively in teaching, research, and design.

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ENGINEERING NEGLIGENCE, THE ENGINEER AND THE LEGAL DUTY OF PROFESSIONAL PERFORMANCE

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I. THE DUTY AND THE STANDARD

MODERN law imposes on the licensed professional engineer the same duty to satisfy a professional standard of competence as it imposes on architects and physicians. The courts have not as yet sharply distinguished between the licensed and the unlicensed performer of engineering projects. In a few isolated cases, they have imposed the professional test on the unlicensed as well as the licensed. It would seem likely, however, that as the law develops the courts will distinguish between the licensed and unlicensed on the basis of the degree of competence and will insist upon a higher standard for the licensed, namely the standard imposed on the traditional "learned professions" of law and medicine.

In what follows we will seldom use the word "negligence." Legal negligence is the equivalent of a breach of the legal duty to satisfy a legal standard of conduct. Our analysis will be in terms of breach of duty and standard of conduct which we shall define as a standard of "competence." Engineering negligence is simply the adjudicated failure of an engineer, as shown from the results of his work, to possess the average skill or knowledge of other qualified engineers in like circumstances or, if he does possess such average skill and knowledge, his failure to use it. Note then that engineering negligence is not necessarily equivalent to mere carelessness. It may consist of carelessness, but it may also consist of ignorance.

Negligence, then, is simply a breach of duty of conduct. In the case of the professional engineer, the duty is the duty to conduct professional work so as to satisfy a professional standard of com-

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petence. Our task is to mark out the bounds of the duty and the standard. One possible description is as follows:

> First, the law requires that the engineer possess that degree of learning, skill, and experience which is ordinarily possessed by others of his profession and specialization in the community where he practices, consistent with the state of advancement of the pertinent technology at the time of performance. Second, the law requires that the engineer will use such ordinary care and diligence in the execution of the performance which he has undertaken as could reasonably be expected in like circumstances of an adequately qualified engineer of average competence.

Another, largely redundant, way of phrasing this duty of professional performance is to say that upon the undertaking of a professional service, the law imposes upon him the following duties:

1. The duty to possess that degree of learning and skill ordinarily possessed by engineers specializing in the same field of technology who are in practice and of good standing in the same locality.
2. The duty to use the care ordinarily exercised in like cases by reputable members of the profession practicing in the same locality.
3. The duty to use reasonable diligence and his own best judgment in the exercise of his professional skills in an effort to accomplish the performance he has undertaken.

As a practical matter, it can be said that the "community" or "locality" in which professional engineering performance standards are to be ascertained is probably the entire nation in view of modern communications, mobility, interstate scope of practice, and the national character of professional societies, both practicing and academic.

Note that the duty is defined in terms of a standard of performance. The standard, roughly speaking, is the hypothetical level of performance reasonably expected of an imaginary average competent professional. Sometimes in what follows, we shall for short refer to the duty as the "duty of professional performance" and to the standard as the "standard of professional competence." Note also that the concept of professional competence contains two elements: one is the element of competent qualification; the other is the element of competent execution. A schematic diagram would look something like this:

Duty of Professional Performance by definition = Duty to Perform within the Standard of Professional Competence

Competent Qualification ↑ Training, Education, Experience, Skill, Know-How, Current Knowledge, etc.

Competent Execution ↑ Methods, Procedures, Carefulness, Skill, Diligence, Precaution, etc.

We can best mark out the limits of the standard of professional competence by stating some of the things which the standard does not require. It does not require that the professional engineer possess extraordinary skill and learning which is possessed only by a man of rare attainments and endowments, although it does require him to keep generally abreast of the progress made in his profession. If the engineer is a specialist, as most are, he is required to possess and exercise the skill which ordinarily is possessed and exercised by others who engage in the same specialty in the profession. The engineer is not responsible for want of success unless it is proved that the want of success resulted from an absence of ordinary professional care, skill, or diligence. In other words, he does not insure perfection. He is not a guarantor of his plans, specifications, designs, analyses, project supervision, other similar undertakings. He is not responsible for errors of judgment in matters of reasonable doubt or uncertainty if he possesses average professional qualifications and diligently applies his qualifications to produce what is, in his opinion, the best result under the circumstances. The law recognizes that a man of competence and sound judgment even in exercising his best judgment may make a mistake.

The development of the duty of professional performance based on the standard of professional competence, which the law ought to expect of licensed professions, has taken place almost entirely within the context of the medical profession. A scattering of cases relate to architects. A mere handful involve professional engineers. Nevertheless, there is no doubt that the principles involved in the architect cases are equally applicable to the licensed professional engineer. It is clear that a modern court compelled to formulate the duty and standard of conduct for the engineer, as well as the architect, will adopt without modification in principle the same standard which has been developed for and is applied to the medical profession. This is a tribute to the fact that engineering professionals have achieved major advances in attaining professional status and recognition. On the other hand, it is evident that this very achievement carries with it the higher duties and standards which the law requires of the traditional "learned professions."

The most common class of cases in which it is important for the professional engineer to persuade a jury or judge, or preferably to persuade opposing legal counsel in negotiating a fair settlement, by demonstrating that his performance has satisfied the standard of professional competence, are cases arising out of defects attributable to designs, plans, drawings, and specifications. In the architect cases, and I am sure in many potential engineering cases, especially those involving industrial special-purpose plans and designs, the attempt of the client or customer to impose liability based on negligent error or omission usually occurs when fixtures or components are not adequate for their intended use, when structural parts such as roof, floors, or walls crack, buckle, collapse, or otherwise fail to serve their purpose, when the foundation does not provide adequate support, or when waterproofing is deficient. If the architect or engineer is found liable by reason of failure to perform in accordance with the legal standard of professional competence, the amount of damages which the client may recover against him will be the cost of curing the defect if the defect can be cured. If, however, the defect is of a kind, perhaps a basic structural defect, such that it cannot be remedied at reasonable expense, then the measure of damages may be the difference between the value of the structure with the defect and the value it would have had if it had been constructed without error. Moreover, as we shall see, liability may not end with the damages recoverable by the client. Damages may also be recoverable by strangers who can establish the professional negligence as the proximate course of their injuries.

II. The Trouble With the Standard and With the Law

Up to this point, we have seen only that the law requires of the engineer that the quality of performance of his professional undertakings must satisfy a certain standard of conduct which we have called the standard of professional competence. In abbreviated form, this standard is the equivalent of that hypothetical level of performance which is normally expected of the imaginary engineer of average professional competence in his special field within the geographic area in which he practices. On the surface, this standard may seem relatively simple. On analysis and in practice, it is in fact extremely complicated and uncertain.

If we think of the standard as a kind of measure, we can say that the measuring rod which the law applies to the performance of the actual engineer is a rod which has marked off on it the point or perhaps the reasonable upper and lower bounds of the hypothetical expected performance level of an imaginary engineer. But consider to whom the law delegates the duty of applying this ideal measuring rod to the performance of the real engineer and taking off a reading, as it were, to determine whether the level of performance of the real engineer has fallen within socially acceptable limts when measured against the standard of the imaginary engineer. This process of measuring the law in most cases delegates virtually to the jury alone, sometimes to the judge alone, and sometimes, but seldom, to the jury controlled by the judge. In legal terminology, the person or persons who make such determinations are called the "trier of fact." The point is that, whether the trier of fact be the jury, judge, or a combination of both, the real engineer finds himself in the hands of a trier of fact who is not competent to determine on the basis of personal knowledge or experience, or for that matter on the basis of common knowledge, whether a given engineering technique, method, practice, design, choice of materials, or whatever, falls too far short of the hypothetical level of performance of the imaginary average engineer.

In this state of ignorance the trier of fact is dependent entirely on so-called expert testimony. The judge or the jury must rely on whatever real engineers who have been duly qualified as expert witnesses testify as to whether a particular method or technique of the actual engineer was one which other engineers, qualified in the same special field and practicing in the same locality, would recognize as a reasonably acceptable choice or course of conduct under existing practices and state of knowledge of the profession in the locality.

This is not a happy state of affairs for the real engineer in trouble. He is at the mercy of one or two of his colleagues, one of whom, in the typical case, is chosen and paid by his opponent, and one chosen and paid by himself. In a real sense these particular individuals become his judge and jury. This procedure may not put the real engineer in undue or unjust jeopardy where the performance in question is of a routine nature and the pertinent methods and technology are well understood and accepted throughout the profession. His plight becomes hazardous when the questioned performance is in a new area of technology where methods and techniques are in process of experiment and development, and there is no strong consensus in the profession as to what constitute acceptable methods and techniques.

The difficulty is enhanced by peculiarity of the Anglo-American legal system. This peculiarity is the nearly exclusive reliance on the adversary system as the accepted method of discovering the basic facts subsidiary to the conclusions of fact which the trier of fact must decide. In the Anglo-American system, it is still the general rule that the judge and jury are entirely dependent on the opposing lawyers for the development of facts and information which are fundamental to deciding the questions at issue. The court cannot even independently summon its own experts, when it feels that the experts procured by the parties are not producing basic information sufficient to enable the trier of fact to arrive at a fair and informed judgment.

This system may not be entirely desirable, but it is at least workable when the issue of fact is whether the defendant was careless in the operation of a motor vehicle or whether the defendant committed and premeditated an alleged murder. The adversary system is, however, inappropriate and undesirable when it makes the trier of fact entirely dependent on selection of expert witnesses by opposing lawyers and on such information as the lawyers may choose to elicit from their chosen witnesses, where the purpose is to establish the degree of acceptance within a profession of highly technical and complex practices, methods, and techniques.

In the experience of the medical profession, the adversary system of informing and, within the rules of the game, misinforming, the trier of fact as to what constitute reasonable standards of medical performance has been wholly unsatisfactory. According to the public image of the medical profession, it is almost axiomatic that physicians of standing will not effectively testify against one another. This public image is well founded in fact.

Reluctance to testify is not, however, something peculiar to the psychology of the medical profession, although the high degree of cohesion of that profession has given force to the unwritten consensus that a professional should ordinarily avoid testifying against a fellow professional. One suspects that in the case of architects, engineers, lawyers, and other true professionals, there must be the same psychology of reluctance to testify on the professional performance of a brother professional or otherwise to give an opinion as to possible errors and omissions on his part which might conceivably have led to the failures in question. Such reluctance greatly increases where the method, technique, or entire area of technology in question is something about which little is known and as to which there are wide differences of opinion amongst qualified professionals.

This same exclusionary reliance of our legal system on adversary parties for the determination of technical issues of fact touches the professional in another way. It affects him in his capacity as an expert witness in a trial between two parties, neither of whom is a member of the profession. The typical example is the case in which a physician is called to testify as to the nature, degree, and permanency of an injury suffered in an automobile accident. Another example, closer to home, would be a case depending entirely on expert engineering testimony as to the fitness of a certain kind of ball bearing for use in the rotational system of a concrete mixer. In this class of cases, particularly in the automobile accident field, the outcome often depends on which side is able to procure the more persuasive expert. This has led in the case of the medical profession to collusive arrangements between less desirable elements of the legal profession and equally less desirable elements of the medical profession for the production of expert medical testimony favorable to plaintiffs alleging extensive and permanent injuries in automobile accident cases. This kind of thing is encouraged by an additional shortcoming of our adversary system, namely the fact that the expert witness is paid by the adversary for whom he appears. In the medical profession, the more reputable practitioners in many of the special fields are not interested in this source of revenue and tend to leave the field to those less qualified to perform the duty of educating the trier of fact. On the other hand, some of these same reputable individuals are inclined to feel quite imposed upon at the suggestion of a system under which they could be summoned into court at the request of the court.

A minimal improvement would be to empower the court to call its own experts and to examine its own experts and experts called by the litigants. A more radical solution being currently discussed and advocated within the legal and medical professions is the establishment of procedures under which the court could call upon an established panel of independent experts in lieu of or in addition to the experts called by the opposing parties. While the legal and medical professions will without doubt spearhead efforts to reform our legal system in this direction, there is no doubt that all established professions have an interest in working for such reforms. The likelihood of pushing some reforms through our state and federal legislatures will be greatly enhanced to the extent that other professions support the medical and legal professions in reform efforts.

But even if these reform efforts successfully result in the desired formal modifications of legal procedures, the effectiveness of the new procedures will depend on the cohesion, ethical maturity, integrity, and dedication of the professional societies of the various professions. The courts will have to rely on these societies for the provision and maintenance of an available pool of reputable members of the profession. Needless to say, those who are willing to serve in such a role will necessarily be those whose sense of professional dedication impels them to recognize and bear the public responsibility and the inherent sacrifices.

III. Duty-Right-Liability Correlations

So far, we have discussed only a duty to observe a certain standard or rule of conduct and have pointed out some of the difficulties inherent in any attempt to use this standard to measure actual engineering performance. How does this standard fit into the broader framework and the basic formulas of legal theory? From the viewpoint of legal analysis, the only basic legal element we have touched on is the element of duty. We have abstracted and discussed out of context only this particular element of the many interdependent elements comprising the matrix of legal relations.

We have in effect said that the law imposes on the engineer the duty to see to it that his performance measures up to a standard of hypothetical competence. By way of footnote, we state here that this basic duty binds the licensed employee engineer as well as the employer engineering organization of whatever legal form. Our discussion does not attempt to bring out various distinctions between the employer and employee status. An important distinction is that contract-based duties such as guaranteed results are not in general binding on the employee. They are commitments of the employer.

According to modern methods of legal analysis, a legal duty (as distinct from an ethical or moral duty) cannot exist by and of itself. It exists in correlation with a number of other cross-consequential legal relations. The theory of legal correlatives consists of certain fundamental formulas relating basic elements, or concepts which are, in a broad sense, analogous to the fundamental formulas and equations of mathematics, of physics, and of the fields of engineering science which are extensions in practice and application of so-called "pure physics." Examples of a set of such fundamental forms in mathematics are the sine, cosine, and tangent of the trigonometrical relations. In the theory of strengths of materials, we have stress, tensile force, and area. In mechanics we find force, mass, and acceleration. When combined or permuted in various ways, these elements yield useful relations expressed by formulas.

It can be said by rough analogy that the legal relations known as "duty," "right," and "liability" constitute a set of correlated elements by which certain basic legal consequences can be expressed in terms of symbolic formulas.

The existence of a legal duty implies the existence of a corresponding legal right, just as sine implies cosine, stress is a function of force, and acceleration is a correlative of mass. If Engineer X owes Client Y a duty to perform an engineering undertaking which Y has engaged him to perform, Y has a right to enforce a liability against X if X commits a breach of his duty of performance. If X owes Y the duty to render performance in accordance with the legal standard of professional competence and if X is untrained, unskillful, or simply careless, then X has committed a breach of duty and Y has a right to enforce a liability against X. The measure of that liability is the amount of pecuniary damage Y has suffered by reason of the breach of duty by X.

This can be expressed as a verbal formula as follows: If there is a duty plus a breach of that duty, there results a liability to those to whom the duty is owed and who suffer harm (to person or property) because of the breach of duty. Symbolically, we denote duty by "D," breach of duty by "B_D" and liability by "L." We write the following formula of basic legal relationship: $D + B_D \longleftrightarrow L$

Now, if we want to express "potential liability" or "liability exposure" (L_P) as a quantitative function, we recall that every duty entails a corresponding right (R) to enforce a liability (L). If there is a breach of the duty (B), we can also write: $D + B_D \longleftrightarrow R_L$.

(R_L) and (L) thus appear as equivalent elements. We then recall that a single duty may, and in fact usually does, generate multiple rights, that is, rights held by a number of persons (n_R). In addition, we bear in mind that the law by its "statute of limitations" puts a time limit (t) on the enforcement of this kind of right. So we can express the dollar quantum of liability exposure or potential liability (L_P) as a function of the number of rightholders (n_R) and as a function of time (t). We also recall that the right (R_L) is ultimately measured by the money amount of damages which the right entitles the rightholder to recover. We agree to use \$ to specify the unit of measure. We then say: Potential dollar liability $= \$L_p = n_R \times t \times \$R$.

IV. The Expansion of (n_R) and the Role of (t)

Potential liability (or liability exposure) formula can be used to show a most significant trend in the law of special significance for the engineering profession. It is the expansion of the factor (n_R), a trend which has steadily gained momentum over the past half century. The development began in connection with product liability via judicially created expansion of the class of persons, to whom the manufacturer of a product owes the duty of due care in the manufacture of his product, to include within the class not only buyers of the product but also such other persons as may be reasonably expected to depend on the safety of the product. The inference by parallel reasoning is that there has occurred a similar expansion of the class of persons to whom the engineer owes the duty to perform in accordance with the standard of professional competence in design, construction, supervision, analysis, report, approval, certification, or other like activity.

This development is sometimes referred to in terms of exposure to "third party liability." This is a short way of saying that if Engineer X violates the duty of professional performance, the result may be liability to strangers in addition to the traditional liability to the client who employed him. The same development is also described as the breakdown in the doctrine of "privity of contract." This is legal shorthand for the statement that the duty of professional performance and the corresponding potential liability are no longer necessarily limited to the client with whom the engineer has that direct employment relationship which the law calls "privity of contract." It says that liability has been extended to include certain classes of strangers.

Specifically, the duty-right-liability correlation now extends potentially to outsiders who fall within the class of persons who may foreseeably suffer harm as a result of substandard professional performance. Such class may, for example, include the occupants or even the guests or business invitees of an unsafe structure in the event of its collapse.

As yet, there appears to have been no court opinion actually imposing on an engineer or architect liability to pay damages to strangers to the contract, after the structure has been turned over to the owner. However, there is a New York court opinion stating the principle that engineers can be held liable to strangers for injuries sustained, even after completion of the structure, at least where the dangerous structural defect is latent and not patent. There are a few cases imposing liability to strangers where the injury or damage occurred while the project was still under supervision of the engineer or architect.

The factor (t) in our liability equation seems to be, and it emphatically ought to be, a reason why the courts have been extremely reluctant to impose liability to strangers on an engineer or architect after the period of supervision has ended and have protected the professional by ad hoc devices like distinguishing between latent and patent defects. The factor (t) symbolizes the statute of limitations, the time in which potential liability continues to exist. Depending on the state in which the injury occurs, the time in which a lawsuit may be commenced to enforce a liability for personal injuries normally is from two to four years after the occurrence of the injury. Of course, an injury may occur at any time during the life of a structure. This means that if liability to strangers can be imposed with respect to defects in long-life structures, the engineer's exposure to potential liability will extend throughout his life.

The situation of the engineer is much worse than that of the physician in two ways. First, the class of strangers to whom a physician is liable for malpractice is narrow and well defined. The corresponding class with respect to the engineer is large and indefinite. Second, if a breach of duty by a physician causes personal injury, the time of the breach of duty and the time of the injury are usually simultaneous and the time period of the statute of limitations begins to run at once. In the case of the engineer, there is frequently an unpredictable time lag between the breach of duty and the consequent occurrence of the structural failure which causes the personal injury.

V. Liability Exposure Control

Where does the concept of professional performance fit into actual engineering practice? The answer is that it should serve as the base point, the guideline, the point of departure for the use of preventative law in the multiform contractual arrangements and other paper work in which engineering is practiced.

Engineering work nearly always functions in the context of some kind of written contract, or a collection of writings which the law will piece together and call a written contract. The contract may be a hundred-page, highly formal document full of "whereas" and "now therefore" clauses, the full boilerplate of the law. Or it may consist of an exchange of short letters constituting a proposal and acceptance. Further, the engineering work product itself often takes written form. The end result may be a writing, such as a design, a design analysis, a progress or completion report or certificate. If the end result is a physical structure or device, there will be writings in the form of underlying designs, plans, specifications, and descriptions. This is another radical difference between the legal situations of the engineer and the physician. The physician seldom works under the control of written undertakings or results. He remains subject solely to the basic duty of professional performance unmodified by writings.

When something goes wrong in an engineering job and the mess lands in the lap of the law, the law must determine, by analysis and interpretation of the mass of writings, which the parties or their lawyers have produced as parts of the job contract and in the process of the job itself, whether and in what specific phases of the bargained-for performance the engineer is to be tested for failure to carry out his basic duty of professional performance, or whether and in what respects he has explicitly or implicitly guaranteed a particular result.

If the writings are silent or neutral, the law will judge the engineer by the measure of his compliance with the duty of professional performance. But the writings may explicitly or implicitly override the duty of professional performance. They may specify, or be construed to intend, one of two contrary results. First, they may be construed to intend that the engineer is to have it easy, that he is to be relieved of the normal responsibility to satisfy the duty of professional performance. Second, and in the opposite direction, the writings constituting the contract may be construed to intend that the engineer is to be responsible beyond the limits of the duty of professional performance, that he is to be guarantor of results.

The first alternative, diminution of basic professional duty, can be dismissed as against public policy and practical business strategy, as well as contrary to professional ethics. The second alternative, the imposition on the engineer of the performance obligations of the guarantor, is a matter of negotiation and decision as between the engineer and his client. It is important to the engineer that he avoid unintentionally taking on the additional burden of a guaranteed result. If he is to be a guarantor, he should knowingly intend to be so and the contract language should be most explicit in its description of the precise result which he is expected to guarantee, the time within which the guarantee can be enforced and the amount of damages to be paid by way of satisfaction on breach of the guarantee.

The engineer can do much to protect himself, and incidentally clarify his relationship and responsibility to his client, by making up and applying a written legal check list against each item and phase of a draft proposal or contract. Our potential liability expression constitutes a useful reference for the composition of such a check list. In order to minimize what we have called "potential liability" or "liability exposure" ($\$L_P = nR \times t \times \$R$), the engineer should minimize insofar as feasible each of the terms of the right-hand side of the equation.

It is assumed throughout the following discussion that the engineer is professionally well qualified and performs up to the standard of professional competence. We are not interested in the incompetent engineer. We seek to minimize the liability escalation factors which operate even in the presence of professional competence.

The term ($R), standing for the amount of damages which a rightholder can recover, is the basic term on the right-hand side. It is the correlative reflection of the entire bundle of engineering duties whether contractual or imposed by law. It reflects at least the correlative basic duty of professional performance for the licensed engineer employee as well as for the engineering organization, be it in corporate, partnership, or single proprietorship form. The engineer can in some degree control the magnitude ($R) of potential rights which may be asserted against him based on alleged breach of the basic duty simply by precise definition of the limitation of certain features of the basic duty. For example, he can spell out that a given technique, method, or material is relatively untried and that its use, while it holds promise of saving time or expense, must be at the risk of the client. Or, for another example, he can have it written into the contract that certain proposed procedures are agreed to constitute "accepted engineering practice."

As to guaranteed results, the engineer in his contract negotiations can, as mentioned above, control the guaranty components of the magnitude of ($R) by careful specification of what results he guarantees and what he does not.

Another mechanism of control over the magnitude of ($R) is careful stipulation between the parties as to the dollar amount which will be deemed to compensate for specific defects or failures, whether such defects or failures relate to guaranteed items or whether they result from a breach of the duty of professional performance. It is evident that since ($R) symbolizes the magnitude of a right to enforce a liability for damages, any limitation on the amount of damages which can be recovered through enforcement of the liability is by definition a direct restriction on the magnitude of ($R).

As to any component of ($R) resulting from possible liability to strangers, no agreement as between the engineer and the client can affect the damage recovery rights of outsider rightholders. In some instances, the engineer may be able to obtain insurance. In other instances, he may be able to require that he be expressly named as beneficiary during construction under the public liability insurance of the contractor or owner. He may, in addition, be able to persuade the client or contractor or others to agree to indemnify him in whole or part in respect of liability growing out of specified circumstances. Otherwise, as to liability to strangers, the engineer must bear in full the consequences of the duty of professional performance.

The magnitude ($R) may also be viewed as a function of maintaining and implementing standard operating procedures in written form, in both office and field operations. The ability of the engineer to demonstrate the effective use of standard procedures designed to promote efficiency and minimize the probability of human errors and omissions is essential to his capacity to defend against allegations of substandard professional performance. This is especially true for the engineering organization using unlicensed personnel in certain phases of operations, such as computation, drafting, or measurement.

The factor (n_R) denotes the number of rightholders generated by the duties undertaken by the engineer. This number consists of rightholders in relation to the basic duty of professional performance, including stranger rightholders together with the client and perhaps the contractor. The number (n_R) also includes the client and others whose rights are by terms of the contract based on the stricter duties of a guarantor. The engineer can do little to control the magnitude of (n_R). Again, he may be able to find protection through insurance, his own or the contractor's or the owner's. In special instances, he may be able to obtain an indemnification agreement from the contractor or the owner, with respect to liability either to the parties to the contract or to strangers arising out of specific phases of the job. But here, as elsewhere, the parties cannot reduce (n_R) by private agreement to restrict liability to strangers.

The third factor is the period of time (t) which symbolizes the statute of limitations and can be thought of as a magnitude attached to the period of the engineer's exposure to enforcement of potential liability. As between the parties, the law permits flexibility in controlling the time in which a liability may be asserted against the engineer. In the absence of any contrary contract provision, the time for enforcement of contract based liabilities is typically on the order of six years. The parties can, however, agree to cut this time to a shorter period. But once again the parties cannot, by their private agreement, affect the time of exposure to potential assertions by strangers of liability against the engineer. In this respect, the engineer must again fall back on insurance or on stipulation that, after a certain point of time, one or more of the other contracting parties will indemnify him against liability.

Our discussion has referred mainly to analysis of writings contractual in nature. Previously, brief reference was made to other writings in the nature of paper work products, such as designs, plans, specifications, drawings, and analyses, constituting either end products or products subsidiary to physical end products. In many of these the engineer makes representations, evaluations, and predictions, as to adequacy, suitability, performance characteristics, and performance limits. Much of the liability exposure analysis applicable to contractual writings is also applicable to these work product writings. The engineer necessarily stakes his reputation on his representations, evaluations, and predictions. In some matters, such as certain cost and capacity estimates, he may reasonably be expected to be a guarantor of range of accuracy. But in many instances, he needlessly and unwittingly commits himself to the strict truth of factual assertions containing inherent uncertainties.

VI. Summary

In summary, the concept of duty of professional performance defined in terms of the standard of professional competence enables the engineer to orient himself in relation to his basic professional duty. With this orientation, he is in a position to exercise perception and control with respect to deliberate, voluntary enlargement of his basic duty. He is better able to recognize technological situations which call for precise precautionary treatment of potential liability. He is more alert to the hazards of ambiguous or vague language which may, in later unforeseen circumstances, be construed to impose a greater burden of liability risk than he intends to assume.

The concept of duty of professional performance is also basic to an understanding of the fundamental duty-right-liability relationship. The engineer who grasps the significance of this relationship as the source of our liability exposure formula ($\$L_P = n_R \times t \times \$R$) is enabled to recall quickly to mind for use in contract negotiations, and in drafting of work product papers, the essential considerations which will determine the magnitude of his long-term liability exposure.

But, when the last word is said, constant reaching for a level of professional competence higher than the minimal legal standard remains the most effective way to minimize the inherent risk of liability exposure. We can postulate that a degree of superiority in professional engineering performance (including effective grasp and use of basic legal factors affecting the conduct and strategy of engineering practice) results in reduction of the stochastic expected value of the fractional amount of the aggregate magnitude of potential liability which can be successfully enforced against the engineer to the ultimate point of damage recoveries. (Bankruptcy is another practical and highly restrictive constraint on recovery potential, but be it noted that bankruptcy discharge may not discharge a large part of the liability due to breach of the basic duty.) In this probabilistic sense we complete the potential liability equation by putting a "probability" factor (p) in the right-hand side as another important element which a good engineer can effectively minimize:

$$\$L_P = p\,(n_R \times t \times \$R)\,;\ 0 < p < 1.$$

OF GENERAL INTEREST

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETING

Boston Society of Civil Engineers

JANUARY 23, 1963:—A regular meeting of the Boston Society of Civil Engineers was held this evening at the Society Rooms, 47 Winter Street, Boston, Mass., and was called to order by President George G. Bogren at 7:00 P.M.

President Bogren stated that the Minutes of the previous meeting held December 5, 1962 would be published in a forthcoming issue of the Journal and that the reading of those Minutes would be waived unless there was objection.

President Bogren announced the death of the following member:—

Peter C. Malkowski, who was elected a member February 10, 1930, and who died June 7, 1962.

The Secretary announced the names of applicants for membership in the Society and that the following had been elected to membership:—

Elected December 17, 1962

Grade of Member—Albert G. Ferron, Nils Skorve, Robert J. Van Epps

Grade of Associate—Harold E. Wescott, Jr.

Elected January 23, 1963

Grade of Member—Frank W. Clark, Paul F. Rittenburg

Grade of Junior—Omar H. Shemdin

President Bogren requested the Secretary to present recommendation of the Board of Government to the Society for action. The President stated that this matter was before the Society in accordance with provisions of the By-Laws and notice of such action published in the ESNE Journal dated January 14, 1963.

Secretary presented the following recommendation of the Board of Government to the Society for action to be taken at this meeting.

MOTION "to recommend to the Society that the Board of Government be authorized to transfer an amount not to exceed $5,500 from the Principal of the Permanent Fund to the Current Fund for current expenditures."

On motion duly made and seconded it was VOTED "that the Board of Government be authorized to transfer an amount not to exceed $5,500 from the Principal of the Permanent Fund to the Current Fund for current expenditures."

President Bogren stated that final action on this matter would be taken at the February meeting.

President Bogren then introduced the speakers of the evening, Charles O. Baird, Jr., Northeastern University and Frank L. Heaney, Camp, Dresser & McKee, who gave a most interesting and informative talk on "Massachusetts Experience with Registration of Professional Engineers and of Land Surveyors, with Discussion of Proposed Legislation."

Seventy-eight members and guests attended the meeting.

The meeting adjourned at 9:30 P.M.

CHARLES O. BAIRD, JR., *Secretary*

FEBRUARY 13, 1963:—A Joint Meeting of the Boston Society of Civil Engineers with the Structural Section was held this evening in the Society Rooms, 47 Winter Street, Boston, Mass., and was called to order by President George G. Bogren, at 7:00 P.M.

President Bogren stated that the Minutes of the previous meeting held January 23, 1963 would be published in a forthcoming issue of the Journal and that the reading of those Minutes would be waived unless there was objection.

The Secretary announced the names of applicants for membership in the Society and that the following had been elected to membership on February 13, 1963:—

Grade of Member—Robert S. Cleary, Nicholas R. D'Alessandro,* Gino M. Ferrini, Jr., Charles E. Fuller,* Herbert C. Moore, Jr.,* Jeremiah P. O'Connor.

President Bogren requested the Secretary to present recommendation of the Board of Government to the Society for action. The President stated that this matter was before the Society in accordance with provisions of the By-Laws and notice of such action published in the ESNE Journal dated February 4, 1963.

Secretary presented the following recommendation of the Board of Government to the Society for action at this meeting:—

MOTION "to recommend to the Society that the Board of Government be authorized to transfer an amount not to exceed $5,500 from the Principal of the Permanent Fund to the Current Fund for current expenditures."

On motion duly made and seconded it was VOTED "that the Board of Government be authorized to transfer an amount not to exceed $5,500 from the Principal of the Permanent Fund to the Current Fund for current expenditures."

President Bogren stated that this was the final action on this matter.

President Bogren announced that this was a Joint Meeting with the Structural Section and turned the meeting over to Percival S. Rice, Chairman of that Section to conduct any necessary business for the section at this time.

Chairman Rice introduced the speakers of the evening, Prof. Robert J. Hansen, Dir. of Laboratory for Structural Models, Depts. of Civil Engrg., and Architecture, M.I.T., and Mr. William A. Litle, Instructor, Dept. Civil Engrg., M.I.T., who gave a most interesting illustrated talk on "Use of Models for Structural Design."

A discussion period followed the talk.

* Transfer from Junior

Sixty-five members and guests attended the meeting.

The Meeting adjourned at 8:30 P.M.

CHARLES O. BAIRD, JR., *Secretary*

FEBRUARY 27, 1963:—A Joint Meeting of the Boston Society of Civil Engineers with the Transportation Section was held this evening at the Society Rooms, 47 Winter Street, Boston, Mass., and was called to order by President George G. Bogren, at 7:00 P.M.

President Bogren stated that the Minutes of the previous meeting held February 13, 1963 would be published in a forthcoming issue of the Journal and that the reading of those Minutes would be waived unless there was objection.

The Secretary announced the names of applicants for membership in the Society.

President Bogren announced that this was a Joint Meeting with the Transportation Section and called upon James W. Haley, Chairman of that Section to conduct any necessary business.

President Bogren introduced the speaker of the evening, Mr. Jean de Valpine, Partner, Powers, Hall, Montgomery and Weston, Law Firm who gave a most interesting talk on "The Legal Aspects of Engineering."

A discussion period followed the talk.

Thirty-nine members and guests attended the meeting.

The meeting adjourned at 8:45 P.M.

CHARLES O. BAIRD, JR., *Secretary*

MARCH 21, 1963:—The 115th Annual Meeting of the Boston Society of Civil Engineers was held today at the Science Museum, Science Park, Boston, Mass., and was called to order at 4:15 P.M. by President George G. Bogren.

President Bogren announced that the reading of the Minutes of Society meetings had been omitted during the year. The Minutes of the January and February 1963 meetings would be published in a forthcoming issue of the Journal. The Minutes of the April, May, September, October, November and December 1962 meetings to be declared approved as published.

It was VOTED "to approve the Minutes as published."

The Secretary announced the names of applicants for membership in the Society and that the following had been elected to membership March 18, 1963:—

Grade of Member—Domenic F. Frangioso, Jr.,* Daniel A. Leone, Jr., Anthony L. Ricci,* James N. White.*

Grade of Junior—Guenther Wilhelm

The Annual Reports of the Board of Government, Treasurer, Secretary and Auditors were presented. Reports were also made by the following committees: —Hospitality, Library, John R. Freeman, Public Relations, Advertising, Subsoils of Boston, Joint Legislative Committee and Committee on Professional Conduct.

It was VOTED "that these reports be placed on file."

The Annual Reports of the various Sections were read and it was VOTED "that the Annual Reports of the various Sections be placed on file."

President Bogren stated that all foregoing reports would be published in the July, 1963 issue of the Journal. [Reports are published in this issue—Ed.]

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* Transfer from Junior

The Report of the Tellers of Election, Benedict J. Quirk and Robert E. Cameron, was presented and in accordance therewith the President declared the following have been elected Officers for the ensuing year:—

President	James F. Flaherty
Vice-President	Leslie J. Hooper
Secretary	Charles O. Baird, Jr.
Treasurer	Paul A. Dunkerley
Directors	James F. Haley
	Fozi M. Cahaly
	James W. Daily
Nominating Committee	Myle J. Holley, Jr.
	Clyde W. Hubbard
	Frank L. Heaney

The retiring President George G. Bogren then gave his address entitled "Public Image of the Engineer."

Thirty-eight members and guests attended the business meeting.

The Meeting adjourned at 5:40 P.M., to re-assemble at 8:00 P.M., the Annual Dinner being held during the interim.

The President called the meeting to order at 8:15 P.M.

Following general remarks and the introduction of the newly elected President, John F. Flaherty, and other guests at the head table, the various prize awards were made.

The Secretary read the various prize awards and asked the recipients to come forward and President Bogren presented the following awards:—

Award	*Recipient*	*Paper*
Desmond FitzGerald Medal	Howard M. Turner	"New England Floods and the Society's Flood Report."
Clemens Herschel Award	Stanley M. Dore	"Investigations and Studies for the Richmond Tunnel to be constructed under New York Harbor."
Sanitary Section Award	Chester J. Ginder	"Design of an Incinerator for the Nut Island Sewage Treatment Plant."
Structural Section Award	Donald G. Ball	"Prudential Center Foundations."
Hydraulics Section Award	Lee Marc G. Wolman	"Some Hydraulic and Hydrologic Aspects of the Niagara Power Project."
Construction Section Award	John J. Scheuren, Jr.	"Arctic Construction."

President Bogren then introduced the guest speaker of the evening, Bradford Washburn, Director of Science Museum who gave a most interesting talk on "Program of Science Museum with Demonstrations and a visit to Planetarium."

At the conclusion of the address President Bogren on behalf of the Society thanked Mr. Washburn for a most enjoyable talk and then turned the meeting over to President-elect John F. Flaherty.

President-elect John F. Flaherty

presented retiring President George G. Bogren with a certificate for services rendered and then adjourned the meeting.

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

CHARLES O. BAIRD, JR., *Secretary*

CONSTRUCTION SECTION

OCTOBER 31, 1962:—A regular meeting of the Construction Section was held this evening in the Society Rooms. Chairman James P. Archibald introduced Mr. Herman G. Protze, of Mass-lite, Inc., Boston, Mass. at 7:00 P.M. Mr. Protze presented a paper entitled "Design and Construction with Lightweight Structural Concretes."

Aggregates for lightweight structural concrete comes from several sources; pumice and volcanic rock, cinders, and commercially processed slag. The most important of these is slag produced from expanded shale. The shale is crushed, burned, fused, and bloated to achieve the desired product. Lightweight aggregate results in a concrete dry density of 110 pcf with ordinary sand and 90 pcf with lightweight sand.

The speaker discussed the advantages of lightweight concrete and pointed out that with good lightweight aggregates, the concrete mix may be designed to achieve a strength about equal to that of average ordinary concrete. Field control is best achieved by checking the wet density prior to placement.

Mr. Protze then presented data on compressive strengths, tensile strengths, and elastic properties of lightweight concrete. His concluding discussion was relative to construction methods, wherein comparisons were made between the practice used in placement of ordinary concrete and lightweight concrete. Because of the lighter aggregates, the mix is less mobile, requires lower frequency vibration, thinner lifts, and more vibratory effort than ordinary concrete.

Forty-five members and guests attended the meeting.

DONALD T. GOLDBERG, *Clerk*

HYDRAULICS SECTION

FEBRUARY 6, 1963:—A meeting of the Hydraulics Section of the Boston Society of Civil Engineers was held in the Society Rooms, 47 Winter Street, Boston, Massachusetts and was called to order by the Chairman of the Section, Mr. Lawrence C. Neale, at 7:05 P.M.

Chairman Neale dispensed with the reading of the minutes of the previous meeting and read the report of the nominating committee which was accepted. The nominating committee, consisting of three former chairmen, was as follows:

Lee Marc G. Wolman
John B. McAleer
Donald R. F. Harleman

The following slate of officers for 1963 was approved:

Richard F. Dutting, Chairman
Keistutis P. Devenis, Vice-Chairman
Peter S. Eagleson, Clerk
Allen Grieve, Executive Committee
Nicholas Lally, Executive Committee
Llewellyn Cross, Executive Committee

The speaker was Joseph M. Caldwell, Chief, Research Division, U.S. Army Corps of Engineers, Beach Erosion Board, who discussed "The North Atlantic Coastal Storm of March, 1962." Mr. Caldwell discussed the changing shore line conditions along the Atlantic Coast of the U.S. in the past.

Slides were shown to illustrate the progressive changes in shore line due to the loss of sand by motion parallel to the shore line and the effect of man-made obstructions to retard this erosion.

The North Atlantic Coastal Storm of 1962 was unusual not only because of the intensity of erosive wave action but also because high waves occurred over a prolonged period of several tidal cycles and at a time when tide levels were very high. The result was extensive damage to the shore line property and the loss of a huge volume of sand from the shore toward the ocean. The loss of these sand barriers left the remaining shore line property vulnerable to future storm damage. Therefore dredging from the ocean to place sand on the shore was undertaken to provide future protection.

A question and answer period followed the talk.

The meeting adjourned at 8:30 P.M. with 36 persons in attendance.

K. PETER DEVENIS, *Clerk*

STRUCTURAL SECTION

DECEMBER 12, 1962:—A regular meeting of the Structural Section was held this evening in the Society Rooms and was called to order by Chairman Percival S. Rice at 7:00 P.M.

The Chairman announced the program for the balance of the year and then introduced the speaker of the evening, Prof. Robert V. Whitman, Associate Professor of Civil Engineering, Massachusetts Institute of Technology, who spoke on "Tests Upon Thin Domes Buried in Sand."

The Speaker presented a comprehensive report on the test program which was conducted on buried domes by the speaker, Prof. Zvi Getzler and Mr. Kaare Höeg at M.I.T. The test procedures used and the results obtained were discussed in considerable detail.

Printed copies of the paper were distributed to those in attendance.

After an extensive question and answer period, the meeting was adjourned at 8:35 P.M.

The meeting was attended by 39 members and guests.

MAX D. SOROTA, *Clerk*

FEBRUARY 13, 1963:—A Joint Meeting was held with the Main Society on this date. President George G. Bogren called the meeting to order at 7:00 P.M., and conveyed his good wishes to our Section. Charles O. Baird, Jr., Secretary made a motion requesting authority to transfer $5500 from the principal of the permanent fund to be used for current expenses. The motion was seconded and carried.

Percival S. Rice, Chairman of the Section, then took charge of the meeting and requested presentation of the nominating committee report. The report, read by Chairman William A. Henderson, recommended the following officers for 1963-64:

Chairman	Harl P. Aldrich, Jr.
Vice Chairman	Max D. Sorota
Clerk	Donald T. Goldberg
Executive Committee	Mark M. Kiley
	Robert L. Fuller
	Maurice A. Reidy, Jr.

These recommendations were duly voted on and accepted by the section.

Chairman Rice then introduced the speakers of the evening: Professor Robert J. Hansen, Director of Laboratory of Structural Models, Dept. of Civil Engineering, M.I.T., and Mr. William A. Litle, Instructor and Doctoral candidate, Dept. of Civil Engineering, M.I.T. They presented a paper entitled "The Use of Models in Structural Design."

Professor Hansen made some brief introductory remarks relative to the applicability of model techniques and some of the long range objectives of his laboratory. Mr. Litle then addressed the members, outlining some of the technical facets of any complete model program. The five stages involved in model work are: (1) planning (selection of dimension, materials, and load system); (2) model fabrication; (3) loading of the model; (4) measurement of stresses and strains; and (5) interpretation of results.

At the conclusion of the meeting, prepared discussions of the paper were made by Messrs. William LeMessurier and Howard Simpson. A lively floor discussion followed.

The meeting was attended by 65 members and guests.

MAX D. SOROTA, *Clerk*

MARCH 13, 1963:—A regular meeting of the structural section was held at the Society Rooms this date.

Dr. Harry Horn, Ass't Prof. of Civil Engrg. at MIT presented a paper entitled "The Design of Antenna Foundations."

In his paper, Dr. Horn showed that the aiming error of a tracking tower can be seriously affected by extremely small angular displacements of the structures or of the foundation.

Foundation displacements occurring under transient loading (such as moment or torque) are most important in contrast to static loading. An evaluation of this effect involves determination of stress-strain soil properties (Young's Modulus, Shear Modulus, and Poisson's ratio, assuming that the soil is an elastic material).

The speaker discussed means by which these physical properties can be determined, and methods of computing angular rotations.

Dr. Horn also devoted some time to considerations of foundation vibrations and potential resonant conditions.

Attendance was 52 and the meeting adjourned at 9:00 P.M.

DONALD T. GOLDBERG, *Clerk*

SURVEYING AND MAPPING SECTION

OCTOBER 24, 1962:—The last regular meeting of the Surveying and Mapping Section of the Boston Society of Civil Engineers was held on this date at the Society Rooms.

The meeting was called to order by the Chairman, Richard D. Raskind, promptly at 7:00 P.M.

Mr. Raskind waived the reading of the minutes of the previous meeting.

There was no introduction of old or new business.

He introduced Mr. John Paddleford of M.I.T. Lincoln Laboratory.

Mr. Paddleford spoke on the survey technique required to align research radar antennae. This was an illustrated lecture.

Mr. Paddleford also showed a movie entitled "The Dew Line in Canada."

There was a brief question and answer period after the lecture and movie.

Twenty members were present at this meeting.

The meeting adjourned at 9:15 P.M.

JOSEPH A. BODIO, *Clerk*

ADDITIONS

Members

Frank W. Clark, 66B Perkins Street, Jamaica Plain, Mass.

Robert S. Cleary, 76 Walnut Street, Lynnfield Ctr., Mass.

Nicholas D'Alessandro, 278 Mt. Vernon Street, Dedham, Mass.

Albert G. Ferron, Zottola Road, Holden, Mass.

Domenic F. Frangioso, Jr., 153 Savannah Avenue, Mattapan, Mass.

William D. French, 132 Priscilla Avenue, Norfolk, Mass.

Gino M. Ferrini, Jr., 61 Fern Avenue, Brockton, Mass.

Charles E. Fuller, 7 LeRoy Drive, Burlington, Mass.

Louis D. Goodman, Civil Engrg. Dept., Syracuse University, Syracuse, N.Y.

Herbert C. Moore, Jr., 145 Beaumont Avenue, Newtonville, Mass.

Thomas R. Parello, 12 Moore Street, Waltham, Mass.

Jeremiah P. O'Connor, 680 Boulevard, Revere, Mass.

Anthony L. Ricci, 291 Pearl Street, Cambridge, Mass.

Paul F. Rittenburg, 17 Gannett Terrace, Sharon, Mass.

Nils Skorve, Structural Concrete Corp., 101 Court Street, Laconia, N.H.

Robert J. Van Epps, Shamrock Motel, Fayville, Mass.

James N. White, 80 Kevin Road, Brockton, Mass.

Associate

Harold E. Wescott, Structural Concrete Corp., 101 Court Street, Laconia, N.H.

Junior

Thomas E. Morello, Jr., 73 Elsie Street, Everett, Mass.

Khalid M. Minhas, Rm. 34, Int'l House, Lund, Sweden

Omar H. Shemdin, 236 Tappan Street, Brookline, Mass.

Student

Dean K. White, 408 Main Street, Concord, Mass.

Deaths

Adnan N. Adsiz, November, 1962

Peter C. Malkowski, Jan. 7, 1962

ANNUAL REPORTS

REPORT OF THE BOARD OF GOVERNMENT FOR YEAR 1962-1963

Boston, Mass., March 21, 1963

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 21, 1963.

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

Honorary	7
Members	999
Associates	6
Juniors	34
Students	1
Total	1047
Student Chapters	2
Summary of Additions	
New Members	30
New Juniors	5
Reinstatements	
Members	4
Summary of Transfers	
Junior to Member	5
Summary of Loss of Members	
Deaths	10
Resignations	11
Dropped for non-payment of dues	27
Dropped for failure to transfer	3

Life Members	104
Members becoming eligible today for Life Membership	6
Applications pending on March 21, 1963	7

Honorary Membership is as follows:

Frank M. Gunby, elected, February 15, 1950
Karl R. Kennison, elected, February 7, 1951
Frank A. Marston, elected, February 15, 1960
Charles M. Spofford, elected, December 19, 1945
Howard M. Turner, elected, February 18, 1952
William F. Uhl, elected, February 7, 1955
Karl Terzaghi, elected, March 3, 1952

The following members have been lost through death:

Adnan Adsiz, November, 1962
LeRoy G. Brackett, May 12, 1962
Ralph B. Brasseur, June 10, 1961
William H. Chase, January, 1963
Frank H. Dillaby, Oct. 8, 1962
James B. Flaws, Oct. 18, 1962
Peter C. Malkowski, June 7, 1962
John A. McAuliffe, Oct. 16, 1962
William C. Paxton, Oct. 22, 1962
Albert E. Sanderson, Aug. 12, 1962

Meetings of the Society

March 22, 1962. Address of the retiring President, James F. Brittain. "Our Profession and Our Society—Then and Now."

April 30, 1962. Joint Meeting with the Massachusetts Section, American Society of Civil Engineers. Edward Roemer, Chairman of Government Center Commission. "General Plans for Government Center from State Viewpoint and Procedures Used for Hiring Professional Engineer's Service."

May 16, 1962. Joint Meeting with Surveying and Mapping Section. Richard L. Cameron, Cambridge Air Force Research Center. "New England During the Ice Age."

May 23, 1962. Joint Meeting with Sanitary and Construction Sections. Mr. Hugh P. Ripman, Head, Industry Division, International Bank for Reconstruction and Development. "The Challenge of Civil and Sanitary Engineering Work in Underdeveloped Countries."

September 24, 1962. Sir George M. McNaughton, President of the Institution of Civil Engineers, Westminster, London, England. "Work and Aims of the Institution of Civil Engineers."

October 17, 1962. Joint Meeting with Massachusetts Section, American Society of Civil Engineers (Student Night). Mr. John H. Fullerton, Project Manager, Jackson & Moreland, Inc. "Lunar Landing Research Facility."

November 28, 1962. Joint Meeting with the Transportation Section. Cranston R. Rogers, Senior Engineer, Chas. A. Maguire & Associates. "Highway Transportation Problems Encountered During the Inner Belt Study."

December 5, 1962. Joint Meeting with the Sanitary Section. Dr. Harold A.

Thomas, Jr., and Dr. Robert P. Burden, Harvard University. "Rebirth of an Asian Breadbasket."

January 23, 1963. Charles O. Baird, Jr., Northeastern University and Frank L. Heaney, Camp, Dresser & McKee. "Massachusetts Experience with Registration of Professional Engineers and of Land Surveyors, with Discussion of Proposed Legislation."

February 13, 1963. Joint Meeting with Structural Section. Prof. Robert J. Hansen, Dir. of Laboratory for Structural Models, M.I.T., and Mr. William A. Litle, Instructor, Dept. Civil Engrg., M.I.T. "The Use of Models in Structural Design."

February 27, 1963. Joint Meeting with Transportation Section. Mr. Jean de Valpine, Partner, Powers, Hall, Montgomery and Weston, Law Firm. "The Legal Aspects of Engineering."

Attendance at Meetings

Date	*Place*	*Meeting*	*Dinner*
March 22, 1962	M.I.T. Faculty Club	40	159
April 30, 1962	Hotel Lenox	94	94
May 16, 1962	United Community Services Building	83	53
May 23, 1962	United Community Services Building	85	53
September 24, 1962	United Community Services Building	60	48
October 17, 1962	Worcester Polytechnic Institute	181	160
November 28, 1962	United Community Services Building	60	49
December 5, 1962	United Community Services Building	50	39
January 23, 1963	Society Rooms	78	
February 13, 1963	Society Rooms	65	
February 27, 1963	Society Rooms	30	

Average Attendance 86

Sections

Twenty-seven meetings were held by the Sections of the Society 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 and published in the April, 1963 issue of the Journal.

*Funds of the Society**

Permanent Fund. The Permanent Fund of the Society has a present value of $69,833.82. The Board of Government authorized the use of as much as necessary of the current income of this fund in payment of current expenses. By vote of the Society (as prescribed by the By-Laws) at the January 14, 1963 and

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

February 13, 1963 meetings, the Board of Government was authorized to transfer an amount not to exceed $5,500 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 $2,746.70.

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 to be devoted to a yearly prize for the most useful paper relating to hydraulics contributed to this Society; or establishing a traveling scholarship every third year open to members of the Society for visiting engineering works, a report of which would be presented to the Society. No expenditures were made this year.

Edmund K. Turner Fund. In 1916 the Society received 1,105 books from the library of the late Edmund K. Turner, a former member of the Society, and a bequest of $1,000 "The income of which is to be used for Library purposes." The Board voted to use $75 of the income of this fund for the purchase of books for the Library. The expenditure from this fund during the year was $75.

Alexis H. French Fund. The Alexis H. French Fund, a bequest amounting to $1,000 was received in 1931, from the late Alexis H. French of Brookline, a former 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 $75 of the income of this fund for the purchase of books for the library. The expenditure from this fund during the year was $75.

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 $2,338.16 on June 30, 1962. Richard V. Goodman, a student in Civil Engineering, class of 1963, was awarded this Scholarship of $100 for the year 1962-63.

Desmond FitzGerald Fund. The Desmond FitzGerald Fund established in 1910 was a bequest 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 10, 1961 to appropriate from the income of this fund the sum of $100 to be known as the Boston Society of Civil Engineers Scholarship in Memory of Desmond FitzGerald, and be given to a student at Northeastern University. It was voted on February 27, 1962 "to adopt the recommendation of the Committee at Northeastern University" namely, that a $100 Scholarship be given to Marcia A. Bush. Presentation was made at the Annual Meeting of the Society March 22, 1962.

Clemens Herschel Fund. This fund was established in 1931, by a bequest of $1,000 from the late Clemens Herschel, a former 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 Board of Government voted on April 10, 1962 that payment of Prize Awards be appropriated from the income of this fund. The expenditures made during the year from this fund were $102.30.

Edward W. Howe Fund. This fund, a bequest of $1,000, was received in 1933 from the late Edward W. Howe, a former Past President of the Society. No restrictions were placed upon the use of this money, 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." The Board voted April 10, 1962 "that a sum not to exceed $70 be appropriated from the income of this fund for general purposes." No expenditure was made from this fund during the year.

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 upon the use of this money, but the recommendations of the Board of Government were "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 the sum of $100 to be known as the Boston Society of Civil Engineers Scholarship in Memory of William P. Morse, and be given to a student at Tufts University." It was voted on February 27, 1961 "to adopt the recommendation of the Committee at Tufts University," namely, that a $100 Scholarship be given to John C. LeFevre. Presentation was made at the Annual Meeting of the Society held March 22, 1962.

Prizes

Award	*Recipient*	*Paper*
Desmond FitzGerald Award	Howard M. Turner	"New England Floods and the Society's Flood Report."
Clemens Herschel Award	Stanley M. Dore	"Investigations and Studies for the Richmond Tunnel to be constructed under New York Harbor."
Sanitary Section Award	Chester J. Ginder	"Design of an Incinerator for the Nut Island Sewage Treatment Plant."
Structural Section Award	Donald G. Ball	"Prudential Center Foundations."
Hydraulics Section Award	Lee Marc G. Wolman	"Some Hydraulic and Hydrologic Aspects of the Niagara Power Project."
Construction Section Award	John J. Scheuren, Jr.	"Arctic Construction."

Library

The Report of the Library Committee contains a complete account of the Library Committee 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.

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.

GEORGE G. BOGREN, *President*

REPORT OF THE SECRETARY

Boston, Mass., March 21, 1963

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 21, 1963

	Expenditures	Receipts
Office		
Secretary, salary & expense	$ 749.07	
Treasurer's Honorarium	400.50	
Stationery, printing & postage	756.21	
Incidentals & Petty cash	152.39	
Insurance & Treasurer's Bond	20.05	
Quarters, Rent, Tel.	5,199.17	
Office Secretary	5,381.06	
Social Security	209.34	
Meetings		
Rent of Halls, etc.	200.00	
Stationery, printing & postage	46.00	
Hospitality Committee	1,082.00	$ 900.75
Reporting & Projection	28.00	
Annual Meeting, March 1962	826.60	586.00
Sections		
Sanitary Section	9.50	
Structural Section	59.85	
Transportation Section	6.00	
Hydraulics Section	12.00	
Construction Section	21.75	
Surveying & Mapping Section	11.41	
Journal		
Editor's salary & expense	749.07	
Printing & Postage	5,163.84	
Advertisement	—	1,577.20
Sale of Journals & Reprints	—	2,459.13
Copyright	16.00	
Library		
Periodicals	84.00	
Binding	83.50	
Forward	$21,267.31	$ 5,523.08

REPORT OF THE SECRETARY (Continued)

	Expenditures	Receipts
Brought Forward	$21,267.31	$ 5,523.08
Miscellaneous		
Binding Journals for Members	8.40	12.90
Badges	—	10.00
Bank Charges	11.19	—
Miscellaneous	2,918.70	1,779.50
Engineering Societies Dues and charge for Journal space	1,143.62	—
Public Relations Committee	64.94	—
Dues from B.S.C.E. Members		11,368.00
Trans. Income from Perm. Fund		3,973.98
Trans. Prin.		2,746.70
	$25,414.16	$25,414.16

Entrance Fees to Permanent Fund $360.00

20 New Members; 5 New Junior Members; 5 Juniors transferred to Member; 1 New Student Member.

The above receipts have paid been to the Treasurer who's receipt the Secretary holds. The Secretary holds cash amounting to $30 included as payment under item 25 (Petty Cash) to be used as a fixed fund or cash on hand. $248.13 withholding tax and $92.38 Social Security which is payable to Collector of Internal Revenue and State of Massachusetts in April, 1963 is not included in the above tabulation.

CHARLES O. BAIRD, JR., *Secretary*

REPORT OF THE TREASURER

Boston, Mass., March 21, 1963

To the Boston Society of Civil Engineers:

This report is for the period beginning March 1, 1962 and ending at the close of business on March 1, 1963.

As has been the custom in past years our investment securities are held by the Boston Safe Deposit and Trust Company which serves as custodian and investment counsel. Any security transactions made during the year were based on the recommendations made by the Boston Safe Deposit and Trust Company with a vote of approval by the Board of Government of the Society. At the close of the fiscal year the auditors of the Boston Safe Deposit and Trust Company furnish the Treasurer of the Boston Society of Civil Engineers with a certified audit of the account.

The financial standing of the Society as of March 1, 1963 is summarized in seven of the tables accompanying this report. These seven tables are as follows:

Table	I	Comparison of Book Values and Market Values of Stocks, Bonds, Savings Bank, and Investment Cash.
Table	II	Comparison of Book and Market Values of Funds.
Table	III	Distribution of Funds—Receipts and Expenditures.
Table	IV	Distribution of Funds—Receipts and Expenditures.
Table	V	Record of Investments—Bonds.
Table	VI	Record of Investments—Stocks.
Table	VII	Record of Investments—Savings Bank.

(Note: In Table II the funds listed Boring Data, Vol. I, and Sanitary Lectures are actually in the form of cash or publications available for sale and are considered to have the same Book Value and Market Value.)

Three tables have been prepared to compare the Book Value, Market Value, and the earnings from our holdings during the past five years. These tables are as follows:

Table	VIII	Comparison of Book Values During Last Five Years.
Table	IX	Comparison of Market Values During Last Five Years.
Table	X	Comparison of Earnings from Invested Fund During Last Five Years.

In a letter addressed to the Secretary of the Boston Society of Civil Engineers dated January 4, 1963 with a copy to the Treasurer Mr. Karl R. Kennison reported on the two irrevocable trusts involving shares in the Massachusetts Hospital Life Insurance Co. established for the Boston Society of Civil Engineers as follows:

Trust #4315 contains the original	178.320 shares
Trust #4444 originally contained	174.563 shares
Added Dec. 1961 by $71.57 Capital Gain	2.963 shares
Added Dec. 1962 by $62.13 Capital Gain	2.860 shares
Subtotal	180.388 shares
Total both trusts	358.708 shares

At the year end market value of $21.82 per share the total value of the two trusts as of December 31, 1962 was $7,827.00.

In a letter from Charles M. Pyle Jr., Senior Investment Officer, of the Boston Safe Deposit and Trust Company dated June 28, 1962 addressed to the Treasurer it is stated in part:

"As of this date, the portfolio was diversified 23% bonds, 72% common stocks, and 5% preferred stocks. It is our feeling that this level of common stocks should be moderately reduced for reinvestment in bonds. Accordingly, we present the following program for your Board of Governors:

Sell	*Approximate Mkt. Val.*
50 shares American Telephone & Telegraph Co. (hold 207 shs.)	$5,000.00
24 shares Standard Oil Company, New Jersey (hold 324 shs.)	$1,152.00
100 shares Texaco Inc. (hold 444 shs.)	$4,600.00
Buy	
$10,000 Flintkote Company Debs 4⅝% 4/1/81	$10,300.00

We are suggesting reductions in the larger holdings in the account."

On July 12, 1962 a special meeting of the Board of Government was convened at the request of the Treasurer to consider the proposal made by the bank. At this meeting, after considerable discussion, it was voted not to sell the stock at this time and that the Treasurer was to make a further study of the recommendations. Pursuant with the mandate of the Board, the Treasurer met with Mr. Pyle on the same date seeking further clarification of the issues. At the regular monthly meeting of the Board of Government held on September 24, 1962 the report of the Treasurer was heard and it was voted to follow the recommendations of the Custodian. The gross receipts from the sale of the stocks were $11,699.00 from which the sum of $10,450.00 was used to purchase a Flintkote bond having a par value of $10,000.00. At its regular monthly meeting in November, 1962 the Board voted upon the advice of the Custodian to purchase a $1,000 U.S. Treasury Bond, short term.

Other security changes which were accomplished by the Boston Safe Deposit and Trust Company with the approval of the Board of Government were as follows:

Consolidated Edison of New York
Sold 50 Rights

Continental Insurance Co.
Received 7 shares in stock dividend
Received 50/100 shares in stock dividend
Bought 50/100 shares
Received 1 share in consolidation
Total increase 8 shares

New England Electric System
Sold 210 Rights

Receipts from the Secretary including dues, advertisements in the Journal, sale of Journals, and other items not specifically listed in Table IV amounted to $18,693.48.

Expenditures are listed in detail in the Report of the Secretary and the membership is referred to this for further information. It is to be noted, however, that the move to the new quarters at 47 Winter Street entailed unusual expenses during the fiscal year which were only partially reimbursed by the grant received from the Boston Redevelopment Authority.

The income to the permanent Fund from dividends and interest less the expenses charged to the Fund amounted to $3,973.78. In order to meet current expenses for the year it became necessary to transfer $6,720.68 from the Permanent Fund. Of this amount $3,973.98 was transferred from income to the Fund and the remainder of $2,746.70 was transferred from the principal of the Permanent Fund.

Of the funds on hand as indicated by the following tables, $340.52 is held in escrow for Federal Withholding Tax, Massachusetts Income Tax, and Social Security Payments.

PAUL A. DUNKERLEY, *Treasurer*

TABLE I

COMPARISON OF BOOK VALUES AND MARKET VALUES OF STOCKS, BONDS, SAVINGS BANK, AND INVESTMENT CASH

	Book Value March 1, 1963	Market Value March 1, 1963
Bonds	62,293.77	58,323.13
Stocks	53,228.79	156,477.51
Savings Bank	4,808.92	4,808.92
Available for Investment	2,919.21	2,919.21
Total 1963	123,250.69	222,528.77
Total 1962	113,394.10	229,709.04
	+9,856.59	—7,180.27

TABLE II

COMPARISON OF BOOK AND MARKET VALUES OF FUNDS

	Book Value March 1, 1963	Market Value March 1, 1963
Permanent	69,833.82	125,981.04
John R. Freeman	40,113.83	72,365.82
Edmund K. Turner	1,436.58	2,591.61
Desmond FitzGerald	2,698.83	4,868.72
Alexis H. French	1,423.85	2,568.64
Clemens Herschel	1,225.63	2,211.05
Edward W. Howe	1,440.76	2,599.15
William P. Morse	2,764.45	4,987.10
Frank B. Walker	1,191.77	2,149.97
Surveying Lectures	618.56	1,115.89
Transportation Lectures	283.61	511.63
Structural Lectures	446.70	805.85
Boring Data	145.50	145.50
Volume I	1,910.30	1,910.30
Sanitary Lectures	—2,283.50	—2,283.50
Sub total	123,250.69	222,528.77
Current Fund	1,500.00	1,500.00
Total	124,750.69	224,028.77

TABLE III
DISTRIBUTION OF FUNDS—RECEIPTS AND EXPENDITURES
BOSTON SOCIETY OF CIVIL ENGINEERS
REPORT OF TREASURER MARCH 1, 1963

	Distribution of Funds			Net Profit or Loss		Transfer of Funds		
	Book Value	Interest and Dividends		at Sale or Maturity		Purchased	Sold	Book Value
	Mar. 1, 1962	Cash	Credit	+	—	+	—	Mar. 1, 1963
	1	2	3	4	5	6	7	8
Bonds	50,818.46	1,892.50				11,475.31		62,293.77
Savings Bank	4,616.55		192.37					4,808.92
Stocks	55,960.99	5,515.00		8,975.96		33.13	2,765.33	53,228.79
Available for Investment	1,998.10					921.11		2,919.21
	113,394.10	7,407.50	192.37	8,975.96		12,429.55	2,765.33	123,250.69

Columns 1 + 3 + 6 — 7 = 8

TABLE IV
DISTRIBUTION OF FUNDS:—RECEIPTS AND EXPENDITURES
BOSTON SOCIETY OF CIVIL ENGINEERS
REPORT OF TREASURER —MARCH 1, 1963

Funds	Book Value Mar. 1, 1962	Allocation of Income-Profit and Loss		Received	Expended	Book Value Mar. 1, 1963
		Income Col. 2 & 3	Net Profit Col. 4 & 5			
Permanent	66,973.66	4,442.49	+5,246.86	360.00	7,189.19*	69,833.82
John R. Freeman	35,306.64	2,341.93	2,766.00		300.74	40,113.83
Edmund K. Turner	1,328.64	88.14	104.09		84.29	1,436.58
Desmond FitzGerald	2,462.76	163.35	192.94		120.22	2,698.83
Alexis H. French	1,317.46	87.38	103.21		84.20	1,423.85
Clemens Herschel	1,167.21	77.44	91.44		110.46	1,225.63
Edward W. Howe	1,266.42	83.99	99.21		8.86	1,440.76
William P. Morse	2,517.80	167.01	197.25		117.61	2,764.45
Frank B. Walker	1,047.54	69.49	82.07		7.33	1,191.77
Surveying Lectures	543.71	36.05	42.60		3.80	618.56
Transportation Lectures	249.27	16.56	19.53		1.75	283.61
Structural Lectures	392.65	26.04	30.76		2.75	446.70
Boring Data	90.50			55.00	0.00	145.50
Vol. I	1,224.69			777.87	92.26	1,910.30
Sanitary Lectures	2,494.85			221.35	10.00	—2,283.50
Subtotal	113,394.10	7,599.87	+8,975.96	1,414.22	8,133.46	123,250.69
Current	1,500.00	3,973.98**		21,440.18	25,414.16	1,500.00
Totals	114,894.10	11,573.85	+8,975.96	22,854.40	33,547.62	124,750.69

Secretary's change fund of $30.00 should be added to show total cash

Cash Balance	
Investment Fund	2,919.21
Current Fund	1,500.00
Total Cash	4,419.21

*	$6,720.68	Transferred from Permanent Fund
**	3,973.98	Transferred from Income to Permanent Fund
	2,746.70	Transferred from Principal of Permanent Fund

Net income to Permanent Fund = $3,973.98

TABLE V
Record of Investments—Bonds
March 1, 1962 to March 1, 1963

Bonds	Date of Maturity	Interest Rate	Interest Received	Par Value	Book Value Mar. 1, 1963	Market Value Mar. 1, 1963
Aluminum Company of America	Apr. 1, 1983	3⅞%	193.75	5,000.00	5,037.50	4,806.25
Associates Investment Co., Deb.	Aug. 1, 1979	5⅛%	307.50	6,000.00	6,000.00	6,247.50
Columbia Gas System Inc. Deb. Series D	July 1, 1979	3½%	70.00	2,000.00	2,066.17	1,840.00
Consumers Power Co., 1st Mortgage	Sept. 1, 1975	2⅞%	86.25	3,000.00	3,140.35	2,625.00
Flintkote Co.	Apr. 1, 1981	4⅝%	0.00	10,000.00	10,450.00	10,350.00
Florida Power Co., 1st Mortgage	July 1, 1984	3⅛%	31.25	1,000.00	1,017.50	833.75
Florida Power Co., 1st Mortgage	July 1, 1986	3⅞%	193.75	5,000.00	5,037.59	4,650.00
General Motors Acceptance Corp.	Sept. 1, 1975	3⅝%	181.25	5,000.00	5,101.80	4,718.75
Georgia Power Co., 1st Mortgage	Dec. 1, 1977	3⅜%	168.75	5,000.00	5,162.50	4,475.00
Province of Ontario	Sept. 1, 1972	3¼%	97.50	3,000.00	2,936.25	2,745.00
Public Service Electric and Gas Co.	June 1, 1979	2⅞%	115.00	4,000.00	4,097.50	3,360.00
So. Pacific 1st Series A Oregon Lines	Mar. 1, 1977	4½%	180.00	4,000.00	4,191.30	4,025.00
Superior Oil Co., Deb.	July 1, 1981	3¾%	150.00	4,000.00	4,000.00	3,830.00
Tidewater Oil Co., Deb.	Apr. 1, 1986	3½%	70.00	2,000.00	2,032.50	1,775.00
U.S.A. Treasury Notes, Series A	May 15, 1964	4¾%	47.50	1,000.00	997.50	1,020.94
U.S.A. Treasury Notes, Series A	May 15, 1964	4¾%	0.00	1,000.00	1,025.31	1,020.94
Totals			1,892.50	61,000.00	62,293.77	58,323.13

TABLE VI

RECORD OF INVESTMENTS—STOCKS

MARCH 1, 1962 TO MARCH 1, 1963

Stocks	Classification	Number of Shares	Dividend Received	Book Value Mar. 1, 1963	Market Value Mar. 1, 1963
American Telephone and Telegraph Co.	Common	157	700.20	5,645.92	18,702.63
Consolidated Edison of New York, Inc.	Common	50	150.00	2,457.24	4,187.50
Continental Insurance Co.	Common	158	343.20	3,539.84	9,440.50
General Electric Co.	Common	150	300.00	2,341.47	10,987.50
Hartford Fire Insurance	Common	104	120.12	1,472.75	7,501.00
General Motors Corp.	Common	126	378.00	5,576.32	7,591.50
Jewel Tea Co., Inc.	Common	62	74.40	1,467.10	3,301.50
National Dairy Products Corp.	Common	100	205.00	1,154.74	6,162.50
New England Electric System	Common	198	221.76	3,070.39	5,172.75
Pacific Gas and Electric Co.	Common	315	315.00	3,594.69	10,316.25
Scott Paper Co.	Common	263	210.40	5,944.04	8,514.63
Southern California Edison Co.	Common	177	169.92	1,932.99	5,487.00
Standard Oil of New Jersey	Common	300	793.20	3,019.13	17,812.50
Texaco, Inc.	Common	344	766.40	2,351.05	20,941.00
Union Carbide Corp.	Common	100	360.00	2,958.44	10,325.00
Pacific Gas and Electric Co.	Preferred	100	150.00	2,704.89	3,325.00
Radio Corporation of America	Preferred	20	70.00	1,720.75	1,590.00
Southern California Edison Co., Ltd.	Preferred	120	112.40	1,140.24	3,600.00
Southern Railway Co.	Preferred	75	75.00	1,136.80	1,518.75
Totals			5,515.00	53,228.79	156,477.51

TABLE VII

RECORD OF INVESTMENTS—CO-OPERATIVE BANK

Co-operative Bank	Classification	Interest Received	Book Value Mar. 1, 1963	Market Value Mar. 1, 1963
First Federal Savings and Loan Association of Boston, Acct. No. 1S-631	Savings Account	192.37	4,808.92	4,808.92

TABLE VIII
Comparison of Book Values During Last Five Years

Year	1959	1960	1961	1962	1963
Bonds	52,944.75	51,942.25	51,942.25	50,818.46	62,293.77
Stocks	52,026.74	52,108.32	55,193.47	55,960.99	53,228.79
Savings Bank	4,155.11	4,291.23	4,442.74	4,616.55	4,808.92
Available for Investment	1,208.18	725.74	3,091.79	1,998.10	2,919.21
Totals	110,334.78	109,067.54	114,670.25	113,394.10	123,250.69

TABLE IX
Comparison of Market Values During Last Five Years

Year	1959	1960	1961	1962	1963
Bonds	47,671.60	44,690.65	47,112.52	45,747.51	58,323.13
Stocks	135,493.75	133,957.52	150,583.26	177,346.88	156,477.51
Savings Bank	4,155.11	4,291.23	4,442.74	4,616.55	4,808.92
Available for Investment	1,208.18	725.74	3,091.79	1,998.10	2,919.21
Totals	188,528.64	183,665.14	205,230.31	229,709.04	222,528.77

TABLE X
Comparison of Earnings from Invested Funds During Last Five Years

Year	1959	1960	1961	1962	1963
Bonds	1,738.85	2,133.52	1,922.50	1,907.50	1,892.50
Stocks	4,708.05	5,000.46	5,028.66	5,259.55	5,515.00
Savings Bank	151.22	136.12	151.51	173.81	192.37
Totals	6,598.12	7,270.10	7,102.67	7,340.86	7,599.87

REPORT OF THE AUDITING COMMITTEE

Boston, Mass., March 21, 1963

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.

HARRY L. KINSEL
ALEXANDER J. BONE

REPORT OF THE EDITOR

Boston, Mass., March 18, 1963

To the Board of Government
Boston Society of Civil Engineers

The Journal was issued quarterly, in the months of April, July and October, 1962 and January, 1963, as authorized by the Board of Government on December 20, 1936.

During the year there have been published 19 papers presented at meetings of the Society and Sections.

The four issues of the Journal contained 297 pages of papers and proceedings, 7 pages of Index and 40 pages of advertising, a total of 344 pages. An average of 1650 copies per issue were printed.

The cost of printing the Journal was as follows:

Expenditures	
Composition and printing	$3,875.89
Cuts	757.45
Wrapping, mailing & postage	325.39
Editor	749.07
Copyright	16.00
Envelopes for mailing	205.11
	5,928.91
Receipts	
Receipts from sale of Journals and reprints	$2,459.13
Receipts from Advertising	1,577.20
	$4,036.33
Net cost of Journal to be paid from Current Fund	$1,892.58

CHARLES E. KNOX, *Editor*

REPORT OF THE HOSPITALITY COMMITTEE

Boston, Mass., March 21, 1963

To the Boston Society of Civil Engineers:

The Hospitality Committee submits the following report for the year 1962-1963.

A total of eleven meetings of the Society were held during the past year. Included in this total were the Annual Dinner, a Student Night Meeting, a joint meeting with the American Society of Civil Engineers, and eight regular meetings of the Society.

Catered dinners were served prior to eight of the eleven meetings.

The average attendance of members and guests for all eleven meetings or dinners (using the larger attendance figure) was 86, as compared to last year's average of 70. Attendance at regular meetings of the Society during the past year averaged 64 persons per meeting. This represents a 23% increase in attendance from the levels recorded during the past two years.

SUMMARY OF MEETINGS AND ATTENDANCE

Date	Place	Attendance	
		Meeting	Dinner
March 22, 1962	M.I.T. Faculty Club	40	159
April 30, 1962	Hotel Lenox	94	94
May 16, 1962	United Community Services Bldg.	83	53
May 23, 1962	United Community Services Bldg.	85	53
September 24, 1962	United Community Services Bldg.	60	48
October 17, 1962	Worcester Polytechnic Inst.	181	160
November 28, 1962	United Community Services Bldg.	60	49
December 5, 1962	United Community Services Bldg.	50	39
January 23, 1963	Society Rooms	78	—
February 13, 1963	Society Rooms	65	—
February 27, 1963	Society Rooms	30	—

CLEMENT D. ZAWODNIAK, *Chairman*

REPORT OF THE LIBRARY COMMITTEE

Boston, Mass., March 21, 1963

To the Boston Society of Civil Engineers:

The Library Committee held its first meeting October 30, 1962 at the Society headquarters. The meeting was devoted to two topics: (1) the expenditure of $150 for purchase of new books, and (2) a study of the library facilities and a discussion of up-dating the present books in the library. Further business of the Committee has been conducted by phone and correspondence.

The Library Committee unanimously agreed that the existing library books should be reviewed carefully and a report submitted as to those books that should be discarded and those to be retained. The Committee recommends that the new Library Committee for 1963-64, or another committee appointed expressly for the assignment, be instructed to study the library facilities and report at the Annual Meeting in 1964. This report should give a complete report on all books and periodicals, and submit lists of those to be retained and those to be discarded.

If the Library Committee is to have this responsibility, the chairman of this Committee should have the power to appoint additional members to assist in the study.

A copy of "Design of Multistory Reinforced Concrete Buildings for Earthquake Motions" was presented to the library by Mr. James P. Archibald.

The following is a list of books purchased for this year. The books purchased have a list value of $187.50 and were purchased for $150.00.

Handbook of Engineering Mechanics, Edited by W. Flugge
Materials for Architecture, by Caleb Hornbostel
Biological Waste Treatment, by Eckenfelder and Fergamon
The Planning and Design of Airports, by Robert Horonjeff
Foundation Engineering, by G. E. Leonards
Non-Destructive Testing of Concrete, by Jonen
Mechanics of Engineering Structures, by G. L. Rogers
Handbook on Fluid Mechanics, by Streeter
Proceedings of the Western Conference on Prestressed Concrete Building, Edited by T. Y. Lin and J. W. Kelly
Concise Guide to Structural Adhesives, by W. H. Guttmann
Prestressed Concrete Cylindrical Tanks, by Creasy
Matrices for Structural Analysis, by McMinn
An Introduction to the Dynamics of Framed Structures, by Rogers

EARLE F. LITTLETON, *Chairman*

REPORT OF THE JOINT LEGISLATIVE COMMITTEE

Boston, Mass., March 1, 1963

To the Boston Society of Civil Engineers:

There were two bills of major interest taken up by the General Court in the 1962 session. Both failed to pass. One related to incorporation of professions to practice specified professions. It was supported by the medical, legal, and other professions. The other bill concerned a requirement that seals of professional engineers bear an identification of the field of practice of said engineers.

Bills of interest in the 1963 calendar are as follows:

Before Committee on Mercantile Affairs:

Senate 368	Requiring the seal of Architect or Engineer on plans and specifications for construction or alteration of buildings and structures.

Before Committee on State Administration:

House 1103	Defining the phrase "Field Engineer" and to provide for registration of field engineers.
House 1104	Requiring that the seals of professional engineers bear an identification of the field or fields of practice of said engineers.

Before Committee on Judiciary:

House 1951 and House 2257	Identical bills to authorize the incorporation of professional corporations to practice specified professions.

Copies of these bills may be obtained at the Document Room, 4th Floor of the State House. Interested engineers should plan to contact their representatives in the legislature.

A Corporation was formed on January 15, 1963, known as Committee to Uphold the Principles of Engineering Registration Laws, Inc. The purposes are briefly to

1. Safeguard and advance the interests of the general public by improving the practice of engineering and of land surveying through increasing the effectiveness of engineering registration laws.
2. Receive and investigate complaints of illegal practice of engineering, of negligence, incompetency, and misconduct of registered and unregistered engineers and land surveyors, and report on same to the proper authorities.
3. The foregoing will include the presentation of complaints to the Board of Registration of Professional Engineers and of Land Surveyors, District Attorneys, or Attorney General, as well as the making of recommendations toward expulsion from Professional and Technical Societies, and to this end to provide liaison with the many engineering societies and appropriate governmental agencies.

This new committee was incorporated with the following Board of Trustees:

Frank L. Heaney, *Chairman*
Walter J. Kreske, *Vice Chairman*
Philip H. White, *Secretary-Treasurer*
Dr. Harl P. Aldrich
Kenneth E. Reynolds
Marshall Schneider
Robert A. Snowber

The authorized number of the members of the corporation is eighteen. The members will be selected from those nominated by various Massachusetts engineering societies. It is hoped that a broad representation can be secured.

Legislative Committee

EDWARD WRIGHT, *Chairman*
RALPH M. SOULE
FRANK L. HEANEY

REPORT OF THE JOHN R. FREEMAN FUND COMMITTEE

Boston, Mass., March 18, 1963

To the Boston Society of Civil Engineers:

Last Spring the Committee offered a Scholarship with a stipend of $5,000 for a single man and $6,000 for a married man, plus expenses for traveling or equipment. There were only two applications, neither of which was accepted by the committee.

The Committee is offering a similar Scholarship this Spring with a stipend of $6,000 for a single man and $7,500 for a married man. Applications close April 1, 1963.

HOWARD M. TURNER, *Chairman*

REPORT OF COMMITTEE ON SUBSOILS OF BOSTON

Boston, Mass., March 18, 1963

To the Boston Society of Civil Engineers:

Following is the Annual Report of the Committee on Subsoils of Boston.

Engineering and Architectural firms are being solicited for Boston boring data, particularly from deep borings put down in the last ten years. This is part of the continuing program to bring up to date the published boring data of Greater Boston.

DONALD G. BALL, *Chairman*

REPORT OF THE ADVERTISING COMMITTEE

Boston, Mass., March 21, 1963

To the Boston Society of Civil Engineers:

The Advertising Committee held no formal meetings during 1962 as it has been the custom to have the Office Secretary act as the advertising agent for the Journal.

The following number of advertisements were printed in the Journal during the past year.

	April, 1962	July, 1962	Oct., 1962	Jan., 1963
Professional Card	36	36	36	36
Full Page	1	1	1	1
½ Page	1	1	1	1
¼ Page	17	17	17	17
Inside Front Cover	1	1	1	1

The total accounts were $1,577.20.

The above table indicates a decrease in the number of participating advertisers as compared to previous years. It is apparent that more personal contact between the society's representative and prospective advertisers is required to increase the volume of advertising.

The Committee recommends that several members of the Society be approached to donate time during normal working hours to solicit new business or that the society engage a part-time solicitor to handle the contact work.

ROBERT C. MARINI, *Chairman*

REPORT OF JOINT COMMITTEE ON PROFESSIONAL CONDUCT

Boston, Mass., March 18, 1963

To the Boston Society of Civil Engineers:

The Joint Committee on Professional Conduct was formed last year. It consists of representatives of three Societies, Massachusetts Section, American Society of Civil Engineers; Boston Society of Civil Engineers; and the Massachusetts Society of Professional Engineers. The statement of purposes was approved by the Board of Government of the Boston Society of Civil Engineers on December 18, 1962, as follows:

1. To receive information regarding and study cases of alleged violation of proper professional conduct.
2. To report to the Societies represented on the Joint Committee all cases

which, in the opinion of the Joint Committee, are violations of proper professional conduct involving a member of one or more of the Societies. This report shall include recommendations for action by the Society or Societies of which the individual or individuals are members. Among the actions taken by the Societies may be notification of the Massachusetts Board of Registration as well as of the Joint Committee of any punitive action taken by the Society or Societies.

3. The Joint Committee may act, consistently with the Codes of Ethics and related professional rules of the member Societies, in correspondence, conferences and negotiations with other engineers, owners, public bodies, authorities and commissions regarding questions of ethics and professional conduct. The results of negotiations which appear to involve a modification in the Code of Ethics or professional rules of any of the member Societies shall be reported to the governing body of each of the member Societies before such negotiations are concluded.

   The Committee shall, from time to time, report on its activities to the member Societies. The Committee may publish and announce to the engineering profession and to the public its existence, purposes and activities.

The Committee has been recently most concerned with methods of awarding engineering contracts. In its opinion the method now used by the Metropolitan District Commission requests in effect competitive bids on engineering contracts. The Committee in two cases has written to all engineers submitting propositions that if prices were submitted it constituted competitive bidding. Copies of these letters were sent to the Commissioner.

The Committee is now engaged in discussion with the Commissioner regarding this method of awarding of these contracts.

HOWARD M. TURNER, *Chairman*

REPORT OF THE EXECUTIVE COMMITTEE OF THE CONSTRUCTION SECTION

Boston, Mass., March 4, 1963

To the Construction Section
Boston Society of Civil Engineers:

The following meetings of the Construction Section were held during the past year:

March 28, 1962—Mr. David A. Werblin, Griffin Wellpoint Corporation, presented an illustrated talk on the "Control of Ground Water in Construction Work." Attendance 65.

May 23, 1962—Joint Meeting with Main Society and Sanitary Section. Mr. H. P. Ripman, Head of Industry Division, International Bank for Reconstruction and Development, presented a talk on the "Challenge of Civil and Sanitary Engineering Works in Undeveloped Countries. Attendance 85.

October 31, 1962—Mr. Herman G. Protze, Vice President of Masslite Inc., presented an illustrated talk on "Design and Construction with Lightweight Structural Concrete." Attendance 45.

JAMES P. ARCHIBALD, *Chairman*

REPORT OF THE EXECUTIVE COMMITTEE OF THE HYDRAULICS SECTION

Boston, Mass., February 19, 1963

To the Hydraulics Section
Boston Society of Civil Engineers:

The following meetings were held during the past year:

May 2, 1962—Mr. Frank E. Perkins, Research Engineer, Hydrodynamics Laboratory, Massachusetts Institute of Technology, discussed "A New Approach to the Study of Transients of Hydro-Power System." Slides were shown and a question period followed. Attendance 21.

November 7, 1962—Mr. K. Peter Devenis, Project Manager, Charles A. Maguire & Associates, gave a talk on "Proposed Dam, Navigation Locks, and Flood Control Pumping Station for Mystic River Basin." A movie and slides were shown which were followed by a question and answer period. Attendance 63.

February 6, 1953—Mr. Lawrence C. Neale called the meeting of the Hydraulics Section to order. The reading of minutes of the previous meeting was dispensed with and the report of the nominating committee was read and accepted. The nominating committee, consisting of three former chairmen, was as follows:

Lee Marc G. Wolman
John B. McAleer
Donald R. F. Harleman

The following slate of officers for 1962 was approved:

Richard F. Dutting, *Chairman*
Keistutis P. Devenis, *Vice-Chairman*
Peter S. Eagleson, *Clerk*
Allan Grieve, *Executive Committee*
Nicholas Lally, *Executive Committee*
Llewellyn L. Cross, *Executive Committee*

The speaker was Mr. Joseph M. Caldwell, Chief, Research Division U.S. Army Corps of Engineers, Beach Erosion Board, who discussed "The North Atlantic Coastal Storm of March, 1962." The meeting was followed by a very interesting discussion period. The meeting was adjourned at 8:30 P.M. Attendance 36.

The total attendance for the three Hydraulics Section Meetings during the year was 120; the average attendance 40.

K. P. Devenis, *Clerk*

REPORT OF THE EXECUTIVE COMMITTEE OF THE SANITARY SECTION

Boston, Mass., March 7, 1963

To the Sanitary Section
Boston Society of Civil Engineers:

A brief account of the four meetings held by the Sanitary Section during the past year is as follows:

March 7, 1962—Annual Meeting. The officers and members of the Executive Committee elected were:

George W. Hankinson, *Chairman*
Charles Y. Hitchcock, Jr., *Vice Chairman*
William C. Traquair, *Clerk*
Francis T. Bergin, *Executive Committee*
James M. Symons, *Executive Committee*
Roland S. Burlingame, *Executive Committee*

Mr. Chester J. Ginder of the Metropolitan District Commission presented a paper on the Incinerator at Nut Island Sewage Treatment Plant. Attendance 36.

May 23, 1962—Joint Meeting with Main Society. Mr. Hugh P. Ripman of the International Bank for Reconstruction and Redevelopment presented a paper entitled "Nature of Bank's Activity in Field of Engineering." Fifty-five members and guests attended the dinner preceding the meeting and seventy attended the meeting.

October 3, 1962—A paper entitled "Sanitary Survey of the Mystic River Basin—Summer of 1961," was presented by Dr. Henry Campbell of the University of Rhode Island. Twenty-one members and guests attended the dinner preceding the meeting and thirty-two attended the meeting.

December 5, 1962—Joint Meeting with Main Society. Professor Harold A. Thomas, Jr., of Harvard University and Dr. Robert P. Burden of Harvard University presented a paper entitled "Rebirth of an Asiatic Breadbasket." Forty-eight members and guests attended the dinner preceding the meeting and fifty-eight attended the meeting.

Four meetings of the Executive Committee were held during the year.

William C. Traquair, *Clerk*

REPORT OF THE EXECUTIVE COMMITTEE OF THE STRUCTURAL SECTION

Boston, Mass., March, 1963

To the Structural Section
Boston Society of Civil Engineers:

There were seven meetings held and one field trip of the Structural Section which were held as follows:

April 11, 1962—Mr. Roland S. Burlingame, Partner, Camp, Dresser & McKee spoke on the "Construction of a Novel Pre-Stressed Water Tank for Calis, Columbia." Attendance 26.

May 9, 1962—Mr. Charles I. Orr, District Engineer, American Bridge Division, U.S. Steel Corp., spoke on the "Structural Aspects of Unisphere." Attendance 28.

October 10, 1962—Mr. William H. Conley, Structural Engineer, Cleverdon, Varney and Pike, spoke on "Design of Prestressed Concrete-Elastic Design Concepts." Attendance 26.

November 3, 1962—Field trip to Hanover, N.H. to inspect Cold Regions Research Laboratory and new Dartmouth College Field House which was designed by Pier Luigi Nervi. Prof. John H. Minnich of Thayer School of Engineering spoke on the field house.

December 12, 1962—Prof. Robert V. Whitman, Associate Professor of Civil Engineering, M.I.T. spoke on "Tests Upon Thin Domes Buried in Sand." Attendance 39.

January 9, 1963—Mr. Stiles F. Stevens, Senior Soils Engineer, Charles A. Maguire & Associates, spoke on the "Foundation and Structural Aspects of the Mystic River Dam." Attendance 55.

February 13, 1963—Joint Meeting with Main Society and Annual Meeting of Structural Section. The following officers for 1963-64 were elected: Chairman, Dr. Harl P. Aldrich, Jr.; Vice-Chairman, Max D. Sorota; Clerk, Donald T. Goldberg; Executive Committee, Mark M. Kiley, Robert L. Fuller and Maurice A. Reidy, Jr.

Speakers of the evening were Prof. R. J. Hansen, Director of Laboratory of Structural Models, Dept. of Civil Engineering M.I.T., and Mr. William A. Litle, instructor and doctoral candidate, Dept. of Civil Engineering, M.I.T., who spoke on "The Use of Models in Structural Design." Attendance 65.

March 13, 1963—Prof. Harry M. Horn, Assistant Professor of Civil Engineering, M.I.T. spoke on "Analysis and Design of Antenna Foundations." Attendance 52.

The total meeting attendance for the year was 271; average 39.

MAX D. SOROTA, *Clerk*

REPORT OF THE EXECUTIVE COMMITTEE OF THE SURVEYING AND MAPPING SECTION

Boston, Mass., February 15, 1963

To the Surveying and Mapping Section
Boston Society of Civil Engineers:

Three meetings of the Surveying and Mapping Section were held during the past year as follows:

May 16, 1962—Joint meeting with the Boston Society of Civil Engineers. Mr. Richard L. Cameron, Cambridge Air Force Research Center, spoke on "New England during the Ice Age." Attendance 85.

October 24, 1962—Mr. John Paddleford of the M.I.T. Lincoln Laboratory spoke on "Surveying at Lincoln Laboratory." In addition, Mr. Paddleford showed a movie entitled "The Dew Line in Canada." Attendance 20.

January 16, 1963—Annual Meeting—The following officers were elected for the coming year:

Joseph A. Bodio	*Chairman*
Alexander E. Manning	*Vice Chairman*
Robert E. Cameron	*Clerk*
John P. Hurney	*Executive Committee*
Robert F. Daylor	*Executive Committee*
Roger C. Collette	*Executive Committee*

Following the elections, Dr. Lloyd Thompson of the Cambridge Air Force Research Center gave an illustrated talk on "The Status of Gravity Measurement Techniques." Attendance 15.

Total attendance for the year was 120; average attendance 40.

The Executive Committee met on October 24, 1962 at which time, plans were formulated to conduct a series of surveying lectures to be held during 1963. Topics for these lectures and prospective speakers were tentatively set-up. Final plans were to be announced at a later date.

RICHARD D. RASKIND, *Chairman*

An 84-page document entitled "Educational and Research Activities in Civil Engineering at the Massachusetts Institute of Technology" has been published recently. The objective of this illustrated document is "to acquaint others with many of the significant activities in civil engineering education and research currently underway at M.I.T. The current professional interests of the faculty and examples of modern civil engineering research are described in a series of specific activity statements, with related information to indicate the scope and magni tude of these activities." Of interest to engineers and students, it is available by writing to Professor C. L. Miller, Head, Department of Civil Engineering, M.I.T., Cambridge 39, Mass.

BOSTON SOCIETY OF CIVIL ENGINEERS

PUBLICATIONS

The Boston Society of Civil Engineers has several publications that are of service to the engineering profession. Some individual Journals are extremely limited and it is possible that the supply will be exhausted in the near future.

Below you will find a list of publications currently available which may be purchased from the B.S.C.E. Price includes postage within the U.S.A. Check must accompany order for publications.

Subscription to Journal per year	\$7.00
Individual copies of Journal	\$1.75
Soil Mechanics, Vol. I, 1925-40	\$4.00
Soil Mechanics, Vol. II, 1941-53	\$4.00
Seminar Papers on Waste Water Treatment and Disposal	\$4.00
Boring Data of Greater Boston	\$5.00

PROFESSIONAL SERVICES

AND

ADVERTISEMENTS

The advertising pages of the JOURNAL aim to acquaint readers with Professional and Contracting Services and Sources of Various Supplies and Materials. You would find it of advantage to be represented here.

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BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

PROFESSIONAL SERVICES

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1963-1964

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James W. Daily
Richard W. Albrecht
Roy L. Wooldridge
(Term expires March, 1964)

Edward C. Keane
Myle J. Holley, Jr.
Clyde W. Hubbard
Frank L. Heaney
(Term expires March, 1965)

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Arthur Quaglieri
Robert L. Fuller

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Ralph M. Soule, *Chairman*

Herman G. Dresser
Saul Namyet

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George M. Reece
Ralph M. Soule

STRUCTURAL SECTION AWARD

Percival S. Rice, *Chairman*

Saul Namyet
Richard H. Olney

HYDRAULICS SECTION AWARD

Clyde W. Hubbard, *Chairman*

Lawrence C. Neale
Lee M. G. Wolman

SURVEYING & MAPPING SECTION AWARD

Charles M. Anderson, *Chairman*

Wilbur C. Nylander
Richard D. Raskind

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Alexander J. Bone, *Chairman*

Thomas C. Coleman
James W. Haley

CONSTRUCTION SECTION AWARD

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