MDC

JOURNAL of the BOSTON SOCIETY OF CIVIL ENGINEERS

FAB TEEN

1848 BOSTON SOCIETY OF CIVIL ENGINEERS

APRIL - 1941

VOLUME XXVIII NUMBER 2

BOSTON SOCIETY OF CIVIL ENGINEERS

JOURNAL OF THE

BOSTON SOCIETY OF CIVIL ENGINEERS

Volume XXVIII | APRIL, 1941 | Number 2

CONTENTS

PAPERS AND DISCUSSIONS

OF GENERAL INTEREST

ANNUAL REPORTS

Entered as second-class matter, January 15, 1914, at the Post Office at Boston, Mass., under Act of August 24, 1912

Published four times a year, January, April, July and October, by the Society
715 Tremont Temple, Boston, Massachusetts

Subscription Price $4.00 a Year (4 Copies)
$1.00 a Copy

Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized on July 16, 1918.

The Heffernan Press
Worcester, Mass.

JOURNAL OF THE

BOSTON SOCIETY OF CIVIL ENGINEERS

Volume XXVIII APRIL, 1941 Number 2

SOME OBSERVATIONS ON ENGINEERING FOR NATIONAL DEFENSE

PRESIDENTIAL ADDRESS BY ARTHUR L. SHAW,* BOSTON SOCIETY OF CIVIL ENGINEERS, MARCH 19, 1941

WHILE I do not find that this subject has ever been dealt with in a presidential address before this society, either during or since the First World War, nevertheless I will venture that a majority of those present would choose it if asked to guess what I might be planning to talk about. I confess that I have been unable to think of a more appropriate topic in these times when national defense, and the conditions which make it necessary, hold the center of the stage.

The point of view of engineering has suddenly turned from *con*struction to *de*struction. The peacetime aims of the engineering profession are mainly concerned with the advancement of human comfort and convenience in an economical manner; in wartime, on the other hand, economy is forgotten and the objectives become essentially those of destruction or its prevention. The skill and brains are the same but the purposes are almost diametrically opposite.

Engineering for defense finds its functions divided between those closely related to military requirements and those primarily concerned with what may be termed civil defense. The military function includes the creation of new, and the expansion of old, cantonments, airfields, ship and navy yards, munitions plants and the like, and indirectly the production of a wide range of materials and equipment for the use

*Member of firm, Metcalf and Eddy, Consulting Engineers, 1300 Statler Building, Boston, Mass.

of the armed forces. The civil function includes the engineering features of such problems as organization for the prevention of sabotage of waterworks and other utilities, and for the prompt restoration of such utilities if damaged by subversive acts or enemy bombs. There is no sharp distinction between the military and civil functions, because in these days of "total war" military success is more concerned than ever before with the security of civilian morale which in turn depends upon the maintenance, as nearly as possible, of the normal routine of life.

Civilian engineers for the past several months have taken on, and are still carrying, a heavy load in connection with the construction of strictly military establishments, working for or with the various branches of the military and naval services. In many, if not most, instances these undertakings are not particularly to the liking of civilian engineers because the paramount requirement of speed is often at the sacrifice of sound economy. Under normal conditions most engineers have the confirmed and admirable habit of deliberate study of all aspects of a problem before making important decisions. In the present emergency, on the other hand, haste is, or is thought to be, the one vital essential. The penalty of having so long deferred national preparedness, is the necessity of now rushing into important undertakings, making decisions in rapid, and often unrelated sequence. To those whose health can stand it, a certain stimulation is derived from the necessity of completing work within arbitrary time limits. Perhaps the normal American way of life has been too complacent, taking too much for granted, and will in some way profit from the jolt of the present emergency. It is to be hoped that some such good may come out of a state of world affairs which seems so altogether bad.

Some progress has been made in the direction of engineering for civil defense although this problem is new and has no background of previous similar experience except such as filters through from the very recent experiences in England and Europe. Outstanding is the work done by waterworks men through their professional associations in codifying means of safeguarding vulnerable spots and planning emergency methods of repair and replacement of vital features of water supply systems. Much has also been accomplished, though with a minimum of publicity, on the engineering of plans for emergency fire fighting. Doubtless engineering will also find indirect application in the civilian organizations for defense, through the exercise of engineering principles in the essential routine of these activities.

In the last war the civil engineer was mainly concerned with cantonments for troops, housing developments, factory expansions, and port facilities. To these the present emergency has added the newer problems of military airfields. Many of the fundamentals such as water supply, sewerage and sewage disposal, drainage and housing are somewhat similar to those of the troop cantonments for which there is a certain amount of past experience, although there are certain fundamental variations due to difference in daily routine as compared with the usual troop cantonment. In the latter, extraordinary peaks are expected because the lives of most of the inhabitants are regimented; they rise, eat, work, and retire on a set schedule throughout the whole community. The airfield, on the other hand, is usually the headquarters of a number of pursuit or bomber squadrons, and has a population whose numbers and habits may be at the other extreme of irregularity due to the variable goings and comings and absences of the several squadrons. The use of water at comparatively high rates in the so-called aqua-system of gasoline feeding also introduces an important new factor in water supply of about the same magnitude as that for fire protection. Furthermore, numerous unusual situations are encountered in developing the leased bases at the outlying British insular possessions; and everywhere the layout, grading and surfacing of runways of unprecedented lengths for huge and heavy military aircraft introduce problems upon which practice has not yet crystallized and in regard to which experience is as yet very limited.

Thus far the emphasis at most of our airfields has been largely upon speed of construction so as to get men under training at the earliest possible moment. Only recently, those who feel that concealment and protection are also of major importance, have been able to bring sufficient pressure to cause these considerations to appear in the basis of design.

The construction and equipment of hangars is one of the controversial matters upon which few military authorities are in agreement, and in which civilian engineers will be able to be of service in weighing non-military considerations. Among the questions to be answered are whether to erect hangars or other distinctive structures in plain sight and depend upon anti-aircraft defense to keep the enemy so high that the chance of a direct hit is small, or to put them underground and risk the blocking of the access elevators or ramps by well placed bombs; and if underground, whether to provide the necessary deep cover essential to protect against direct hits, or to bury them merely for concealment.

The dispersion of buildings to avoid conspicuous regularity of pattern, the protective coloring of runways, the special treatment of cuts and grading for railroad sidings, and the elimination of landmarks such as elevated water tanks, are beginning to have serious consideration. In these and other directions the civilian engineers who are assisting the army and navy will increasingly find scope for ingenuity, unlimited except by the call for speed in execution.

The use of the airplane as a military weapon is comparatively new and opportunity for improvement is therefore enormous. The existing peacetime developments in aviation have been rapidly adapted to warlike purposes; and in addition, the science of aeronautics is leaping ahead at a rate impossible in peace time. The engineer and scientist is no longer limited by financial and economic considerations in this or in fact in any field of research related to defense or offense. All economic restrictions are now removed, permitting experimentation and development regardless of cost, all with a view to improving the weapon as speedily as possible. Thus when the emergency has passed and the improvements developed in airplanes for military purposes in speed, capacity, maneuverability and instrumental control later find adaptation in commercial aircraft, the industry will find itself far ahead of the point which would have been reached had new development been limited by the need to keep the balance sheet out of the red. This is one bright spot in the outlook which has so many gloomy aspects.

The requirements of national security not only create a heavy demand upon the time of engineers already in the profession, but also place a severe drain upon the supply of new material. The technical schools and colleges are studying means for grinding out a larger grist of new graduates in a time shorter than normal, but there is reason to believe that at best this can supply but temporary relief. If courses are shortened from four to three years, and assuming that the number of college entrants will remain about the same, the annual output after the third year will be no greater than at present; and the experiences of the last war are not encouraging as to the relative value of acquiring engineering fundamentals by intensive instruction as compared with conventional procedure. At a time when the trend has been definitely toward five or even six years for engineering education the proposal to shorten the term to three years is of doubtful expediency.

Selective service, or "the draft", is in competition for the services of the younger men, and can cause serious embarrassment in disrupting the office and field organizations of engineers engaged in intensive work on defense undertakings. A perfectly proper "hard-boiled" attitude of draft authorities toward deferment adds to the difficulties. While young active engineers are extremely important in the production of closely scheduled undertakings, they can seldom be convincingly represented as "indispensible" within the interpretation of the authorities, no matter how difficult it may be to replace them promptly. This is equally true in industry, as well as in engineering, and must be accepted as an inevitable part of the confused helter-skelter and growing-pains of national defense.

The engineer has an increasing importance in strictly military functions as well as in the civilian capacity. Engineering intelligence and instinct have always been valuable in military road and bridge work, topographic and map reproduction units, field water supply and sanitation. To these is now added the comparatively recent adaptation of standard contractors' equipment of many types for hasty military construction; this and the recent extensive adoption of motorized units calls for engineering ingenuity in maintenance and operation as well as in mass production.

However well the engineer may meet the demands of national defense, and however successful the fruits of this service may be in keeping a destructive enemy away from our shores, it will have been of no avail unless the problems of readjustment, when peace again comes, are adequately met. Hundreds of thousands of men will have been uprooted from their normal status and used in the armed forces, in defense industries, and in all the other extraordinary activities of the scramble for national defense. Only the most thoughtful and intelligent planning for the re-establishment of these men and the re-normalizing of industry and national life after peace comes can prevent chaos which may be worse than war. The highest service of engineers will be required, planning and working with the nation's economic and industrial leaders, if normal activity is to be resumed, and man-power re-absorbed, with a minimum of upheaval. Planning for peace is as important a part of the present duty of the engineering profession as is working at the immediate job of national defense.

DESIGN OF FABRICATED PLATE STEEL TEES, LATERALS AND WYES OF LARGE DIAMETERS FOR THE PRESSURE AQUEDUCT OF THE BOSTON METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

BY CHESTER J. GINDER* AND EDWIN B. COBB,** MEMBERS

(Presented at a meeting of the Designers Section of the Boston Society of Civil Engineers held on November 13, 1940.)

PURPOSE OF THIS PAPER

THE purpose of this paper is to show in more or less detail some of the problems which were encountered in the design and construction of pipeline fittings such as Tees, Laterals, and Wye Branches of fairly large sizes, fabricated from plate steel and reinforced either by steel structural members or reinforced concrete to withstand internal pressure. The sizes of the fittings concerned in this paper vary from a 60 inch x 48 inch x 48 inch Lateral which was the smallest fitting built, to the largest fittings which were 108 inch x 72 inch x 72 inch Wye Branches.

The fundamental problem which this type of construction presents is that of satisfactorily supplying to the plate steel pipe shell some form of reinforcement or anchorage where the shell is interrupted by an opening for the branch of a tee, lateral or wye.

At the time this problem presented itself a considerable search was made through engineering literature, for suggestions on design and construction methods for this type of work with little or no success.

The search for information was continued throughout the design period and during the preparation of this paper, with the result that a few articles and illustrations were found. Several references were located which covered experiments relative to the stress distribution in boiler and steam header shells around openings for take-offs. These dealt primarily with thick walled cylinders and with openings of diameters small in relation to the diameter of the boiler or header and were of little assistance. Several pictures and articles, however,

*Asst. Civil Engineer, Metropolitan District Water Supply Commission.
**Formerly Senior Civil Eng. Draftsman, Metropolitan District Water Supply Commission.

were found showing how Tees and Laterals had been designed on other projects, particularly the Penstock Wye at the Elephant Butte Power Plant and the outlet Pipe Lateral at the Deer Creek Dam, both by the U. S. Bureau of Reclamation, and it is interesting to note that the solutions arrived at independently by the Commission are quite similar to those shown in these articles.

Scope of Investigations

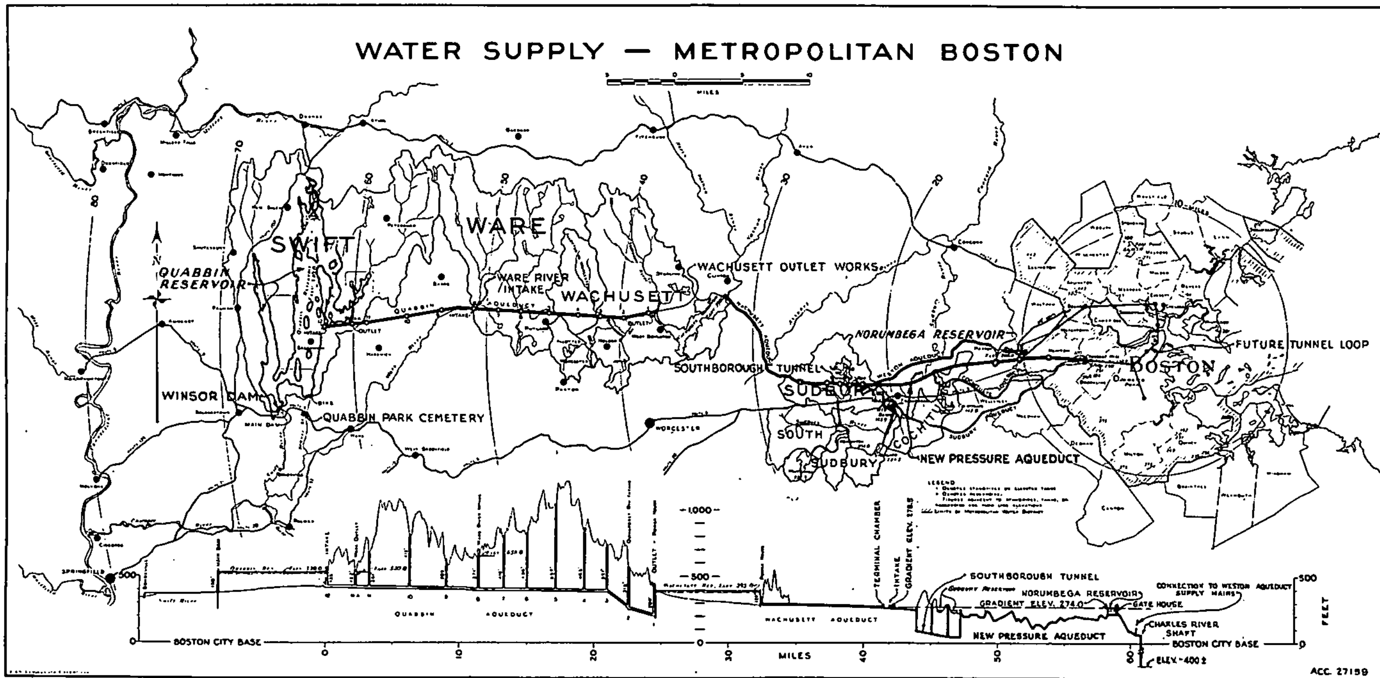
It is not to be presumed that the designs developed in the course of these studies represent the last word or a complete treatment of the subject. The studies were restricted by the fact that a very limited amount of time could be expended upon that part of the work without seriously delaying the construction. It appears that had more time been available, certain modifications would undoubtedly have been introduced in both the design methods and also the construction. However, it is felt that the methods used will be of interest to many inasmuch as information with respect to this particular type of problem appears to be limited.

The fittings with which this paper is concerned were incorporated in the construction of a pressure aqueduct line recently built by the Metr. Dist. Water Supply Commission and a brief general description of the work follows.

Pressure Aqueduct. General Description

The Metropolitan District Water Supply Commission in 1938 began construction on a 23-mile pressure aqueduct for the Boston Metropolitan District from the Wachusetts Aqueduct terminal chamber to Chestnut Hill. The aqueduct includes a section of 12.5-foot diameter surface conduit paralleling and superseding the open channel into Sudbury Reservoir; a section of tunnel 14 feet in diameter, running beneath and by-passing the Sudbury Reservoir; and a section which parallels and supersedes the Sudbury and Cochituate Aqueducts consisting in part of an 11.5-foot diameter surface conduit, and in part a pressure tunnel terminating at Chestnut Hill.

This new pressure aqueduct will eliminate the necessity of pumping at Chestnut Hill and is part of a plan of distribution which will include a pressure-tunnel loop under the central portion of the District and eliminate the necessity of pumping at Spot Pond.



WATER SUPPLY — METROPOLITAN BOSTON
MILES
SWIFT
WARE
QUABBIN RESERVOIR
WARE RIVER INTAKE
WACHUSETT
WACHUSETT OUTLET WORKS
NORUMBEGA RESERVOIR
FUTURE TUNNEL LOOP
BOSTON
SOUTHBOROUGH TUNNEL
SUDBURY
SOUTH SUDBURY
COCHITUATE
NEW PRESSURE AQUEDUCT
WINSOR DAM
QUABBIN PARK CEMETERY
WORCESTER
1,000
500
0
TERMINAL CHAMBER
INTAKE
GRADIENT ELEV. 278.5
QUABBIN AQUEDUCT
WACHUSETT AQUEDUCT
SOUTHBOROUGH TUNNEL
NORUMBEGA RESERVOIR
GRADIENT ELEV. 274.0
GATE HOUSE
CONNECTION TO WESTON AQUEDUCT SUPPLY MAINS
CHARLES RIVER SHAFT
NEW PRESSURE AQUEDUCT
BOSTON CITY BASE
ELEV. -400±
FEET
MILES
0
10
20
30
40
50
60
ACC. 27159

FIG. 1

Weston Aqueduct which in recent years has carried the bulk of the entire supply to the district has been developed to its ultimate capacity and will be used principally in emergencies or as a standby once the new pressure aqueduct is placed in operation.

No attempt will be made in this paper to discuss any of the features of the new Pressure Aqueduct line except the design and construction of certain large plate steel pipe fittings which were incorporated in the work. Specifically this paper is concerned with the connection and control works which were built in the vicinity of the up-take shaft of the Southborough Tunnel, designated as Shaft 4, where a surface connection has been made between the tunnel section of the pressure aqueduct and the 11.5-foot diameter surface conduit which forms the adjacent portion of the pressure aqueduct line.

Location of the Work

Fig. 1 shows a general plan of the distribution system from

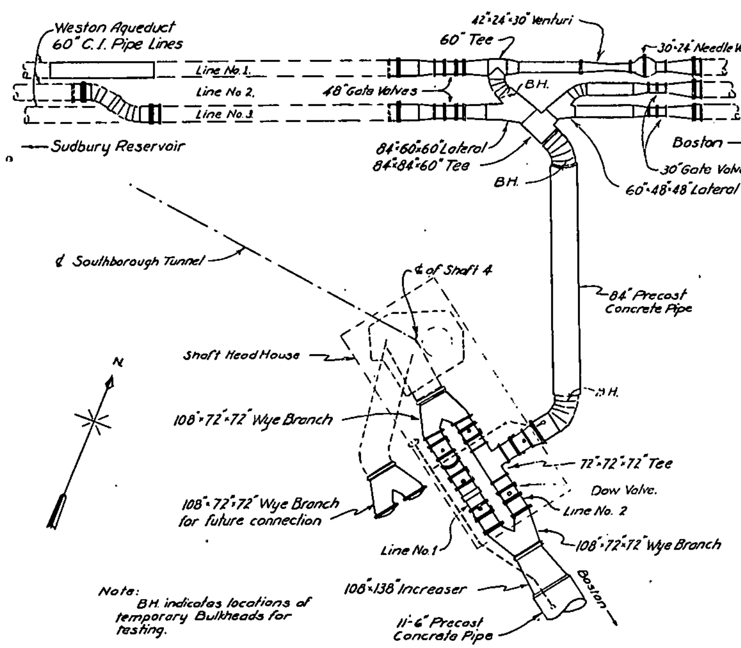


Fig. 2.—General Piping Layout. Connection at Shaft 4 and at the Weston Aqueduct.

Quabbin Reservoir to the District and includes the area traversed by the new Pressure Aqueduct.

Fig. 2 shows in larger detail the location of the up-take shaft of the Southborough Tunnel with respect to Sudbury Reservoir, the Weston Aqueduct, and the adjacent portion of the pressure aqueduct which consists of precast concrete pipe. From the vicinity where the surface connection between the up-take shaft and the precast concrete pipe occurs, a cross-connecting line to the Weston Aqueduct has been built. This cross-connection is principally composed of precast concrete pipe having an inside diameter of 7 feet with mortar lined plate steel pipe and fittings used to effect the connections required at either end of the concrete pipe. The plate steel fittings which have been built into this cross-connection to Weston Aqueduct and those built into the surface connection of the aqueduct line are the subject of this discussion.

SURFACE CONNECTION AT SHAFT 4

Shaft 4, the up-take shaft from the Southborough Tunnel, terminates in a plate steel 90° elbow, 108 inches in diameter. Connected to this elbow is a plate steel wye which divides the line into two parallel branches each 72 inches in diameter in which are located motor operated control and throttling valves of the Dow Disc type. In line number one there are three valves, two acting as guard gates and one for throttling purposes; while in line number two, two valves have been placed. Beyond the valves the two lines are rejoined by means of another plate-steel wye similar to the one mentioned previously, bringing the line up to the 108 inches in diameter. From this point a plate steel increaser 108 inches to 138 inches in diameter completes the connection to the first length of 11.5-foot precast concrete pressure pipe. In referring to the sizes of the plate steel pipe and fittings the diameters mentioned are in each case the net clear diameters to a 2 inch mortar lining, the actual inside diameters to the plate steel being 4 inches greater.

With respect to the valves, sizes smaller than the main pipe are used in order to reduce the cost and because smaller valves are easier and quicker to operate. The accompanying table gives the comparative costs of furnishing and delivering the larger valves.

Size Inches	Item	Cost
72	dow valve—cast iron body	$ 6,676
72	dow valve—cast steel body	11,237
48	gate valve—cast iron body	2,883
30	gate valve—cast iron body	2,523
42 x 24 x 30	Venturi meter tube	1,909
30 x 24	Flow regulator (needle valve)	7,680

In line number two is located a plate steel Tee 72 inch x 72 inch x 72 inch which is the take-off for the connection to Weston Aqueduct. This Tee is constructed with bell rings of cast steel welded to the plate steel permitting a lead slip joint connection to the cast iron adaptor pieces on either side.

On each of the wyes cast steel flanges riveted and welded to the plate steel allows a bolted connection to be made to the 72 inch flanged cast iron adaptor pieces adjacent to them. Except for the throttling valve which is cast steel, and the Tee which is of plate steel, with cast steel bells, the various items in the lines between the wyes are made of cast iron.

Connection to Weston Aqueduct

The connection from the pressure aqueduct to the existing Weston Aqueduct begins at the plate steel Tee located between the Dow valves in line number two of the surface connection already described. A 72 inch cast iron flange and spigot adaptor piece is next to the Tee then follow a 72 inch Dow valve, a flange and flange 72 inch to 84 inch cast iron increaser and finally an 84 inch plate steel bend running to the lower end of a section of 84 inch diameter precast concrete pipe. The 84 inch bend connects on to the spigot end of the precast concrete pipe and in order to accomplish this connection a rolled steel bell ring very similar in design to those built into the precast pipe was welded to the plate steel bend. This arrangement permitted the use of the same kind of a lead gasketed joint as is employed between the different lengths of precast concrete pipe. Beyond the precast concrete pipe, plate steel pipe and fittings are again employed to complete the connection to the Weston Aqueduct itself.

Weston Aqueduct at Sudbury Reservoir

The major part of the water delivered to the District from Sudbury Reservoir was, up to recently, carried from the Power House on Sudbury Dam to the Head Chamber of the Weston Aqueduct through two of three existing 60 inch cast iron pipes. The third 60 inch line, though not now connected to the Reservoir at the Power House was laid to the Head Chamber at the time the original works were built. Its connection to the Reservoir was cut at the time the power plant was installed at the Dam.

The construction work at this point had to be planned in such a way that the supply to the District could be maintained without interruption and a convenient means of accomplishing this was afforded by use of the third 60 inch line which was not then being used to supply Weston Aqueduct.

Construction Procedure

The first step in the construction at this point was to carry all the flow from Sudbury Reservoir to Weston Aqueduct through the 60 inch pipe designated as line number one so as to enable the contractor to break into lines number two and number three. The pipe within the area to be occupied by new construction was then removed, together with a number of additional lengths of the 60 inch pipe in line number two and these were taken to the site of other work being constructed at that time by the Commission and put back into service.

The first item of new construction consisted of a Reverse Bend Cross-over from line number two to line number three fabricated from plate steel and placed at a point about 130 feet west of the section where the principle construction was to be located. Cast steel flanges were welded and riveted on each end of the cross-over and by means of cast iron adaptor pieces satisfactory connections to the existing 60 inch cast iron pipe were made.

Following this step the entire new construction work for all the piping which had to be placed within the area formerly occupied by lines number two and number three were built including part of the 84 inch plate steel connection running from the precast concrete pipe to line number one. This 84 inch pipe was carried up as close to line number one as convenient and a bulkhead placed in the end so that it would then be possible to transfer the flow to Weston Aqueduct through the new work and proceed with the installation of the pipe and fittings designed for line number one.

In the new construction as shown in Fig. 2 it will be seen that plate steel.pipe and fittings form a considerable portion of the work. However, in each of the lines valves or other special items have been placed to properly control or measure the flow and this has required numerous changes in the size of the plate steel pipe and also numerous special connections. Built into line number one are a 48 inch gate valve, a 42 inch x 24 inch x 30 inch cast iron venturi meter tube and a 30 inch x 24 inch Larner Johnson Flow Regulator of the needle valve type. Line number three now has a 40 inch gate valve and a 30 inch gate valve placed in it and a 30 inch gate valve has been placed in the new portion of line number two. In most instances cast iron flange and spigot adaptor pieces are located adjacent to one side of each of the valves with plate steel increases connected to the other side by means of cast steel flange rings. However, on the discharge side of the needle valve and also thc 30 inch valves, the 30 inch x 60 inch increasers are made of cast steel because of the possible development of cavitation at those points.

Operation

The interconnections which have been built into the system at and near Shaft 4 allow considerable flexibility of operation. In brief the method of operation and control is as follows.

The new aqueduct line is now the principle carrier for the supply to the District. At the present the control of the flow is maintained at Wachusett, but at some time in the future when the entire system is under pressure the control will be at the surface connection at the top of Shaft 4, by use of the throttle valve in line number one. For flows amounting to less than the capacity of either line alone the valves in line number two will be kept closed and the desired flow maintained by throttling line number 1. When the required flow exceeds the capacity of line number one the valves in lines number two will be opened up wide and the throttling in line number one continued. When it becomes desirable to reduce the flow through the aqueduct the reverse procedure will be followed.

The arrangement of the other gates at this point are such as to permit access to the aqueduct to inspect or repair the various valves as well as to adequately control the flow.

It is also possible to direct flow from the tunnel into the Weston Aqueduct both when the new Pressure Aqueduct is being operated and when it is shut down. Nominally the flow will be divided at this point and both the new Pressure Aqueduct and the Weston Aqueduct used. Also the further conditions of sending water from Sudbury Reservoir to Weston Aqueduct as formerly, or sending water from Sudbury Reservoir through the new Pressure Aqueduct are possible as well as that of sending flow from the tunnel up into Sudbury Reservoir, though this latter condition of operation is unlikely inasmuch as if it becomes desirable to store water in Sudbury Reservoir a more convenient method is to do so by means of the spillway at Shaft 1 which discharges into the channel at the upper end of Sudbury Reservoir.

One of the reasons for the construction of the tunnel being the discontinuance of Sudbury Reservoir as a part of the system it will be seen that its use in the future either as a source of supply or for storage will be resorted to only in the event of an emergency. The regulation of the amount of flow through Weston Aqueduct is also accomplished by throttling. In this instance a needle valve in line number one has been used and when the required flow exceeds the capacity of line number one the hand operated 30 inch gate valves in line number two and then line number three are opened. The recording device for the venturi meter is located in the Head House at Shaft 4 and at this same location are the controls for the selzin motors which operate the needle valve.

Plate Steel Pipe Fittings

The connection to Weston Aqueduct was made at 45° to the pipe line rather than at 90° for several reasons: one being, that the head losses might be kept as low as possible in the event that it became necessary to take water from the Sudbury Reservoir through the new Pressure Aqueduct, and secondly, that a reasonable length of straight approach to the venturi be provided. In order to make this connection two Tees, two Bends and two Latterals of large diameters were built of Welded Steel Plate, the design of which presented interesting problems. Recent years have seen the construction of numerous pipe lines and penstocks from plate steel, involving construction of fittings of perhaps larger diameters than those with which this discussion is concerned. However, there seems to be a very limited amount of printed matter on the subject and even less definite information as to the actual design of such fittings. Included as a part of this paper are references to certain types of fittings which were found and also a Bibliography which may be of assistance to persons interested in this type of design problem. While the approach has been from the theoretical standpoint, the structures as designed have withstood the specified tests and the designs seem adequate.

Factors Governing Design of the Plate Steel Pipe

The maximum normal working pressure under which the pipe and fittings built for the connections already described must operate is 50 pounds per square inch. The specifications stipulated that the plate steel pipe should be tested to this full working pressure of 50 pounds per square inch and that the leakage should not exceed one gallon per day per foot length of conduit.

Inside of the pipe and fittings is a two inch mortar lining while around the outside has been placed a concrete envelope. The concrete envelope was placed while the pipe was under pressure and the specifications require that the pressure be maintained for 14 days so that the pipe would be kept as nearly as possible to a circular cross-section in order that the cracking of the concrete would be kept to a minimum.

The design pressure used was 70 pounds per square inch. This figure was arrived at by virtue of the fact that at the top of Shaft 4 there is installed a system of pressure relief valves designed to relieve excessive pressures due to surges in the tunnel up-take shaft. These valves are set to open at a pressure of 70 pounds per square inch. For the extremely remote possibility that the relief valves might fail to function it is felt that the factor of safety built into the structures will take care of the momentary overload.

Theory of Thin Hollow Cylinders

Plate steel pipe of a diameter relatively large in comparison to the plate thickness approaches the theoretical assumption of a thin hollow cylinder having perfectly non-rigid walls. The laws governing the stresses in such theoretical cylinders are perhaps elementary, but a brief restatement of some of them may be of assistance.

Hoop Stress

On Fig. 3 is shown a cross section of a thin hollow cylinder, of radius (r), which is subjected to a uniform, unit, internal pressure (p). Consider a unit length of this cylinder and assume that all the forces

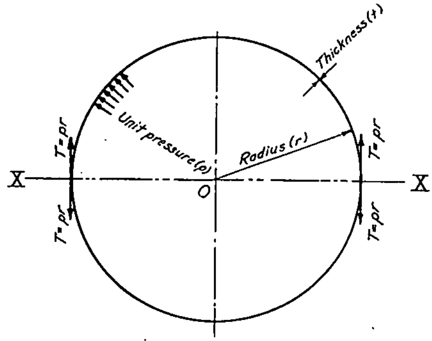


Fig. 3.—Thin Hollow Cylinder Subjected to a Uniform Internal Pressure.

acting upon it are in equilibrium. If the cross-section is bisected with any plane such as XX through center O the resultant of the forces normal to the bisecting plane in either of the semicircles formed by the plane is ($2\ pr$) and these resultant forces being in opposite directions tend to separate the two semicircles. Resisting these forces is the stress in the cylinder membrane. If the membrane thickness is (t) the unit stress may be expressed as follows:

$$s = \frac{2pr}{2t} = \frac{pr}{t}.$$

This stress (s) is usually called "hoop tension" stress or hoop stress.

Since (s) acts normal to plane XX it also acts tangent to the cylinder membrane. Any other plane through center (O) will give the same values of (s) which are also tangent to the membrane so it follows that the stress is uniform throughout the circumference. Because every point on the circumference is equidistant from the center (O) it also follows that there occurs no unbalance bending moments in the membrane, and

$$\Sigma M = O.$$

Consider any thin walled cross-section other than that of a circle, such as an elipse or a rectangle which is subjected to a uniform internal pressure, it will be seen that all bisecting planes through the geometrical center do not have the same length nor the same applied loads, thus the membrane stress will vary from point to point and furthermore, it is evident that the stress could not be tangent to the membrane at all points. Under such conditions unbalanced bending moments should occur and cause deformation of the membrane. In brief, any thin walled cross-section when subjected to a uniform internal pressure will tend to assume a circular shape because only under this shape does equilibrium of the bending forces in the membrane exist.

Effect of Removing a Portion of Circumference

Fig. 4 shows the cross-section of a thin hollow cylinder similar

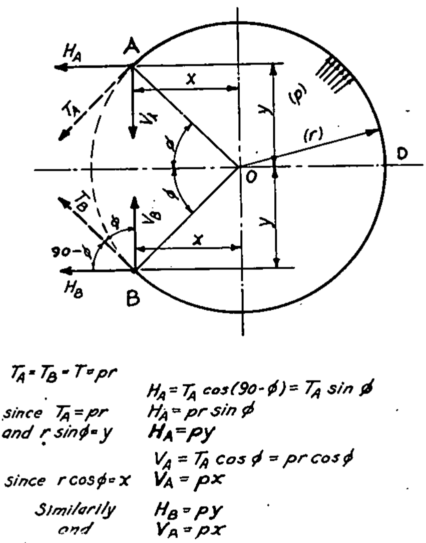


FIG. 4.—THIN HOLLOW CYLINDER. EFFECT OF REMOVING A PORTION OF THE CIRCUMFERENCE.

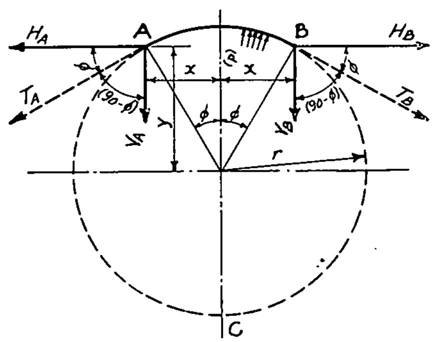
to that just discussed. Located on the circumference are two points, A and B, lying equi-distant from the plane COD. The total stress (T) at either point A or B is

$$T = pr$$

and this stress acts tangentially to the membrane. If tangential forces such as T_A and T_B having the magnitude of (T) are applied at points

A and *B* respectively, then *ACB* could be removed without affecting arc *ADB* assuming, of course, that the internal pressure remains undisturbed. It is quite possible to substitute for (T_A), horizontal and vertical components (H_A) and (V_A) and for (T_B), (H_B) and (V_B).

On Fig. 5 is shown a portion of a thin non-rigid membrane, ends



$$V_A = V_B = px$$

$$T_B = \frac{V_B}{\cos(90-\phi)} = \frac{V_B}{\sin\phi} = \frac{px}{\sin\phi}$$

$$\frac{x}{\sin\phi} = r \qquad T_B = pr$$

$$H_B = V_B \tan(90-\phi) = V_B \cot\phi = px \cot\phi$$

$$x \cot\phi\, y \qquad H_B = py$$

$$\text{Similarily} \qquad H_A = py$$

FIG. 5.—THIN NON RIGID MEMBRANE ASSUMES SHAPE OF CIRCULAR ARC WHEN SUBJECTED TO UNIFORM FLUID PRESSURE.

A and *B* of which are fixed in space, and the concave side subjected to a uniform unit fluid pressure (p). Since the membrane is non-rigid the only forces it can resist are tangential forces, therefore the problem is what shape will it assume and what are the reaction forces at points *A* and *B?* Consider that the membrane and its end points *A* and *B* lie in the circumference of a cross-section of a circular non-rigid membrane, of radius (r), and which is subjected to the uniform unit internal pressure (p). From the previous discussion it is known that a cross-section of this shape would be stable and that all points in the circumference would be subjected to a uniform tangential tension (T). If tangential forces (T_A) and (T_B) each equal to (T) are applied at points *A* and *B* respectively and the portion *ACB* of the membrane is removed, *AB* would still remain the arc of a circle and also stable. Component forces (H_A), (V_A), (H_B) and (V_B) may be substituted for forces (T_A) and (T_B) respectively.

Movement of Supporting Points

Fig. 6 shows several cross-sections of thin hollow cylinders, sub-

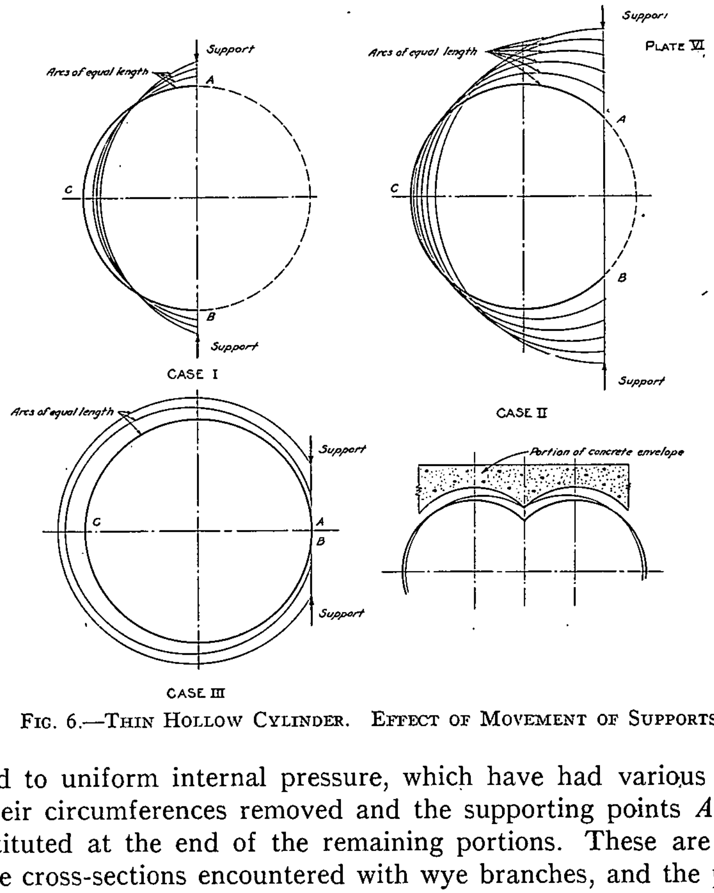


Fig. 6.—Thin Hollow Cylinder. Effect of Movement of Supports.

jected to uniform internal pressure, which have had various lengths of their circumferences removed and the supporting points A and B substituted at the end of the remaining portions. These are similar to the cross-sections encountered with wye branches, and the purpose is to determine the relative motion of points in the circular arcs if the supports A and B are allowed to spread along the extension of the chord which joins them. The arc in each case is kept at a constant length. Note that for any spreading of A and B the parallel movement of any other point on the arc is relatively less. Motion in a horizontal direction also takes place in portions of the membrane and in Cases I and II point C moves inward whereas in Case III point C moves outward. No attempt was made to determine the transition from Case II to III. It appears evident that it would be unwise to expect an envelope placed around a plate steel pipe, having a portion of its circumference removed, to carry any of the hoop stress if points A and B are allowed to spread due to deflection of the reinforcement.

Longitudinal Stress

Another factor which may enter into problems involving thin wall cylinders is that of longitudinal stress. If bulkheads are attached to the ends of a cylinder of radius (r), thickness (t) and of any length, which is subjected to a uniform unit internal pressure (p), then the total reaction of the bulkheads must be carried by the cylinder wall as longitudinal stress. The total load (T_L) on the bulkhead is

$$T_L = p\pi r^2$$

and the total area of cross section of the cylinder wall which carries this load is

$$2\pi rt$$

thus the unit longitudinal stress (s_2) is

$$s_2 = \frac{p\pi r^2}{2\pi rt} = \frac{pr}{2t}$$

From the previous discussion the unit hoop stress (s_1) is

$$s_1 = \frac{pr}{t}$$

and the relation between unit hoop stress and unit longitudinal stress may be expressed as

$$s_1 = 2s_2$$

Design of Plate Steel Pipe

Plate thickness is usually the first consideration in the design of plate steel pipe. It has been demonstrated in the preceding theoretical discussion that of the stresses set up by internal pressure in a pipe that the hoop stress is twice the longitudinal stress; hence the hoop stress requirements generally determine the minimum plate thickness. The fundamental formula for plate thickness as determined by hoop stress is

$$T = \frac{PR}{S}$$

Because of certain practical considerations the theoretical plate thickness may be increased.

(1) Joint efficiency—riveted or welded joints are generally not as strong as the solid plates which they join, therefore, the plate thickness must be increased to give the joints sufficient strength to carry the applied load.

The efficiency of riveted joints may vary from 91% to 74% and the efficiencies of the various types of welded joints from 90% to 70%.

(2) Minimum thickness—it is quite usual to set a minimum plate thickness to enable the pipe to have sufficient strength to prevent it from buckling under its own weight when handled, or to deform excessively, thus straining the joints, when emptied. The minimum thickness used by different designers varies from ¼ inch to ½ inch, depending somewhat on size and length.

The ASME Boiler Code of 1937 was employed to determine plate thickness of the plate steel pipe and fittings used in this portion of the project. This code employs the following formula for plate thickness

$$T = \frac{P \times FS \times R}{TS \times E}$$

T = thickness of plate (¼ inch minimum)
P = working pressure (lbs. per square inch)
FS = factor of safety (5 for new construction)
R = inside radius of shell (inches)
TS = ultimate tensile strength of plate (ASTM A89-33 Grade A = 45,000 lbs. per square inch)
E = efficiency of joint (90% for fusion wells)

The factor of safety of 5 may appear conservative but when it is considered that much of the pipe had openings cut in its shell, and that the stresses acting around these openings are not always apparent, it seems reasonable.

To facilitate erection the pipe was broken into a number of sections and joined with quadruple welded butt straps. Two inch clearance was allowed between the ends of each section, which could be varied to compensate for errors in fabrication or warping from welding.

Design of a Wye Branch

There are several practical methods of reinforcing Wye Branches against bursting due to internal pressure. Three methods have been investigated and the relative advantages and disadvantages of each studied. Included in this paper are typical computations and sketches

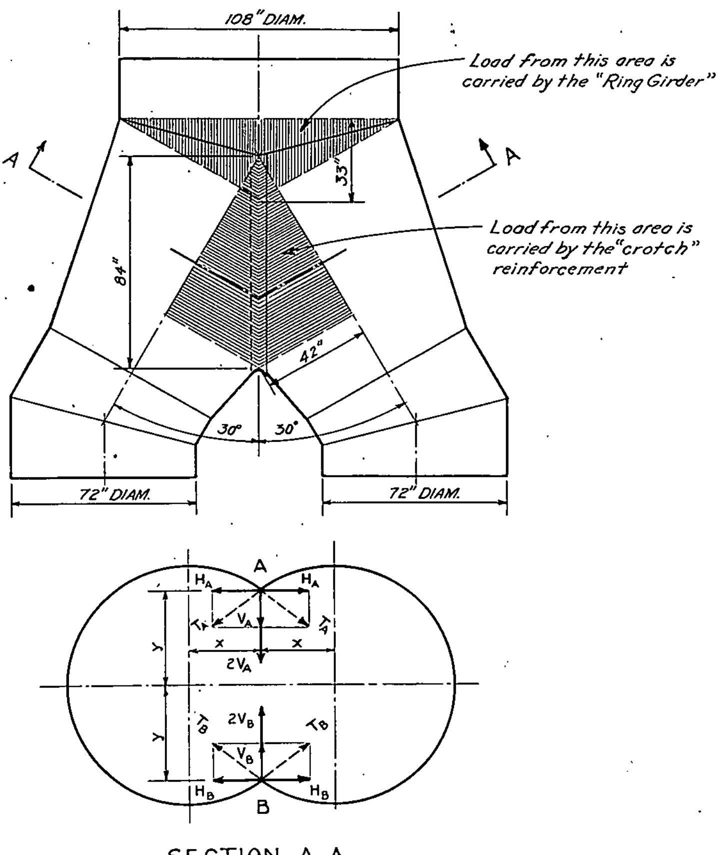


Fig. 7.—Wye Branch, Typical Design.

showing the various steps in the design, and the methods of applying reinforcement. Some refinements could, perhaps, be made in the design of the members shown, if the additional labor and study which would be involved were warranted by the size of any project.

The typical Wye Branch shown on Fig. 7 consists of a 108 inch diameter pipe dividing into two parallel 72 inch diameter branches. For the design an internal pressure of 70 pounds per square inch has been assumed. For this pressure, the hoop tension requirements for straight lengths of pipe of 108 inch diameter indicate that the shell plates should be ½ inch thick. In designing fittings of this type every effort should be made to keep the parts truly circular in section to take advantage of hoop tension as much as possible.

A type of reinforcement best described as an internal or inside web will first be considered. Any section through the wye such as *A-A* indicates portions of two circular arcs joined at points *A* and *B*. Referring to the theoretical discussion, if points *A* and *B* are assumed fixed in space then the arcs remain circular and the principle stress in the plates is hoop tension. Since the section is symmetrical about the axis *A-B*, the radii of the branches are equal and thus the horizontal and vertical components of the forces acting through points *A* and *B* are also symmetrical about this axis. Therefore

$$H_{A_L} = H_{A_R} \text{ and } H_{B_L} = H_{B_R}$$

Since the vertical components have the same direction and line of action,

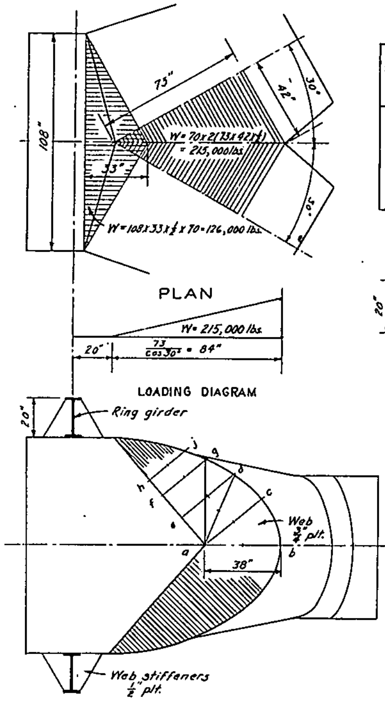
$$V_{A_L} + V_{A_R} = 2V_A \text{ and } V_{B_L} + V_{B_R} = 2V_B$$

Furthermore,

$$V_A = px \text{ and } V_B = px$$
$$V_A = V_B$$

If a tension member sufficient to carry $(2V_A)$ or $(2V_B)$ is placed between points *A* and *B* the section would be stable under internal pressure. In this design the tie consists of a web in the shape of a horizontal *"U"*, welded to the inside of the crotch joint.

To indicate the proportions of the web, the design of which is shown on Fig. 8, a loading diagram was made having as ordinates the (x) distances from the plane of the crotch joint to the vertical plane through the center line of either of the branches (shaded area

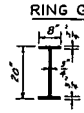


SECTION ON ¢

INSIDE WEB

Section	Width of Section (Ins.)	Tension Normal to Section (Lbs.)	$f_t = \frac{P}{A}$ (Lbs/Sq.In.)	Moment About N.A. of Section (In. Lbs.)	$f_M = \frac{Mc}{I}$ (Lbs/Sq.In.)	$f = f_t + f_M$ (Lbs/Sq.In.)
ab	38"	215,000	7050	1,935,000	10,700	17,750
ac	36"	128,000	4720	1,370,000	8460	13,180
ad	38"	43,100	1510	1,430,000	7950	9460
ag	42"	0	0	915,000	4200	4200
ed	34"	84,500	3300	770,000	5150	8450
fg	28"	47,100	2740	308,000	3140	5380
hj	22"	30,300	1840	158,000	2650	4490

RING GIRDER



$+M = \frac{WD}{6} = \frac{126,000 \times 129}{6} = 2,710,000$ in. lbs.

$S = \frac{2,710,000}{18,000} = 150$ ins.^{3}

I_{NA} $2(8 \times \frac{3}{4} \times 9.6^2) = 110$
$18\frac{1}{2}" \times \frac{3}{4}"$ plt. $= 395$
1505 ins.^{4}

$S = \frac{1505}{10} = 150$ ins.^{3} OK

Check Combined Stresses at Sides

$-M = .0908\,WD = .0908 \times 126,000 \times 129 = 1,470,000$ in. lbs.

$P = \frac{W}{2} = \frac{126,000}{2} = 63,000$ lbs.

$A = 2 \times 8 \times \frac{3}{4} + 18.5 \times \frac{3}{4} = 25.9$ sq. ins.

$f = \frac{P}{A} + \frac{Mc}{I} = \frac{63,000}{25.9} + \frac{1,470,000 \times 10}{1505} = 12,200$ lbs/sq.in OK

COST OF METAL IN REINFORCEMENT

Inside Web = 840 lbs
Ring Grd. = 3320
4160 lbs @ $10 = $416

FIG. 8.—WYE BRANCH. INSIDE WEB REINFORCEMENT.

on sketch) multiplied by the unit pressure. The "horns" of the web were proportioned as cantilevers and the plate at the center line was given sufficient section to carry the summation of all the vertical forces carried by the web. As it is difficult to determine how much of the shell plate along the crotch joint could properly be considered as flange for the "horns" of the web no such allowance was made, and the internal web was designed to carry the load without aid from the shell.

Where the two branches join the 108 inch diameter portion of the wye there is a point at which hoop tension is not very effective. To strengthen this portion a "ring girder" was placed around the 108 inch pipe as close to the joint as possible. In proportioning the girder it was assumed that the active load consisted of the vertical components of the internal pressure on the shaded area indicated on the sketch which is the area in which hoop action could not be counted upon. The application of the load to the ring girder is somewhat difficult to analyze, so to be conservative, it was treated as single concentrated loads applied diametrically opposite each other. The stiffeners indicated were arbitrarily added to brace the ring girder.

A second method of reinforcement which was considered, involved the use of external girders in the crotch instead of the internal web just described. (Fig. 9.) In the design shown by the sketch the

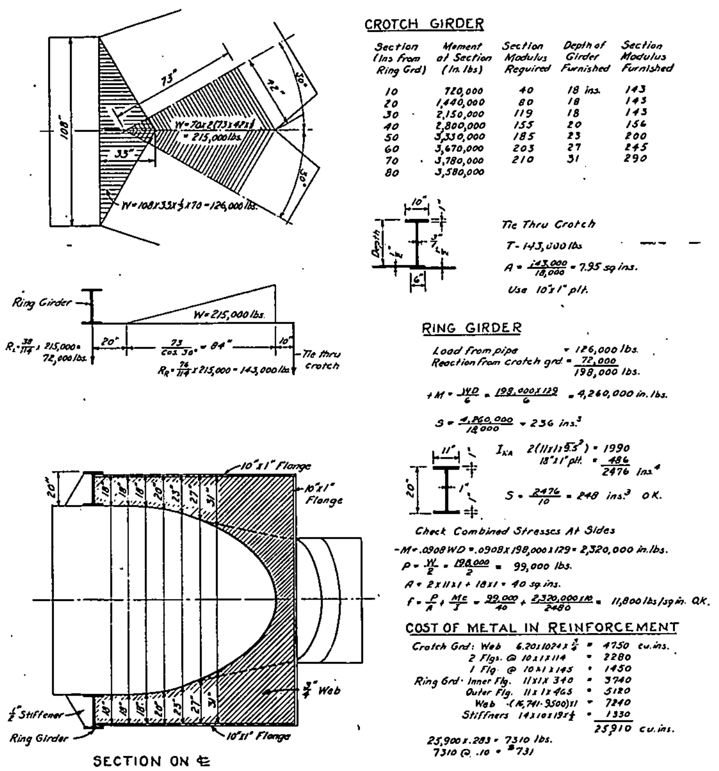


FIG. 9.—WYE BRANCH, CROTCH GIRDER REINFORCEMENT.

same loading diagram was employed as for the preceding design. The "crotch girder" was figured as a simple beam spanning from the ring girder to a tie consisting of an extension of the girder web which passes through the crotch of the wye to another crotch girder on the other side. Flanges were required along the outer edges of the webs and in this particular instance a portion of the shell plate was considered as an inner flange, its width being selected by means of a "scientific guess." Because deflection of the ring girder might cause the inner edge of the web at the center line where it passes through the crotch as a tie to be over-stressed, a flange was added to the outer edge having sufficient cross-section to carry the entire reaction at the ends of the crotch girder.

The "ring girder" was designed as before but with the added concentrated loads of the reactions of crotch girders.

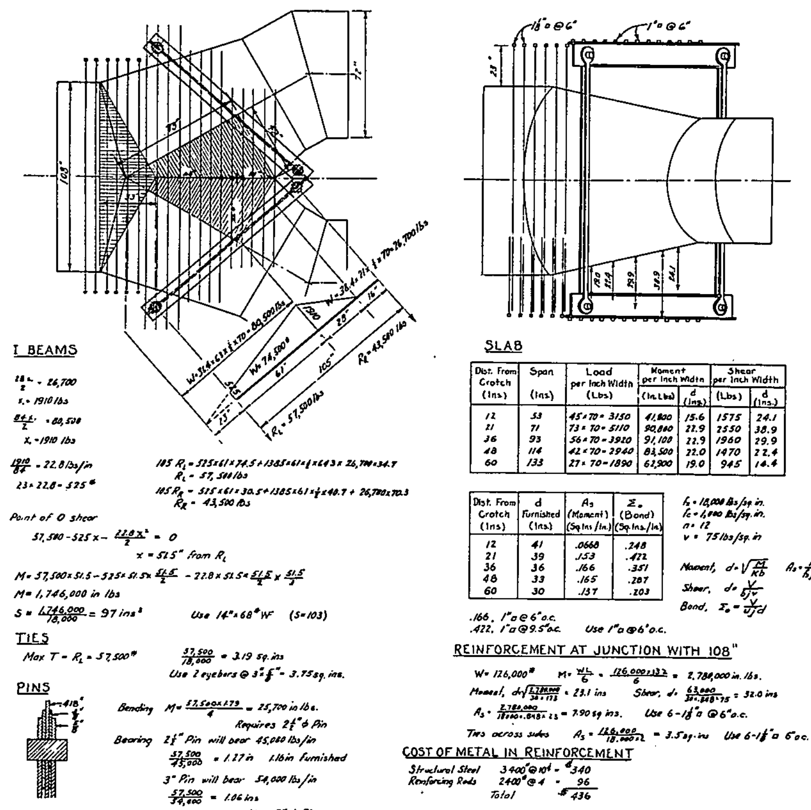


FIG. 10.—WYE BRANCH, CONCRETE REINFORCEMENT.

A third method of reinforcement studied was the reinforced concrete envelope type in which case no reinforcement is attached to the fitting itself. The general layout of this method is indicated on Fig. 10 and the same loading diagrams were employed as were used with the two preceding methods. A slab was placed over the crotch joint and the loading was considered as concentrated along the plane of the joint. (See relative movement of cylinder walls in theoretical discussion.) The reactions of the slab are carried by a frame of structural members consisting of steel I beams tied together at the outer ends and through the crotch by tie rods. A relatively thick slab was found necessary to care for the high shearing stresses.

In place of the ring girder, rectangular concrete beams designed as simply supported were placed top and bottom of the wye. The ends of these beams were tied together by reinforcing bars embedded in the concrete.

A rough estimate of the comparative relative cost of materials required for the three methods outlined is given herewith. Structural steel is figured at 10 cents per pound and reinforcing bars at 4 cents per pound in accordance with the contract unit prices for these items. The costs are as follows:—

Inside web, 4160 lbs. structural steel at 10 cents =		$416
Crotch girder, 7310 lbs. structural steel at 10 cents =		$731
Concrete envelope reinforcing		
3400 lbs. structural steel at 10 cents =	$340	
2400 lbs. reinforcing rods at 4 cents =	96	$436

The cost of the concrete itself has been omitted because generally more concrete is required for the protective envelope than is necessary for structural reasons.

The use of a concrete envelope precludes the possibility of making a good test for leakage at the joints. The inside web is perhaps the most effective type of reinforcement and probably in many instances the cheapest but it has two disadvantages. First, if, as in the work being described, the inside of the pipe is to be lined with cement mortar for protection against corrosion it would be difficult to hold this lining in place on the flat sides of the web, and as a result this important member might become exposed and corroded. Secondly: its location inside the pipe makes its regular inspection a matter of considerable inconvenience and expense. The outside web is probably the most expensive type but it does leave the cross-section unobstructed and the members can be readily protected by concrete of ample thickness and durability. If a concrete envelope is not placed around the fitting the reinforcing members are readily available for inspection. The exterior web type also allows the pipe to be subjected to full internal pressure for testing the joint tightness with no additional preparation.

Because a leakage test, previous to placing concrete envelopes around the wye branches, was not practical on the tunnel portion of the Pressure Aqueduct, and because of the desirability of having the anchorage which the concrete envelopes would provide when the Aqueduct was under pressure, the concrete envelope type of reinforcement was used for the 108 inch to 72 inch wye branches which were built in the Aqueduct line.

Laterals

The lateral is another form of the wye branch and the design of the reinforcement is similar. The most important point to remember is to keep the conical branch sections of the same diameter where they intersect so as to provide balanced forces and to provide a straight joint in which to place the web. Because the designs follow the same general method as for the wyes just described the computations are omitted, however, sketches of some laterals actually built are included. (Fig. 11.) The plates shown in the sketches as tying the branch to the run were added to brace the web and to provide a safety tie across the joint, actually there may be some question as to their effectiveness.

The use of an internal web reinforcement in a lateral causes a rather severe decrease in the waterway area and the objection to having a thin web plate covered with mortar again holds as in the case of a wye branch, therefore the internal web type of reinforcement was not used.

Instead the external web type of reinforcement was used on the two laterals built into the connection between the new Pressure Aqueduct and the present Weston Aqueduct in order that the joints might be tested for water tightness prior to placing the concrete envelope.

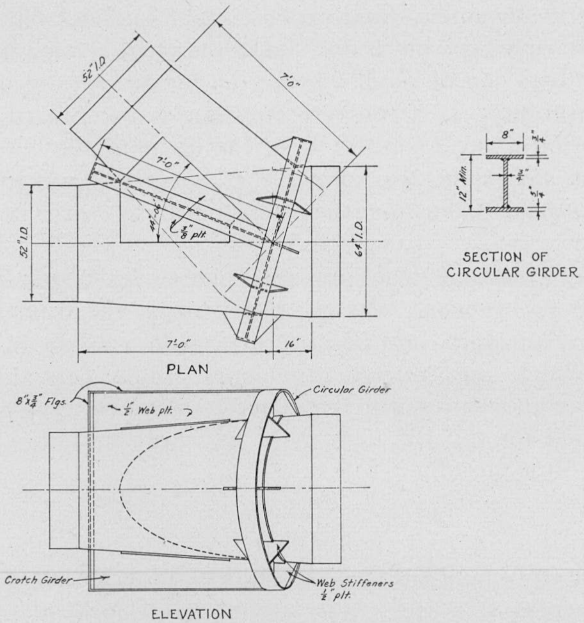


FIG. 11.—TYPICAL LATERAL, OUTSIDE CROTCH GIRDER TYPE REINFORCEMENT.

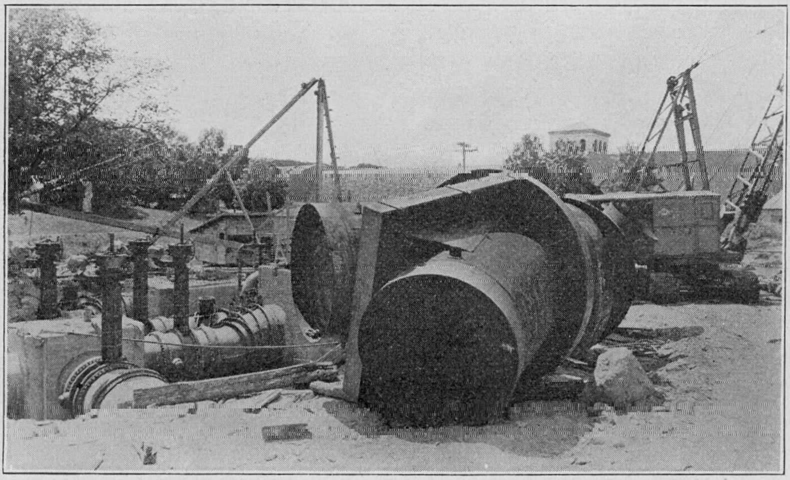


FIG. 11a. PLATE STEEL LATERAL 84"×60"×60"

Design of a Tee

The reinforcement of a tee against bursting from internal pressure requires the exercise of some ingenuity. When the diameter of the branch approaches that of the run, the tee is greatly weakened and the loads to be handled may become relatively great. A number of methods of handling the problem have been developed and several of these will be discussed.

At Boulder Dam internal tie rods were used for reinforcement in several Tees in a penstock. There is some question as to the concentration of stress at the connections between the tie rod and the shell plates and special precautions must be taken in the design to insure the proper distribution. This method is open to the same objections as the use of internal reinforcement in wye branches unless the size is such that corrosion of the tie rods can be taken care of readily.

Two types of heavy external webs for the reinforcement of tees were developed and used at Boulder Dam. The authors are not familiar with the procedure for this type of reinforcement and it is mentioned merely as a matter of interest. It is believed that in the case of at least one of these types, that of the heavy arch frame, the design is patented by the Babcock and Wilcox Company, who developed it.

The Commission developed two methods for reinforcing tees, each of which were designed to meet certain special conditions. The first method was the use of external structural reinforcement and was developed to permit the pipe to be tested previous to the placing of the protective concrete envelope. Where no preliminary testing was required a reinforced concrete envelope was developed.

Fig. 12 indicates the steps in the design of the structural type reinforcement. Consider a 60 inch $\times$ 60 inch $\times$ 60 inch tee of steel plate construction and subjected to an internal pressure of 70 pounds per square inch. The method used is based on the assumption that if the joint between the run and the branch is held in position the remainder of the plate can act in hoop tension. As shown in the sketch heavy webs are placed along each joint, one end of each web being welded to the channel. The applied loads on the webs are derived as follows: Consider a section through the tee such as *A-A* which passes through points in the joint between the pipe and branch which will

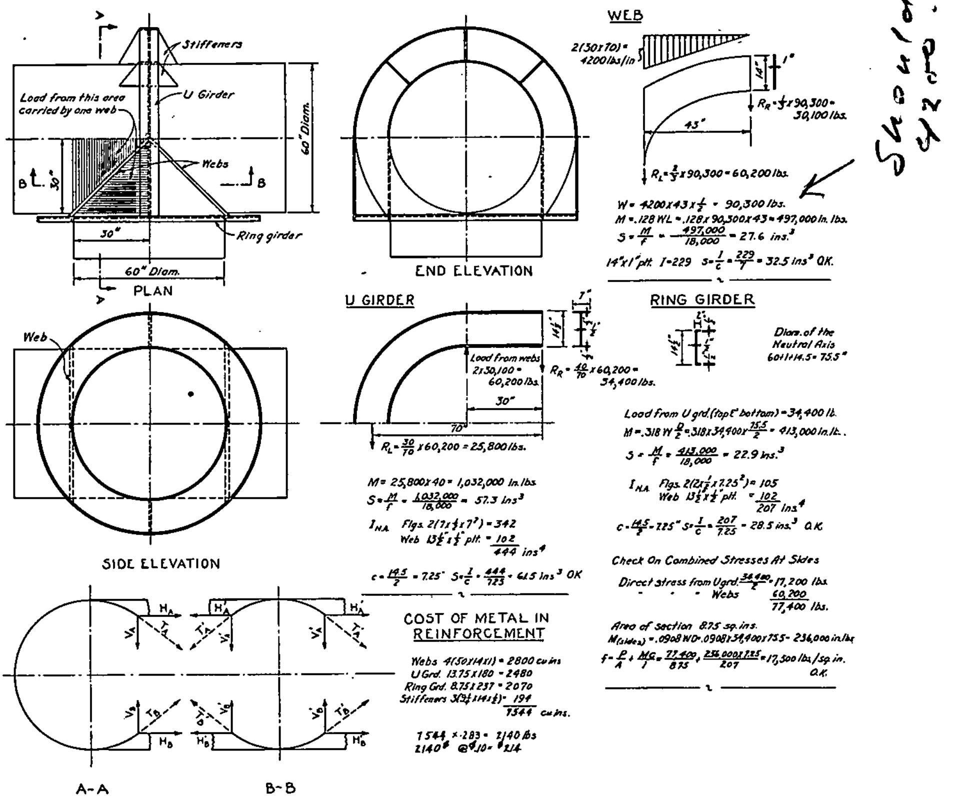


Fig. 12.—Tee, Structural Reinforcement.

be designated as points A and B. Referring to the theoretical discussion (Fig. 4), it was demonstrated that if similar points A and B were held fixed and a portion of the thin membrane between them removed, then the remaining arc ADB would remain circular, and that the points A and B could be held fixed by components (V_A), (H_A) and (V_B) (H_B). It was also shown that

$$H_A = H_B = py$$

and that

$$V_A = V_B = px$$

Since (H_A) and (H_B) act at the joint with the branch these forces can be furnished by tension in the shell of the branch. (V_A) and (V_B) must be furnished by an exterior force such as would be supplied by a web along the joint. Similarly consider a section such as BB through the same points A and B and cutting the branch. As before, points A and B may be held by components (H'_A), (V'_A) and (H'_B), (V'_B).

$$H'_A = H'_B = py$$

and

$$V'_A = V'_B = px.$$

(H'_A) and (H'_B) act at the joint with the main pipe and may be furnished by tension in the shell of the main pipe. (V'_A) and (V'_B) must be furnished by a web along the joint. The total load on the webs is the summation of all the vertical components from the branch and run, along the joints and for one web may be taken as the area shaded on the sketch multiplied by the unit pressure. Since only vertical forces act on the webs their span was taken as the horizontal distance between the supports. No reduction in section was allowed for fixity at the ends.

The U-shaped I-beam is considered as loaded only by the webs and to have a span equivalent to the horizontal distance from the neutral axis at the center line, to the channel about the branch.

The channel is designed as a circular beam loaded by concentrated loads at the top and bottom consisting of the reactions of the I-beam.

The stiffeners are located arbitrarily.

Fig. 13 outlines the steps used to design a reinforced concrete envelope type of reinforcement. The same tee is used as before with the same internal pressure. To hold the joints in place concrete slabs are placed on top and on the bottom of the tee. The load on the slab was considered as the summation of the vertical components along the joints, or more simply the shaded area multiplied by the unit pressure. One end of the slabs were tied together by reinforcing rods across the back of the tee. The other ends of the slabs were held by concrete beams across the top and bottom of the branch. These beams were in turn tied together by rods along the sides of the branch. Considerable concrete is required owing to the high shearing stresses.

A comparison of the cost of the metal used in the two methods is as follows:

Structural reinforcement:

2140 lbs. at 10 cents = \$214

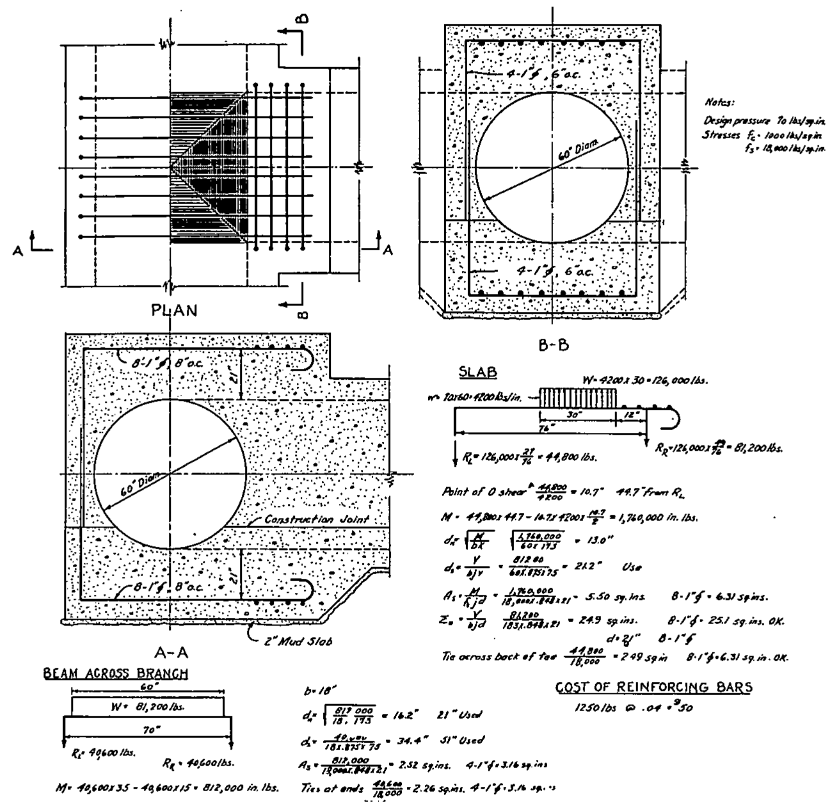


FIG. 13.—TEE, CONCRETE ENVELOPE REINFORCEMENT.

Reinforced concrete envelope:

1250 lbs. at 4 cents = $ 50

BENDS

Changes in alinement in plate steel pipe lines are made by means of bends, called cut curves. The bends are formed by a series of cylinders, each known as a cut, having beveled ends, and these ends joined together. Fig. 14 shows the method of laying out the bevels for a typical bend.

The distribution of stress in any one section of a bend is somewhat complex. It seems apparent that there is a concentration of the hoop stress at the narrowest side of the section, and thus it would

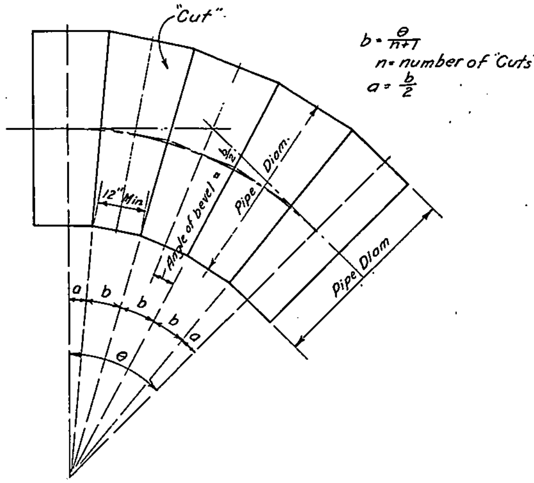


FIG. 14.—LAYOUT OF TYPICAL BEND.

not seem good practice to make this portion of the section too narrow, and an ample factor of safety should be used in determining the plate thickness. The "Tentative Standard Specification for Electric Fusion Welded Steel Water Pipe"—for sizes 30 inches and over, published in the *Journal of the A. W. W. A.*, 1940, mentions this point in Section 3-2.7 entitled "Special Sections . . . the angular change for welded plate specials shall not exceed 22½ degrees per cut for curves . . . and the minimum chord distance between welds for curves shall be not less than twelve (12) inches."

There are two ways to prevent movement of a bend under pressure. The first method is to anchor the tangents on both sides of the bend against longitudinal tension, and then to make all sections and joints between the anchors strong enough to carry the longitudinal tension, or more briefly, have no slip joints between the anchors.

The second method is to supply some sort of anchorage to the convex side of the bend such as by a block of concrete or a brace.

CONCRETE ENVELOPE

It is the practice of the Commission to surround all plate steel pipe with a concrete envelope to protect it against corrosion and to provide it with proper support. Reinforcement may be placed in the envelope for such reasons as, to reduce cracking due to temperature changes and shrinkage, to carry exterior loads especially when the pipe is empty, or to provide reinforcement for special fittings such as tees, wyes, etc.

The envelope is usually placed in three operations. First, if the bottom is wet, a 2-inch concrete mud slab is placed to insure good placing condition under the pipe. Second, a cradle is placed under the pipe, covering say the bottom quadrant in alternate sections, care being taken to prevent the pipe bottom from having waves in it due to unequal support.. Usually the pipe is tested for leakage at this point. Third, and finally, the remainder of the envelope is placed.

To prevent the cracking of the envelope due to the stretching of the pipe shell under load, it has been the practice to require that the pipe be kept under a pressure equal to the working pressure during the placing of the final portion of the envelope and for 14 days thereafter.

Mortar Lining

The specifications required that a 2-inch lining of mortar be placed in all of the plate steel pipe and fittings, and that a wire mesh reinforcing be used to hold the lining in place.

The reinforcing, which consisted of a 3 inch $\times$ 3 inch No. 12 gauge wire mesh, was first placed in the pipe and fittings, supported on spacers which kept the mesh about ¾ of an inch from the inside face of the plate steel. Where necessary in the fittings the reinforcing was tack-welded in place, but welding was not necessary in the straight length of pipe as the mesh will generally stay in place in pipes under 7 feet in diameter.

The mortar lining was applied by means of the cement gun method wherein the mix is delivered dry at about 50 lbs. per square inch pressure to a nozzle, at which point water at about 70 lbs. per square inch pressure is introduced, and the resulting mixture applied to the surface to be mortar lined. The water is carefully controlled so that there is no excess to be cared for or removed.

Application

The cement gun into which the dry sand and cement were placed was operated outside the pipes, the material hose and water hose lines being run inside through manholes. The invert section of the pipes was the first part covered, and the mortar was applied back and forth in layers across the invert with a motion of the nozzle perpendicular to the axis of the pipe. Following the placing of the invert, the sides and arch were placed, the mortar being applied in this instance by a motion of the nozzle parallel to the axis of the pipe.

As the thickness of the lining approached the required amount a wire gauge was used to probe the depth to the plate steel and thin places were given more mortar.

The actual mix, as applied, varies somewhat from that placed in the cement gun, due to rebounds of the sand particles. From tests made it appears that, if a 1 to 3 mix is being delivered dry to the nozzle, the mortar as actually applied to the invert will consist of about 1 to 2¾ mix, whereas the mortar on the arch will be about a 1 to 2¼ mix.

Screeding was begun as soon as the lining had taken a slight set, which was usually from one to three hours after the application of the last layer. The temperature and humidity conditions are the principal factors governing the rate of setting.

Acknowledgment

The facilities which were generously offered by the Metr. Dist. Water Supply Commission under the direction of Karl R. Kennison, Chief Engineer, and Stanley M. Dore, Assistant Chief Engineer, have made the preparation of this paper possible. Charles L. Coburn, Principal Designing Engineer, Lawrence M. Gentleman, Associate Civil Engineer, W. F. Covil, Assistant Civil Engineer, Frederick W. Gow, Division Engineer, and several others provided valuable assistance.

Data covering the methods used on work of the U. S. Bureau of Reclamation was received through the courtesy of Mr. P. J. Bier, Mechanical Engineer of the Bureau at Denver, Colorado.

BIBLIOGRAPHY

Effect of Openings in Pressure Vessels
J. Hall Taylor and Everett O. Waters A.S.M.E. APM—56—3

Penstocks for Boulder Dam
C. M. Day and Peter Bier. *Mechanical Engineering,* Aug., 1934, pp. 451-465.

Openings in Cylindrical Drums
D. S. Jacobus. *Mechanical Engineering,* May, 1932, pp. 368-370

Investigations of Stress Conditions in a Full Size Welded Branch Connection
F. L. Everett and Arthur McCutchon
A.S.M.E. FSP—60—12—P. 399

Analysis of Stresses in Circular Plates and Pipes
A.S.M.E. APM—54—2

Large "Y" and Reducer Section Fabricated by Welding
F. G. Sherbondy. *The Welding Engineer,* Nov., 1936, p. 42

FOUNDATION INVESTIGATIONS FOR THE FRANKLIN FALLS DAM

BY F. STEWART BROWN

(Presented at a joint meeting of the Boston Society of Civil Engineers and Hydraulics Section B.S.C.E. on November 20, 1940.)

INTRODUCTION

THE Franklin Falls Dam, the construction of which is in progress and is scheduled for completion in the summer of 1942, is located on the Pemigewasset River two miles north of Franklin, New Hampshire. Having a flood control storage capacity of 170,000 acre-feet and controlling a drainage area of 1,000 square miles, the Franklin Falls Reservoir will form the principal unit of a system of reservoirs for the control of floods in the Merrimack Valley.

DESCRIPTION OF DAM

The retaining section of the dam is a rolled fill embankment heavily protected on both slopes with dumped rock fill. (Fig. 1) The earth section is composed of a central impervious core flanked by pervious fill, which in turn is flanked by selected pervious fill. Accessory provisions consist of an impervious upstream blanket, a deep longitudinal drainage trench in the foundation downstream from the core, and a downstream terrace composed of dumped rock fill. The crest length of the embankment is 1,700 feet, the average height of the river section is 130 feet, and the gross volume of fill in place is 3,500,000 cubic yards.

The east end of the embankment abuts against the sloping face of a glacial terrace. The junction is formed upstream by an extension of the impervious blanket up the slope weighted with earth and rock fill and downstream by a tapering drainage blanket of sand and gravel and rock fill.

The west abutment is a broad bedrock nose which permits a positive foundation seal for the embankment core and provides a suitable

*Engineer, Chief of Design Section, U. S. Engineer Office, Park Square Building, 31 James Avenue, Boston, Mass.
Statements and opinions are to be understood as individual expressions of the author and not necessarily those of the Engineer Department.

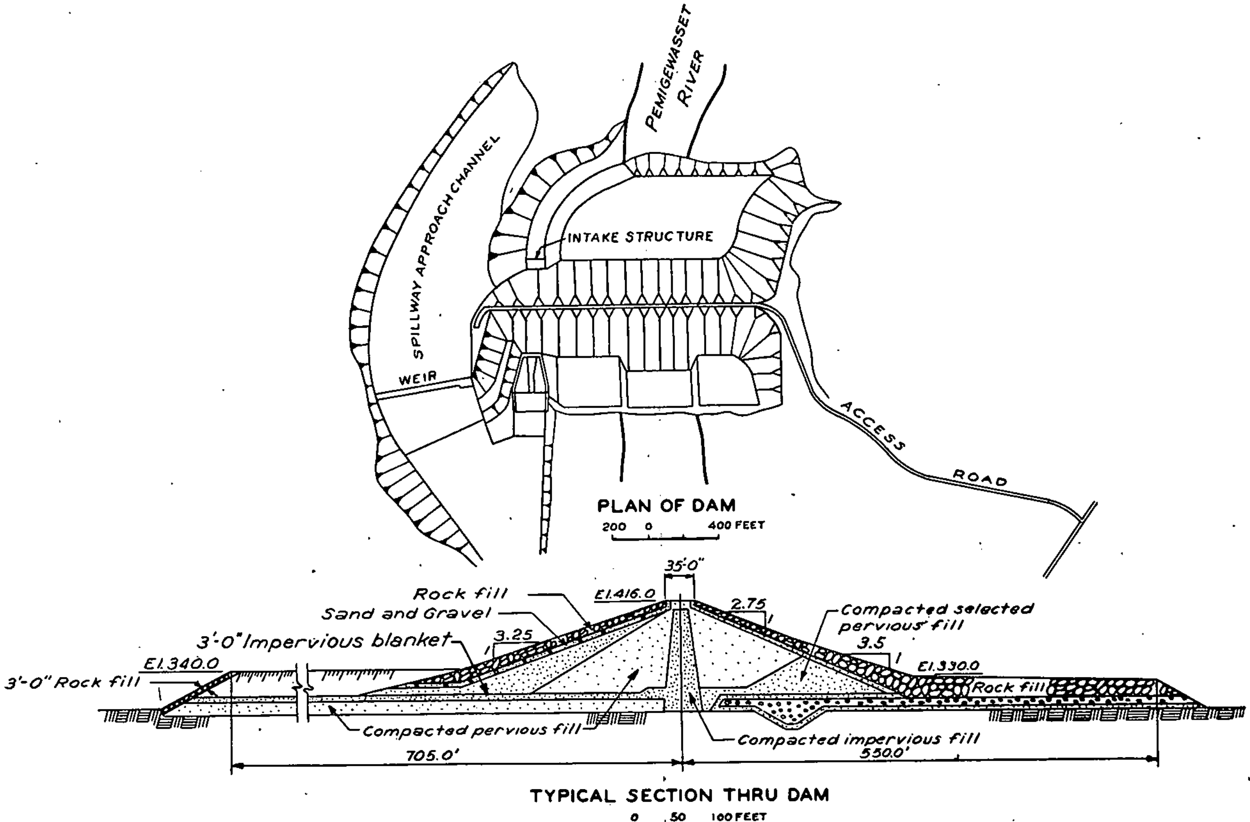


Fig. 1.—Franklin Falls Dam

location for the spillway and outlet structures. The spillway is a long sweeping channel excavated in earth and rock and separated from the embankment by a concrete retaining wall founded on rock. The spillway is 550 feet wide at the control weir, which is designed for a surcharge of 22 feet. The flood control outlet works, consisting of an intake structure, two conduits extending through the embankment, and a stilling basin, are constructed of reinforced concrete and are founded on bedrock throughout. The pervious fill and rock for the embankment are being obtained from the required excavation for the spillway and outlets. The impervious and selected pervious fill and sand and gravel for filters are secured from borrow pits.

Geological Construction of Site

At the Franklin Falls dam site, the Pemigewasset River meanders across a narrow sandy flood-plain which is walled on both sides by high sand terraces, which in turn abut against the bedrock walls of the preglacial valley. (Fig. 2.)

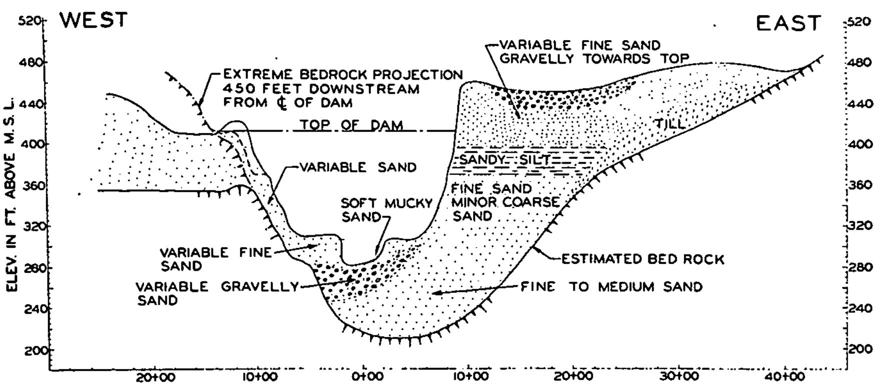


Fig. 2.—Geological Profile, 200 Feet Upstream from Center Line of Dam.

The present river occupies a position about 75 feet above its preglacial level and lies close to the west wall of the old valley. Bedrock is inaccessibly buried beneath the east terrace abutment and under the greater length of the embankment foundation, but under lies the west terrace in the form of a broad, partially exposed promontory as previously described. The east terrace is of variable stratified sands, the top of which contains deposits of sand and gravel.

These deposits constitute the source of the selected pervious fill and the sand and gravel for filters and concrete aggregates. The section of the east terrace forming the abutment of the dam is composed of stratified variable silty fine to medium sands, only a few small zones of which can be distinctly classed as pervious. The base foundation of the embankment is of water-laid stratified loose sands varying from silty fine sand to fairly clean coarse sand and fine gravel. Not pertinent to the foundation of the embankment, but of geological interest, is the chance location, during recent well drilling operations, of a deposit of glacial till deeply buried under the east terrace as indicated on the profile of Fig. 2.

Exploration for Structures

The foundation investigations for the Franklin Falls Dam can be divided into two parts: investigations pertaining to the location and design of the concrete control structures, and investigations pertaining to the treatment of the embankment foundation. The former was accomplished without difficulty by driving 3-inch cased bore holes to the bedrock surface and coring the rock with diamond or bortz drills. Seventy such holes, indicated by the symbols for structure borings on Fig. 3, were drilled, in the spillway and outlet areas. These holes were extended generally from 30 to 40 feet into rock with an average core recovery of 95%. Objectives of this exploration were the general de-

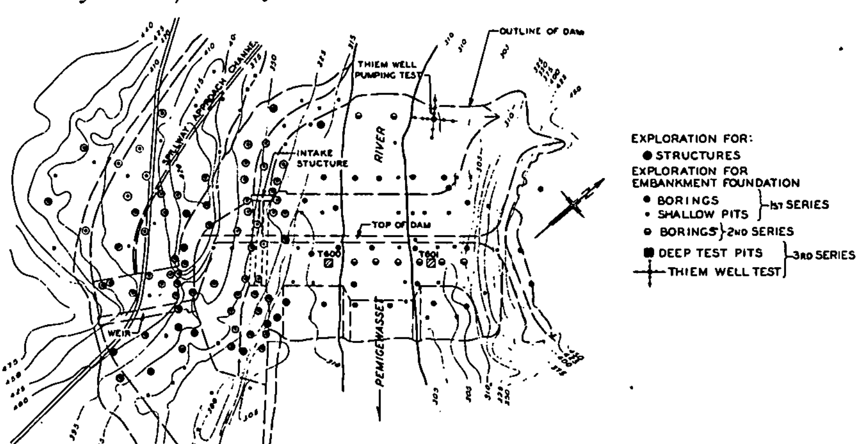


Fig. 3.—Franklin Falls Dam. Plan of Exploration.

velopment of the bedrock surface to enable economical planning of the structures, and determination of the quality of the rock from the core samples and from occasional pressure tests.

Bedrock was found to be largely a hard granular schist containing numerous fractures in the upper weathered zones and scattered fractures throughout. With only moderate surface removal, the rock was judged to be entirely suitable for supporting the structures planned, shallow cut-off grouting where the reduction of seepage and uplift pressures was a factor constituting the only treatment required. The blockiness of the rock in combination with its inherent hardness generally resulted in irregular breaking.

Embankment Foundation Investigations

The investigation of the embankment foundation required more difficult exploration than for the structures owing to the extremely variable and troublesome nature of the valley bottom glacial deposits. The investigations were conducted over a period of 18 months, during which time numerous office studies were prepared in conjunction with the field and laboratory work, and a board of consulting engineers was retained on several occasions to render valuable assistance in formulating progressive solutions to the problems.

From both a chronological and functional standpoint, the investigations can be divided into four groups. The first group consisted of exploration by borings and shallow test pits, which disclosed the composition of the foundation in good detail but with incomplete qualitative assurance. The 24 borings of this group were placed generally on three parallel lines, one line approximating the centerline of the embankment and the other lines occupying positions upstream and downstream of the centerline, as shown on Fig. 3.

Samples from these borings, taken either continuously or at changes of material, were obtained with a conventional type drive sampler, which consisted essentially of a long 2-inch tube fitted with a bottom flap valve. In making the borings, the general practice was followed of washing to the bottom of the casing and taking the sample below the casing. In some instances, material rose in the casing during boring operations, and occasionally the sampling spoon was brought up with little or no recovery.

Laboratory work on these samples consisted of sieve analyses and permeability and shear tests. The permeability tests were of most importance. In order to define completely the permeability characteristics of the foundation and yet avoid much tedious labor, actual permeability tests were limited to a group of prepresentative materials remolded to several different densities. Some of the soils tested are shown on the lower left chart, Fig. 4, and resulting curves of the

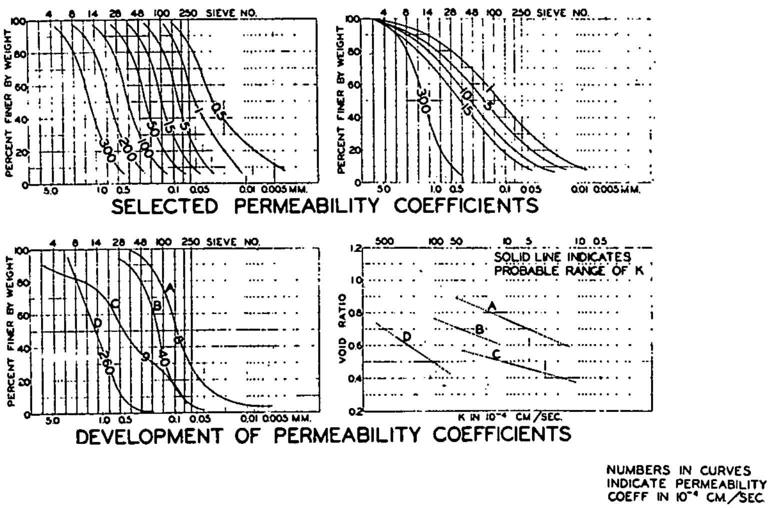


FIG. 4.—FRANKLIN FALLS FOUNDATION. PERMEABILITY STUDIES.

permeability versus void ratio for these samples on the lower right. The coefficients corresponding to the most probable natural density were obtained from the latter chart and assigned to the grain-size curves of the former. The two upper charts show some of the master grain-size curves derived in turn from a series of such studies. With the aid of these control curves, and by visual inspection and comparison of the materials, coefficients of permeability were assigned rapidly to all samples.

The results of the foregoing study are depicted graphically on the profiles of Fig. 5. These profiles occur along the three lines where the borings principally were located. The materials of the foundation are classified by permeability into three groups: Highly permeable material composed largely of coarse sand and having coefficients greater than 100×10^{-4} cm/sec; materials of intermediate permeabil-

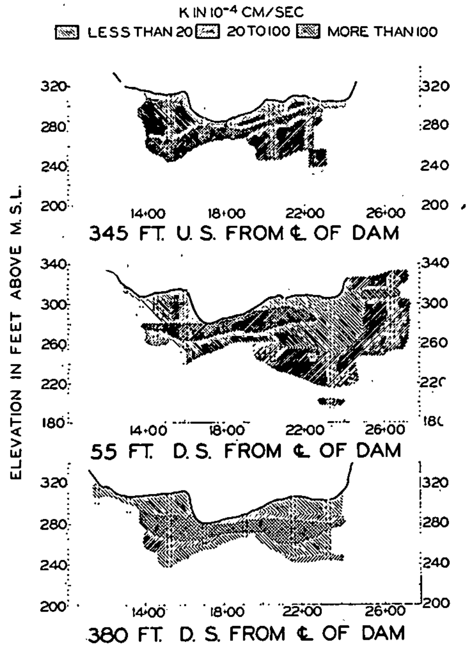


FIG. 5.—FRANKLIN FALLS DAM. PERMEABILITY PROFILE OF FIRST SET OF BORINGS.

ity from 100 to 20×10^{-4} cm/sec; and the less pervious variable fine sands, less than 20×10^{-4} cm/sec. No impervious materials were found with the exception of a few scattered thin bands of silt in the upper levels. These profiles were exceedingly valuable in clarifying the general condition of the foundation, the probable continuity of the several zones throughout the length of the dam site being apparent at a glance. It is to be noted that materials of high permeability lie closely exposed to the river bed but are buried to depths of 20 to 25 feet in the adjoining valley bottom areas.

SECOND SERIES OF BORINGS

Referring again to Fig. 3, the field work for the second series of investigations consisted of 8 borings concentrated on two lines, six on the centerline of the downstream drainage trench, and two on the centerline of the upstream cofferdam. These additional borings were intended to furnish more reliable permeability data through the medium of undisturbed samples obtained with 2-inch thin-walled, seamless tubes. It was desired particularly to verify the depths to which a drainage trench should be excavated to reach more pervious materials and to determine the grading of the various materials to be intercepted by the trench as a guide in the design of the trench filters. The boring procedure otherwise followed closely the same described for the first series and was accompanied largely by the same difficulties. Although many good samples were obtained with the seamless tubes, the material so obtained usually was the less pervious type, a fact which in itself marked well the transition from the finer to the coarser sands. Very good permeability values consequently were obtained of the variable silty sands, with correspondingly doubtful values for the medium to coarse sands, particularly where some gravel was found to be present. The laboratory analysis on samples from these borings was performed at Harvard University under the supervision of Dr. Arthur Casagrande.

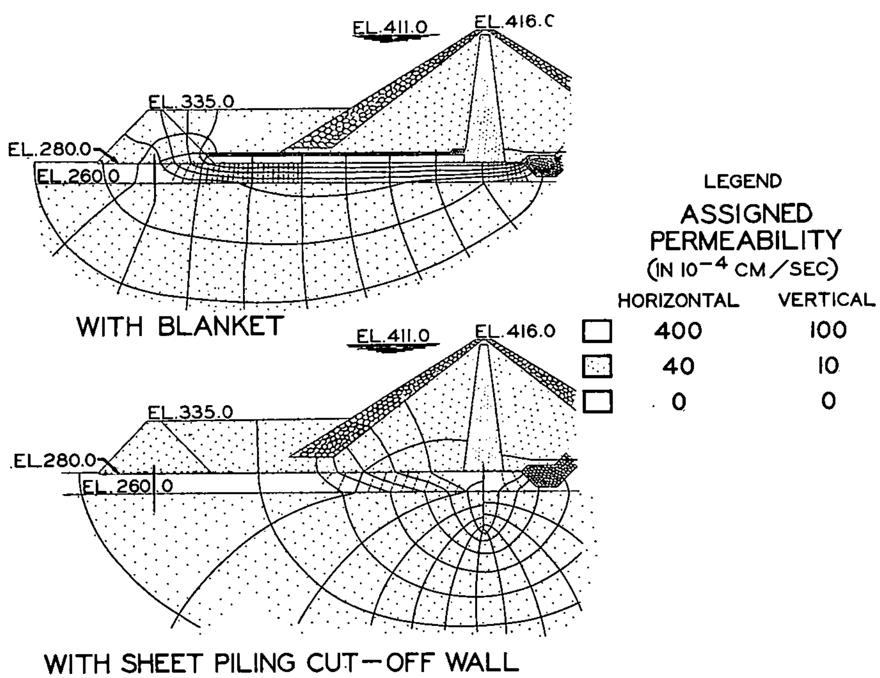


FIG. 6.—FRANKLIN FALLS DAM. FOUNDATION SEEPAGE STUDIES.

In connection with these investigations, seepage studies of a number of alternate designs of the Franklin Falls embankment were prepared by Dr. Casagrande, two of which are illustrated on Fig. 6. The upper study incorporates an impervious upstream blanket which corresponds to the adopted plan, and the lower study utilizes a sheet piling diaphragm under the impervious core which is cut-off only in the sense that it intercepts the flow of water through the highly pervious zone, causing it to pass through the underlying less pervious region of the foundation. The highly pervious zone has been assumed to form a continuous horizontal stratum 20 feet in thickness; the remainder of the foundation and the compacted fill materials of the embankment, have been assumed to have a horizontal permeability one-tenth as pervious as the former, and the blanket and core have been assumed to be entirely impervious. The dam is drawn to a distorted scale of one to two to permit a consistent solution under further assumption that the horizontal permeability of all materials is four times the vertical. The quantity of seepage, calculated from the solutions shown, is identical for the two types of treatment and is about 40% of the amount of seepage calculated from a similar study for this section with no control provided. It can be noted that the sheet piling diaphragm causes the seepage load at the drainage trench to be more evenly distributed, an advantage not considered significant in view of the results of subsequent laboratory investigations on filter design. Less cost and greater certainty of effective construction were the practical advantages of the blanket which led to its adoption.

Special Foundation Investigations

The third series of investigations was undertaken to establish finally the requirement for the excavation of an expensive drainage trench, a less costly alternate system of drainage wells being considered; and, further, it was desired to obtain reliable values for the density of the fine sand deposits of the valley bottom for the study of possible flow failure, the theory and importance of which were being brought to the attention of engineers with increasing stress at this time. Accordingly, as shown on Fig. 3, two deep test pits were excavated on the river banks on the centerline of the proposed drainage trench, and a well pumping test was conducted on the east bank of the river opposite the proposed cofferdam location.

The pits were lined with sheeting and braced, and well points were used to permit the excavation to be made in the dry, the major part of which was below the river level. As illustrated in Fig. 7 the

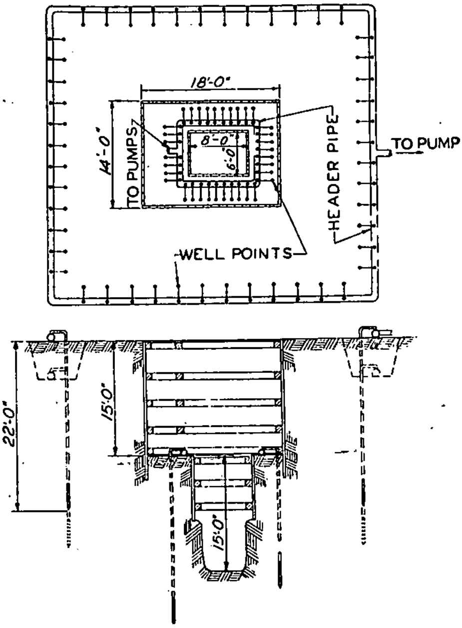


FIG. 7.—FRANKLIN FALLS. DRY PIT, FOR FOUNDATION EXPLORATION.

planned depth of both pits was 30 feet, and accordingly operations were divided into two 15-foot lifts for both sheeting and well points. The dewatering of each pit was accomplished with a total of about 80 well points, distributed equally between the upper and lower sets. One 6-inch pump was connected to the upper set and two 6-inch pumps, placed in the pit, to the lower set. Due to stratification of the soil, it was necessary at times to change the original setting of the well points to increase the efficiency of the system as the excavation progressed.

Three types of samples were obtained from the pits; jar samples for classification and sieve analysis, large undisturbed samples for permeability, and constant volume samples for evaluating the degree of compaction of the material in its natural state. The large undisturbed samples, one cubic foot in dimension, were obtained with a metal box sampler with removable sides and with guides for inserting a bottom shear plate after the sampler has been pressed into the soil. Permeability tests were made on these samples in both the horizontal and vertical directions, the sample being placed and sealed with paraffin in a wooden box falling head permeameter. Initial saturation in an upward direction to insure displacement of the air from the voids was accomplished by placing the permeameter in a tank of water.

Constant volume samples were taken at the same elevations and in close proximity to the undisturbed samples with a brass cylinder 4 inches in diameter by 5 inches long, which was pressed gently into the soil until full. The ends of the samples were trimmed flush with the cylinder before dumping into a bag for shipment to the laboratory. Three void ratio determinations were made on each constant volume sample corresponding to three states of the material: the natural, the loosest, and the densest. All three were required for finding the degree of compaction of the material in its natural state.

Logs of the test pits and results of the laboratory tests for permeability and degree of compaction are shown in Fig. 8. In test pit 600, the material encountered in the upper 15 feet is a slightly stratified, loose, silty, fine to medium sand having a coefficient of permeability of 20 to 100×10^{-4} cm/sec. and a degree of compaction aver-

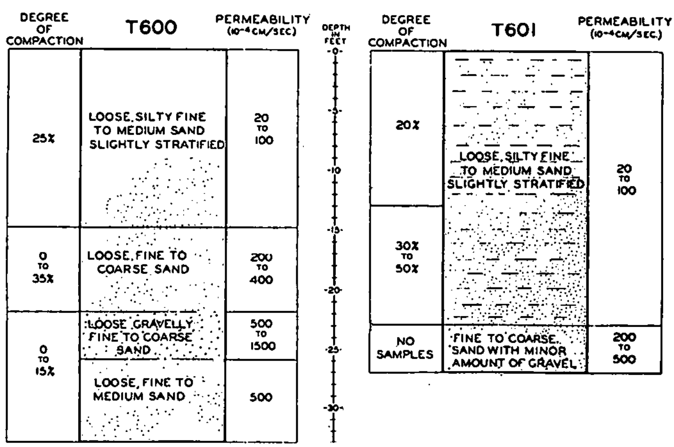
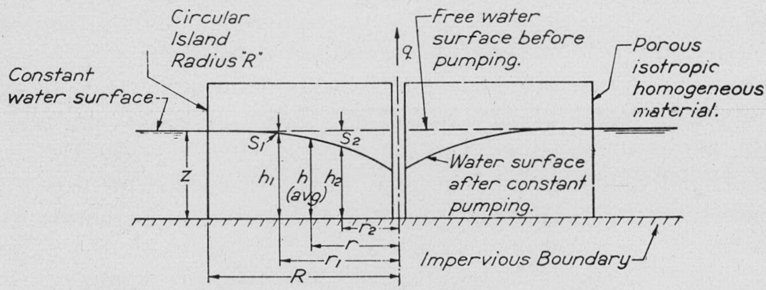


Fig. 8.—Franklin Falls Dam. Deep Test Pits. Summary of Results.

aging 25%. A loose, fine to coarse sand was next encountered which had a permeability of 200 to 400×10^{-4} cm/sec. and compacted of 0 to 35 per cent. Below this stratum, a very pervious 4-foot layer of gravelly fine to coarse sand having a permeability of 500 to 1500 was found, which was underlain for the balance of the excavation by loose, fine to medium sand with a coefficient of 500×10^{-4} cm/sec. These lower two zones of pit T600 were found to be very loose, the degree of compaction ranging from 0 to 15 per cent. The vertical permeability of all the samples, except for the very pervious material, was found to be roughly one-half the horizontal.

The well pumping test, which was conducted immediately prior to excavation of the deep test pits, provided an approximate means of evaluating the permeability of character of the foundation in the locality surrounding the well. Fig. 9 illustrates the theoretical case



$$K = \frac{q \log_e \frac{R}{r}}{(z^2 - h^2)\pi} \quad \text{In another form: } K = \frac{q \log_e \frac{r_1}{r_2}}{\pi 2h(S_2 - S_1)}$$

FIG. 9.—THEORY OF THIEM WELL PUMPING TEST.

of a well located in a porous, isotropic and homogeneous material resting on an impervious boundary. If a constant quantity of water is pumped from the well for an extended period, the free water surface will be drawn down until a condition of equilibrium is approached. From an examination of the final equation solved for the permeability of the material, it can be seen that the physical data required for this approximate solution consist of: the rate of pumping from the well, the radial distances to the observation pipes, the draw down at these pipes, and the average depth of the material through which the water flows to the well.

The well consisted of 6-inch slotted casing coupled in 5-foot lengths and driven to refusal at a depth of 57 feet. Ten observation pipes were jetted below the ground water table around the well. After three days of preparatory work, required to clear the well of sand, water was pumped from the well at a uniform yield of 4200 gallons per hour. The draw-down along the four radial lines projecting from the well were in close agreement.

The soil conditions at the test were explored by one boring which indicated that the foundation materials in the vicinity consisted principally of two types: a silty fine sand and a gravelly fine to coarse sand, the latter being many times more pervious than the former. From these boring data, it is apparent that the ideal conditions for Thiem's solution, shown on Fig. 9, did not prevail in this test due to the stratification of the material and the lack of an impervious

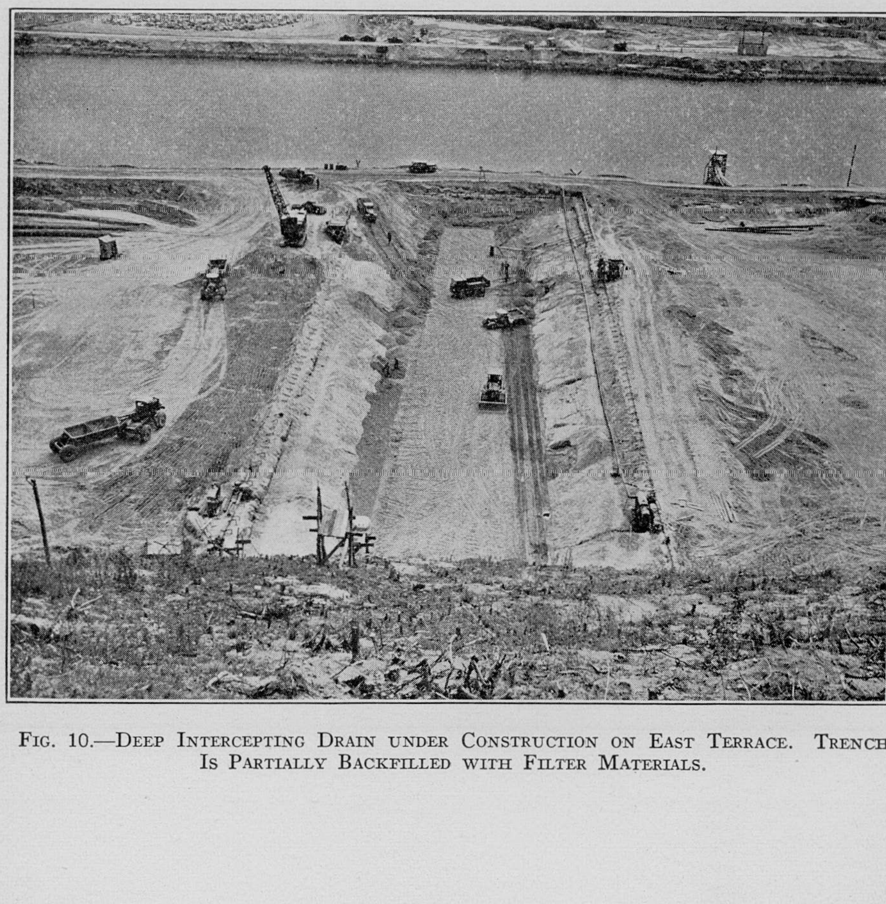


Fig. 10.—Deep Intercepting Drain under Construction on East Terrace. Trench Is Partially Backfilled with Filter Materials.

boundary at the bottom of the well. The theory, however, was extended to account for the stratification of the material, the ratio of permeability of these two soils constituting a factor in the equation. By assigning limiting values for this ratio and for the effective depth of the well, an extreme range of permeability values of 800 to 2000×10^{-4} cm/sec. for the more pervious material and 20 to 150 for the less pervious was obtained. These coefficients agree fairly well with those for corresponding deposits encountered in the deep test pits.

These special investigations, particularly the deep test pits, established conclusively that the strata of gravelly coarse sand were very pervious, considerably more so than recognized from previous exploration. This conclusion led to the adoption of a deep intercepting drainage trench under the entire length of the embankment for positive control of the seepage in place of an alternate, less expensive and less positive control by means of drainage wells. One section of this drainage trench is shown under construction in the photograph of Fig. 10. It is further concluded from these investigations that the probable permeabilities of all deposits of the foundation were approximately twice the values derived from tests on boring samples.

Trench Filter Studies

Along with these special field investigations, laboratory studies to check the proposed grading of the filters of the drainage trench were performed by Mr. G. E. Bertram at Harvard University.[1] The filter tests pertaining to the Franklin Falls Dam were made in conjunction with a general program of filter studies supervised by Dr. Casagrande and arranged through cooperation of the University and the Boston District Office. It is required of a protective filter, first, that it must be many times more pervious than the soil which is to be protected in order that the grain structure of the filter will remain absolutely stable, i.e., so that no washing out of the filter material itself will take place, and, second, that its pores must be sufficiently fine so that soil grains of the base material will not be washed through the filter.

For practical reasons, it was desired to use a two-layer filter in the drainage trench constructed of materials conforming essentially to fine and coarse concrete aggregates. The tests were run, first using

[1]"An Experimental Investigation of Protective Filters," by G. E. Bertram, Soil Mechanics Series No. 7, Harvard University.

a base layer of fine foundation material protected by a single filter of concrete sand, and second, using two different grades of fine foundation material each protected by a two-layer filter of fine and coarse concrete aggregates. The respective grain size curves of these materials appear on Fig. 11. The former tests, of which there were nine,

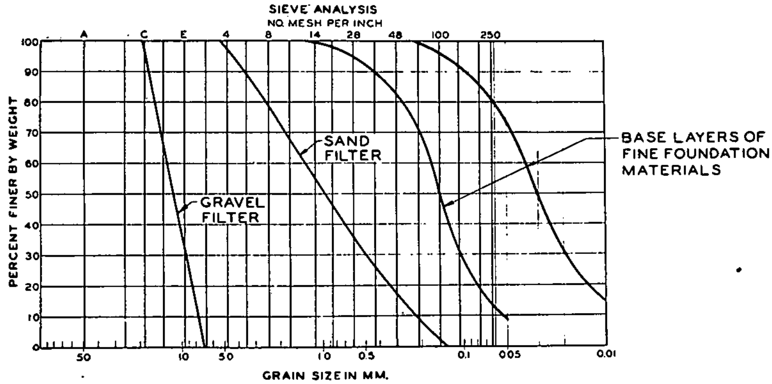


FIG. 11.—GRADING OF FILTER TEST MATERIALS.

were run for a period of ten days under an extreme hydraulic gradient of 50, and the latter were run for 16 hours under gradients of 7 for one test and 11 for the other. The loss of the base material was immeasurable in most cases, the maximum loss being 2.5 per cent for one of the tests run under the extreme gradient of 50. The stability of the filter layers was unquestionably ample. Evidence to support a rather common conception that ground water filters will have a tendency to become less efficient due to clogging under continued load was found to be entirely lacking.

COMPACTION OF EMBANKMENT FOUNDATION

The fourth and last series of investigations pertained to the problem of compacting the loose, fine sand deposits of the foundation It is known that a dense, cohesionless soil in a saturated state has a tendency to increase its void spaces under deformation, which results in a temporary deficiency of pore water and consequent increased shearing resistance of the soil due to the tension created in the water. Opposite effects are caused when a loose, cohesionless soil is deformed. The pore spaces decrease, excess pore water is formed, and the shearing strength of the mass is reduced due to the partial or complete transfer of load from the soil grains to the confined pore water. If of general extent and not otherwise relieved, this latter condition is capable of causing a flow failure. The intermediate state of the material in which deformation causes neither an increase nor a decrease of the pore spaces is termed the state of critical porosity which corresponds to the minimum state of compaction of the material required to prevent a possible flow failure.

The application of buried charges of explosives as a practical method for compacting a large area of existing loose deposits was conceived personally by Colonel Lyman, former District Engineer of the Boston Office. To test the effectiveness of this method and to develop a practical procedure in its application, a number of field experiments were conducted at the site. The area of one of the tests, approximately 40 feet square (Fig. 12), was subjected to five suc-

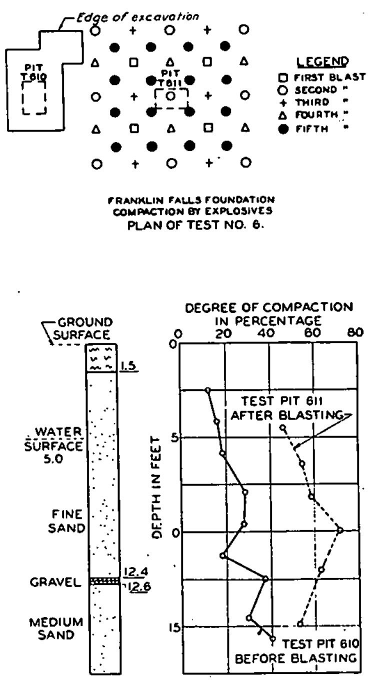


FIG. 12.—COMPACTION OF FRANKLIN FALLS FOUNDATION. RESULTS OF TEST NO. 6.

cessive applications of explosives arranged in distribution and pattern as appearing on the plan shown here. Samples were obtained from a test pit adjacent to the area prior to the blasts and compared with samples from a test pit excavated in the disturbed area after all charges had been applied.

Charges were fabricated by binding and taping sticks of dynamite around skeleton spools which were jetted to the desired depths, usually about 15 feet. The blasts caused the ground surface to momentarily heave upward approximately one foot, but in general the surface remained unbroken. Immediately thereafter, gases from the explosion emitted from the ground, followed by a temporary rise in the ground water table of the vicinity, considerable water flowing for as long as 30 minutes from the blast holes and from small springs and geysers which broke out over the test area. The initial blasts had a muffled and deadened sound, while the later blasts sounded much sharper, and compaction was further evidenced by the increased resistance to jetting of the later charges.

As shown in Fig. 12 an average increase in the degree of compaction of 30 per cent resulted from the five blasts used in this test, the compaction effect extending to depths of 15 to 20 feet. It is worthy of mention, also, that a large reduction in permeability was brought about by the compaction operations which is attributed to two causes: First, the reduction in void spaces between soil grains; and second, the breaking up of lensing and stratification of the natural deposits.

In view of these favorable results, practically the entire embankment foundation area, except for the river bed section in which no fine sand deposits existed, was systematically compacted with explosives. The subsidence of the compacted areas averaged from 2.0 to 2.5 feet, with estimated reduction in void ratio from an average of 0.95 to 0.80. Based on a subsequent stress analysis of the foundation, this increased density is considered to be satisfactory for safety against a foundation flow failure.

Downstream Rock Terrace

One other feature of the embankment which is worthy of brief mention because it is related to the foundation treatment is the downstream rock fill terrace. This terrace, which is underlain throughout by a two-layer filter of sand and gravel, forms a second line of defense against seepage forces in the foundation which conceivably could be transmitted to the toe of the embankment through some minor unexplored geological formations below the bottom of the trench; and, further, it can be credited with increasing the general stability of the embankment and foundation. The rock fill placed in this terrace is being obtained from surplus structure excavation.

Nearly all field exploration, laboratory tests, and design studies for these investigations were performed by Government forces with Government-owned plant. For the greater part, these operations have been supervised or performed by the Soils and Geology Section located in the District's sub-office at Concord, New Hampshire. This arrangement provides a desirable unified control of the investigations from the preliminary stage to the final design.

These investigations were conducted under the general supervision of Colonel A. K. B. Lyman as District Engineer, Major James H. Stratton as Chief of the Engineering Division for the greater duration of the work, and Mr. John E. Allen as Chief of the Flood Control Sub-Division. Mr. R. M. Haines was in charge of the Soils and Geology Section and directly supervised the investigations, except for the initial borings, which were conducted under a separate Geology Section with Mr. A. J. Holmberg in charge.

The dam is being constructed by Coleman Bros. Corporation of Boston, under the direction of Lieut. Colonel L. G. Gallagher, District Engineer, and Mr. H. C. Byrnes, Resident Engineer for the Government.

NEW METHODS AND TECHNIQUE IN SUBSURFACE EXPLORATIONS

By Frank E. Fahlquist*

(Presented at a joint meeting of the Boston Society of Civil Engineers and Hydraulics Section, B.S.C.E., on November 20, 1940.)

Undisturbed Samplings in Borings

The procuring of undisturbed samples in borings is one of the chief problems encountered in the geological investigation of dams, and in fact, of any structures requiring foundation constructions. The importance of sampling methods has long been recognized by engineers and geologists and, although improvements have come slowly, marked advances have been made. For an example of this, I need only to refer you to the difference in reliability and usefulness of the modern specialized undisturbed clay sample and the primitive wash boring sample. A very important advance made recently is publication (March, 1940) of the preliminary report[1] of the Committee on Soil Sampling and Testing, American Society of Civil Engineers. This report classifies soils, from the viewpoint of undisturbed sampling, into five types, common cohesive and plastic soils, very soft and loose soils, cohesionless soils, brittle, compacted and partly cemented soils, and swelling soils. This paper will discuss, in part, undisturbed sampling of soft, loose, and cohesionless sediments by means of a new technique, developed by the author and staff of the U. S. Engineer Office, Providence, R. I., assisted by M. Juul Hvorslev, consultant.

It is impossible to procure truly undisturbed samples. To achieve this ideal, as Hvorslev[1] has pointed out, would require removal of a soil sample from below the surface without any disturbance of the soil structure, or change in density, hydrostatic pressure in the pore-water, or stresses due to loading. Recognizing these limitations, he uses the term "practical undisturbed sample," in those cases only where the soil structure has not been disturbed, and the void ratio has not been changed.

---

*Senior Geologist, U. S. Engineer Office, Providence, R. I.

[1]"The Present Status of the Art of Obtaining Undisturbed Samples of Soil." Report prepared by M. Juul Hvorslev, Research Engineer.

Undisturbed sampling of cohesionless materials has been attempted many times by means of the ramming method. In these cases, mechanical devices have been used in an attempt to prevent loss of the sample. Recently,[2] at Denison Dam, Texas, attempts were made using a rotary method of drilling and a double tube core barrel equipped with a spring core catcher. Complete or partial failure generally results when using these or similar methods in loosely compacted sediments. This is due to initial disturbance of soil structure and change in density, caused by impact and vibration, and inability to retain the soil sample upon withdrawal from the boring.

New Technique for Sampling Cohesionless Materials

4. The technique herein described was developed while investigating fine and medium sand formations, which comprise the foundations of Birch Hill Dam, located on the Millers River in Massachusetts. All of the strata involved in this special exploration lie beneath the water table. All three borings scheduled were successfully completed, and a total of nineteen samples, each about 3 inches in diameter and 25 inches long, were recovered from depths as great as 50 feet.

The new technique provides for, (1) excluding all disturbing vibrations and impact shocks, which in the older methods are induced by ramming of sampler and driving of casing, (2) procuring soil samples within a thin walled piston type sampler, penetration of the sampler being accomplished by a fast continuous drive, and (3) forming, in the bottom of the sampler, a temporarily immovable soil plug, which prevents movement and loss of the sample. The equipment is simple in construction and comparatively inexpensive to build. The method is not involved, but it does require careful and attentive operation.

Each sampling operation requires six steps as outlined in diagram form in Fig. 1. All sampling is done within a standard 6-inch flush-jointed casing equipped with shoe and cutting edge. This casing is carefully lowered in stages, friction on the outside being reduced by jet action. Sinking is facilitated by turning the casing as material within the casing is removed by a special auger and controlled horizontal jet action. At the start of operations, any overlying stratum, which

[2] "Improved Sampler and Sampling Technique for Cohesionless Materials." H. L. Johnson, Civil Engineering, June 1940.

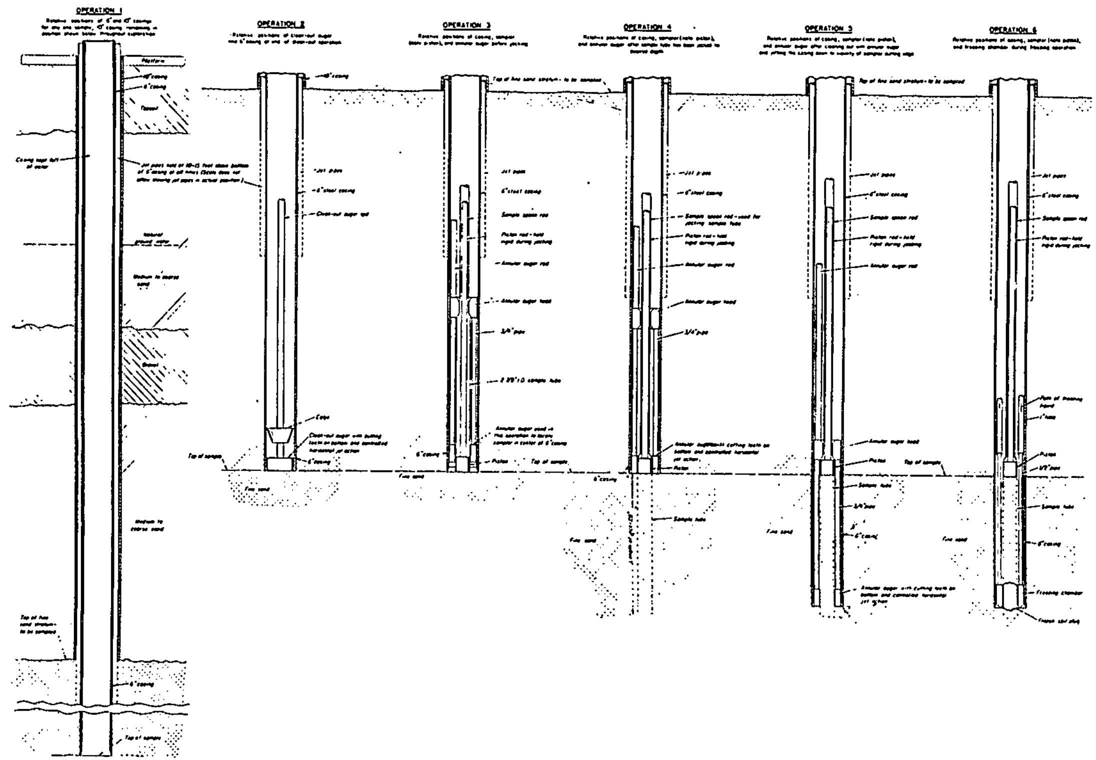


FIG. 1.—PROVIDENCE U. S. E. D. METHOD. UNDISTURBED SAMPLING PROCEDURE IN COHESIONLESS FINE SAND.

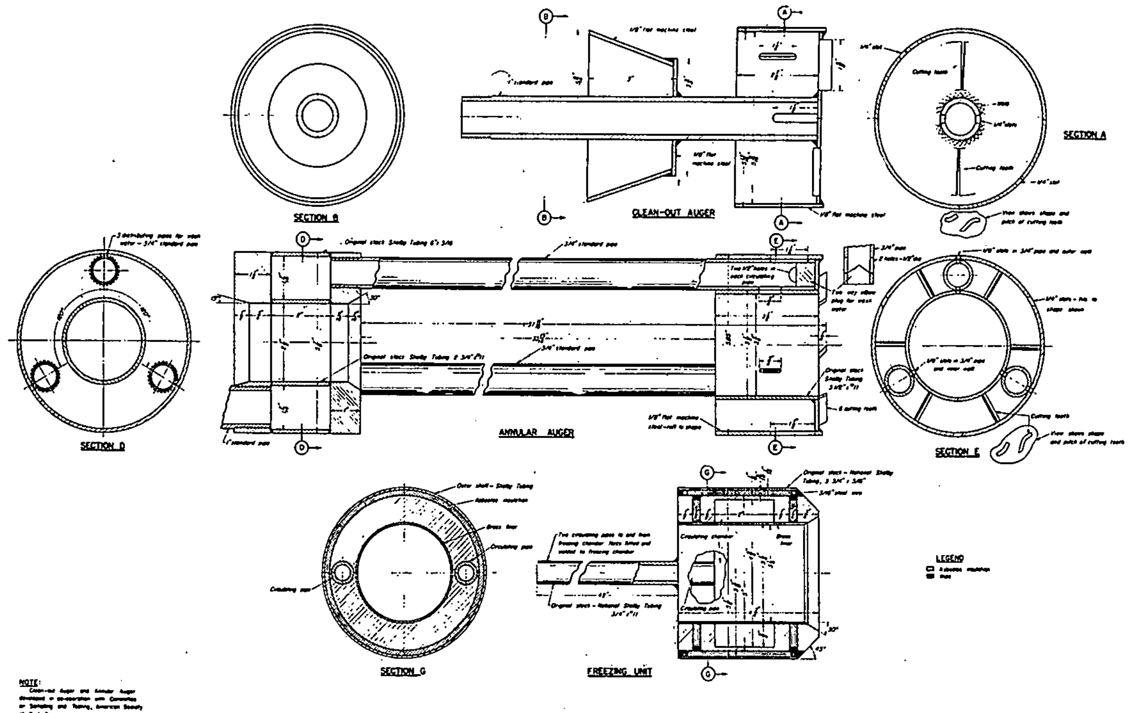


FIG. 2.—PROVIDENCE U. S. E. D. METHOD. CLEAN-OUT AUGER, ANNULAR AUGUR AND FREEZING CHAMBER.

it is not necessary to sample, is cased off by means of a 10-inch casing, thus reducing friction on the 6-inch casing. An excess head of water is maintained in the casing at all times, thus preventing any upward movement of soil.

The undisturbed soil sample is obtained within a 2⅞ inch I.D. steel tube, 36 inches long, equipped with a tight-fitting piston and removable cutting edges, dimensioned to provide different clearances. In taking a sample, the sampler is driven into the soil a distance of 28 inches below the cutting edge of the 6-inch casing by a fast continuous drive, while the piston is held rigidly at the same elevation by pipes extending to and clamped at the surface. A diagram, illustrating this step, is shown in Fig. 1—Operation 4. Details of the casing clean-out auger are shown in Fig. 2, and of the sampler and driving method in Fig. 3.

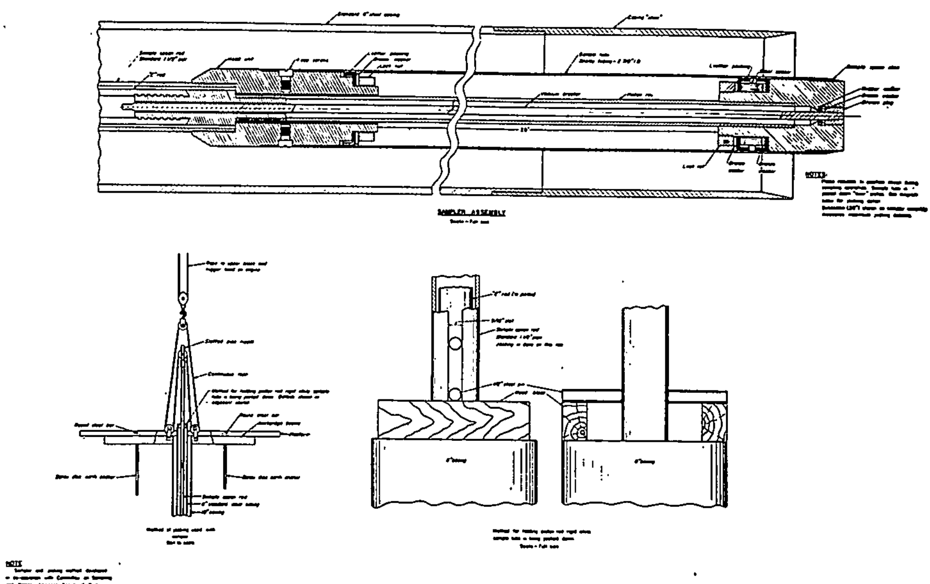


FIG. 3.—PROVIDENCE U. S. E. D. METHOD. SAMPLER AND JACKING SYSTEM.

To aid in centering the sample tube and maintain its vertical position during jacking, a special piece of equipment, called annular auger, is used. The chief function of this equipment, however, is to aid after jacking, in the removal of sand surrounding the sampling tube, and in simultaneously lowering the 6-inch casing to the position as indicated in Fig. 1 for Operation 5. By turning this auger, sand on the outside of the sampler is loosened, being immediately carried away by controlled jet action. Completion of this operation provides an annular space between sampler and casing which upon removal of the auger, provides clear to the bottom of the boring sufficient space to accommodate a small freezing chamber or refrigerating unit. This step is shown in the diagram for Operation 6, Fig. 1.

The refrigerating unit, which is lowered to the bottom of the boring, produces a frozen plug of soil of variable length, but averaging

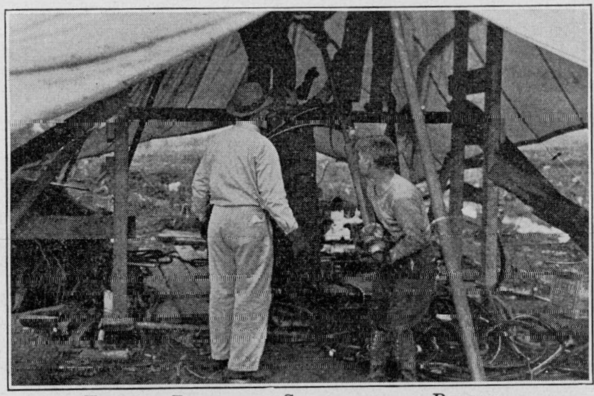


FIG. 4.—REMOVING SAMPLE FROM BORING.

FIG. 5.—SHOE END OF SAMPLER, FREEZING CHAMBER AND FROZEN PLUG AFTER WITHDRAWAL FROM BORING.

about 7 inches, in the lower part of the sample. Freezing is accomplished by circulating pure grain alcohol through the chamber for about 15 minutes at approximately —30°C. This low temperature is obtained by pumping the alcohol through a copper coil immersed in alcohol maintained by dry ice at a temperature of about —80°C. The next step, withdrawal of the sampler from the boring without movement or loss of sample, which in all other methods is frequently the cause of failure, is easily accomplished. Figs. 4 and 5 show this operation and indicate certainty of complete success whenever this technique is used.

Handling Samples in Laboratory

In order to maintain the undisturbed condition of the soil, it is necessary to test samples as soon as possible after they have been obtained. As noted previously, the samples furnished by this technique are contained within a steel tube about 3 inches in diameter and 36 inches long. Although the length of drive is 28 inches, the length of sample recovered is always about three or four inches less, due to material dropping out of that portion of the sampler extending below the frozen plug. This cannot be avoided, for to lower the casing and freezing unit this additional depth might seriously disturb the soil structure of the sample and change its void ratio.

Upon withdrawal of the sampler from the boring, the freezing chamber is slid off the lower end, and the vacuum breaker rod is removed. This vacuum breaker (see Fig. 3) is necessary to establish atmospheric conditions at the top of the sample, so that the sampler head may be removed. The open (upper) end of the sample tube is then tightly but temporarily plugged, and the sample taken to the laboratory set up near the scene of boring operations.

In the laboratory, the soil sample is removed in cylindrical increments ranging in heighth from one to one and a half inches. At this stage of testing, very careful handling is required to establish those measurements of volume and weight necessary for moisture content and void ratio determinations. During these operations, the soil plug is maintained in a frozen condition. After all unfrozen material has been removed from within the sampler, the soil plug is withdrawn, coated with paraffin, and preserved for further study and photographic record.

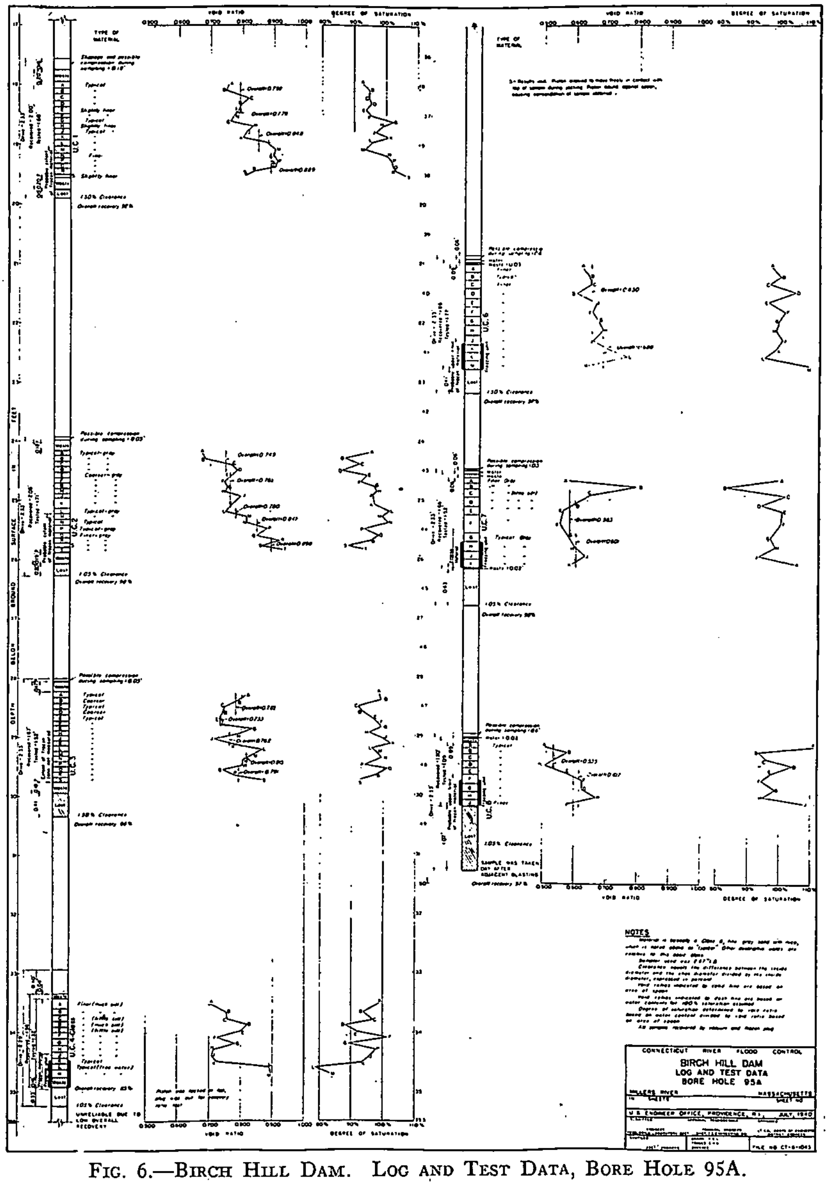


FIG. 6.—BIRCH HILL DAM. LOG AND TEST DATA, BORE HOLE 95A.

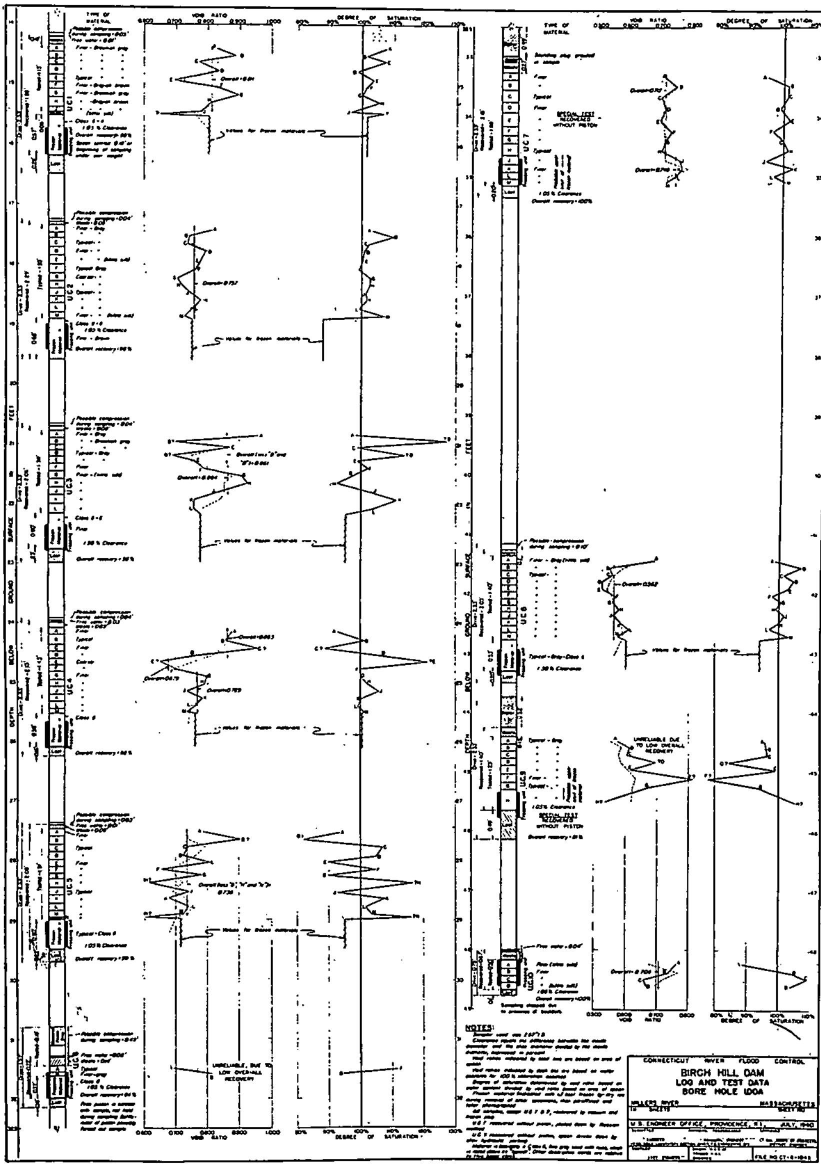


FIG. 7.—BIRCH HILL DAM. LOG AND TEST DATA, BORE HOLE 100A.

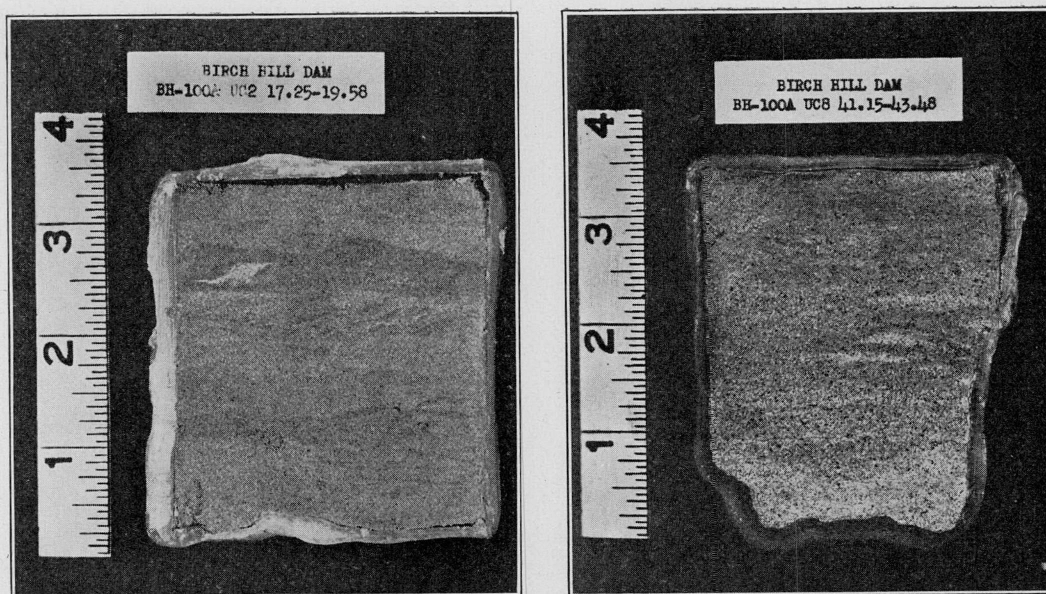


Fig. 8.—Sections of Frozen Plugs Showing Undisturbed Stratification.

Undisturbed Condition Demonstrated

Summarized test data for two of the three borings completed is shown in Figs. 6 and 7. Variations in the void ratio or density and saturation are shown graphically. In these graphs, void ratio determinations, based on the inside diameter of the cutting edge, are connected by solid line, and those based on water contents for an assumed 100% saturation are connected by broken line. For those samples, obtained according to the regular procedure, there is a close agreement in the void ratios. During sampling operations, a few special tests were performed in which variations from the normal procedure were tried. In most cases these trials produced samples of unsatisfactory quality for accurate void ratio determinations. Demonstrating a concordance in results such as shown in Figs. 6 and 7 together with the fact that such high over-all recoveries were obtained is the only way that the author knows of proving that sampling has been accomplished with essentially no change in density of the soil. An additional proof is the appearance of stratifications, as shown in Fig. 8. Such a demonstration, however, is not always valid, for it is obvious that marked changes in soil density may be induced during the sampling process without any visible disturbance of the stratification or bedding.

Cost Data

The several cost items shown below are based upon expenditures for sampling operations to a maximum depth of 50 feet at the last of three successfully completed borings. Costs for the first two borings were considerably higher, due to the fact that progress was retarded by necessary experimentation with the equipment and technique. It is the author's belief that a reduction in these costs may be affected by a few simple improvements. Much valuable time could be saved by using sections of pipe which with couplings are of precisely the same length. Savings in the cost of refrigeration are possible by reducing the size of container for coil and cooling liquid. The costs presented here compare favorably with prices often quoted for undisturbed sampling operations in clay.

Table—Cost of Undisturbed Sampling

Equipment

Basic—ordinary wash boring outfit,	————
Special—annular auger, sampler, extra sample tubes, clean-out auger, miscellaneous (barrels, coils, tank, fittings, hose, etc.),	$700.00 total
Supplies—Alcohol,	$1.00 per sample
Dry ice,	$4.50 per sample
Operations—Labor,	$10.00 per foot (includes sampling)
Progress—Average advance per day,	5½ feet
Samples per day,	1½

Seismic Method of Exploration

Explorations involving costly undisturbed sampling operations, such as those previously discussed, are usually made after preliminary boring explorations have been completed. During the last three years, for such preliminary explorations there has been in the U. S. Engineers organization an increasing application of the seismic method of exploration, supplemented however by borings. Due to the fact that from three to five bedrock determinations may be made by this method in one day, it is possible to investigate a large area in a small fraction of the time it would take to cover the same area by borings, and at much less expense. Although the method has its limitations, which will be discussed shortly, it can and does occupy a considerable sphere of usefulness as an auxiliary tool in geological explorations.

The seismic method is based on the fact that vibrations are transmitted through overburden and rock at various speeds ranging from 600 feet per second to over 20,000 feet per second, depending upon the kind of materials through which the wave travels, the saturation, and degree of compaction or consolidation. This wide range in velocities, as shown in Fig. 9, may be used to advantage by engineers for quickly evaluating the rigidity of materials comprising foundations. Overlapping of velocities in one material with those in another constitutes however one of the uncertainties in the geologic interpretation of results. As more data are accumulated and the method is improved and tried under a large variety of conditions, we may expect more accurate interpretations.

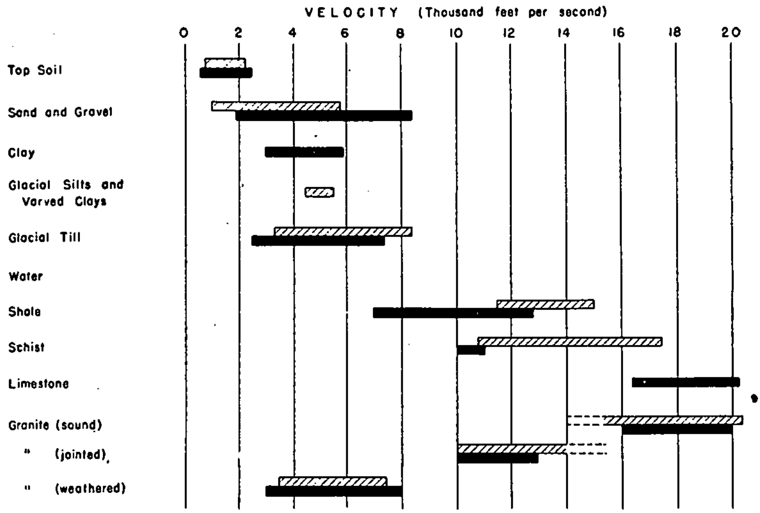


TABLE I. Speed of Propagation of Seismic Waves in Different Materials.

▬ - After E. R. Shepard, The Military Engineer, Sept. - Oct. 1939.

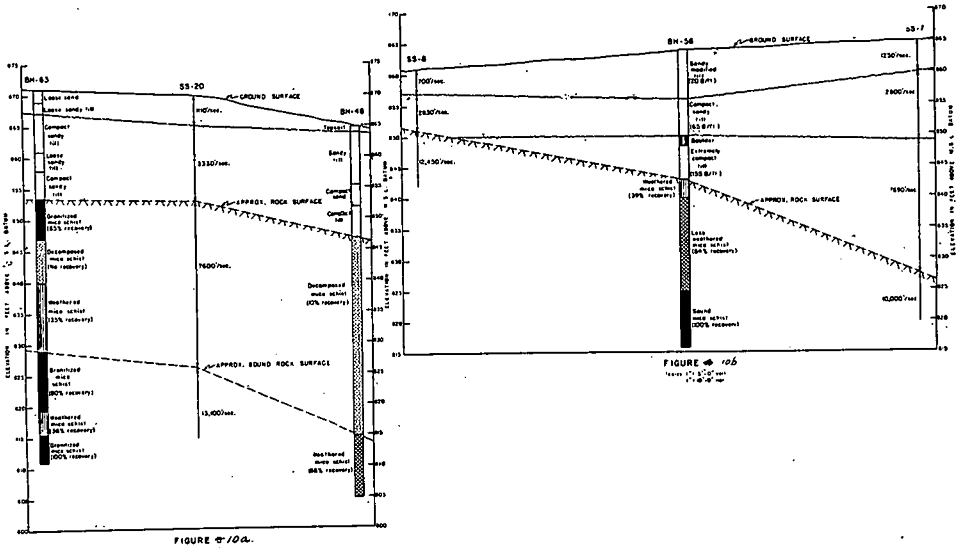
▨ - Records for New England area. By seismic party, Prov. Dist., U.S. Engineers.

FIG. 9.

An overburden of relatively low velocity overlying rock of relatively high velocity produces the best seismic data for depth determination and geologic interpretation. Throughout the New England area where, due to glacial action, the bedrock surface is generally sharply defined, depth determinations are often accurate within 5 to 10 percent. A condition often occurs, however, where the bedrock is broken into blocks or is badly weathered. In such a case the speed of wave propagation is less than that in sound rock by an amount proportional to the weathering and jointing. In addition, if the weathered rock is overlaid by a compact overburden, for example a glacial till, the velocities may be nearly equal, and correct interpretation is difficult.

Correlation of Seismic Data with Borings

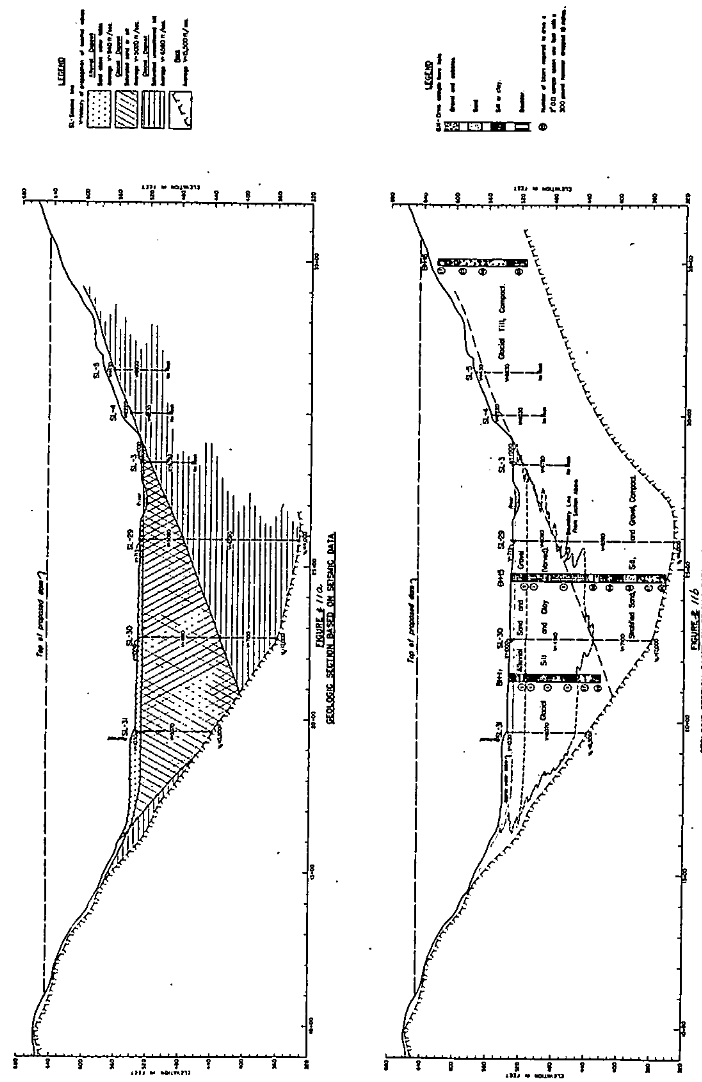
The results of preliminary geologic data, obtained by seismic investigations, and borings is shown in Figs. 10a and 10b. The seismic record of SS-20 in Fig. 10a indicated a four-layer condition, one layer being a thick formation of either very compact glacial till or badly weathered bedrock. Subsequent borings showed this layer



FIGS. 10A AND 10B.—BIRCH HILL DAM. CORRELATION BETWEEN BORE HOLES AND SEISMIC DETERMINATIONS.

to be an unusually deep weathered zone in the underlying bedrock. The difficulty often experienced in correctly classifying materials is shown in Figs. 10a and 10b. In the latter section, material of 7690 feet per second velocity was found to be an extremely compact till, whereas in the former section, material having a similar velocity was found to be weathered bedrock.

Many of the tributary valleys, contiguous to the main valley of the Connecticut River, contain large accumulations of dissimilar sediments. The simplest geologic combination usually includes a relatively thin and recent alluvial deposit overlying a relatively thick glacial formation of sand or varved silt and clay. Compact glacial till deposits usually occur throughout the side hill area and often as an intermediate formation directly overlying bedrock. Such a combination lends itself to geologic delineation, based upon interpretation of seismic data, as shown in Fig. 11a. A delineation of the same section, based on borings completed after the seismic investigation, is shown in Fig. 11b. The greatest discrepancy is in the prediction of shallow depths to the top of a large mass of saturated sand or silt of 5020 feet per second average velocity. Actually, the line delimiting materials



FIGS. 11A AND 11B.—CLAREMONT DAM. SUBSURFACE INVESTIGATIONS.

of 940 and 5020 feet per second average velocities is the water table, with dry sand lying above and saturated sand or silt below. The line of separation of relatively soft and loose materials and compact materials was predicted as shown with considerable accuracy.

Application and Limitation of Seismic Method

The best application of the seismic method is in reconnaisance where location of the bedrock surface is of major consideration. For this type of work the method has a distinct advantage in cost. For example, the three seismic lines SL 29, 30, and 31 shown in Fig. 13b were completed in one day at a cost of about $90.00, whereas the two borings, BH15 and BH17, cost over five times this amount. By making this comparison, the author does not wish to imply that use of the more costly boring method is not justified. Some of the most important problems in the design and construction of dams involve detailed investigations of the overburden, which can be accomplished only by using boring methods. Whether or not a site has been explored by the seismic method should not influence the number of borings required for design.

The seismic method is well adapted to geological investigation of engineering projects of great linear extent, such as highways and railroad locations. Where rod soundings and wash borings of limited usefulness have been used in the past, it is now possible, with aid of the seismograph, to quickly and cheaply determine an appropriate rock profile and furnish better estimates of common and rock excavation items. In location of tunnels the method can be of great assistance in quickly discovering deeply buried pre-glacial river valleys, which if explored by borings would require considerable time. In summation it should be stated that the seismic method is a new tool of exploration which may be used to advantage in geological investigation of dams and other engineering projects. However, it should be used with discretion.

Acknowledgments

Opportunity for conducting the investigations referred to was provided in connection with studies for the Connecticut River Flood

Control Projects. These studies were made by the Providence U. S. Engineer District, J. S. Bragdon, Lieut. Col., Corps of Engineers, U. S. Army, District Engineer, and T. S. Burns, Chief, Engineering Division. The author wishes to acknowledge the assistance of several associates, including John LeRoy, Chief Inspector of Borings, Gerald Lynch, Driller, and William Bode, Draftsman. The cooperation of the Committee on Sampling and Testing, Soil Mechanics and Foundation Division, American Society of Civil Engineers, and of M. Juul Hvorslev, Research Engineer to the Committee, is also appreciated.

DISCUSSION

By M. Juul Hvorslev of the Paper "New Methods and Techniques in Subsurface Exploration"

(Presented at a joint meeting of the Boston Society of Civil Engineers and Hydraulic Section BSCE on November 20, 1940.)

THE retention of very soft or cohesionless soils in the sampling tube during its withdrawal from the bore hole has presented one of the major difficulties in general sampling of soils and has so far been achieved by means of springs and valves of various types. The use of such springs or valves in undisturbed sampling of soils has the disadvantage that it increases the effective thickness of the walls of the sampling tube, may cause serious disturbance of the soil as it enters the tube, and requires a downward movement of the sample in order to effect complete closure of the springs or valves. In the Fahlquist method these sources of disturbance are eliminated, and the author and his associates deserve credit not only for having conceived the idea of freezing the lower part of the sample but also for doing something about it and for persisting until a successful and practical solution was attained.

In undisturbed sampling it is not sufficient to retrieve the sample but, first of all, to get the soil into the sampling tube without disturbing the soil structure or causing any changes in the void ratio. Furthermore, it must be avoided that such changes or disturbances take place during the subsequent withdrawal of the sampler, during the transportation of the sample and its removal from the container or tube, and during the final preparation of test specimens in the laboratory. These problems have also been given thorough consideration in the sampling procedure described by the author and have formed the principal subject of the investigations carried out on behalf of the Committee on Sampling and Testing, Soil Mechanics and Foundations Division, American Society of Civil Engineers, in which investigations the

*Research Engineer, Soil Mechanics and Foundations Division, American Society of Civil Engineers.
Research Fellow in Soil Mechanics, Graduate School of Engineering, Harvard University.

Providence District of the U. S. Engineer Department has given very generous cooperation. A paper containing a summary of the results of these experiments was presented before the Annual Convention of the American Society of Civil Engineers in Denver on July 25, 1941.[1] Basing his opinion on the results of these experiments and on observations made during the sampling at Birch Hill Dam, the writer believes that the sampler and sampling procedure described by the author will cause a minimum of disturbance to the soil in comparison with other currently available methods for sampling of cohesionless soils. As indicated by the author, various minor improvements in the equipment and sampling procedure can be made, but, since some disturbance of the soil or at least a change in stress conditions always will occur during the sampling, the principal remaining problem is to determine the probable magnitude of the disturbance of the soil, or, in this case, the probable change—if any—in the void ratio of the soil during the sampling. A definite answer to this question cannot be given before further experiments have been made, but some of the possibilities will be outlined in the following.

Let e be the void ratio of the soil in its undisturbed state and V the corresponding total volume of the sample; V' is the total volume and e' the void ratio determined in the laboratory, and $\Delta V = V - V'$ is the change in total volume caused by the sampling or inaccuracies in measurements; $\Delta e = e - e'$ is the corresponding change or error in the void ratio and is determined by

$$\Delta e = \frac{\Delta V}{V}(1 + e) = \frac{\Delta V}{V}(1 + e' + \Delta e).$$

Since the inside diameter of the sampling tube usually is determined with satisfactory accuracy, we may replace $\Delta V/V$ in the above equation with $\Delta L/L$, where L is the actual length of the sample corresponding to e, and $\Delta L = L - L'$ is the change of error in measuring this length. When ΔV or ΔL is due only to errors of measurement or to changes in void ratio without corresponding changes in the water content, an error ΔS in the degree of saturation results,

$$\Delta S = -\frac{\Delta e}{e}.$$

In Figs. 6 and 7 is shown that the sample was divided into seg-

[1]Progress in the Development of Improved Methods for Obtaining Undisturbed Samples of Soils.

ments averaging 1½ inches in height. Each segment was removed from the sampling tube by means of a specially constructed auger, and the height of the individual segments can probably not be measured with a greater accuracy than 1/32 inches; that is, $\Delta L/L = \pm 0.02$ and for $e = 0.80$, $\Delta e = \pm 0.036$ and $\Delta S = \mp 0.045$. These probable errors correspond approximately to the scattering of the results shown on Figs. 6 and 7. Errors resulting from other laboratory operations, such as determination of the wet and dry weight and the specific gravity of the soil, have been considered negligible in comparison with the error in measuring the heights of the individual segments. The probable error in the average void ratio and degree of saturation of a number of segments is, of course, much smaller and decreases in this case directly with the sum of the heights of the segments.

Before discussing the possible changes in the void ratio and total volume of the sample it will be helpful briefly to review what happens during the actual sampling. When a sampler is forced into the soil an amount of soil approximately equal to the volume of the walls of the sampling tube is displaced. During the first part of the drive when the total force due to friction between the sample and the tube still is small, a considerable part of this displaced soil may find its way into the tube and will thereby increase the length of the sample and cause disturbance of the soil structure. During the above-mentioned experiments by the Committee on Sampling and Testing it was found that such an entrance of excess soil into the sampling tube can be practically but probably not entirely eliminated and the general disturbance of the soil in and below the sampler reduced by decreasing the thickness of the walls of the sampling tube to 2½ to 5 percent of the diameter of the sample, but the experiments were made close to the soil surface and other experiments have shown that the tendency to entrance of excess soil increases with the depth of the borehole. The tendency to entrance of excess soil is smaller in case of sandy and silty soils than in case of plastic cohesive soils.

The friction between the sample and the tube increases with the depth of penetration and the length of the sample and may cause some disturbance close to the surface of the sample and a slight compaction of the soil. The most important influence of this friction is, however, that at a certain depth of penetration it has increased to such an extent that the soil load below the sampler exceeds the bearing capacity of the soil; the soil layers will then be deflected downwards, stretched and reduced in thickness with consequent serious disturbance of the soil structure. This stretching and reduction in thickness of the soil layers before the soil enters the sampling tube and not an actual compaction of the soil is the principal cause of any material shortening of the sample. It is evident that in undisturbed sampling the depth of penetration of the sampler should not exceed the depth at which the downward deflection of the soil layers below the sampler starts. The friction between the sample and the tube can be decreased by making the diameter of the cutting edge slightly smaller than the inside diameter of the tube. The provision of such an inside clearance will decrease the disturbance of the sample and increase the above-mentioned safe depth of penetration, but the clearance should not be so large that the sample undergoes excessive lateral deformations or the inside friction is entirely eliminated since this may cause an equally serious disturbance of the sample or its loss during the withdrawal of the sampling tube.

The disturbance of the soil and the length of the sample are also greatly influenced by the method used to force the sampling tube into the soil. A minimum of disturbance and a maximum undisturbed length of sample is attained when the sampling tube is pushed into the soil in a fast continuous motion. The completion of the drive in a few seconds has the further advantage that material changes in the water content or void ratio of fully saturated soils cannot take place in so short a time except in the case of very permeable soils.

In spite of improvements in the design of sampling tubes and methods of sampling, some disturbance of the soil will occur during the sampling. Such a disturbance may or may not cause a change in the void ratio. Two years ago Professor J. Jaky[2] of Budapest, Hungary, made a series of soil sampling experiments on fine grained cohesionless soils. The experiments were made close to the ground surface and with thin, short sampling tubes of various diameters. It was found that the void ratio of loose soils decreased and that of dense soils increased with a few percent during the sampling. These findings are in agreement with the now well-established fact that failure or disturbance of cohesionless soils may cause a decrease or an increase

[2]Communication to the Committee on Sampling and Testing; see page 37 in the preliminary report on "The Present Status of the Art of Obtaining Undisturbed Samples of Soils."

in the void ratio depending upon whether the original void ratio is greater or smaller than the critical void ratio. However, the critical void ratio is not a constant for a given soil but decreases rapidly with increasing pressure, and it can therefore be expected that the tendency of the void ratio to decrease upon disturbance of the soil will increase with the depth of the bore hole. Vibrations will nearly always produce a decrease in the void ratio while a strong upward flow of water tends to increase the void ratio. It is again emphasized that changes in the void ratio of fully saturated soils do not take place instantaneously but require a certain period of time depending upon the permeability of the soil. The sampling operation should therefore be completed and the total volume of the sample determined as rapidly as possible.

Returning now to the sampling procedure described by the author, the functions of the piston will first be discussed. During the first part of the drive, the piston will prevent any entrance of excess soil except for a small amount which may be required to compensate for the clearance at the cutting edge. Later, when the top of the sample tends to pull away from the piston, a partial or full vacuum will be created. This reduction in the pressure on top of the sample will decrease the friction between the sample and the tube, will reduce the soil load below the sampler, and will thereby increase the safe depth of penetration, but it will also create an upward flow of water which, if large enough and sustained for a sufficient length of time, may cause an increase of the void ratio. Immediately after completion of the drive, the elevation of the top of the sample should be determined by withdrawing the stop pin in the drill rod and allowing or forcing the piston to settle to the top of the sample. Likewise, the movements of the piston during the subsequent operation of the annular auger and the freezing of the lower part of the sample should also be accurately determined. When the piston is solid, any water found between the piston and the top of the sample must be forced out through the sample before the exact elevation of the top of the sample can be determined. To avoid this delay and the consequent danger that further changes in void ratio may take place, the piston was originally provided with a ball check valve through which the water could escape into the hollow piston rod. Since 97 to 100 percent recovery was quite consistently obtained, the ball valve was later replaced with the vacuum breaker rod shown in Fig. 3. Rapid observation of the elevation of the top of the sample can also be attained by allowing the piston to move freely during the drive. Automatic regulation of the pressure on top of the sample will thereby be lost and the safe depth of penetration probably decreased, but the danger that a strong upward flow of water through the sample takes place is also eliminated. We shall now consider the following possibilities, assuming that we are dealing with medium dense cohesionless soils and bearing in mind that the void ratio of very dense soils tends to increase and that of very loose soils to decrease during the sampling.

1. There is no settlement of the piston immediately after completion of the drive; the recovery is equal to 100 percent.

The diameter of the cutting edge is, say, one percent smaller than the inside diameter of the tube and the volume of the tube therefore approximately two percent greater than that corresponding to the diameter of the cutting edge. Since the stresses are reduced after the soil has passed the cutting edge, it is possible that this additional two percent in volume, required to fill the tube completely, may be supplied through an increase in void ratio, but it is also possible that it may be supplied, in part or in toto, through entrance of excess soil. Furthermore, the soil directly below the sampler is subjected to large stresses and some disturbance, and it is probable that its void ratio has been slightly decreased before it enters the sampling tube, except in case of very dense soils. Taking these more or less opposing influences into consideration, it is probable that the void ratio of the sample does not differ materially from that of the undisturbed soil but—in the writer's opinion—it is questionable whether it would be safe to correct the void ratio of the sample as determined in the laboratory for the abovementioned two percent increase in volume ($e' = 0.80$, $\Delta V/V = -0.02$, $\Delta e = -0.035$, $e = 0.765$).

2. A slight settlement of the piston takes place immediately after the completion of the drive.

If this settlement is very small—say, not more than two or three percent of the length of the sample—and takes place rapidly, it is probable that the entrance of excess soil has not been sufficient to compensate for the effect of the clearance at the cutting edge or that the safe depth of penetration has been slightly exceeded. It is also possible that a decrease of the void ratio has contributed to the settlement, but a tendency to such a decrease is counteracted by the slight upward flow of water through the sample. Under these circumstances it is probable that the void ratio of the upper or unfrozen part of the sample does not differ materially from that of the undisturbed soil. On the other hand, a slow settlement of the piston indicates that water accumulated on top of the sample is being forced out through the sample or that a decrease in void ratio is taking place. Estimates of the amount of water which could enter or pass through the sample during the time required for the driving and for the settlement of the piston may indicate whether a correction of the void ratio corresponding to the settlement or a part thereof should be made.

3. A material settlement of the piston takes place immediately after completion of the drive.

Such a settlement indicates that the safe depth of penetration has been exceeded and probably also that a strong upward flow of water and changes in the void ratio have taken place. During the last part of the drive the soil layers have been deflected, stretched and reduced in thickness before they enter the sampling tube, and the settlement of the piston does not correspond to the actual changes in void ratio. A comparison of recovery ratios and void ratios of samples taken with different depths of penetration of the tube may indicate whether changes in the void ratio actually have taken place.

4. A settlement of the piston takes place during the operation of the annular auger and the lowering of the casing.

Such a settlement is undoubtedly caused by slight vibrations of the sampling tube during these operations and indicates an actual decrease of the void ratio for which a correction corresponding to this settlement of the piston should be made.

5. During the freezing of the lower part of the sample the water in the frozen part will expand 9 percent and may thereby cause an increase in the void ratio or, more likely, that 9 percent of the water is expelled from this part of the sample. In case the frozen soil extends clear across the sample before the flow of freezing liquid is stopped, water may thus be forced into the upper part of the sample, accum-

ulate on top, and cause the piston to rise. It is unlikely that this slow flow of water will cause any change in the void ratio of the unfrozen part of the sample, but the rise of the piston should be observed and the water accumulated on top of the sample measured in order to determine whether the piston was in actual contact with the top of the sample during the foregoing observations.

OF GENERAL INTEREST

PRIZES AWARDED AT ANNUAL MEETING ON MARCH 19, 1941

The Desmond FitzGerald Medal

TO ALMON L. FALES AND HARRISON P. EDDY, JR., MEMBERS

Presentation made by Carroll A. Farwell, Chairman of Committee on Award

The Desmond FitzGerald Medal was instituted and endowed in 1910 by the late Desmond FitzGerald, a Past President and honorary member of this Society, and is awarded annually for a paper, presented to the Society by a member, and published during the year, which is adjudged worthy of special commendation for its merit. The Committee on Award this year, consisting of Carroll A. Farwell, James E. Lawrence, and Robert Spurr Weston, selected from the list of a number of excellent papers one which was recommended to the Board of Government for the Award. The paper selected was entitled "Discussion of Problems of Sewerage and Sewage Disposal in Boston Metropolitan District", by Almon L. Fales and Harrison P. Eddy, Jr., members, co-authors, presented at a joint meeting of the Society and Sanitary Section held on January 24, 1940, and published in the JOURNAL of the Society for April, 1940. On behalf of the Board of Government Mr. Farwell presented the Desmond FitzGerald Medals to Mr. Fales and Mr. Eddy. Due to the fact that Mr. Eddy was not present, Mr. Fales expressed his appreciation of the honor bestowed upon them by the presentation of these medals and stated that he would transmit the prize to Mr. Eddy.

The Sanitary Section Prize

TO PROF. THOMAS R. CAMP, MEMBER

Presentation made by Robert Spurr Weston, Chairman of Sanitary Section Prize Award Committee

On behalf of the Board of Government, Robert Spurr Weston, Chairman of the Committee on Sanitary Section Prize Award, presented the prize to Prof. Thomas R. Camp, member, for his paper on "The Filtration System for the New M. I. T. Swimming Pool—Design and Operation", presented at a meeting of the Sanitary Section on December 4, 1940 and published in the January, 1941, JOURNAL. The prize consisted of books: "Sewage-Treatment Works", by C. E. Keefer; "Recent Advances in Surface Chemistry and Chemical Physics", by Forest Ray Moulton; "The Principles of Electrochemistry", by Duncan A. McInnes. Prof. Camp accepted the prize with appropriate remarks.

The Designers' Section Prize

TO RICHARD S. HOLMGREN, MEMBER

Announcement of Award made by President Arthur L. Shaw

The President announced that the Board of Government had awarded the Designers' Section Prize to Mr. Richard S. Holmgren, member, for his paper on "The Pittsburgh Conservation Reservoir Development of the New Hampshire Water Resources Board", presented at a joint meeting of the Designers' Section held on February 14, 1940, and published in the April, 1940 JOURNAL. Mr. Holmgren was unable to be present to receive his prize but the President stated the prize would be forwarded to him later.

The prize consisted of books: "Yacht Cruising", by Claude Worth; "Yachts —Their Care & Handling", by Winthrop P. Moore; "Sailing Made Easy", by Rufus G. Smith.

The Clemens Herschel Prize Awards

TO MILES N. CLAIR, MEMBER, AND ROBERT D. CHELLIS

Presentation made by Ralph W. Horne, Past President of the Society

The Clemens Herschel prize was established by a gift from the late Clemens Herschel, a Past President and Honorary member of the Society, and is awarded for a paper which has been particularly useful and commendable and worthy of recognition. This year two prizes were awarded; one to Miles N. Clair, member, for his paper on "Concrete Technology", presented at a meeting of the Society on April 17, 1940, and published in the July, 1940 JOURNAL; the second prize was awarded to Robert D. Chellis, for his paper on "A Consideration of Pile Driving with Application of Pile Loading Formula", presented at a meeting of the Designers' Section on March 13, 1940, and published in the January, 1941, JOURNAL. On behalf of the Board of Government, Past President Ralph W. Horne presented the Prizes which consisted of the book "Frontinus and the Water Supply of the City of Rome", by Clemens Herschel. Mr. Clair and Mr. Chellis each accepted the prizes with appropriate remarks.

The Northeastern University Section Prize

TO JOHN E. BAMBER, STUDENT MEMBER

Presentation made by Carroll A. Farwell, Chairman of Prize Awards Committee

In accordance with the recommendations of the Committee on Prize Awards a prize was given this year for an original paper prepared by a member of the Northeastern University Section and presented during the year at a regular student conference meeting at the University. This award was made to John E. Bamber, member of this section, for his paper on "Construction of Spur Railway Track to Camp Edwards, Bourne, Mass.", presented at a meeting of Students at the University on January 10, 1941.

The prize consisted of books: "Navigation", by George L. Hosmer; "Contracts, Specifications and Engineering Relations", by Daniel W. Mead; "Timber Design and Construction", by Henry S. Jacoby and Roland P. Davis; "Soil Mechanics and Foundations", by Fred L. Plummer and Stanley M. Dore.

BOSTON SOCIETY OF CIVIL ENGINEERS

COMMITTEE ON FLOODS

The Boston Society of Civil Engineers Committee on Floods was re-appointed by President Albert Haertlein at the meeting of the Board of Government held on April 8, 1941. This Committee was originally appointed on April 6, 1936, by President H. K. Barrows, to study the March, 1936 Floods, and Mr. Arthur T. Safford, Engineer, Proprietors of Locks & Canals on Merrimack River was Chairman.*

The Committee has been re-appointed each year and its work has logically developed into a study of subsequent floods, so that its name is now designated as the Committee on Floods.

At the Annual meeting of the Society on March 19, 1941, a report of that Committee was presented for the Committee by Mr. Howard M. Turner, present Chairman, with the recommendation that the Committee be continued.

The present membership of this Committee is as follows:

Howard M. Turner, Chairman, 12 Pearl Street, Boston, Mass.

H. K. Barrows, Cons. Engr., 6 Beacon Street, Boston, Mass.; Paul L. Bean, Cons. & Hydraulic Engr., 11 Lisbon Street, Lewiston, Maine; B. L. Bigwood, Dist. Engr., U. S. Geol. Survey, 410 Asylum St., Hartford, Conn.

Col. John Bragdon or Capt. R. E. York, U. S. Engr. Office, Providence, R. I.; Harry P. Burden, Tufts College, Medford, Mass.; Allen J. Burdoin, Metcalf & Eddy, 1300 Statler Bldg., Boston, Mass.

W. S. Cummings, Chg. Engr. B&M. R. R., North Station, Boston, Mass.; Ernest J. Christie, Meterorologist, U. S. Weather Bureau, Hartford, Conn.; Lt. Col. Leonard B. Gallagher, U. S. Engr. Office, Park Square Bldg., Boston.

Prof. J. W. Goldthwait, Dartmouth College, Hanover, N. H.; Arthur C. Grover, Civil Engr., 55 Evergreen Avenue, Rutland, Vermont; Gen. R. K. Hale, Dept. Pub. Works, 100 Nashua Street, Boston.

R. S. Holmgren, Chf. Engr. Water Resources Bd. of N. H., Concord, N. H.; S. S. Kent, Secretary, 66 Broadway, Lowell, Mass.; H. B. Kinnison, Dist. Engr., U. S. Geol. Survey, Federal Bldg., Boston.

A. W. Ladd, Hydraulic Engr., Holyoke Water Power Co., Holyoke, Mass.; Francis H. Kingsbury, Mass. Dept. Pub. Health, State House, Boston, Mass.; Prof. A. C. Lyon, University of Maine, Orono, Maine.

R. R. Marsden, 22 South Spring Street, Concord, N. H.; F. H. Mason, Chf. Engr. Central Maine Power Co., Augusta, Maine; L. G. Morphy, Gen. Supt. Rutland Railroad Co., Rutland, Vermont.

William Noyes, Oper. Engr. Pub. Service Co. of N. H., Manchester, N. H.; H. M. Nelson, New England Power Co., 441 Stuart Street, Boston; W. W. Peabody, Div. Engr. Met. Dist. Wtr. Supply Comm., Holden, Mass.

Prof. L. F. Puffer, Civil Engr. Univ. of Vermont, Burlington, Vermont; Arthur T. Safford, Engr. Prop. of Locks & Canals, 66 Broadway, Lowell, Mass.; A. D. Ross, Weather Bureau, Concord, N. H.

C. M. Saville, Engr. & Chf. Met. Dist. Comm., 1026 Main Street, Hartford, Conn.; M. R. Stackpole, Dist. Engr. U. S. Geol. Survey, Augusta, Maine; R. H. Suttie, Assoc. Prof. Yale Engr. School, Yale Univ., New Haven, Conn.

William F. Uhl, 201 Devonshire Street, Boston, Mass.; Arthur D. Weston, Chf. Engr. Dept. Pub. Health, State House, Boston, Mass.; George V. White, Asst. San. Engr. Dept. Public Health, State House, Boston, Mass.

*The April, 1936, Journal gives a list of members of Committee as then appointed.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

FEBRUARY 19, 1941.—A regular meeting of the Boston Society of Civil Engineers was held this evening at the Engineers Club and was called to order by the President, Arthur L. Shaw, at 7:00 P. M. Eighty members and guests attended the meeting and 78 persons attended the dinner.

The President announced the death of Edward S. Larned, who died on January 6, 1941 and who had been a member since February 17, 1904.

The President introduced the speaker for the evening, Mr. Clarence B. Humphrey, Engineer for the Land Court, Boston, Mass., who gave a very interesting paper on "The Land Court, Registration of Title to Land in Massachusetts, its Surveying procedure and use of Massachusetts Plane Coordinate System."

Adjourned at 8:40 P. M.

EVERETT N. HUTCHINS, *Secretary.*

MARCH 19, 1941.—The ninety-third annual meeting of the Boston Society of Civil Engineers was held today at the Boston Chamber of Commerce and was called to order at 4:30 P. M. by the President, Arthur L. Shaw.

The minutes of all previous meetings of the year from meeting of January 24, 1940, to January 8, 1941, which have been printed in the various issues of the JOURNAL were approved as printed.

The Annual Reports of the Board of Government, Treasurer, Secretary and Auditors were presented. Reports were also made by the following committees: Social Activities, Relations of Sections to Main Society, Welfare, Library, 1936 Floods, John R. Freeman Fund, and Headquarters.

Voted that the reports be accepted with thanks and placed on file, and that they be printed in the April, 1941, JOURNAL.

Voted that the incoming Board of Government be authorized to appoint such Committees as it deems desirable.

Vice-President Albert Haertlein presented his resignation which was accepted as Vice-President, effective as of the date of this meeting, after serving one year of his two-year term, having been nominated for the office of President.

The report of the Tellers of Election, Stanley M. Dore and R. M. Soule, was presented and in accordance therewith the President declared the following had been elected officers for the ensuing year:

President — Albert Haertlein
Vice-President (for one year) — Charles R. Main
Vice-President (for two years) — Athole B. Edwards
Secretary — Everett N. Hutchins
Treasurer — Charles L. Coburn
Directors (for two years)
C. Frederick Joy, Jr. and Waldo F. Pike

Nominating Committee (for two years)
Anthony S. Coombs, Howard T. Evans, William L. Hyland

The retiring President, Arthur L. Shaw, then gave his annual address on "Some Observations on Engineering for National Defense."

Sixty members attended this part of the meeting.

The meeting adjourned to assemble at 7:30 P. M., the Annual Dinner being held during the interim.

The President then called the meeting to order, for the presentation of Prizes.

The President requested Mr. Carroll A. Farwell, Chairman of the Committee on Award of the Desmond FitzGerald Prize, to present this prize to Mr. Almon L. Fales (member), and to Mr. Harrison P. Eddy, Jr., (member), joint authors, for their paper on "Discussion of Problems of Sewerage and Sewage Disposal in Boston Metropolitan District," presented at a joint meeting of the Society and Sanitary Section on January 24, 1940, and published in the JOURNAL, April, 1940. Due to the fact that Mr. Eddy was not present, Mr. Fales stated that he would transmit the prize to Mr. Eddy.

Mr. Robert Spurr Weston, Chairman of the Committee on Award of Sanitary Section Prize, was requested by the President to present the Sanitary Section Prize to Prof. Thomas R. Camp, (member), for his paper on "The Filtration System for the new M. I. T. Swimming Pool—Design and Operation," presented at a meeting of the Sanitary Section on December 4, 1940, and published in the January, 1941, JOURNAL.

The President stated that the Board of Government had awarded the Designers' Section Prize to Mr. Richard S. Holmgren, (member), for his paper on "The Pittsburgh Conservation Reservoir Development of the New Hampshire Water Resources Board," presented at a joint meeting of the Designers' Section on February 14, 1940, and published in the April, 1940, JOURNAL. Mr. Holmgren was unable to be present to receive the prize but the President stated the prize would be forwarded to him later.

The President requested Past President Ralph W. Horne, to present the Clemens Herschel Prize, one to Miles N. Clair, (member), for his paper on "Concrete Technology," presented at a meeting of the Society on April 17, 1940 and published in the July, 1940, JOURNAL; and one to Robert D. Chellis for his paper on "A Consideration of Pile Driving with Application of Pile Loading Formula," presented at a meeting of the Designers' Section on March 13, 1940, and published in the January, 1941, JOURNAL.

Mr. Carroll A. Farwell, Chairman of the Prize Award Committee, presented the Northeastern University Section Prize to John E. Bamber, Student Member, for his paper on "Construction of Spur Railway Track to Camp Edwards, Bourne, Mass.," presented at a meeting of Students at the University on January 10, 1941.

The newly elected President, Prof. Albert Haertlein and other distinguished guests were introduced.

President Shaw then introduced the guest speaker, Mr. Charles E. Smith, Vice-President of the New York, New Haven and Hartford Railroad Co., who gave an especially interesting talk on "Railroad Transportation as affected by Waterway, Highway, Airway and Pipe Line Transportation."

One hundred fifteen members and guests attended the dinner.

The meeting adjourned at 9:00 P. M.

EVERETT N. HUTCHINS, *Secretary.*

SANITARY SECTION

JANUARY 15, 1941.—A meeting of the Sanitary Section was held at 7:00 P. M., this evening in the Society Rooms. Twelve members and guests were present at the supper at Patten's Restaurant which preceded the meeting.

Future meetings and the publication of recent papers presented before the Sanitary Section were discussed.

The Chairman, C. Frederick Joy, Jr., introduced the speaker, Mr. Bayard F. Snow, Consulting Engineer, Boston, who spoke on "New Sewage Plant at the Monson State Hospital."

Mr. Snow read a very interesting and carefully prepared paper on the new sewage treatment plant which he designed and which was constructed under his supervision, for the Monson State Hospital. His paper was very interestingly illustrated by numerous slides showing details of construction. This plant is one of the most up to date and complete sewage treatment plants in the state.

After an interesting discussion of the paper, the meeting adjourned at 9:30 P. M. Thirteen members were present at this meeting.

GEORGE W. COFFIN, *Clerk.*

FEBRUARY 11, 1941.—A meeting of the Sanitary Section was held at 7:30 P. M., this evening in the Society Rooms. Twenty-five members and guests were present at the supper at Patten's Restaurant which preceded the meeting.

The Chairman, C. Frederick Joy, Jr., introdûced the speakers, Walter E. Merrill, Senior Sanitary Engineer and Clarence I. Sterling, Jr., Assistant Sanitary Engineer, State Department of Public Health, who spoke on "Tour of Typical American Sewage Treatment Plants." Messrs. Merrill and Sterling recently completed a trip covering nearly 3,000 miles in which they visited 22 sewage treatment plants and 4 water treatment plants in New York, New Jersey, Ohio, Indiana, Illinois, Michigan, Maryland and Washington, D. C. They took several reels of motion pictures of the operation of these plants, and also several hundred photographs of typical details of these plants. Two reels of motion pictures and about fifty still pictures were shown.

After an interesting discussion of this paper the meeting adjourned at 9:30 P. M. Forty-six were present at this meeting.

GEORGE W. COFFIN, *Clerk.*

MARCH 5, 1941.—A regular meeting of the Sanitary Section was held this evening at the Society rooms, attended by 50 members and guests, preceded by a supper at Patten's Restaurant attended by 27 persons.

The meeting was called to order at 7:30 P. M. by the Chairman, C. Frederick Joy, Jr.

The clerk read the report of the Executive Committee which was accepted and placed on file.

Mr. Frank L. Flood, Chairman of the "Committee to Study Limiting Velocities of Flow in Sewers," presented a progress report. The report was accepted and it was *VOTED* to authorize the committee to continue its studies and to submit a final report on or before the Annual Meeting in March, 1942.

Voted to accept the recommendation of the Committee on Relations of Sections to Main Society, that Article II of the By-Laws of the Sanitary Section be amended so as to read as follows:

"Section 1. Members of the Boston Society of Civil Engineers in all grades shall be members of the Sections except that membership in the Northeastern University Section is limited to members of the Society in all grades, who are students, graduates, or members of the faculty of Northeastern University."

"Section 2. Only members of the Northeastern University Section who are students at Northeastern University are eligible to hold office in that section."

Chairman Paul F. Howard of the Nominating Committee read the report of the committee, and it was voted that the Clerk be authorized to cast one ballot for the nominees as read. Accordingly, the following officers were elected to serve for the year 1941-1942.

Chairman	George W. Coffin
Vice-Chairman	Charles O. Baird
Clerk	Walter E. Merrill

Executive Committee

C. Frederick Joy, Jr., Frank L. Heaney, William L. Hyland

The Chairman introduced the speaker of the evening, Prof. Gordon M. Fair, Professor of Sanitary Engineering, Harvard Graduate School of Engineering, who gave a talk on "Sanitation—Southern Style."

Prof. Fair has recently made an extensive tour of several of the southern states in which he made studies of the sanitary conditions in many of the typical rural communities of Florida, Mississippi, Alabama and other states. He discussed the relationship of sanitation to the prevalence of three common diseases of the south, namely; malaria, hook worm and typhus fever, the latter disease having been recently brought into the South from rat infested ships. He paid tribute to the ingenuity of the young southern sanitary engineers who were doing excellent work in improving sanitary conditions by way of mosquito control, rat elimination and education. Professor Fair's talk, given in his inimitable style, was interestingly illustrated and gave a very clear picture of sanitary conditions in the far south, and the methods being employed for improving them. A discussion followed Professor Fair's talk and the meeting adjourned, after giving him a vote of thanks, at 9:30 P. M.

George W. Coffin, *Clerk*.

DESIGNERS' SECTION

January 8, 1941.—A joint meeting with the Boston Society of Civil Engineers, preceded by a dinner, was held at the Engineers' Club this evening. President Arthur L. Shaw presided.

Kimball R. Garland, Chairman of the Designers' Section, expressed the pleasure of the Section for the opportunity to participate in this joint meeting.

Mr. Shaw then presented Dr. Karl Terzaghi, the speaker for the evening, who discussed the subject "The Critical Load on Strata of Clay Beneath Foundations."

Dr. Terzaghi began his talk with a summation of the manner in which clay behaves in the laboratory and in place. The difference in behavior under the two conditions can be attributed to the inability to procure undisturbed samples and the method of testing. Plots were shown showing the relationship between void ratio and applied pressure under various circumstances. It would appear that consolidation goes on indefinitely, which we know is incorrect. Insufficiency of extensive and long time observations contribute to the lack of coordination between field and laboratory tests.

Dr. Terzaghi introduced interesting observations on the settlement of the Leaning Tower of Pisa which could be associated in that case with the time factor due to the piece-meal construction of the tower over a long period of years.

In conclusion, he spoke of the need for sub-surface bench marks and observations taken during construction as well as following in order that complete information may be obtained of the behavior of soils under actual field conditions.

Mr. Shaw expressed the thanks of the society to Dr. Terzaghi for his very fine and interesting presentation.

Meeting was adjourned at 9:15 P. M.

Dinner attendance, 73; meeting attendance, 98.

EMIL A. GRAMSTORFF, *Clerk.*

FEBRUARY 12, 1941.—A regular meeting of the Designers' Section was held today jointly with the Boston Post, Society of American Military Engineers at Society Headquarters, preceded by a dinner at which thirty-four members were present.

In preparation for the annual meeting in March, the Chairman was authorized to appoint a Nominating Committee composed of the last three chairmen of the Section to prepare a slate of the officers. The members of this committee are Herman G. Dresser, Anthony S. Coombs, and J. Donald Mitsch.

The chairman then presented a member of the Society, Mr. LeRoy M. Hersum, who gave an interesting and instructive talk on "Underground Protective Structures." Mr. Hersum is associated with the War Department in Washington and is carrying on special work in this particular field.

Following an expression of thanks to the speaker, the meeting was adjourned at 8:30 P. M. Attendance 65.

EMIL A. GRAMSTORFF, *Clerk.*

MARCH 12, 1941—The annual meeting of the Designers' Section was held this evening in the Society's rooms. Chairman Kimball R. Garland called the meeting to order at 7:30 P. M.

The Clerk's report of the last meeting was accepted as read. For the information of the members present, the report of the Executive Committee on the Section's activities for the year was presented by the Clerk. The Nominating Committee, composed of the three recent past chairmen of the Section, submitted its report through Prof. J. D. Mitsch, Chairman of that committee. The report was accepted and, no nominations being made from the floor, the following officers were elected for the ensuing year:

Chairman	John E. Wilbur
Vice-Chairman	Emil A. Gramstorff
Clerk	Herman G. Protze

Executive Committee
Frank A. Lincoln, Wilber S. Colby, Lawrence M. Gentleman.

Following this business session, the chairman introduced the speaker of the evening, Mr. Wesley H. Blank, Structural Engineer, E. B. Badger & Sons Co., and a member of the Section. Mr. Blank spoke on the "Analysis of Rigid Knee Braced Bents and Application to Chemical Plant Design." The talk was well illustrated with charts and slides and was presented in the light of providing food for individual thought for the solution of multi-story bents by the use of simplified charts in conjunction with the Method of Least Work. The illustrative examples dealt with symmetrical multi-tiered knee braced bents, one bay wide, which were analyzed as a series of single bents. Mr. Blank drew freely from his experience and expressed the opinion that building codes must soon realize the need of recognizing the fact that bending moments at column-beam connections are not zero.

An interesting discussion period followed this able presentation of a difficult subject. The meeting adjourned at 9:00 P. M. Attendance 20.

Herman G. Protze, *Clerk*.

HIGHWAY SECTION

December 11, 1940.—A combined meeting of the Highway and Designers' Section of the Boston Society of Civil Engineers was held in the Society Rooms in Tremont Temple this evening.

The meeting was called to order at 7:05 P. M. by Donald W. Taylor, Chairman of the Highway Section.

Records of the previous meeting were read and approved.

The Chairman stated that a nominating committee should be designated at this meeting.

The Chairman appointed to the nominating committee the three past presidents, Messrs. Harding, Coleman and Bone.

There being no other business the meeting of the Highway Section was adjourned and the meeting was turned over to Mr. Kimball R. Garland, Chairman of the Designers' Section.

Mr. Garland introduced the speaker for the evening, Mr. D. G. Sumner, bridge and structure engineer for the Connecticut State Highway Department. Mr. Sumner gave an interesting talk on the Merritt Parkway and Housatonic River Bridge, illustrated by color slides prepared by the Bureau of Street Traffic Research of Yale University.

A question period followed the talk. Mr. Sumner was given a rising vote of thanks.

The meeting adjourned at 8:25 P. M.

Louis H. Smith, *Clerk*.

February 26, 1941.—The Annual Meeting of the Highway Section of the Boston Society of Civil Engineers was held in the Society Rooms, 715 Tremont Temple, on February 26, 1941.

The meeting was called to order at 7:25 P. M. by the Chairman, Mr. Donald W. Taylor.

The records of the previous meeting were read and approved.

The report of the Nominating Committee was read, and upon motion made, seconded and passed unanimously, the Chairman of the Nominating Committee cast one ballot in favor of the following:

Chairman Herman S. Swartz
Vice-Chairman Louis H. Smith
Clerk William C. Paxton, Jr.
Exexcutive Committee
Prof. Charles O. Baird, Jr., Edgar F. Copell, Donald W. Taylor

The Chairman then presented Mr. Philip H. Kitfield, Assistant Project Engineer, Massachusetts Department of Public Works, who spoke on "The Future of Highway Building in Massachusetts."

Mr. Kitfield outlined the trends in highway use and engineering practice in the design of highways in the state. He commented on the super-highway and its probable place in Massachusetts and described the future program of the Massachusetts State Highway system.

A discussion followed. Mr. Kitfield was given a rising vote of thanks for his most interesting and instructive talk.

The meeting adjourned at 9:07 P. M. The attendance was 24 persons.

LOUIS H. SMITH, *Clerk.*

HYDRAULICS SECTION

NOVEMBER 20, 1940.—A joint meeting of the Society and the Hydraulics Section was held today, at the Engineers Club, Boston. 110 members and guests attended. Vice-President, Albert Haertlein presided. Acting Chairman of the Hydraulics Section, Scott Keith, conducted a brief business meeting of the Section at which he was authorized to appoint a committee to nominate officers for the election at the annual meeting in February.

The technical program was devoted to the subject of Dam Foundations. The speakers and subjects were:

F. Stewart Brown, Chief of the Flood Control Design Section of the U. S. Engineers Boston Office, "Foundation Investigations for the Franklin Falls Dam."

Frank E. Fahlquist, Senior Geologist of the U. S. Engineer Providence Office, "New Methods and Technique in Sub-Surface Explorations."

Irving B. Crosby, Consulting Geologist, "Objectives and Methods of Geological Investigations of Dam Sites."

The talks were illustrated and were followed by considerable discussion.

MEDFORD T. THOMSON, *Clerk.*

FEBRUARY 5, 1941.—The annual meeting of the Hydraulics Section was held today in the Society Rooms. Following a supper at the Ambassador Restaurant at which 20 were present, 45 members and guests took part in the meeting. In the absence of Mr. Scott Keith, Acting Chairman, M. T. Thomson, Clerk, conducted the meeting. The clerk's annual report and the minutes of the two preceding meetings were read and accepted.

Following the report of the nominating committee, the officers for the next year were elected..

Chairman Stanley M. Dore
Vice-Chairman George N. Bailey
Clerk Medford T. Thomson
Executive Committee
Allen J. Burdoin, Dr. Kenneth C. Reynolds, Dr. Harold A. Thomas

The officers were introduced and the business meeting was closed.

The speaker for the evening was Professor Leslie J. Hooper, M.E., of the Alden Hydraulic Laboratory, Worcester Polytechnic Institute, who gave an interesting and instructive illustrated talk on the subject of "Recent Model Tests." Following considerable discussion the meeting was adjourned with a rising vote of thanks to the speaker.

MEDFORD T. THOMSON, *Clerk.*

NORTHEASTERN UNIVERSITY SECTION

At 6:00 P. M. on November 8, 1940, members and guests of the Society met and had dinner at the "Old France". Following the dinner, the meeting was opened in 440W at 7:30 P. M. by Walter B. Kelley, the President. There were forty in attendance.

President Kelley introduced the speaker for the evening, Mr. Frederick W. Gow, Division Engineer for the Water Supply Commission, who had charge of rock tunneling for the Quabbin Aqueduct and who was also in charge of the construction of the main dam of the new Quabbin Reservoir. Mr. Gow also supervised the building of nine miles of the new Metropolitan Aqueduct. The subject of his talk was "Tunnel Construction for Pressure Aqueduct", which covered the preliminary work, the drilling, blasting, mucking, cleaning, and the lining of the twelve-foot tunnel which was part of the new pressure aqueduct.

JOHN E. BAMBER, *Secretary*

At 6:00 P. M. on December 13, 1940, members and guests of the Society met and had dinner at the "Old France". Following the dinner, the meeting was opened in 440W at 7:30 P. M. by President Walter B. Kelley.

The business transacted was the election of a new Treasurer to replace the former Treasurer, who had left school. From the nominees selected by the Executive Committee at their November 25 meeting, Mr. Ralph F. Johnson was elected. Other business was the adoption of the following resolution by unanimous vote:

"The Northeastern Civil Engineering Society is deeply indebted to Mr. William P. Morse for the donation of his entire civil engineering library. We are grateful and most appreciative of his kindness. Further, the Secretary is directed to incorporate this resolution in the records of the Society, and the President shall forward this expression of thanks to Mr. Morse."

President Kelley then introduced the speaker for the evening, Mr. Oliver G. Julian, structural engineer for Jackson and Moreland. From his wide experience, Mr. Julian chose for his subject "A Few Moot Questions in Structural Design and Analysis." Mr. Julian stated that all structural mechanics was based on three things:

1. Basic laws of statics.
2. Relationship between stress and strain.
3. Conservation of energy.

JOHN E. BAMBER, *Secretary*

At 1:00 P. M. on December 31, 1940, members and guests gathered in Room 201S where the President, Walter B. Kelley, introduced the speaker, Mr. William W. Lewis, Assistant Engineer (retired) of the Boston Transit Commission, whose subject was "A Slide Lecture on the Panama Canal." There were 35 in attendance.

Throughout the lecture Mr. Lewis showed slides of Panama, the canal and surrounding country. Mr. Lewis has made two trips to Panama, once during the construction of the canal and once quite recently. He therefore, described various changes which have taken place there, particularly in reference to housing and sanitation. Slides were shown of the earth-filled dams at Gatun Lake and Alleulla and also slides covering the passage of a boat through the canal. Also he showed a slide of a bridge built in 1635 and still in use.

JOHN E. BAMBER, *Secretary*

At 6:00 P. M. on January 10, 1941, members and guests met for dinner at the "Old France." Following the dinner the meeting was opened in 440W at 7:30 P. M. by the President, Walter

B. Kelley. This was the annual meeting set aside for the presentation of student papers for the yearly award presented by the Boston Society of Civil Engineers.

The business of the meeting was the adoption of the following by unanimous vote: "Amendment to Article II of the By-Laws of the Section.

SECTION I Members of the Boston Society of Civil Engineers in all grades shall be members of the Section except that membership in the Northeastern University Section is limited to members of the society in all grades who are students, graduates, or members of the faculty of Northeastern University.

SECTION II Only members of the Northeastern University Section who are students at Northeastern University are eligible to hold office in that section.

President Kelley then introduced the speaker of the evening, Mr. John E. Bamber, '41, whose subject was the "Construction of a Spur Railway Track to Camp Edwards". Mr. Bamber pointed out the object and necessity of the project. He also discussed construction methods and the type of country through which the track ran, from the reconaissance work through to the actual grading of the track roadbed and track itself. The talk was materially aided by the use of a general plan of the entire project.

JOHN E. BAMBER, *Secretary*

APPLICATIONS FOR MEMBERSHIP

[April 20, 1941]

The By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

Transfer from Grade of Student

NORMAN B. CLEVELAND, Beverly, Mass. (b. March 6, 1916, Beverly, Mass.) B.S. Degree in Civil Engineering from Northeastern University in 1939. Harvard University, M.S. Degree in Civil Engineering in 1940. Summer School, Aeronautical Engineering, 1940 at Massachusetts Institute of Technology. Experience, 1937, 1938, Surveying with W. S. Crocker; 1939 Inspector on Road Construction, Mass. Department of Public Works; also testing materials laboratory, Thompson & Lichtner Company, at present with Jackson & Moreland Company as Structural Engineer. Refers to *C. O. Baird, M. N. Clair, E. A. Gramstorff, A. Haertlein, E. N. Hutchins.*

ADDITIONS

Members

GEORGE ANTHONY, 65 Louis Prang Street, Boston, Mass.

Juniors

HERBERT J. ALBEE, 62 Thomas Road, Swampscott, Mass.

JOHN L. BEAN, 131 Washington Street, Ayer, Mass.

HARRY L. FREEMAN, 2 Nutting Road, Cambridge, Mass.

LOUIS G. REINIGER, 47 Denver Street, Saugus, Mass.

Deaths

EDWARD S. LARNED, January 6, 1941.

EDGAR A. NORWOOD, September 24, 1940.

ANNUAL REPORTS

REPORT OF BOARD OF GOVERNMENT FOR THE YEAR 1940-1941

Boston, Mass., March 19, 1941.

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 19, 1941.

Early in the year the Society suffered the loss of its President, Frank B. Walker, who died June 3, 1940, after serving less than three months of his term. Due in no small measure to the tentative plans which he had already made, his successor and your Board of Government are able to report a successful year in spite of this misfortune.

Membership

Fifteen new members, 1 junior, and 23 students have been added during the year, and 4 members, and 1 student have been reinstated, making a total addition of 44 members.

During the year nine members have died, 12 have resigned, 2 members have had dues remitted and resignations accepted, 26 members have been dropped for non-payment of dues making a total deduction of 49.

The present net membership of the Society consists of 4 honorary members, 617 members, 39 juniors, 77 students, 7 associated, 1 member of Sanitary Section, making a total membership of 745, a net loss for the year of 5.

The honorary membership list is as follows:

Charles T. Main, elected January 28, 1932.
Dr. Karl T. Compton, elected February 17, 1932.
Prof. C. Frank Allen, elected March 16, 1932.
Joseph R. Worcester, elected February 21, 1934.

Deaths

Members:

Walter E. Spear, March 29, 1940
Robert B. Farwell, May 7, 1940
Frank B. Walker, June 3, 1940
Charles E. Wells, August 15, 1940
Henry C. Hartwell, October 27, 1940
Arthur L. Plimpton, July 6, 1939
Charles R. Felton, November 22, 1939
Edward S. Larned, January 16, 1941
Edgar A. Norwood, September 24, 1940

Remission of Dues and Extension of Time

The membership of the Society has been subject during recent years to the effects of the depression. During this period the Board of Government has granted a number of members an extension of time for payment of dues and has remitted the dues of other members. With much regret the Board voted this year to drop from membership those who had not paid their 1940 dues, for which an extension had been granted. The Board has remitted dues and accepted resignations from 2 members. In the case of 2 members, dues for the year ending March 19, 1941, have been remitted.

The Board has granted 22 members an extension of time for payment of dues for year ending March 19, 1941.

Exemption of Dues

Eighty-nine members are now exempt from dues in accordance with By-Law 8, which provides that "a member of any grade who has paid dues for forty years, or who has reached the age of seventy years and has paid dues for thirty years, shall be exempt from further dues."

Meetings of the Society

Eight regular meetings, since the Annual, have been held during the year.

The October meeting was the Annual Student Night, attended by Student Chapters, American Society of Civil Engineers, at Harvard, Massachusetts Institute of Technology, Tufts, Brown University, Rhode Island State College, New Hampshire University, Worcester Polytechnic Institute and the Northeastern University Section of the Boston Society of Civil Engineers, which is a Student Chapter, A. S. C. E.

The total attendance at all meetings was 1024 persons; the largest attendance was 204 and the smallest 55. Suppers have been a feature at all meetings and they were well attended.

The papers and addresses given were as follows:

March 20, 1940. Annual Meeting. Address of retiring President, Gordon M. Fair, "The Genius of Sanitation"; followed by dinner and entertainment.

April 17, 1940. Joint Meeting. Boston Society of Civil Engineers and Northeastern Section, American Society of Civil Engineers. "Concrete Technology", by Miles N. Clair, Vice-President, The Thompson & Litchner Co., Inc.

May 15, 1940. "Contributions to a Study of the Allen Salt-Velocity Method of Water Measurement", by Martin A. Mason, Chief of the Research Section, Beach Erosion Board, War Department, Washington, D. C.

June 8, 1940. Marine Excursion and Joint Outing, Boston Harbor Boat Trip, made by the Boston Society of Civil Engineers and the Sanitary Section, BSCE.

September 18, 1940. Joint Meeting. Boston Society of Civil Engineers and the Society of American Military Engineers, Boston Post. "The Corps of Engineers of the U. S. Army in Relation to the National Defense", by Major General Julian L. Schley, Chief of Engineers, Corps of Engineers, U. S. Army.

October 16, 1940. Student Night. Joint Meeting Boston Society of Civil Engineers and American Society of Civil Engineers, Northeastern Section and Student Chapters ASCE and Northeastern University Section, BSCE, "Engineering Personality as an Aid to Professional Success", by Charles R. Gow, President, Warren Bros., Cambridge, Mass.

November 20, 1940. Joint Meeting. Boston Society of Civil Engineers and Hydraulics Section, BSCE. A Symposium—"Geological Explorations for Dam Sites". Speakers, F. Stewart Brown, Chief of the Flood Control Design Section of the U. S. Engineer Office in Boston, "Foundation Investigations for the Franklin Falls Dam"; Frank E. Fahlquist, Senior Geologist of the U. S. Engineer Office of Providence, R. I., "New Methods and Technique in Sub-surface Investigations"; Irving B. Crosby, Consulting Geologist, "Objectives and Methods of Geological Investigations of Dam Sites."

December 18, 1940. "The Huntington Avenue Subway", by Harry T. Carroll, Resident Engineer, Boston Transit Department.

January 8, 1941. Joint Meeting. Boston Society of Civil Engineers and Designers' Section, BSCE. "The Critical Load on Strata of Clay Beneath Foundations", by Dr. Karl Terzaghi, Lecturer on Soil Mechanics and Engineering Geology, at Harvard University.

February 19, 1941. "The Land Court, Registration of Title to Land in Massachusetts, Its Surveying Procedure and Use of Massachusetts Plane Co-ordinate System", by Clarence B. Humphrey, Engineer for Land Court, Boston, Mass.

Sections

Thirty-six meetings were held by the Sections of the Society during the year. These meetings of the Sections, offering opportunity for less formal discussion, have continued to demonstrate their value to their members and to the Society. The variety of subjects presented has made an appeal to the members, as indicated by the general attendance at these meetings.

Sanitary Section Meetings. The Sanitary Section has held seven meetings during the year, with an average attendance of 49. The papers and meetings are listed in the report of the Executive Committee.

Designers' Section Meetings. The Designers' Section has held eight meetings during the year, with an average attendance of 59. The papers and meetings during the year are listed in the report of the Executive Committee.

Highway Section Meetings. The Highway Section has held three meetings during the year, with an average attendance of 28. The papers and meetings are listed in the report of the Executive Committee.

Hydraulics Section Meetings. The Hydraulics Section has held three meetings during the year, with an average attendance of 79. The papers and meetings are listed in the report of the Executive Committee.

Northeastern University Section Meetings. The Northeastern University Section held fifteen meetings and an excursion during the year, with an average attendance of 40. The present membership included 78 now in attendance in the University. The meetings held are listed in the report of the Executive Committee.

Journal

The complete report of the Editor of the JOURNAL for the calendar year 1940 will be printed in the April, 1941, JOURNAL.

*Funds of the Society**

Permanent Fund. The Permanent Fund of the Society has a present value of about $50,000. The Society again authorized the use of as much as necessary of the current income of this fund in payment of current expenses.

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

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

was established as the John R. Freeman Fund, the income from which is about $1,000. 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 travelling scholarship every third year open to members of the Society for visiting engineering works, reports of which would be presented to the Society. No additional scholarship was authorized during the year.

Edmund K. Turner Fund. In 1916 the Society received 1,105 books from the library of the late Edmund K. Turner, and a bequest of $1,000, "the income of which is to be used for library purposes". The Board voted to use $25 of the income for the purchase of books for the Library.

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 $30 of the available income for the purchase of books for the library.

Desmond FitzGerald Fund. The Desmond FitzGerald Fund, established as 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 11, 1940, 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 to be given to a student of Northeastern University. Presentation of this scholarship was made by Vice-President, Arthur L. Shaw, at a student meeting of the University on May 3, 1940, to Daniel W. Miles, of Norwood, Mass., a senior student in Civil Engineering.

Tinkham Memorial Fund. The "Samuel E. Tinkham Fund", established in 1921, at the 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 $2,525.89 on June 30, 1940. John Melvin Biggs, of Johnstown, Pennsylvania, a senior student in Civil Engineering has been awarded this scholarship for the year 1940-1941.

Clemens Herschel Fund. This fund was established in 1931, by a bequest 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 the presentation of prizes for particularly useful and commendable papers presented at meetings of the Society. The present value of this fund is about $1,000. The expenditure made during the year from this fund was for prizes.

Edward W. Howe Fund. This fund, a bequest of $1,000, was received December 2, 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 is that the fund be kept intact, and that the income be used for the benefit of the Society or its members. An expenditure of $36 from this fund was made during the year for improvement of office equipment.

Desmond FitzGerald Medal

The Desmond FitzGerald Medal (bronze) was provided for in 1910 as an endowed prize by the late Desmond FitzGerald, a former past President and honorary member of the Society. The prize is awarded annually to a member who presents an original paper to the Society which is published in the JOURNAL for the current year.

In accordance with the recommendation of the Committee on Awards, the Board of Government voted to award a Desmond FitzGerald Medal to each, Harrison P. Eddy, Jr., and Almon L. Fales, co-authors, members, for their paper "Discussion of Problems of Sewerage and Sewage Disposal in Metropolitan Boston", presented at a joint meeting of the Society and Sanitary Section BSCE on January 24, 1940, and published in the April, 1940, JOURNAL.

Section Prizes

The Board of Government voted on April 12, 1924, to present a prize for a worthy paper given in each section by a member of that section, "this award to consist of books suitably inscribed".

Sanitary Section Prize. The Board adopted the recommendation of the Sanitary Section Prize Award Committee, and voted that the Sanitary Section Prize be awarded to Thomas R. Camp, member, for his paper on "The Filtration System for the New M. I. T. Swimming Pool—Design and Operation", presented at a meeting of the Sanitary Section held on December 4, 1910, and published in the January, 1941, JOURNAL. The prize consisted of the following books:—"The Principles of Electrochemistry". Duncan A. MacInnes. "Recent Advances in Surface Chemistry and Chemical Physics, Symposium No. 7, American Association for Advancement of Science", "Sewage-Treatment Works". C. E. Keefer.

Designers' Section Prize. The Board adopted the recommendation of the Designers' Section Prize Award Committee and voted that the Designers' Section Prize be awarded to Richard S. Holmgren, member, for his paper on "The Pittsburg Conservation Reservoir Development of the New Hampshire Water Resources Board", presented at a meeting of the Designers' Section held on February 14, 1940, and published in the April, 1940, JOURNAL. The prize consisted of the following books:—"Yacht Cruising", Claude Worth. "Yachts—Their Care and Handling", Winthrop P. Moore. "Sailing Made Easy", Rufus G. Smith.

Northeastern University Section Prize. The Board of Government voted on March 10, 1931, to provide for the award of a prize to a member of the Northeastern University Section.

The Board adopted the recommendation of the Committee on Awards and voted that the Northeastern University Section Prize be awarded to John E. Bamber, for his paper on "Construction of Spur Railway Track to Camp Edwards, Bourne, Mass.", presented at a meeting of Students at Northeastern University, held on January 10, 1941. The prize consisted of the following books:—"Timber Design and Construction", Henry S. Jacoby and Roland P. Davis; "Soil Mechanics and Foundations", Fred L. Plummer and Stanley M. Dore; "Navigation", Daniel W. Hosmer; "Contracts, Specifications and Engineering Relations", Daniel E. Meade.

Clemens Herschel Award. The late Clemens Herschel, a former past president and honorary member, gave to the Society a number of copies of his book on "Frontinus and the Water Supply of the City of Rome", with the request that the Board award one or more of the books each year as prizes for papers which have been particularly useful and worthy of grateful acknowledgment. On recommendation of the Committee on Awards, the Board voted to award two Clemens Herschel prizes as follows: to Robert D. Chellis, for his paper on "A Consideration of Pile Driving with Application of Pile Loading Formula", presented at a meeting of the Designers' Section held on March 13, 1940, and published in the January, 1941, JOURNAL; and to Miles N. Clair, member, for his paper on "Concrete Technology", presented at a meeting of the Society held on April 17, 1940 and published in the July, 1940, JOURNAL.

Social Activities

Seven of the regular meetings were held at the Engineers' Club; one was held at the Walker Memorial Bldg., M. I. T., preceded by suppers, under direction of the Social Activities Committee. As usual the most enthusiastic meeting was Student Night, held in October, and attended by members of the Student Engineering Societies of Massachusetts Institute of Technology, Harvard University, Tufts, Rhode Island State College, Brown University, Worcester Polytechnic Institute, University of New Hampshire and Northeastern University Section of the Boston Society of Civil Engineers. An excursion to Boston Harbor was made on June 8, 1940, attended by 67.

Library

The report of the Committee on Library contains a complete account of the library activities during the past year.

Society Activities

The usual special committees dealing with the general activities and conduct of the Society have included the following: Program, Publication, Membership, Library, Social Activities, Relations of Sections to Main Society. Other special committees have included the following:—1936 Floods, Subsoils of Boston, Desmond FitzGerald and other prizes, the Welfare Committee, Investments, The John R. Freeman Fund and the Committee on Headquarters. Each of these Committees has made a distinct contribution to the Society and has developed fields of endeavor which will prove a great benefit to the members.

The Society has co-operated with the Engineering Societies of New England, and many members of the Society have served on Engineering Societies' Committees.

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.

ARTHUR L. SHAW, *President.*

REPORT OF THE TREASURER

Boston, Mass., March 11, 1941.

To the Boston Society of Civil Engineers:

The financial standing of the Society on March 10, 1941, at the close of the fiscal year, is shown in the following:

Table 1. Distribution of Funds—Receipts and Expenditures.
Table 2. Record of Investments.

This year, receipts from dues have been somewhat better than in recent former years, but nevertheless it has again been necessary to transfer some of the income from the Permanent Fund to make up the deficit from current operations. I am happy to report that the amount transferred this year is less than in any of the last five years during which I have had the honor to be your Treasurer,—being $383.83 or about 16% of the income of the Permanent Fund, compared with a little over 40% in the two preceding years. The Permanent Fund now amounts to $60,527, or an increase of $7,832 during the last five years.

The amounts transferred from the Permanent Fund during the last five years are shown in the following table, being the difference between expenditures from the Current Fund less receipts other than from dues and from investments, and receipts from dues.

	1936-37	1937-38	1938-39	1939-40	1940-41
Total expenditures from the Current Fund less receipts other than from dues and from investments	$6,807	$6,622	$5,860	$5,860	$5,345
Receipts from dues	5,358	4,886	4,874	4,853	4,961
Transfers from income of Permanent Fund	$1,449	$1,736	$ 986	$1,007	$ 384

Although the return on investments this past year is slightly higher in dollars than during the previous year, the percentage return remains practically the same because of the increased book value of our holdings. Nevertheless, an average return of 4.08% is probably about all we can hope for in these days, with a reasonable assurance of safety of principal. The market value of all investments as of March 10, 1941, is $82,391.30, compared to a corresponding book value of $93,711.58. During the year a few of our bonds have been called, and the problem of reinvestment has been a matter of some concern.

The following table shows the comparative book values of the two principal funds at the close of each year and the ratio of market to book values. It should be kept in mind that the value of the Freeman Fund is largely dependent upon expenditures made from this fund during the year. The growth of the Permanent Fund is affected not only by the percentage of return on investments but also by the amounts it has been necessary to transfer from the income of this fund to meet current expenses.

	Mar. 10 1937	Mar. 10 1938	Mar. 10 1939	Mar. 10 1940	Mar. 10 1941
Permanent Fund	$54,865	$55,064	$56,672	$58,138	$60,527
John R. Freeman Fund	29,073	26,679	26,949	26,522	27,666
Market Value in per cent of Book Value	103.90%	84.17%	92.75%	92.28%	87.92%

The following table will show for the past five years the book values of securities and bank deposits and the total value of all holdings not including the value of the library and physical property.

	Mar. 10 1937	Mar. 10 1938	Mar. 10 1939	Mar. 10 1940	Mar. 10 1941
Bonds	$32,236.34	$33,198.71	$32,279.96	$32,524.96	$30,782.49
Co-operative Banks	14,292.80	13,585.21	15,041.52	16,512.94	17,971.92
Stocks	44,930.09	41,747.17	41,747.17	41.747.17	44,957.17
Cash	407.17	1,049.65	2,454.98	1,767.45	2,428.01
TOTAL	$91,866.40	$89,580.74	$91,523.63	$92,552.52	$96,139.59

In addition to the Treasurer's cash balance of $2,428, the Secretary has a "change fund" of $30.00, which should be included to show total assets.

Respectfully submitted,

CHARLES R. MAIN, *Treasurer.*

TABLE 1.—DISTRIBUTION OF FUNDS—RECEIPTS AND EXPENDITURES

	Book Value March 10, 1940	Interest and Dividends	Net Profit (or loss) at Sale or Maturity	Transfer of Funds Purchased	Transfer of Funds Sold	Book Value March 10, 1941
Bonds	$32,524.96	$1,115.90	$ 292.14	$5,255.39	$7,290.00	$30,782.49
Co-operative Banks	16,512.94	510.43		8,492.23	7,033.25	17,971.92
Stocks	41,747.17	2,090.36		3,210.00		44,957.17
				Net Increase		
Cash (except Current Fund)	267.45			660.56		928.01
TOTALS	$91,052.52	$3,716.69	$ 292.14	$17,618.18	$14,323.25	$94,639.59

	Book Value March 10, 1940	Allocation of the Above @4.08%	Allocation of the Above @0.32%	Miscel. Receipts	Miscel. Expenditures	Book Value March 10, 1941
Permanent Fund	$58,137.11	$2,372.70	$ 186.51	$ 215.00	$ 383.83	$60,527.49
John R. Freeman Fund	26,522.14	1,082.50	85.09		23.60	27,666.13
Edmund K. Turner Fund	988.00	40.45	3.20		25.15	1,006.50
Desmond FitzGerald Fund	2,018.88	82.40	6.48		125.25	1,982.51
Alexis H. French Fund	994.02	40.70	3.19		13.20	1,024.71
Clemens Herschel Fund	1,223.01	50.09	3.92		29.73	1,247.29
Edward W. Howe Fund	1,169.36	47.85	3.75		36.00	1,184.96
	$91,052.52	$3,716.69	$ 292.14	$ 215.00	$ 636.76*	$94,639.59
Current Fund	1,500.00			8,977.19*	8,977.19	1,500.00
TOTALS	$92,552.52	$3,716.69	$ 292.14	$9,192.19*	$9,613.95*	$96,139.59

*Includes transfer of $383.83 from the income of the Permanent Fund to the Current Fund.

TABLE 2.—RECORD OF INVESTMENTS

	Date of Maturity or Classification	Fixed or Current Interest Rate	During the Year March 10, 1940 to March 10, 1941				March 10, 1941		
					Sold or Matured				
			Interest Received	Additional Amount Invested	Amount Received	Profit (or Loss)	Par Value	Book Value	Market Value
BONDS									
Baltimore & Ohio RR	Aug. 1, 1944	4 %	$ 80.00	....	....	..	$2,000.00	$2,013.75	$1,140.00
Canadian Pacific RR	July 2, 1949	4 %	170.50	....	....	..	5,000.00	5,342.50	3,200.00
Central Maine Power Co.	Oct. 1, 1960	4 %	92.00	....	$2,110.00	$ 74.64	....	....	....
Chicago & Northwestern Ry. Co.	Nov. 1, 1987	5 %	..	....	....	..	1,000.00	1,102.50	218.75
The Cleveland Union Term. Co.	Apr., 1, 1973	5 %	50.00	....	....	..	1,000.00	998.75	786.25
The Cleveland Union Term. Co.	Oct. 1, 1977	4½%	45.00	....	....	..	1,000.00	980.00	698.75
Eastern Mass. Street Railway	Jan. 1, 1948	4½%	—1.50	$1,022.50	....	..	1,000.00	1,022.50	1,025.00
Illinois Power & Light Co.	Dec. 1, 1956	5 %	50.00	....	....	..	1,000.00	981.25	1,048.75
Louisiana Power & Light Co.	Dec. 1, 1957	5 %	50.00	....	....	..	1,000.00	835.00	1,081.25
Mississippi Power & Light Co.	Dec. 1, 1957	5 %	50.00	....	....	..	1,000.00	972.50	1,050.00
Penn. Central Light & Power Co.	Nov. 1, 1977	4½%	—9.00	1,052.89	....	..	1,000.00	1,052.89	1,052.50
The Pennsylvania Railroad Co.	June 1,1965	4½%	45.00	....	....	..	1,000.00	1,017.74	1,067.50

TABLE 2.—RECORD OF INVESTMENTS—*Continued*

	Date of Maturity or Classification	Fixed or Current Interest Rate	During the Year March 10, 1940 to March 10, 1941				March 10, 1941		
			Interest Received	Additional Amount Invested	*Sold or Matured* Amount Received	*Sold or Matured* Profit (or Loss)	Par Value	Book Value	Market Value
The Pennsylvania Railroad Co.	April 1, 1970	4½%	$ 45.00	....	....	..	$1,000.00	$ 971.58	$ 935.00
Peoria Water Works Co.	Aug. 1, 1950	5 %	50.00	....	....	..	1,000.00	1,010.00	1,010.00
Puget Sound Power & Light Co.	June 1, 1949	5½%	—6.42	$1,025.00	....	..	1,000.00	1,025.00	1,011.25
Southern Calif. Water Co.	Oct. 1, 1960	4½%	45.00	....	$2,080.00	$205.00	....	....	....
Southern Pacific Co.	Mar. 1, 1977	4½%	45.00	....	....	..	1,000.00	955.00	500.00
Southwestern Gas & Electric Co.	Nov. 1, 1960	4 %	15.55	....	1,040.00	45.00	....	....	....
Standard Oil Co. of N. J.	July 1, 1953	2¾%	27.50	....	....	..	1,000.00	1,021.25	1,043.75
Texas Electric Service Co.	July 1, 1960	5 %	100.00	....	....	..	2,000.00	2,000.00	2,142.50
The Toledo Edison Co.	July 1, 1968	3½%	70.00	....	....	..	2,000.00	2,092.50	2,150.00
United States Savings	Jan. 1, 1950		30.00	30.00	....	..	3,000.00	2,280.00	2,280.00
United States Steel Corp.	June 1, 1948	3¼%	40.44	....	2,060.00	—32.50	....	....	....
Union Pacific RR	June 1, 1980	3½%	—8.17	2,125.00	....	..	2,000.00	2,125.00	2,090.00
Western Maryland RR Co.	Oct. 1, 1952	4 %	40.00	....	....	..	1,000.00	982.78	945.00
TOTALS			$1,115.90	$5,255.39	$7,290.00	$292.14	$31,000.00	$30,782.49	$26,476.25

TABLE 2.—RECORD OF INVESTMENTS—*Continued*

	Date of Maturity or Classification	Fixed or Current Dividend Rate	During the Year March 10, 1940 to March 10, 1941		*Sold or Matured*		March 10, 1941		
			Dividends Received	Additional Amount Invested	Amount Received	Profit (or Loss)	Number of Shares	Book Value	Market Value
CO-OPERATIVE BANKS									
Codman Co-operative Bank	Series 37	3½%	$116.80	$ 356.80	....	..	20	$3,596.80	$3,596.80
Merchants Co-operative Bank	Series 140	3 %	184.45	569.45	$7,033.25	..	35	....	....
Merchants Co-operative	Series 145	3 %	..	7,026.80	....	..	40	7,026.80	7,026.80
Suffolk Co-operative Bank	Series 134	3 %	179.18	539.18	....	..	30	6,348.32	6,348.32
Suffolk Co-operative Bank	Mat. Shares	3 %	30.00	....	....	..	5	1,000.00	1,000.00
TOTALS			$510.43	$8,492.23	$7,033.25			$17,971.92	$17,971.92

TABLE 2.—RECORD OF INVESTMENTS—*Continued*

	Date of Maturity or Classification	Fixed or Current Dividend Rate	During the Year March 10, 1940 to March 10, 1941		*Sold or Matured*		March 10, 1941		
			Dividends Received	Additional Amount Invested	Amount Received	Profit (or Loss)	Number of Shares	Book Value	Market Value
STOCKS									
American Tel. & Tel. Co.	Common	$9.00	$414.00	....	....	..	46	5,346.04	7,584.25
Bankers Trust Co.	Common	2.00	60.00	....	....	..	30	1,590.00	1,657.50
Central Hanover Bank & Trust Co. of N. Y.	Common	3.00	90.00	$3,210.00	....	..	30	3,210.00	2,955.00
Commonwealth & Southern Corp.	Cum. Pref.	3.00	24.00	....	....	..	8		
Commonwealth & Southern Corp.	Common	..	..	....	....	..	25	1,019.89	441.38
Commonwealth & Southern Corp.	Opt. Warrants	..	..	....	....	..	12		
Consolidated Gas of N. Y.	Common	2.00	40.00	....	....	..	20	1,906.50	435.00
General Electric Co.	Common	1.85	92.50	....	....	..	50	2,341.47	1,706.25
Hartford Fire Insurance Co.	Common	2.50	25.00	....	....	..	10	761.25	820.00
Home Insurance Co.	Common	1.60	49.60	....	....	..	31	1,245.00	992.00
Minnesota Power & Light Co.	Pref. 7%	7.00	70.00	....	....	..	10	980.00	942.50
National Dairy Products Co.	Common	.80	40.00	....	....	..	50	1,154.74	681.25
National Fire Insurance Co.	Common	2.00	40.00	....	....	..	20	1,240.00	1,185.00
New England Power Association	Pref.	6.00	120.00	....	....	..	20	1,815.00	960.00
New York Central RR	Common	..	..	....	....	..	10	870.45	131.25

TABLE 2.—RECORD OF INVESTMENTS—*Continued*

	Date of Maturity or Classification	Fixed or Current Dividend Rate	During the Year March 10, 1940 to March 10, 1941				March 10, 1941		
			Dividends Received	Additional Amount Invested	*Sold or Matured* Amount Received	*Sold or Matured* Profit (or Loss)	Number of Shares	Book Value	Market Value
STOCKS									
North American Trust Shares	Cum. July 15 1955	$0.136	$204.00	....	....	..	$1,500	$5,342.00	$3,495.00
Pacific Gas & Electric Co.	Cum. 1st Pref. 6%	1.50	90.00	....	....	..	60	1,922.02	2,625.00
Pacific Gas & Electric Co.	Cum. 1st Pref. 5½%	1.376	27.52	....	....	..	20		
Pacific Gas & Electric Co.	Common	2.00	128.00	....	....	..	64	1,808.79	1,728.00
Southern Calif. Edison Co. Ltd.	Cum. Orig. Pref.	1.90	76.00	....	....	..	40	1,161.22	1,720.00
Southern Calif. Edison Co. Ltd.	Common	1.75	35.00	....	....	..	20	539.75	507.50
Standard Oil Co. of N. J.	Common	1.75	17.50	....	....	..	10	479.54	347.50
Tampa Electric Co.	Common	2.13	63.90	....	....	..	30	1,151.25	667.50
Timken Roller Bearing	Common	3.00	45.00	....	....	..	15	1,018.97	641.25
Trimount Dredging Co.	Pref. C	..	..	....	....	..	2	..	..
U. S. Smelting, Refining & Mining Co.	Pref.	3.50	70.00	....	....	..	20	1,365.04	1,460.00
United States Steel Corp.	Common	3.00	30.00	....	....	..	10	860.75	595.00
United States Trust Co. of Boston	Conv. Pref.	.80	180.00	....	....	..	225	4,837.50	2,925.00
Utah Power & Light Co.	Cum. Pref.	5.834	58.34	....	....	..	10	990.00	740.00
TOTALS			$2,090.36	$3,210.00	....	..		$44,957.17	$37,943.13

REPORT OF THE SECRETARY

Boston, March 5, 1941.

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 19, 1941
CURRENT FUND ACCOUNT

	Account Number	Expenditures	Receipts
Office			
Secretary, salary and expense	(1)	$ 240.00	
Stationery, printing and postage	(2)	325.83	
Incidentals and Petty Cash	(3)	150.40	
Insurance and Treasurer's Bond	(4)	38.00	
Safety deposit box	(5)	11.00	
Quarters, rent, light, telephone	(7)	1,800.04	$620.00[a]
Office, clerical	(8)	1,310.00	
Auditors for 1940 accounts and Investment Services	(9)	225.00	$620.00[a]
Meetings			
Rent of halls, etc.	(11)	209.15	
Stationery, printing and postage	(12)	66.55	
Social Activities	(13)	233.95	55.70
Stereopticon and Reporting	(14)(15)	0.00	
Annual Meeting (March 1940)	(16)	84.36	
Sections			
Sanitary Section	(21)	44.29	
Designers Section	(22)	35.00	
Highway Section	(23)	11.00	
Northeastern University Section	(24)	4.00	
Hydraulics Section	(25)	4.00	
Journal			
Editor—Salary and Expense	(31)	308.00	
Printing and postage	(32)	1,609.22	
Reprints	(33)	1,011.06	
Advertising, Commission and Receipts	(34)	411.45	1,314.00
Sales of Journals and reprints	(35)		1,577.55
Library			
Librarian—Salary and Expense	(41)	51.15	

[a]From E. S. of N. E., $600. and $20 from other tenant.

Periodicals	(43)	83.33	
Binding	(44)	40.00	
Fines, Overdue books	(45)		6.09
Bank Charges	(53)	3.90	
Miscellaneous Receipts	(54)		2.29
Dues to Engineering Societies of N. E.	(59)	606.26	
Dues from B.S.C.E. members	(70)		4,961.42
Transfer Income Permanent Fund to Current Fund			383.83
Badges for Members		41.25	36.00
Binding Journals for members		19.00	20.31
Total, Current Fund, to be accounted for		$8,977.19	$8,977.19
Entrance Fees to Permanent Fund			$ 215.00

15 new members, 1 junior, 23 students; 3 juniors transferred to members; and 4 students transferred to juniors; but 2 new members and 1 junior transferred to member and 1 student transferred to junior were exempt from payment of entrance fees and transfer fees.

The above receipts have been paid to the Treasurer, whose receipts the Secretary holds. The Secretary holds cash amounting to $30, included as a payment under Item 3 (Petty Cash) to be used as a fixed fund or cash on hand for making change at buffet suppers.

Respectfully submitted,

EVERETT N. HUTCHINS, *Secretary.*

REPORT OF THE AUDITING COMMITTEE

Boston, March 19, 1941.

We have reviewed the records and accounts of the Secretary and Treasurer of the Boston Society of Civil Engineers and the report of William J. Hyde, Certified Public Accountant, who has examined said records and accounts and we have examined the securities enumerated by the Treasurer.

We have accepted and present herewith with our approval the signed report of the accountant.

HARVEY B. KINNISON,
THOMAS R. CAMP,

Auditing Committee of the Directors of the Boston Society of Civil Engineers.

STATEMENT OF CERTIFIED PUBLIC ACCOUNTANT

Boston, March 14, 1941.

MR. H. B. KINNISON,
Chairman of the Auditing Committee,
Boston Society of Civil Engineers,
Boston, Massachusetts.

DEAR SIR:

In accordance with instructions, I have audited the books and accounts of the Treasurer of the Boston Society of Civil Engineers for the fiscal year ended March 19, 1941.

Receipts reported to have been received by the Secretary were in agreement with his records and were found to be correctly entered in the Treasurer's accounts.

I attended at the vault of the Old Colony Trust Company and examined the securities held at the close of the fiscal year and found them all properly accounted for. All coupons for interest due were collected except ten of the Chicago and Northwestern Railroad, (total $250.00) which are in default. Dividends earned were correctly accounted for. All changes in securities were checked by reference to the brokers' bills and other memoranda.

Cooperative Bank earnings were verified and found correct.

All payments were supported by proper vouchers approved by the Preesident and Secretary.

A verified copy of your Treasurer's report is attached hereto, and summarizes the detailed accounts shown in his ledger. I have checked the records in detail and found all of same in excellent condition.

Respectfully submitted,

WILLIAM J. HYDE, *Certified Public Accountant.*

REPORT OF THE EDITOR

Boston, Mass., January 25, 1941.

To the Board of Government,
Boston Society of Civil Engineers:

The JOURNAL for the calendar year 1940, (Volume XXVII) was issued quarterly, in the months of January, April, July and October, as authorized by the Board of Government on December 20, 1935.

During the year 1940 there have been published eleven papers presented at meetings of the Society and Sections, and three other technical articles. The Table of Contents and Index for the year are included in the October, 1940, issue.

The four issues of the JOURNAL contained 295 pages of papers and discussions, 7 pages of Index, and 35 pages of advertising, a total of 337 pages. An average of 1106 copies per issue were printed. The net cost was $1,023.31 as compared with $1,514.23 for the preceding year.

Table I includes a comparison of the costs for the JOURNAL from 1936-1940 inclusive. In Table II details of cost for Volume XXVII of the JOURNAL for the calendar year 1940 are shown.

During the year many requests for copies of papers on the subject of Soil Mechanics, printed in the JOURNAL over a period of several years, could not be filled, so that the Board of Government authorized the reprinting in book form of all the articles on this subject published in the JOURNAL, 1925-1940, inclusive. This book entitled "Contributions to Soil Mechanics", contains 14 articles. One thousand copies were printed at a cost of $1,004.95. The number of copies sold up to December 31, 1940 is 425, the receipts for which amount to $550.75.

Respectfully submitted,

EVERETT N. HUTCHINS, *Editor.*

TABLE I—COMPARISON OF COSTS OF JOURNAL, 1936-1940, INCLUSIVE

Year	Vol.	No. of Pages*	Gross Total	Cost per page	Net Total	Cost per page	No of cuts
1936	XXIII	356	$2,666.42	$7.49	$1,711.16	$4.80	90
1937	XXIV	380	2,737.48	7.20	1,375.62	3.62	101
1938	XXV	566	3,869.49	6.83	2,505.74	4.42	142
1939	XXVI	428	2,561.58	5.98	1,514.23	3.53	125
1940	XXVII	337	1,840.29	5.46	1,023.31	3.03	55

*Includes Advertising Section and Annual Index. Gross cost includes editing, printing and mailing. Net cost equals gross cost less amounts received for advertising, subscriptions and sales of JOURNALS.

TABLE II—1940 JOURNAL—VOLUME XXVII

Number of Pages:		*Cost of* JOURNAL:	
Papers and Discussion	288	Composition and printing	$1,196.23
Advertising and Index	35	Cuts	250.56
Index	7	Wrapping, mailing, postage	85.50
	——	Editing	300.00
	330	Copyright	8.00
		Total Gross Cost of JOURNAL	$1,840.29

Receipts		
Receipts from Subscriptions and sale of JOURNALS and Reprints	$355.03	
Receipts (net) from Advertising	461.95	816.98
Net Cost of JOURNAL		$1,023.31

REPORT OF THE COMMITTEE ON SOCIAL ACTIVITIES

Boston, March 19, 1941.

To the Boston Society of Civil Engineers:

The Committee on Social Activities submits the following report for the year 1940-41.

Seven regular meetings were held at the Engineers' Club during the year. The total number of members and guests served with supper was 569, an average of 81 per meeting. This average is greater by 4 than for the previous year, continuing the upward trend of the past few years. An average of 14 additional persons attended the meetings following the supper.

One hundred and twenty-eight members and guests attended the Annual Dinner at the Chamber of Commerce Building. This was 14 more than for the previous Annual Meeting. Two hundred and four were served at the Student Night meeting in November in the Walker Memorial at M. I. T. This meeting included the Student Chapters of the American Society of Civil Engineers at Harvard, Tufts, M. I. T., Brown, Rhode Island State, New Hampshire State, Worcester Polytechnic Institute, and the Northeastern University Section of the Boston Society of Civil Engineers. The attendance at the meeting following the supper was increased to a total of 240.

In spite of the slightly inclement weather, 67 persons went on the Marine Excursion around Boston Harbor on June 8th. Box lunches were served.

A summary of attendance at the various meetings follows:

		Attendance	
		Dinners	Totals
March 20, 1940	Annual Dinner, Chamber of Commerce	128	128
April 17, 1940	Engineers' Club	78	114
May 15, 1940	Engineers' Club	53	55
June 8, 1940	Marine Excursion	67	67
Sept. 18, 1940	Engineers' Club	137	170
Oct. 16, 1940	Walker Memorial Student Night	204	240
Nov. 20, 1940	Engineers' Club	93	110
Dec. 18, 1940	Engineers' Club	56	60
Jan. 8, 1941	Engineers' Club	73	98
Feb. 18, 1941	Engineers' Club	79	90
Totals		968	1,132

The average attendance at meals for all ten meetings, including the Excursion, was 97. The average total attendance at the meetings was 113.

Respectfully submitted,

John H. Harding, *Chairman.*

REPORT OF THE COMMITTEE ON WELFARE

Boston, March 19, 1941.

To the Boston Society of Civil Engineers:

The employment situation in the engineering fields of activity appears to have improved materially during the past year. No matters relating to the welfare of members of the Society have come to the attention of the Welfare Committee for action. Consequently, it has not been necessary to hold any meetings of the Committee during the year.

The employment service of the Emergency Planning and Research Bureau, Inc., for the year 1940, reports a record of more legitimate engineering placements than for any year since the Bureau established the practice of charging a fee for its services. In 1940 there was a total of 204 placements, which is nearly 100 per cent in excess of the placements in 1939. At the present time the Bureau has registrations for employment slightly in excess of 2300.

Members of the Society who are desirous of obtaining employment or of changing their employment connections are urged to make full use of the registration and placement facilities offered by the employment service of the Emergency Planning and Research Bureau, Inc.

Respectfully submitted,

RALPH W. HORNE, *Chairman.*

REPORT OF THE LIBRARY COMMITTEE

Boston, March 12, 1941.

To the Boston Society of Civil Engineers:

The activities of the Library Committee during the past year were confined to the acquisition of new books. Twenty-three books were purchased with the authorized expenditure of fifty-five dollars. Two books were donated by their authors. A complete list is given below.

The number of books in circulation during the year was 128. A total of $6.09 was collected in fines.

The following books were purchased:

Construction Estimates and Costs—H. E. Pulver
Legal Aspects of Engineering—Walter C. Sadler
Low Dams—Government Printing Office
Geology for Civil Engineers—D. G. Runner
Engineering Metallurgy—Stoughton and Butts
Land Drainage and Reclamation—Ayres & Scoates
Railway Engineering & Maintenance Cyclopedia—4th Ed.
Highway Location and Surveying—Crosby & Goodwin
Examination of Waters and Water Supplies—Thresh, Beal Suckling
Law of Surveying & Boundaries—Frank E. Clark

Mathematical Methods in Engineering—Karman and Biot
Modern Sewage Disposal—Langdon Pearse
Public Buildings—Government Printing Office
Highway Research, 1920-1940—Highway Research Board
Elementary Fluid Mechanics—J. K. Vennard
Engineering Mechanics—Timoshenko & Young
Construction Planning & Plant—Ackerman & Locher
Applied Economics for Engineers—B. Lester
Theory of Plates and Shells—Timoshenko
The Modern Railway—Parmelee
Principles of Sedimentation—W. H. Twenhofel
Swimming Pool Standards—F. W. Luehring
Transportation Economic Principles & Practices—Johnston, Huebener, Wilson

The following books were donated:

Cofferdams—White and Prentiss, gift of the Publishers, Columbia University Press
Sewage Treatment—K. Imhoff and G. M. Fair, gift of Gordon M. Fair

Respectfully submitted,

EUGENE MIRABELLI, *Chairman.*

REPORT OF THE COMMITTEE ON THE 1936 FLOOD

Boston, March 19, 1941.

To the Boston Society of Civil Engineers:

I present herewith a preliminary report of the Committee on the 1936 Flood. Except for a bibliography, this report contains practically all the material that will go to make up a finished report, but to the extent that it has not been consolidated or completely reviewed by the members, it is not a final report. It is hoped that the Society will continue the Committee for another year to enable it to put this material into final form for publication if that should be authorized. If this is done it is suggested that the name be changed to the Committee on Floods.

It is planned to have a small steering committee revise the report and submit it for final approval to the full committee membership. The final report should be completed next autumn.

Respectfully submitted,

HOWARD M. TURNER, *Chairman.*

REPORT OF THE COMMITTEE ON THE JOHN R. FREEMAN SCHOLARSHIP FUND

Boston, March 19, 1941.

To the Boston Society of Civil Engineers:

It is not practicable to send Freeman scholars to Europe as has been done in the past. The hydraulic laboratories in this country have been sufficiently reported on for the present. As far as the Committee is informed, there are no translations to be made or books to be printed on hydraulics which need assistance.

The Committee has inquired if there are any important hydraulic problems in the immediate Engineering Schools needing financial assistance and find there are such problems worthy of assistance.

The amount allocated to the Freeman Fund Committee as of March 10, 1941, is $2,666. The income for the fiscal year will be approximately $1,000.

The Committee has made the following awards:—

1. To the Harvard University Graduate School of Engineering for investigation of sedimentation and suspension of granular particles within the range of Reynolds' number, $800.

2. To the Massachusetts Institute of Technology for further study and reports of the transition between laminar and turbulent flow, $800.

3. To the Alden Hydraulic Laboratory of the Worcester Polytechnic Institute for further research on the effect of turbulence of water, $800.

All of the above awards are to be as of May 1, 1941.

The obligation to pay a portion of the cost of the preparation and printing the report of the Flood Committee is continued.

The suggestion that the Freeman Committee allocate some funds to sending an engineer to England to investigate and report on measures taken to protect water supplies and sewerage systems in case of bombing was discussed. The Committee decided that such a project should be undertaken by the National authorities as a part of the regular defense program rather than by an engineering society such as this, acting independently.

For the Committee,

CHARLES T. MAIN, *Chairman.*

REPORT OF THE COMMITTEE ON RELATIONS OF SECTIONS TO MAIN SOCIETY

Boston, March 19, 1941.

To the Boston Society of Civil Engineers:

This Committee has met only once, at the meeting of the Board of Government in May, 1940, when plans for the year were discussed by the chairmen of the various sections. The Chairman of this committee has visited section meetings frequently, and can state that the activities of the sections have been fully maintained. This year there have been many joint meetings; the Main Society has combined with the Sanitary Section on the Harbor Excursion in June, with the Student Chapters in October, with the Hydraulics Section in November, and with the Designers Section in January; the Designers Section has combined with the Highway Section, with the Sanitary Section, and with the Boston Post, Society of American Military Engineers; the Sanitary Section has combined with the Hydraulics Section.

The new Hydraulics Section was organized in May, 1940, and has functioned successfully.

In March, 1937, the Committee on Relations made the suggestion that all the Sections, except the Northeastern University Section, should change their by-laws so as to automatically include in their membership all members of the Main Society; whereas the latter Section should continue to restrict its membership to the Faculty, graduates and students of that University. During the following year, the Designers and the Highway Sections adopted this change in their by-laws. The Northeastern University Section adopted the change at its meeting in January, 1941, and the Sanitary Section did so at its meeting on March 5th, 1941.

Respectfully submitted,

KIMBALL R. GARLAND, *Chairman.*

REPORT OF THE COMMITTEE ON HEADQUARTERS

Boston, March 15, 1941.

To the Boston Society of Civil Engineers:

The Committee on Headquarters at the request of the Board of Government has investigated the possibilities of changes in the headquarters of the Society.

As stated in the Progress Report submitted in December, 1940, the problem was divided into two parts: first, the consideration of new quarters in or near the Engineers' Club, and, second, the consideration of such changes as might be made in our present quarters to make them more serviceable and attractive.

In the study of the first part of this problem the Committee held a number of conferences with the officers of the Engineers' Club and with the real estate men representing the owners of the Club building and the adjacent property. These conferences did not bring forth any proposals which would be particularly desirable from the standpoint of the Society's needs. The Board of Government decided at the December meeting that further studies along this line were unnecessary. This decision was based upon the fact of the generally unsettled economic and social conditions prevailing in the country today due to the European War. The Board felt that no major move toward the establishment of new quarters, which would necessarily involve increased expenses, should be made at this time.

The second part of the problem, that of rearrangements within the present quarters, was then considered. Several different layouts of the quarters were suggested and studied. Those layouts which would materially increase the capacity of the rooms for meetings were found to be so expensive that it was deemed advisable to maintain the present layout. The studies showed that the present layout uses the available space to rather good advantage.

The problem of making the rooms somewhat more attractive and serviceable was then considered. The owners of the building, at the request of this Committee, completed some improvements during the Christmas holidays. These improvements consisted of refinishing the floors and walls, supplying new shades for the windows and of cleaning some of the books. This was done at no expense to the Society.

The Committee feels that there are several other changes which might be made to improve the general appearance of the rooms. These are as follows:

A new lighting system for the library section including new fixtures and wiring.
A rearrangement of the wiring for lights in the meeting room section.
Refinishing of the furniture for the library section.
A new cabinet for the storage of valuable books.
Thorough cleaning of the books in the present stacks.
Miscellaneous items such as coverings and shelves for magazine rack.

The approximate cost of the above work based on actual estimates for the principal items is Five Hundred Dollars ($500.00). It is quite possible that further estimates for these items will reduce this amount somewhat.

The Committee therefore recommends that the above changes be made at the best prices consistent with satisfactory work.

It is further recommended that the Committee on the Library be asked to study the problem of the value of the books and periodicals in the Library so that proper insurance protection may be obtained. The Library Committee should also consider the disposal of such material on the shelves of the Library as is no longer of any value to the Society.

It is the hope of the Committee on Headquarters that the funds will be appropriated for the completion of this project. They feel that improvements in the quarters will be advantageous to the Society and will accomplish the desired results.

This Committee wishes to acknowledge its appreciation to the men outside of the Society who have aided them on the detailed considerations of the many questions which arose in connection with the work of this Committee.

Respectfully submitted,

Committee on Headquarters

EDWARD S. AVERELL
J. B. BABCOCK
KIMBALL R. GARLAND
C. FREDERICK JOY
E. MIRABELLI
D. W. TAYLOR
J. D. MITSCH, *Chairman.*

REPORT OF THE EXECUTIVE COMMITTEE OF THE SANITARY SECTION

Boston, March 5, 1941.

To the Sanitary Section, Boston Society of Civil Engineers:

During the past year this Section has held eight meetings including a joint excursion with the Main Society, and a joint meeting with the Designers Section. The attendance, not including that at the joint meetings, has varied from 13 to 81 and has averaged 49.

March 6, 1940. Society Rooms—Tremont Temple. Annual meeting and election of officers. Speaker: Earle B. Phelps, Professor, Sanitary Science, College of Physicians and Surgeons, Columbia University. Subject: "Air Sanitation." A committee to study the question of "Limiting Velocities of Flow in Sewers" was appointed by the Chairman. *Attendance, 50.*

May 1, 1940. Society Rooms—Tremont Temple. Speaker: William L. Hyland, Assistant Engineer, Fay, Spofford & Thorndike. Subject: "Asbestos-Cement Pipe for Water Mains and Sewers." A new section known as the Hydraulic Section was formed and the officers were elected for this new section at this meeting. *Attendance, 81.*

June 6, 1940. Joint outing and marine excursion with Main Society—Boston Harbor and Port Facilities. See pages 243 to 245, July, 1940, issue of the JOURNAL, Boston Society of Civil Engineers, for full account of this excursion.

October 2, 1940. Society Rooms—Tremont Temple. Speaker: Roy S. Lanphear, Supervising Chemist of the Bureau of Sewers of the Department of Public Works, Worcester, Mass. Subject: "Operation of the Worcester Sewage Treatment Works." Secretary Merrill of the Committee on Limiting Velocities of Flows in Sewers read a preliminary report of the Committee. *Attendance, 39.*

November 13, 1940. Society Rooms—Tremont Temple. Joint meeting with Designers Section. Speakers: Chester J. Ginder, Assistant Civil Engineer; and Edwin B. Cobb, Senior Civil Engineering Draftsman—both of the Metropolitan District Water Supply Commission. Subject: "Design of Fabricated Plate Steel Tees, Laterals, and Wyes of Large Diameters for the Pressure Aqueduct of the Boston Metropolitan District Water Supply Commission." *Attendance, 30.*

December 4, 1940. Pritchett Hall, Walker Memorial—M. I. T., Cambridge, Mass. Speaker: Professor Thomas R. Camp, Professor of Sanitary Engineering, M. I. T. Subject: "The Filtration System for the New M. I. T. Swimming Pool—Design and Operation." An inspection of the filtration system of the pool was made at the conclusion of Professor Camp's paper. *Attendance, 65.*

January 15, 1941. Society Rooms—Tremont Temple. Speaker: Bayard F. Snow, Consulting Engineer, Boston. Subject: "New Sewage Plant at the Monson State Hospital." *Attendance, 13.*

February 11, 1941. Society Rooms—Tremont Temple. Speakers: Walter E. Merrill, Senior Sanitary Engineer, and Clarence I. Sterling, Jr., Assistant Sanitary Engineer, State Department of Public Health. Subject: "Tour of Typical American Sewage Treatment Plants," illustrated with motion pictures and photographs *Attendance, 46.*

Executive Committee meetings have been held prior to each Section Meeting.

Respectfully submitted,

For the Executive Committee,

GEORGE W. COFFIN, *Clerk.*

REPORT OF THE EXECUTIVE COMMITTEE OF THE DESIGNERS' SECTION

Boston, March 8, 1941.

To the Designers' Section, Boston Society of Civil Engineers:

The following is a list of the meetings which took place during the year, March, 1940, to March, 1941.

March 13, 1940. Mr. Robert D. Chellis spoke on "Pile Driving Formulae." Attendance, 65.

April 10, 1940. Professor Howard R. Staley spoke on "Structural Characteristics of Brick Masonry." Attendance, 53.

May 8, 1940. Colonel Charles R. Gow spoke on "Some Practical Suggestions to the Modern Engineers Derived from the Experiences of an Old Timer." Attendance, 60.

October 9, 1940. Mr. Frank J. Crandall spoke on "Failures and Their Causes." Attendance, 60.

November 13, 1940. Mr. Chester J. Ginder spoke on "Design of Fabricated Plate Steel Tees, Laterals, and Wyes of Large Diameters for the Pressure Aqueduct of the Boston Metropolitan District Water Supply Commission." This was a joint meeting with the Sanitary Section of the Boston Society of Civil Engineers. Attendance, 30.

December 11, 1940. Mr. Earl G. Sumner spoke on "Merritt Parkway and the Housatonic River Bridge." This meeting was a joint meeting with the Highway Section of the Boston Society of Civil Engineers. Attendance, 43.

January 8, 1941. Dr. Karl Terzaghi spoke on "The Critical Load and Strata of Clay Beneath Foundations." This was a joint meeting with the Boston Society of Civil Engineers. Attendance, 98.

February 12, 1941. Mr. LeRoy M. Hersum spoke on "Underground Protective Structures." This was a joint meeting with the Boston Post, Society of American Military Engineers. Attendance, 65.

The total attendance at the meetings was 474. The average attendance was 59.

Respectfully submitted,

EMIL A. GRAMSTORFF, *Clerk.*

REPORT OF THE EXECUTIVE COMMITTEE OF THE HIGHWAY SECTION

Boston, Mass., March 1, 1941.

To the Highway Section, Boston Society of Civil Engineers:

During the past year the Section held the following meetings:

April 24, 1940. Mr. Dwight W. McCracken, Director of the Traffic and Safety Bureau of the Liberty Mutual Insurance Company, spoke on "Methods and Uses of a Traffic Safety Survey." *Attendance, 27.*

December 11, 1940. Joint meeting with Designers' Section. Mr. L. G. Sumner, Bridge and Structures Engineer for the Connecticut State Highway Department, spoke on the Merritt Parkway and Housatonic River Bridge. *Attendance, 43.*

February 26, 1941. Annual meeting. Election of officers. Mr. P. H. Kitfield, Assistant Project Engineer, Massachusetts Department of Public Works, spoke on "The Future of Highway Building in Massachusetts." *Attendance, 24.*

The total attendance at all meetings during the year was 85. The average attendance was 28.3.

Respectfully submitted,

LOUIS H. SMITH, *Clerk.*

REPORT OF THE EXECUTIVE COMMITTEE OF THE HYDRAULICS SECTION

Boston, Mass., March 10, 1941.

To the Hydraulics Section, Boston Society of Civil Engineers:

During the past year the Section held the following meetings:

May 1, 1940. Organization meeting, election of officers, adoption of by-laws. The meeting took place at a regular meeting of the Sanitary Section. Speaker, Mr. William L. Hyland, Assistant Engineer, Fay, Spofford & Thorndike; subject, "Asbestos-Cement Pipe for Water Mains and Sewers." *Attendance, 81.*

November 20, 1940. Joint meeting with the Boston Society of Civil Engineers. Speakers and subjects were: F. Stewart Brown, Chief of the Flood Control Design Section of the U. S. Engineer Boston Office, "Foundation Investigations for the Franklin Falls Dam"; Frank E. Fahlquist, Senior Geologist of the U. S. Engineer Providence Office, "New Methods and Technique in Sub-Surface Explorations"; Irving B. Crosby, Consulting Geologist, "Objectives and Methods of Geological Investigations of Dam Sites." *Attendance, 110.*

February 5, 1941. Annual meeting, election of officers; Professor Leslie J. Hooper, Alden Hydraulic Laboratory, Worcester Polytechnic Institute; subject, "Recent Model Tests." *Attendance, 45.*

The total attendance at the meetings was 236. The average attendance was 79.

Respectfully submitted,

MEDFORD T. THOMSON, *Clerk.*

REPORT OF THE EXECUTIVE COMMITTEE OF THE NORTHEASTERN UNIVERSITY SECTION

Boston, March 11, 1941.

To the Northeastern University Section, Boston Society of Civil Engineers:

During the past year this Section has held the following meetings and field trips:

March 15, 1940. Inauguration of the Northeastern University Civil Engineering Society as a Student Chapter of the American Society of Civil Engineers at Northeastern University. Delegates were present from seven New England colleges. Total attendance was 101.

March 19, 1940. Division A joint luncheon and field trip with the Rhode Island Student Chapter to the new Jamestown Bridge at Jamestown, Rhode Island. Twenty-two Section members attended.

April 11, 1940. Formal adoption of new by-laws formulating the Northeastern University Civil Engineering Society with student membership in both the Boston Society of Civil Engineers and American Society of Civil Engineers.

April 25, 1940. Election of officers for the year 1940-1941.

April 26, 1940. Twenty-one Section members attended the Annual Conference of Student Chapters of New England at Worcester Polytechnic Institute.

May 21, 1940. Division B trip to Jamestown Bridge at Jamestown, Rhode Island. Attendance was 30.

September 27, 1940. Dean William C. White of the E. S. N. E. Committee on Public Relations spoke on the "Registration of Engineers." Attendance was 32.

October 16, 1940. Sixty-five Section members attended the Student Night sponsored by the B. S. C. E. and Northeastern Section of the Am. Soc. C. E. at M. I. T.

October 24, 1940. The Section voted its disapproval of an amendment proposed by the Student Chapter at North Carolina State College to the constitution of the Am. Soc. C. E. providing for individual student memberships to replace the present system of chapter memberships.

November 8, 1940. Mr. Frederick W. Gow, Division Engineer for the Metropolitan District Water Supply Commission, addressed the Section on "Tunnel Construction for New Pressure Aqueduct." Attendance was 40.

December 13, 1940. Mr. Oliver G. Julian, Structural Engineer, Jackson and Moreland, presented "A Few Moot Questions in Structural Design and Analysis." Attendance was 52.

December 31, 1940. Mr. William W. Lewis, Assistant Engineer (retired) Boston Transit Commission, gave a "Slide Lecture on the Panama Canal." Attendance was 35.

January 10, 1941. Mr. John E. Bamber presented a student paper entitled "Construction of a Spur Railway Track to Camp Edwards." Attendance was 25.

February 11, 1941. Mr. T. Alfred Fleming, Director of Conservation of the

National Board of Fire Underwriters, spoke on "Conflagrations." Attendance was 50.

February 18, 1941. Fifteen members of the Section attended a joint meeting of the Junior Association, Northeastern Section Am. Soc. C. E. and the New England Student Chapters at M. I. T.

The total attendance at meetings and trips was 488. The average attendance was 40.

Respectfully submitted,

JOHN E. BAMBER, *Clerk.*

ADVERTISEMENTS

Vol. XXVIII APRIL, 1941 No. 2

BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

INDEX TO ADVERTISERS

COMMITTEES

NOMINATING COMMITTEE

Past Presidents (Members of the Committee)

JOHN B. BABCOCK, 3d
HAROLD K. BARROWS
ARTHUR D. WESTON

MILES N. CLAIR
GEORGE W. COFFIN
J. DONALD MITSCH
(Term expires March, 1942

ANTHONY S. COOMBS
HOWARD T. EVANS
WILLIAM L. HYLAND
(Term expires March, 1943)

SPECIAL COMMITTEES

Program

ALBERT HAERTLEIN, *Chairman, ex officio*

GEORGE W. COFFIN
STANLEY M. DORE
SAMUEL M. ELLSWORTH
HERBERT D. HURLEY
EVERETT N. HUTCHINS
HERMON S. SWARTZ
WILLIAM F. UHL
JOHN B. WILBUR

Publication

EVERETT N. HUTCHINS, *Chairman*

J. STUART CRANDALL
GORDON M. FAIR
JOHN B. BABCOCK

Membership

J. DONALD MITSCH, *Chairman*

CHARLES O. BAIRD
WILLIAM F. DONOVAN
CHARLES W. BANKS
WILLIAM F. CUMMINGS
CHESTER J. GINDER
FRANCIS H. KINGSBURY
AUSTIN B. MASON
HAROLD A. THOMAS
FREDERIC N. WEAVER

Library

EUGENE MIRABELLI, *Chairman*

EDWARD S. AVERELL
GEORGE C. BOGREN
ALLEN J. BURDOIN

Social Activities

JOHN H. HARDING, *Chairman*
JOSEPH D. GUERTIN
EDWARD F. KELLEY

Relations of Sections to Main Society

STANLEY M. DORE, *Chairman*

GEORGE W. COFFIN
WALTER B. KELLEY
HERMON S. SWARTZ
JOHN B. WILBUR

Committee on Floods

HOWARD M. TURNER, *Chairman*

Welfare

RALPH W. HORNE, *Chairman*

John R. Freeman Fund

CHARLES T. MAIN, *Chairman*

CHARLES M. ALLEN
ROBERT SPURR WESTON
HOWARD M. TURNER

Desmond Fitzgerald Award

RICHARD S. HOLMGREN, *Chairman*

MILES N. CLAIR
DONALD W. TAYLOR

Sanitary and Hydraulics Section Awards

RICHARD S. HOLMGREN, *Chairman*

HARVEY B. KINNISON
RALPH M. SOULE

Designers Section Award

MILES N. CLAIR, *Chairman*

ANTHONY S. COOMBS
KIMBALL R. GARLAND

Highway Section Award

DONALD W. TAYLOR, *Chairman*

A. J. BONE
GEORGE A. GRAVES

Subsoils of Boston

ARTHUR CASAGRANDE, *Chairman*

IRVING B. CROSBY
HENRY A. MOHR
CHARLES D. KIRKPATRICK
CHARLES W. ROBINSON

Investment Committee

CHARLES L. COBURN, *Chairman*

ALBERT HAERTLEIN
CHARLES R. MAIN