Ko17

# Reclamation of Union Bay Swamp in Seattle

WALTER L. DUNN, *Associate Professor of General Engineering*

W. L. Dunn

ABSTRACT

A waste-fill procedure is described that added 166 acres, formerly a part of a lake, to the University of Washington campus in Seattle. Land suitable for parking lots, playfields, open storage, and certain kinds of structures was constructed with rubbish and garbage cells covered with earth. General conclusions are made concerning the effect on the water quality of the lake and concerning refuse-fill methods perhaps applicable elsewhere.

Just east of the hill that supports the nerve center as well as the bulkier central part of the University of Washington campus is a big bell-shaped section of reclaimed land. These 166 acres built during the last 30 years on a swamp are the remnant of a former bay on the west shore of Lake Washington near the outlet of the lake. When the work of recovery by means of refuse began in 1933, the swamp generally had the consistency of thick sludge, much of it over 60 ft deep. It has been built into a usable part of the campus.

Now is an opportune time to describe the process of reclaiming these acres, for the fill is in its final stage of being reclaimed. The description deserves some detail since this kind of reclamation has widespread current interest. Nowadays most branches of engineering are concerned in some way with waste disposal, including landfill methods and pollution. The results reported here cover fairly long-term situations and developments; so they obviously may be applicable elsewhere.

## General Procedure

The main campus lies to the west; south is Union Bay; east, a residential district; and north, an up-to-date shopping center. The fill material was nearly all waste, including household "garbage,"* rubbish, ashes, stumps, lumber, and rubble. In fact, the extent and depth of the swamp was such that filling with earth alone would not have been practicable.[1] A map (Fig. 1) shows the location and present usage of the land plots; Figs. 2 and 3 are pictures of some of its features in 1933 and in 1965. Section D on the map is where the fill began.

*Under the definitions used by the American Public Works Association, garbage is food waste, and rubbish is such waste as paper, boxes, cartons, tin cans, and bottles. In Seattle the word "garbage" is used for all household waste, both garbage and rubbish.

Disposal operations have been under the direction of the Seattle Engineering Department in cooperation with the University Architect and Physical Plant Director. The expansion of the campus with this fill has been accomplished at very nominal expense to the University, inasmuch as the cost for the basic filling and grading was done by the City as a part of its refuse-disposal operations. This location was ideal for a refuse site serving the north part of the City as collection trucks had a short haul; so the operation was mutually beneficial to the University and the City.

During most of the years of filling, there were two separate disposal operations. Domestic garbage or household waste was collected and placed by a contractor, this operation being conducted as a sanitary landfill since 1956.[2] The earth cover was temporarily dumped on top of the cell placed the previous day, and pushed over the top and face of the new cell at the end of the day (Fig. 4). The contractor was paid for earth trucked to the site each day for cover. The average operation during the last 10 years was about 110 truckloads of domestic garbage daily (for a 5-day week) and about 9000 cu yd of dirt each month, which was trucked in for cover.

The City operated the public rubbish dump, providing a disposal facility for individuals and industries who hauled their own waste materials to the site. This rubbish was largely paper, lumber, glass, metal, yard trimmings, and brush. As many as 2500 private vehicles dumped waste at this site on a single spring Sunday.

The total amount of fill is not known, but an estimate is that 7 to 8 million cu yd of waste were deposited during the last 10 years. Records kept since 1960 show another 2,000,000 cu yd of earth and rubble were used for final cover and dike construction. Over 1,000,000 cu yd of earth and rubble

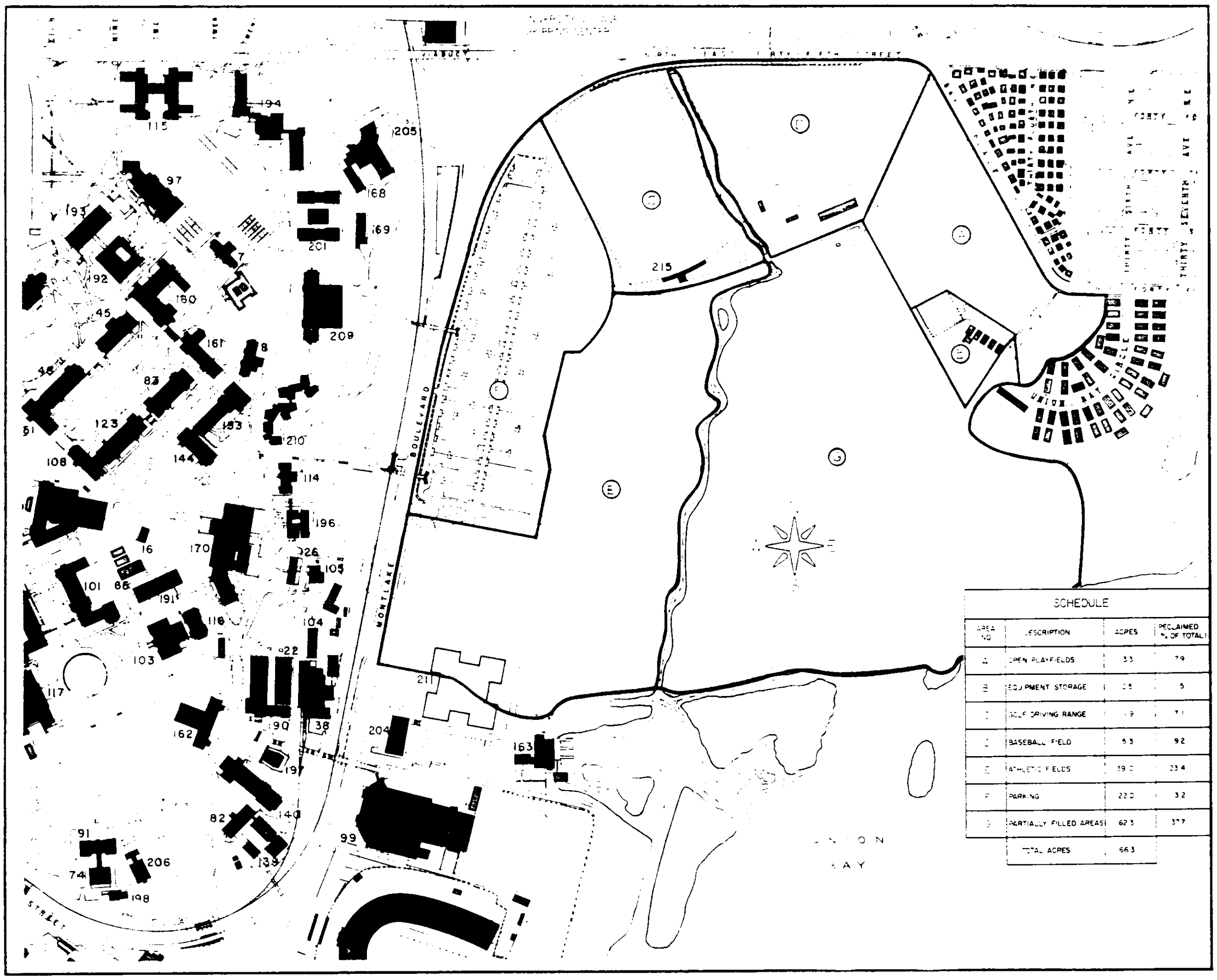


FIG. 1. MAP OF THE AREA RECLAIMED

FIG. 2. AERIAL VIEW OF THE CAMPUS AND PART OF THE SWAMP, 1933

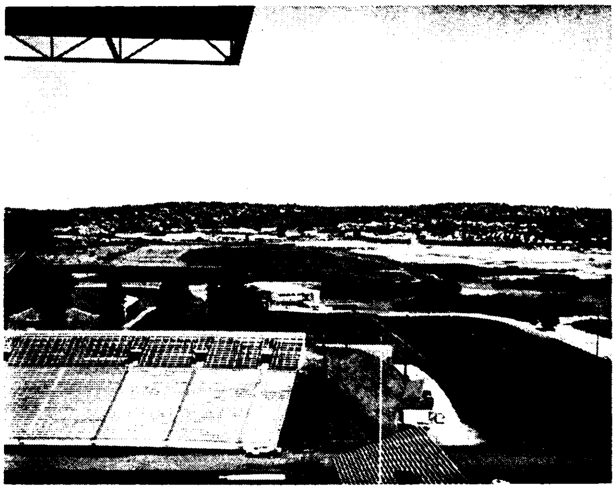

FIG. 3. AREA RECLAIMED FROM UNION BAY, 1965

were received free from Seattle freeway construction, making possible the construction of a drainage canal.[3]

Prior to September 15, 1954, the public rubbish site was operated as a burning dump, but this practice was discontinued because of protests of citizens.

FIG. 4. FACE OF THE NEARLY COMPLETED LANDFILL IN 1965, WITH A DISPOSAL TRUCK UNLOADING AND THE NEW DORMITORY BUILDINGS AS A BACKGROUND

On November 30, 1964, rubbish disposal was discontinued completely, and the garbage disposal will be discontinued within this year, the cutoff date depending upon the amount of consolidation of the underlying peat.

Prior to 1955, the reclamation process consisted of dumping and filling from the sides of the swamp toward the center. However, considerable peat was displaced outward as the filling progressed, and during the last 10 years the procedure has been to place a timber and rubbish mat extending from the shoreline out into the swamp, enclosing a portion of the area. The first layer of the mats was a minimum of 15 ft thick, sufficient to support a 35-ton tractor, and was 150 to 200 ft wide. At the locations where the peat extended to greater depths, the mats were 30 to 40 ft thick. Earth was then spread evenly over the mats in sufficient depth to provide the weight necessary to sink them into the underlying peat. These partial dikes provided a relatively stable base for roadways and also encircled the underlying peat to retard displacement.

This system was modified slightly to provide for drainage through the fill, inasmuch as storm water from the Ravenna area, a district to the north that includes University Village shopping center, passes through the swamp and into Lake Washington. Loading with earth was continued until the lumber mats were sunk into the peat below the water level. Drainage ditches were then excavated in the earth portion of the dike to provide clean, stable banks. Figure 5 is a schematic drawing of the drainage canal; Fig. 6 shows the canal while it was being excavated.

After the areas were enclosed with dikes, a rubbish mat was placed over the peat. Garbage was then placed, compacted, and covered in cells 6 ft on top of the rubbish. Depending on the depth of the underlying peat and on the desired final elevation, the depth of garbage fill varied from 6 to about 40 ft.

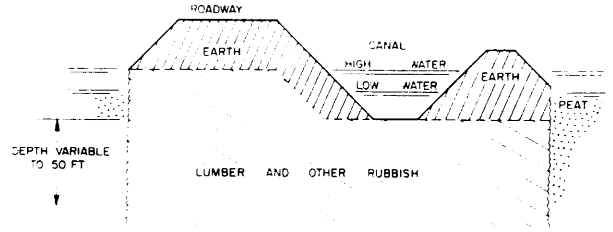


FIG. 5. SECTION OF LANDFILL SHOWING THE CANAL

FIG. 6. CANAL DURING THE PROCESS OF EXCAVATION

## Settlement and Characteristics of the Peat

The depth of the peat varies from a few feet at the original shoreline to a maximum depth of over 100 ft. It is all below the surface of Lake Washington and is largely a raw, fibrous, humus material consisting of partially decayed roots, stems, and leaves of small plants that have grown on the water surface and died in place.[4] The peat varies in color from light brown to black; it is slightly acid, so is subject to limited bacterial growth and hence only partial decay. The water content varies from 400% (under the fill) to 1500% in the virgin swamp. It looks somewhat like sewage sludge, and is not solid enough to walk on nor viscous enough to swim in.

The amount of settlement varies with the depth of the refuse placed as fill and also with the thickness of the underlying peat. In one study, during a 2-year period, the known maximum settlement (waste and underlying peat) of filled sections was about 4 ft. This occurred where the original peat depth was 30 ft and 25 ft of fill had been placed over it. Other field data indicate such settlement is typical, and the settlement curve tends to level off after 4 or 5 years. Laboratory experiments indicate the consolidation curve for confined peat levels off more rapidly; however, confinement of the peat in the swamp has not been complete, so the proportions of the settlement due to displacement and to consolidation are not known.

Laboratory and field experiments show that the peat is nearly impossible to dewater while in place, but if it is removed from below water level and placed in piles it drains rapidly. The dewatered peat has been used as a soil conditioner and for water retention. It has been mixed with existing fill, or with soil hauled in, and used as topsoil for the large playfields and golf driving range.

### Drainage and Burning of Waste Gas

Because of the large reclaimed area involved, the drainage of storm water was a particular problem. Temporary drainage was provided at some locations by building into the fill large French (rubble-type) drains.[5] Waste lumber from razed buildings was used to construct these drains about 20 ft wide, 10 ft deep, and up to several hundred feet long. The drains extended from the filled areas underground, carrying the storm water out into the swamp. The upper ends of the underground drains terminated in a 24-ft length of 24-in. culvert, which was covered with earth. An inlet and catch basin was constructed over the upper end of the culvert, and a "gas burner" 5 ft in diameter was placed above the inlet. As water passed through the drains and leached into the adjacent fill (ordinarily this was rubbish only), decomposition occurred, releasing gas composed of about 60% methane and 40% carbon dioxide and nitrogen, with traces of odor-causing compounds, and one such burner was in nearly continuous operation for about three years. The French drains are still being used for the disposal of storm water, but decomposition of putrescible material has proceeded so far that burning is not necessary or even possible.

Other drainage was taken care of by surface ditches into the drainage canal. Eventually a regular storm-drainage system will be required on the reclaimed land.

### Effect of the Refuse Fill on Water Quality

As the filling extended out from the shoreline into the swamp, there was concern over the possibility of leaching and transport of soluble organic and inorganic products from the decomposing refuse into Union Bay. Since 1957 data on water quality have been obtained regularly from Union Bay and Lake Washington proper, and since 1961 this study has been carried out at the University by Robert W. Seabloom, Professor of General and Civil Engineering. He has noted three categories of water quality, as indicated in these conclusions:[6]

1. Intense degradation of water quality occurred in the storm-drainage canal within the swamp and the fill. "Part of the deterioration of water quality in the drainage ditch must be attributed to the organic load in storm drainage from the business area located north of the refuse disposal site." There was also some evidence of transport of water through the refuse and into the drainage ditch. The writer believes that most of this leaching into the drainage canal is from the storm drains previously described.
2. Another zone, around the periphery of the refuse fill, was one where the water quality was improved over that in the drainage canal. "However, the water quality was definitely influenced by its proximity to the marsh."
3. The water in Lake Washington proper, sampled just above the swamp and also below it at the outlet in the Lake Washington Ship Canal, was completely saturated with dissolved oxygen and was relatively low in turbidity and color. Apparently there was sufficient dilution to minimize the enrichment and deterioration of water quality adjacent to the Union Bay disposal site. The writer believes that the Lake proper has not been polluted by the process of reclamation.

The writer believes that, in addition to the dilution, the huge mass of peat acts as a buffer to the discharge of pollutants into the Lake. Moreover, inasmuch as rubbish was used for fill in the periphery, garbage was placed in cells and covered with earth each day, and the entire fill was surrounded by peat, there was little or no leaching through the garbage. Field observations have indicated that to get water to move into or through well-compacted household refuse is nearly impossible because it consists largely of paper and plastic materials.

When a regular storm-dranage system is installed, the French drains can be closed so that little or no leaching into the drainage canal should occur, and there should be little odor. The peat is nearly impossible to dewater (by such practicable methods as pumping) because of the physical barrier formed by leaves and pieces of plants. This would indicate there is little or no movement of water through the peat.

### Use of the Reclaimed Land

Swamp land that has been reclaimed by filling with refuse placed over the peat will never become entirely stable. However, it is quite suitable for automobile parking, open storage, athletic fields, open playfields, and certain kinds of structures. The value of the reclaimed land is unknown, but this swamp is the only location anywhere near the campus where such large land areas could be obtained at any price. Following is a tabulation showing the

*(Continued on page 27)*

and it is the first dual-purpose plant anywhere. The capacity of the plant when completed is capable of supplying about 90% of the power needs of the City of Seattle. Operation of the transmission lines and switchyard at 500,000 volts (500 kv) introduces EHV for the first time west of the Rocky Mountains. Features of the reactor and its power system were described in the *Trend* article "Atomic Energy—a Reality for the Pacific Northwest," and the thermal and electrical features of the power-generation (export) plant were covered in "Electrical Features of an Atomic Giant," both of which are listed in the bibliography following these paragraphs.

The photographs on the preceding page were chosen to complement as far as possible those used in the earlier articles and to show the stages of progress for the past year. They also are evidence of engineering research and design translated into specifications, which in turn are transformed into a composite achievement, an integrated project.

The heart of the plant is of course the turbogenerators mounted on a concrete deck on the ground floor of the main building. Each of the units is 150 ft long, 70 ft wide, and 38 ft high. Figure 1, a photograph taken in August of 1965, shows the generator (right side) almost completed and the wheels of the turbine in place and about to be enclosed. Some of this blading was pictured in *Trend* for last October. Figure 2 is a view of the unit as it appeared last February. The control of these generators and liasion with the reactor is handled by three operators stationed in the control room just off the generator floor. Figure 3 indicates the complexity of one of the control boards. Electrical power is fed at 22,000 volts in ducts through the west wall of the powerhouse to two banks of power transformers, where the voltage is raised to 500,000. A nearly completed bank of transformers is shown in Figure 4. These transformers are approximately 38 ft high from the deck to the top of the bushing. A second bank of them has been completed.

Conductors from the transformer bushings are carried on steel towers around the end of the building to the high-voltage switchyard just to the southeast of the powerhouse (Figure 5). The outstanding features of this yard are the high-speed, 500-kv, heavy-duty circuit breakers, which can interrupt 35,000 mva (35,000,000 kva) at 500 kv in three cycles or less. The interrupting medium is $SF_6$ rather than the mineral oil generally used. These are the first 500-kv breakers in the United States built to interrupt 35,000 mva. From this yard, power is carried northwestward across the Columbia, thence northward to the Vantage switching station of the Bonneville Power Administration, where it is fed into the Northwest Power Pool. The high-voltage takeoff towers and the transmission lines are shown on Figure 6, a photograph taken last December.

**Bibliography of *Trend* Articles on Northwest Power**


July, 1950, Vol. 2, No. 3, "Hydroelectric Power in the Pacific Northwest"

Jan., 1951, Vol. 3, No. 1, "Steam Plants Would Save Fish and Relieve Power Shortage"

Oct., 1951, Vol. 3, No. 4, "Steam Plants and the Northwest Power Shortage": Part I

Jan., 1952, Vol. 4, No. 1, "Steam Plants and the Northwest Power Shortage": Part II

July, 1955, Vol. 7, No. 3, "Ultramodern Steam Plants for the Pacific Northwest Power System"

April, 1962, Vol. 14, No. 2, "Prospects for Nuclear Power in the Pacific Northwest"

Oct., 1962, Vol. 14, No. 4, "Atomic Energy—a Reality for the Pacific Northwest"

Oct., 1963, Vol. 15, No. 4, "A Philosophy of Nuclear-Reactor Safety"

Jan., 1965, Vol. 17, No. 1, "Electrical Features of an Atomic Giant"


**F. D. Robbins**, ***Dept. of Electrical Engineering***

## RECLAMATION OF UNION BAY SWAMP IN SEATTLE

***(Continued from page 11)***

present status of reclaimed Union Bay Swamp according to the sections shown on the map (Fig. 1):

| | |
|---|---|
| A. Open playfields (along Union Bay Place) | 13 acres |
| B. Equipment storage | 3 acres |
| C. Golf driving range | 12 acres |
| D. Baseball field (under construction) | 15 acres |
| E. Athletic fields | 39 acres |
| F. Parking (capacity: 2000 autos regular parking; 3000 autos bumper-to-bumper) | 22 acres |
| G. Partially filled areas (central portion of the swamp) | 62 acres |
| TOTAL | 166 acres |

This reclaimed land is most suitable for open use such as parking and playfields. However, with special treatment of the land, buildings can be constructed, both on land reclaimed by sanitary landfills[7] and over peat bogs.[8] A number of problems are involved, and such construction is considerably more expensive. Building should not be planned until at least 5 to 10 years after filling, because after this time decomposition is more complete and the relative stability of the particular area will be known. Experience in Canada indicates the feasibility of constructing buildings on peat bogs where 35-ft pilings are sufficient to support the structure.

A recent investigation was made for locating a new University building, the Intramural Field House, on the reclaimed swamp, but because of the depth to the solid material needed to support the pilings (about 75 ft), the proposed site was changed. The Golf Driving Range does include a piled structure to support the driving tees and cover, as well as a small structure for storage, office, and a classroom. Pilings for this structure were driven through about 20 ft of garbage and another 20 ft of peat.

### REFERENCES


1. W. L. Dunn, "Proposed Reclamation and Utilization of Union Bay Swamp." Report to the University Architect, U. of Wash., Sept. 15, 1959.
2. ———, "Seattle's Refuse Disposal Reformation." *The American City*, March, 1957.
3. ———, "Status and Recommendations for Continued Reclamation of Union Bay." Report to the University Architect, U. of Wash., Sept. 26, 1962.
4. ———, "Some Characteristics of Union Bay Peat." Report to the University Architect, U. of Wash., Nov. 21, 1960.
5. ———, "Storm Drainage and Waste Gas Burning at a Refuse Disposal Site," *Civil Engineering*, Aug., 1960.
6. R. W. Seabloom, "Study of the Effect of Refuse Disposal on the Water Quality of Union Bay. Report, U. of Wash., Dec. 28, 1962.
7. C. A. Rogus, "Use of Completed Sanitary Landfill Sites. Report, Dept. of Sanitation, New York City, Sept. 1, 1959.
8. "Report to the Corporation of the District of Burnaby on Foundation Conditions in Central Valley and Fraser Delta Peat Areas, Foundation of Canada Engineering Corp., Vancouver, B.C., July 29, 1960.


## A NEW APPLICATION OF MOIRÉ FRINGES IN STRUCTURAL ANALYSIS

*(Continued from page 19)*

recommendations made are based on the findings from use of the model:

1. With the use of sufficiently fine grids, the moiré method is successful for small-deflection analysis. Thus only one deformation need be made at each reaction. This is concluded from the influence lines plotted in Figs. 4, 5, 6, and 7 since the fringe patterns for both possible deflections are nearly identical.
2. By using the dot grid the influence lines for both vertical and horizontal loadings may be obtained simultaneously.
3. Utilization of photography produces the following advantages over conventional drawing-board procedures:
   a. The fringe pattern is made more distinct.
   b. The model may be reduced to a desirable scale.
   c. Photographs provide a permanent record of the analysis.
   d. Plotting of the fringes is made easier.
4. Points of maximum and zero deflections, i.e., the influence of the model, may be obtained from observation of fringe movement.
5. With the exception of the design of the model, all work prior to the drawing of the influence lines may be carried out by a technician.
6. The following material may be used in the preparation of the model:
   a. Model and base, Lucite.
   b. Moiré grids, commercially available grids reproduced on Kodalith thin-base film.
   c. Adhesive, nonpermanent 3M.
7. All model analysis must be carried out at the same temperature at which the moiré grids were attached to the Lucite. The moiré model could be employed to analyze other structural problems. It might be used to analyze foundation problems if they occur after the structure has been constructed. For instance, if the soil foundation were lost beneath a column, the investigator could simply go to the model and analyze this effect by removing the pin at the support and carrying out the moiré procedure. Possibly shock loading due to earthquakes could be analyzed by simultaneously imposing an acceleration to the base and photographing the resulting fringe pattern.

### ACKNOWLEDGMENTS

The model was prepared at the Structural Research Laboratory of the Civil Engineering Department, College of Engineering, University of Washington, Seattle, Washington. The authors of this paper are thankful to Dr. D. D. Vasarhelyi, Professor of Civil Engineering, for his guidance in the conduct of this project.

### REFERENCES


1. T. M. Charlton, *Spons Civil Engineering Series*, E. & F. N. Spon Ltd., London, 1954.
2. W. T. Eney, "Large Displacement Deformeter Apparatus for Stress Analysis with Elastic Models," *Proc.* SESA, Vol. 6, 1948, p. 84.
3. Ch. Massonet, "L'Etude des Constructions sur Modeles Reduits sous Complai de Microscopes," *Bull.* Centre de'Etudes, Res. et d'Essais du Genie Civil, Vol. VI, 1953, Bruxelles.
4. Morse, Durelli, and Sciammarelle, "Geometry of Moiré Fringes in Strain Analysis," *Trans* ASCE, Vol. 126, Part I, 1961.
5. A. T. Durelli and I. M. Daniel, "Structural Model Analysis by Means of Moiré Fringes," *Jour.* Struct. Div. ASCE, Vol. 86, Dec. 1960, p. 93.
6. *Design of Cylindrical Concrete Shell Roofs*, ASCE Manual No. 31, 1961.
7. *Handbook of Frame Constants*, Portland Cement Assoc., 1947.