I — Introduction

DEVELOPMENT OF USA-USSR EXCHANGE

In August 1957, a Soviet delegation attended the Fourth International Conference on Soil Mechanics and Foundation Engineering held in London, England. After the conclusion of the Lacy-Zarubin Agreement on cultural exchanges between the USA and USSR in 1958, Prof. G. P. Tschebotarioff, who had met the Soviet soil engineers at the London Conference, suggested to Mr. Fred Burggraf, Director of the Highway Research Board, the possibility of arranging an exchange between American and Soviet engineers. The purpose of this exchange was to facilitate an interchange of knowledge in the field of soil engineering, including theoretical and applied research, laboratory and field testing of soils, and design and construction procedures.

After exploring various possibilities, an official invitation from the Highway Research Board and the U. S. Bureau of Public Roads was sent by the State Department to the Soviet Embassy in Washington, D. C., in September 1958. It was hoped that a visit could be arranged that would enable a Soviet group to present papers at the annual meeting of the Highway Research Board in January 1959. This planned exchange could not be carried out for various reasons, but as an outcome of these negotiations, the National Association of Soil Mechanics and Foundation Engineering at the Academy of Construction and Architecture, USSR, proposed to Mr. Burggraf an exchange of small delegations (5-7 men) for "a mutual exchange of experiences in the field of soil mechanics research and its applications."

At the suggestion of Mr. Burggraf the proposed exchange was discussed at the annual meeting of the Highway Research Board in January 1959, and approval to proceed was voted by the Executive Committee. A special committee was appointed by Chairman Harmer E. Davis to work out the plan. The Soil Mechanics and Foundations Division of the American Society of Civil Engineers and the U. S. National Committee of the International Society of Soil Mechanics and Foundation Engineering were invited to join with the Highway Research Board as co-sponsors of the exchange, and these groups accepted.

A proposal to finance the exchange was prepared and submitted to the National Science Foundation in Washington, D. C., and was acted upon favorably. Mr. Joel Orlen, Professional Associate in the Office of International Relations, National Academy of Sciences, was very helpful in all of the negotiations leading to the successful exchange.

A delegation of Soviet engineers visited the United States between May 31 and June 21, 1959. The six members of this delegation were:

Ivan M. Litvinov, Active Member and Secretary, Academy of Construction and Architecture, Ukrainian SSR. Chairman of the delegation.

Nikolai A. Tsytovich, Active Member, Academy of Construction and Architecture, USSR; Professor and Doctor of Technical Sciences; Chairman, National Association of Soil Mechanics and Foundation Engineering, USSR.

Roman A. Tokar, Corresponding Member and Director of the Institute of Foundations, Academy of Construction and Architecture, USSR.

Alexander V. Gladyrevskiy, Chief Specialist of Gosstroy (State Construction Commission), Moscow.

Mikhail M. Levkin, Chief Engineer, Department of Large Bridges, Moscow.

Vassily M. Bezruk, Professor, State Highway Research Institute, Moscow.

The Soviet delegation participated in regional seminars at Princeton, Boston, Urbana, Berkeley, and Washington, D. C., and visited construction jobs in the vicinity of New York, Boston, Chicago, San Francisco and Washington, D. C., as well as the

AASHO test road at Ottawa, Ill. Papers presented by members of the Soviet delegation at these five seminars are published herewith in English translation.

Upon recommendation of the Highway Research Board, in consultation with the American Society of Civil Engineers, President D. W. Bronk of the National Academy of Sciences-National Research Council, approved the appointment of the American delegation to make the return visit to the Soviet Union.

Members of the American delegation received a number of books, reports and pamphlets describing Soviet research projects, design procedures and construction methods—all in the Russian language. These publications, along with those donated during the visit of the Soviet delegation, are listed in Appendix A. They have been filed at the Highway Research Board office in Washington, and are available for use by any interested persons. In addition, Prof. Tschebotarioff has received over a period of time a number of personal copies of Soviet publications. These are listed separately in Appendix A, and provision has been made to furnish microfilms or photostats at cost, or to arrange inter-library loans.

ITINERARY FOR THE DELEGATION

The seven delegates left New York City on September 13 and arrived in Moscow the following day. Three weeks were spent in the Soviet Union in the environs of four principal cities—Moscow, Kiev, Leningrad, and Stalingrad. As was the case for the Soviet visit to the United States, the American delegation had previously requested that the host committee from the Academy of Construction and Architecture, USSR, draw up a preliminary program to include visits to research and design institutes, field construction sites, and educational institutions. This plan worked very well. A few minor changes were suggested by members of the group, mostly to include additional construction sites, and these were incorporated in the final plan.

Transportation, hotels, guides, and the like were also arranged by the Soviet host committee. The delegation was not under the direction of the Soviet Intourist Agency, which resulted in considerable savings in cost and much added convenience. The Soviet host committee, the interpreters, and the engineers in the agencies visited by the American delegation made every effort to insure a successful visit and the visitors were impressed by the preparations which had been made for the technical presentations. Exhibits and photographs of equipment and diagrams for technical descriptions of research studies were exceptionally well prepared. The itinerary follows:

Monday, September 14

4 p.m. Arrival in Moscow from New York City via Copenhagen.

8 p.m. Reception dinner with members of host committee, Academy of Construction and Architecture, USSR.

Tuesday, September 15

9 a.m. Greetings from President N. V. Bekhtin at USSR Academy of Construction and Architecture. Discussion of program.

10 a.m. Visit to Exhibition of National Economic Developments — Construction Section.

4 p.m. Visit to Research Institute of Foundation Engineering of USSR Academy of Construction and Architecture. Reports on activities by Soviet engineers and inspection of laboratories.

Wednesday, September 16

10 a.m. Visit to the laboratories of the Research Sector of "Hydroproject" (Institute for design of hydropower plants). Reports and demonstration of activities by Soviet engineers.

Thursday, September 17

9 a.m. Visit to Moscow Geological Trust. Field demonstration of soil drilling and vibratory soil sampling.

2 p.m. Visit to Institute for Foundation Design of the USSR, Academy of Construction and Architecture. Reports on activities by Soviet engineers.

6 p.m. Visit to field investigation, site for TV tower.

Friday, September 18

9 a.m. Seminar at Moscow University. Tour of building and soil mechanics laboratory between morning and afternoon sessions.

Saturday, September 19

9 a.m. Visits to laboratory of the Research Institute of Frost Studies of the USSR Academy of Sciences.

3 p.m. Visit to construction site of apartment houses.

Sunday, September 20

9 a.m. Visit to Kremlin.

Monday, September 21

10 a.m. Departure for Kiev.

1 p.m. Arrival at Kiev, sight-seeing in city.

8 p.m. Reception dinner, Academy of Construction and Architecture, Ukrainian SSR.

Tuesday, September 22

9 a.m. Visit to Ukrainian Academy of Construction and Architecture. Technical presentations by Ukrainian engineers.

Wednesday, September 23

9 a.m. Visit to Ministry of Construction of the Ukrainian SSR. Discussions of construction and foundation problems for industrial buildings.

12 noon Visit to Kiev Polytechnical Institute.

3 p.m. Visit to Kiev Civil Engineering Institute. Discussion of civil engineering education in Soviet Union and United States.

Thursday, September 24

10 a.m. Seminar at House of Architects. Papers by American delegates.

6 p.m. Continuation of seminar. Discussion and papers by Ukrainian engineers.

Friday, September 25

9 a.m. Sight-seeing.

1 p.m. Departure for Leningrad.

4 p.m. Arrival in Leningrad. Sight-seeing in city.

8 p.m. Reception dinner at House of Scientists.

Saturday, September 26

10 a.m. Visit to construction site of apartment houses.

3 p.m. Leningrad Polytechnic Institute. Laboratory visits, and technical presentations by Prof. V. A. Florin. Presentation of papers by two members of American delegation.

Sunday, September 27

9 a.m. Sight-seeing. Visit to Pushkin and Petrodvoretz (Peterhof).

Monday, September 28

9 a.m. House of Scientists. Presentation of information on vibratory pile driving by Soviet engineers. Visit to field sites for demonstrations of vibratory pile driving.

4 p.m. House of Scientists. Seminar: Presentation of papers by four members of American delegation.

Tuesday, September 29

8 a.m. Departure for Stalingrad.

3 p.m. Arrival at Stalingrad.

Wednesday, September 30

9 a.m. Visit to Stalingrad Hydroelectric Station (dam under construction across Volga River).

Thursday, October 1

9 a.m. Visit to Volga-Don Canal.

1 p.m. Visit to cofferdam construction; vibratory driving of sheet piles.

4 p.m. Visit to pavement construction, hydraulic filling of gullies and apartment-building construction.

6 p.m. Visit to House of Architects. Discussion of master plan for Stalingrad.

Friday, October 2

9 a.m. Sight-seeing.

2 p.m. Departure for Moscow.

6 p.m. Arrival in Moscow.

Saturday, October 3

9 a.m. Visit to highway construction, Moscow area.

3 p.m. Closing discussion at the Academy of Construction and Architecture, USSR.

4 p.m. Visit to soil mechanics laboratories at Moscow Civil Engineering Institute. Presentation of research reports by graduate students.

Sunday, October 4

8 p.m. Farewell dinner.

Monday, October 5

9 a.m. Departure from Moscow.

The Soviet committee also served as hosts for entertainment features whenever time permitted. During the three-week stay members of the delegation attended three ballets, an ice show, two circuses, a puppet show and Cinerama; visited the Kremlin, several museums and art galleries, and were guests at a number of banquets.

In this short report it is not possible to acknowledge all of the Soviet engineers who were so helpful to the members of the American delegation. However, special thanks and acknowledgment are given to Prof. Dr. N. A. Tsytovich, Chairman of the USSR National Association of Soil Mechanics and Foundation Engineering; Director R. A. Tokar, chairman of the Soviet reception committee; Academician I. M. Litvinov, in charge of arrangements at Kiev; Prof. Dr. V. A. Florin, in charge of arrangements at Leningrad; and E. I. Seredinzev who handled arrangements at Stalingrad. The delegation also expresses its appreciation to the many other Soviet engineers who contributed to making the visit so informative and pleasurable.

SEMINARS

Members of the American delegation presented prepared papers at seminars held in Moscow, Kiev and Leningrad. These presentations had a total audience of about 700 persons.

The seminar at Moscow was held at Moscow University. It consisted of two parts and occupied a full day. The first four papers were given at a morning session, from 9 a.m. to 1 p.m. After luncheon a visit was made to the soil mechanics laboratories of Prof. N. V. Ornatsky and to other parts of the Moscow University building. The seminar reassembled at 4 p.m. and continued until 8 o'clock. The following papers were given:

"Studies of Frost Problems in a Northern State," by Prof. Kersten.

"Soil Stabilization," by Prof. Lambe.

"Analysis and Design of Concrete Slab on Ground," by Prof. Leonards.

"Floating Caisson Foundations. Steel Piles with Attachments," by John Lowe, III.

"Recent U.S.A. Research on Soil Strength and Deformation Characteristics Under Dynamic Loading Conditions," by Prof. Seed.

"Certain Features of the Lateral Pressures of Soils," by Prof. Tschebotarioff.

"Critical Elements of Design and Construction of Heavy-Duty Flexible Pavements," by Dr. Turnbull.

Prof. Kersten also displayed a Bureau of Public Roads film on the American Associations of State Highways Officials test road at Ottawa, Illinois, and gave some introductory remarks on the nature and status of the test road.

There were a considerable number of questions on all papers and several of the Soviet engineers gave five-minute talks on the subjects covered. It is understood that the papers given by the American delegates will be published in Moscow in the Russian language.

The seminar at Kiev was held at the House of Architects, and was also a full-day program. The morning session was from 10 a.m. until 2:30 p.m. and the evening program from 6 to 9 p.m. The AASHO Road Test film was again shown by Prof. Kersten. Prof. Leonards, Mr. Lowe, Prof. Tschebotarioff and Prof. Lambe gave papers on the same subjects as listed above for the Moscow seminar. Additional papers, not previously presented, were:

"Foundations for Large Bridges Across San Francisco Bay," by Prof. Seed.

"Summary of Rotary Cone Penetrometer Investigations," by Dr. Turnbull.

Again there were a number of questions on the various papers. At the evening session four of the Soviet engineers presented papers or discussions of soil problems. The papers presented by the Americans will be published in Kiev in the Ukrainian language by the Academy of Construction and Architecture.

At Leningrad the presentations were divided into two parts. Prof. Tschebotarioff presented his paper on lateral pressures and Prof. Lambe discussed "Soil Structure" at the Leningrad Polytechnic Institute on Saturday afternoon, Sept. 26. The second part of the seminar was held at the House of Scientists on Monday afternoon, Sept. 28, and Prof. Kersten first presented his talk on frost problems. He and Prof. Leonards then retired to another room, where a portion of the audience assembled for a two-hour discussion period on frost. The seminar continued with Prof. Seed's talk on dynamic loads, Dr. Turnbull's paper on the cone penetrometer, and one not previously presented: "Current Practice in Soil Sampling in the United States," by Mr. Lowe.

The good attendance of Soviet engineers at the seminars and their stay through the many hours of presentation and discussion evidenced their genuine interest, as did the large number of questions received and answered. Members of the American delegation appreciated the feeling of cordiality demonstrated in these open discussions, and felt that this direct exchange of information was the most effective method of gaining an understanding between the engineers of the two countries.

Nearly all the papers had been translated into Russian before their presentation and could be read directly by one of the Soviet engineers. In one instance a Soviet engineer presented a paper in the Russian language reading directly from the English manuscript. Prof. Tschebotarioff was the only member of the delegation able to present his paper in the Russian language.

Papers presented by members of the American delegation, containing information not currently available in the United States, are published with this report. For the sake of completeness, short summaries of the remaining papers are included.

II — Observations and Impressions

The development of soil engineering in the USSR, its present status and, indeed, its future potential are related to the social and economic "climate" of the country. As a consequence of widespread destruction during World War II, large numbers of structures of all types, especially housing, had to be replaced as rapidly as possible. Enormous manpower losses during the war, superimposed upon an existing scarcity of skilled labor, led to the mechanization of construction processes and to the increased employment of women—as engineers, as technicians, and as skilled and unskilled labor on construction jobs.

The Soviet Union is in a state of rapid economic expansion. This was illustrated by the major construction activities visited by the delegation, which were concentrated on apartment buildings and hydroelectric stations. Large-scale construction of roads and airfields seems to have begun only very recently. Although potential development is obviously great, it is apparent that manpower and material resources have tended to lag behind desired production goals. Accordingly, economy and speed of construction have been emphasized, while quality and aesthetics have been relegated to a role of secondary importance. There is evidence, however, that this emphasis on low initial cost is gradually yielding to considerations of quality.

Central planning of research, design, and construction activities is a basic feature of the Soviet system. Projects of importance to the entire Union are planned and controlled by central administrations located in Moscow. Each of the fifteen republics of the Union has a similar organization for projects of regional importance. Districts and municipalities handle such local matters as housing, streets and secondary roads. Planning, research, design and construction agencies operate as separate entities within the larger organizations.

In its visits to the various academies, institutes, ministries, trusts and construction jobs, the delegation was accorded the greatest respect and cordiality by everyone it encountered. These favorable circumstances were undoubtedly facilitated by the relaxed climate of USSR-USA relations coincident with the visit to America of N. S. Khrushchev, Chairman of the Council of Ministers USSR, which took place during the delegation's stay in the Soviet Union. However, an important factor was the goodwill created by the friendly reception accorded the Soviet delegation during its visit to this country in June 1959. It is felt that the most significant benefit derived from the entire exchange was not the interchange of current knowledge, valuable as this may be, but the personal contacts which, it is believed, will lead to friendly and fruitful exchanges of new developments on a long-term basis.

STATUS OF SOIL ENGINEERING IN USSR

State control and central planning of all activities in the USSR have channeled the development of soil engineering along lines specifically intended to solve the immediate problems associated with the economic development of the country. Heavy demands for maximum economy have engendered a healthy attitude towards large-scale experimentation with new techniques, materials and construction methods. Furthermore, considerable funds appear to be available in support of such work.

Specific accomplishments include the development of precast footings, vibratory driving of piles and hollow caissons, hydraulic filling with sands and clays, thermal stabilization of loess, and construction on permafrost. Extensive data on field performance of structures have been collected and codified into manuals of recommended practice, such as those on the design and treatment of "bases"* and of footings subject to sustained and vibratory loadings. Theoretical treatment of slabs on ground, stress distribution, three-dimensional con-

* Soil layers that support a foundation.

solidation, seepage, and model similarity are exceptionally well developed.

Important projects, such as large dams, canals, locks, and main roads are accorded individual attention. The design of these structures evidence a high level of competence, and, in many instances, ingenious construction methods have been utilized. On the other hand, the quality of finished surfaces and general appearances seem to have been considered of secondary importance, and standardized designs and techniques (particularly for apartment buildings) have not always taken the best advantage of local geologic conditions.

For example, precast reinforced concrete spread footings have been used under soil conditions where large settlements could be expected. Experiments are currently under way on the use of short piles as an alternative to deep footings in situations where the surface soils are highly compressible or the depth of frost penetration is large. The piles require less concrete and are lighter than the equivalent footings.

Soil testing equipment, both field and laboratory, was found to be of generally good design and excellent workmanship. With rare exceptions, all of this equipment was manufactured in the USSR and is of conventional design. Somewhat novel were the torsion shear apparatus and the attachments for conducting direct shear tests under vibratory loading conditions.

Loading systems for consolidation tests generally utilized dead weights with and without lever systems; some oedometers were equipped with pore pressure measuring devices. Triaxial shear apparatus was not plentiful. The delegation did not observe any of advanced design, although drawings were seen for new apparatus that incorporated many of the desirable features now generally recognized. Field plate-loading apparatus of novel design is in use, as are empirical tests for evaluating the danger of liquefaction of sands. These will be described later in the report.

Due perhaps to the general absence of deep deposits of soft plastic clay in the USSR, extensive work on the properties of such soils is not yet apparent; also, the properties of compacted clays and associated field compaction problems appear to have received only minor attention. Work on some of the aspects of cement, bitumen, and chemical stabilization of soils has been only recently activated. While novel methods of soil sampling using vibratory techniques were demonstrated to the delegation, modern equipment for undisturbed sampling of clays was not observed.

EDUCATION AND RESEARCH

Education in general, and especially scientific and engineering education, enjoys a higher level of importance and prestige in the USSR than in the USA. The highly selective system and the large incentives** for scholarly achievement have developed a student body of high caliber and seriousness of purpose that could hardly be excelled anywhere in the world. Undergraduate civil engineering curricula have a broader and more advanced mathematical and scientific base than their counterparts in America. However, at the professional and research level, education in the USSR appears to be more specialized than is the case in most western universities.

The quality of the educational system is reflected in the many highly motivated, dedicated and competent soil engineers and researchers—both men and women—which the members of the U. S. delegation had the pleasure of meeting. In his specialty, the Soviet researcher is apparently completely familiar with work done abroad. A member of the U. S. delegation would often be surprised to find that the Soviet worker with whom he was talking had studied very carefully his latest publications. (The delegation must note with some embarrassment that the reverse of this situation was not true. It is hoped that this exchange may pave the way toward the elimination of this undesirable situation.) The number and quality of scientific and technical personnel being developed are factors whose importance can hardly be overemphasized.

Basic research in the Soviet Union appears to be carried out mainly by the academies of sciences. Research and design in-

** In terms of prestige, higher financial stipend while studying, choice of curriculum and of the type and location of jobs upon graduation.

stitutes concentrate on applied research projects which are, for the most part, directly related to current problems. A considerable amount of applied research is also carried out by the engineering schools, or institutes, as they are called, although basic research also is conducted in them to some extent. Considerable evidence of a gradual broadening of research activities in soil and foundation engineering was apparent in many places.

State support and centralization of research as practiced in the USSR have led to substantial advances in fields which are deemed of particular importance to the economy of the country. The current seven-year plan (1959-65) contemplates a tremendous program of civil works. Ample funds are being provided to sustain a continuous research effort by teams of scientists, engineers and construction specialists. With cleverness and boldness, the Soviet engineers are making every effort to save money in construction and to circumvent the shortage of skilled workers.

They are willing to experiment with new techniques and materials in actual soil engineering projects and apparently have research teams for evaluating these experiments on a scale beyond anything presently contemplated in the United States with the exception of highway construction.

SUMMARY

The American delegation is of the unanimous opinion that the entire exchange was most productive and worthwhile, both in terms of the knowledge gained, as summarized in the remainder of the report, and in terms of potential long-term exchanges of information and experiences.

The status of soil engineering in the USSR is well advanced in areas which, in the past, have been deemed of particular importance to the economic development of the country; these include the development of precast foundation units, vibratory driving of piles and hollow caissons, thermal stabilization of loess, construction on permafrost, etc. However, the delegation saw little evidence of any extensive studies of the shear strength of clays or the properties of compacted soils and field compaction problems; work on cement, bitumen and chemical stabilization had apparently only been recently activated and modern equipment for undisturbed sampling of clays was not observed. As the economy expands, the scope of the Soviet effort probably will be broadened.

Education in soil engineering at both undergraduate and graduate levels is of high quality. Fostered by a highly selective system and by large incentives for scholarly achievement, substantial numbers of highly motivated, dedicated, and competent soil engineers and researchers are being developed.

In anticipation of a large civil works program, funds, facilities and personnel are being provided for long-term research on the performance of actual structures by teams of scientists, engineers and construction specialists. The magnitude of the effort expended on large-scale experimentation and subsequent evaluation appears to exceed that being done in the United States.

Soviet soil and foundation engineers are better informed of work being done in the United States than their American counterparts are of developments in the Soviet Union. The American delegation feels strongly that better methods for obtaining and disseminating Soviet technical knowledge in this field are urgently needed.

III — Academies, Research and Design Institutes

The delegation had the opportunity to visit four research or design institutes in Moscow, the Ukrainian Academy of Construction and Architecture in Kiev, the local branch of the Academy of Construction and Architecture in Leningrad, and the City Trust of Geological Engineering and Mapping in Moscow. At each of these a report of the respective general purposes and activities was first presented, and this was usually followed by technical reports from members of the organization and visits to the laboratories or to field activities.

During these visits the delegation heard many interesting reports and saw numerous pieces of apparatus for laboratory and field testing of soils. A concise review of these experiences follows. In a number of instances, certain types of apparatus and procedures were in use at more than one institute. In such cases, mention of a particular item will be made under the heading of the institute where it was first encountered, or where it appeared to be used most extensively. Thus, the items listed for any one institute should not be construed to comprise all of its activities or facilities.

Institute of Foundation Engineering Research, Academy of Construction and Architecture, Moscow

Dr. R. A. Tokar, director of the Institute, welcomed the delegation. Prof. D. I. Polshin gave a general outline of the Institute's work which is concerned largely with theoretical soil mechanics as this may apply to design and construction problems. Observation on full-scale structures, to evaluate theories, is an important part of the program.

Prof. M. I. Gorbounov-Possadov and colleagues reviewed earlier work and described current studies on the application of theories of elasticity and plasticity to stress distribution and bearing capacity of beams, slabs, and footings on ground. Complete solutions for beams on an elastic half-space, for any loading conditions, are given in Ref. 47, Appendix A. It was stated that solutions had also been obtained for rectangular slabs subjected to a concentrated load (anywhere, except near the edge), or to a symmetrical rectangular loaded area. Warping effects were not considered. Other special loading conditions for which solutions had been obtained also were mentioned.

Work is proceeding on a rigorous solution of the bearing capacity problem based on elastic and plastic zones that differ materially from those of the Prandtl theory. The distribution of contact pressure can also be obtained from the new approach. It is thought that the Terzaghi theory gives values that are too high, and that this will be corrected by the new theory. Preliminary calculations of contact pressures show good agreement with measured values. No reports or papers on the new theory were available at the time of the visit.

The Institute's laboratory contained conventional equipment for routine testing of soils. One project is concerned with possible correlations, on a regional basis, between soil characteristics (Atterberg limits, porosity, etc.) and the engineering properties of sediments.

A section of the laboratory is devoted to research on soil stabilization. The following items were being studied: bituminous stabilization (using emulsions), cement, clay and silicate grouting, soil cement (primarily for building foundations), electrical and electro-chemical stabilization, and stabilization with polymeric materials such as formaldehyde compounds.

Construction jobs where stabilization had been used were described. These included the addition of 7 to 11 per cent portland cement to loess for footings, calcium chloride plus electric current to arrest the movement of slopes, two-stage calcium chloride and sodium silicate injection and injection of sodium silicate alone in loesses already containing salt for foundation strengthening.

Institute for Design of Hydropower Plants, Moscow

V. I. Sevastianov, Chief of the Scientific Research Sector, welcomed the delegation. The Institute is concerned with research and design of large hydroelectric plants, and has laboratories and sections dealing with:

*1. Hydraulic questions related to the design and construction of control structures—including models.
2. Hydraulic machinery — including model turbines.
*3. Foundations and earth construction.
*4. Instrumentation for measurement of stress and strain in structures.
5. Concrete laboratory. (Problems in manufacture of concrete elements.)
6. Field laboratories for measurements on prototype structures.

The hydraulic model laboratory was large and well-equipped. The first model exhibited was of a lock, spillway and powerhouse in the Neman River. The scale was 1:75. Earth embankments exist at each abutment but spillway, powerhouse and lock structure are constructed at some distance out from the abutments. The navigation lock is located at the left end of the spillway structure with the powerhouse beneath it. Flood flows would be passed through the lock.

A hydraulic test on a section of Saratov Dam spillway presently under construction on the Volga between Kuibyshev and Stalingrad was being conducted in a glass flume. The principal problem under study was uplift under the stilling basin. The source of this problem seemed to be wave development up to about 1 meter high. A sill wall at the downstream end of the floor slab was not used for reasons of economy and because it was found that by proper design of the ogee sections a hydraulic jump could be created. The wave, however, caused excessive uplift pressures (up to 6 ft) to develop at the upstream end of the floor slab, thus requiring corrective measures. The measures adopted were (a) a heavier filter, and (b) more weep holes through the slab.

* Visited by the delegation.

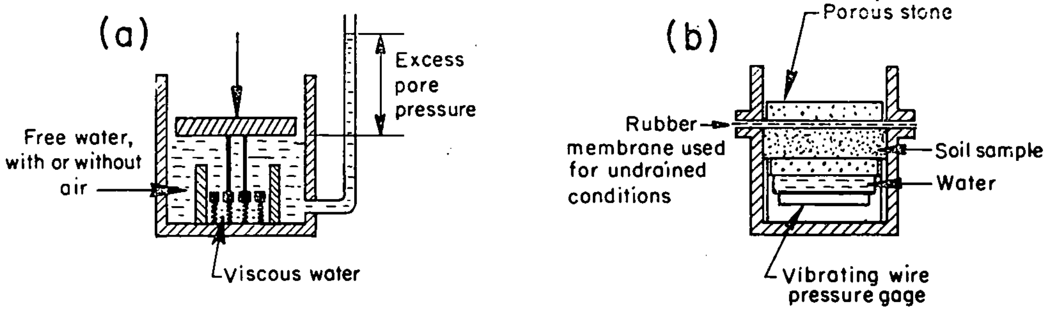
A model of the hydroelectric plant at Saratov was briefly inspected. Vibrational effects of operation were being studied since they were unduly severe. Pulsation pressures were being measured on all elements on which such pulsations might be detrimental. Prototype studies were being made on the Kuibyshev plant. The scale of this model was 1:25.

A model of a navigation lock, 1:40 scale, was demonstrated. This lock is in connection with a hydroelectric plant on a tributary of the Volga River. The purpose of the model was to find the minimum time of filling and emptying compatible with other physical features of operation. The model was completely instrumented so that one man could operate it. Instrumentation measured such factors as speed of gate opening, water rise rates, and all physical conditions pertaining to operational features. Directional forces on model barges in the lock chamber were also measured.

A model demonstrating a pneumatic method of investigating the effects of current in fixed and movable bed channels was inspected. In model studies of open channel flow it is necessary to observe the requirements of both the Froude and Reynolds numbers. Consequently, the scale of the model must usually be quite large. If the Froude number is not followed, surface deformations in free flow will develop; the difficulty is avoided with the use of pneumatic pressure models.

The model was constructed to a small scale and covered with an airtight glass plate in order to confine the flow. The small size of the model and rapidity of testing make it a very economical method of investigation. A demonstration was made using burning sawdust. The lines of flow (sparks) were clearly seen and can readily be photographed. Measurements of head losses and other physical parameters are taken. Fine to medium sand can be used in movable bed studies. Heads are duplicated by varying pressure. The model is verified by keeping the ratio of the critical erosive velocity to the actual velocity a constant.

The section dealing with foundations and earth construction had one of the best equipped soil mechanics laboratories visited



(a) Model for Concept of Consolidation (b) Pore pressure measurement in consolidation test

FIGURE 1
Model of consolidation process (a) and device for measurement of pore pressures in consolidation test (b).

by the delegation, and a number of active research programs were in progress. The consolidation of saturated and unsaturated clays was being investigated both theoretically and experimentally. The theoretical model under study is shown diagrammatically *(Fig. 1a)*; pore pressures were being measured in the consolidation test with apparatus illustrated *(Fig. 1b)*.

The soil mechanics laboratory at the Hydrotechnical Institute possessed one of the few triaxial compression cells seen by the delegation during the entire visit. It was stated that the apparatus was outmoded, and plans for a new triaxial apparatus were shown. This latter apparatus would accommodate specimens 6 in. in diameter and 15 in. high, apply confining pressures up to 15 kg/cm^2 and axial loads up to 25 kg/cm^2 at deformation rates as slow as 0.03 microns per minute. An automatic null meter for measuring pore pressures *(Fig. 2a)* was exhibited: a field pore pressure meter that could be placed in embankments or on the face of structures was also shown *(Fig. 2b)*. It was stated that measurements of pore pressures in embankments showed that the isochrones do not follow the Terzaghi theory, and the equation

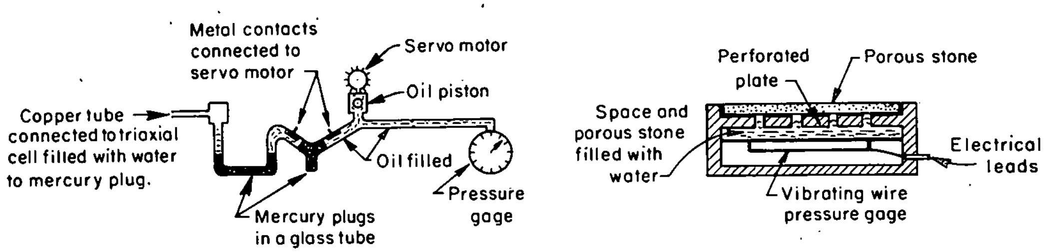
$$\sigma = \sigma' + u + S_t$$

where, σ = total stress
σ' = effective stress
u = pore pressure
S_t = viscous secondary effect

is being used to evaluate effective stresses.

A torsion shear apparatus *(Fig. 3)* is used to evaluate the effects of large strains and to determine the shearing resistance at the boundary between two dissimilar soils. This same apparatus was also seen in a number of other laboratories.

Experiments were being conducted on the liquefaction of sands subject to dynamic



(a) Automatic null meter for pore pressure measurements in laboratory (b) Field pore pressure gage used in embankments and at the face of structures

FIGURE 2
Pore pressure measuring devices.

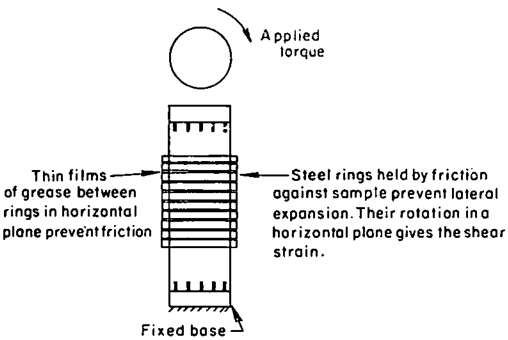


FIGURE 3
Torsion shear apparatus.

loads by measuring the excess pore pressures developed under a variety of conditions. Data were presented to show that the possibility of liquefaction decreases rapidly with increasing confining pressure. Stratification decreases the possibility of over-all liquefaction but localized liquefaction is enhanced.

An interesting aspect of the liquefaction of sands was a study being conducted of the thixotropic properties, exhibited by clayey sands, that were associated with the breakdown of alumino-silicates in the soil by bacteria. Organic matter must be present to enable the bacteria to live under water. To develop thixotropic properties, significant amounts of iron aluminum silicates must be present; when the proportion of silicates reaches about 30 per cent, the sands will exhibit "quicksand" characteristics.

Studies of natural quicksand deposits showed that they were invariably associated with swamps where an ample supply of organic matter was available. The organic matter often took the form of wood-like lignite. After the sands were cleaned by washing, their thixotropic characteristics were greatly reduced.

Model tests on bearing capacity with eccentric and inclined loads were in progress. It was stated that preliminary tests agreed with Meyerhof's theory.

Effects of vibrations in earth dams produced by hydraulic jump in the stilling basin of overflow wiers was being studied with models. It was stated that vertical accelerations as high as 1/10 g could develop. Methods of minimizing the resulting horizontal and vertical displacements of the embankment were being investigated.

Several types of model studies were being conducted on appropriate methods for placing hydraulic fill in a dense condition. One of these models was for the cofferdams being contemplated for use in construction of the high Aswan dam. Stone is first placed under water and the voids are then filled by hydraulic sluicing. The key factor is the grading and percentage of sand in the slurry, which is related to the size of the voids in the rock. Model tests were being conducted to develop design criteria for widely varying conditions. The method had already been used successfully in the field.

The instrumentation laboratory uses SR-4 gages for measuring strains, and vibrating-wire gages for measuring pressures against surfaces and tensions in anchor rods. An electrical analog computer, specifically designed to solve bi-harmonic differential equations, was in use. The biharmonic is broken down into two second order equations, each equation is placed on a separate network, and the computer automatically couples them in the solution. Typical problems being solved are the stresses in a rigid rectangular corner and in rectangular plates on an elastic foundation acted upon by concentrated loads.

Institute of Foundation Design, Academy of Construction and Architecture, Moscow

Director J. Trofimenkov outlined the work of the Institute, where designs for especially difficult foundation problems are worked out. Sections dealing with site investigation, laboratory tests, and field tests provide the basic data for the design section. Close liaison is maintained with the Institute of Foundation Engineering Research.

Reports by the Institute's engineers followed. A typical view of one such session is shown *(Fig. 4)*.

A new vane shear apparatus was described and exhibited. An accurate hole is drilled with rotary tools. A tube with retractable vanes is inserted to the desired depth. Twisting the inner tube causes the

FIGURE 4
Delegation listening to reports of Soviet engineers, Institute of Foundation Design, Moscow.

outer tube to make contact with the sides of the hole and forces the four vanes into the soil. A torque is then applied in the conventional manner.

The economics of short piles, 10 in. square and up to 16 ft long, had been investigated for foundations of 4- to 5-story apartment buildings. Their use has been adopted in cases where the surface soils are compressible, or to minimize excavation (especially in the winter), to avoid the expense of ground water lowering, and where a reduction in dead load of the foundation was desirable.

Foundations subject to dynamic loads were discussed briefly. The delegation was shown a copy of the latest code of practice where tables of allowable bearing pressures for different soil conditions and different classes of machinery are included.

A classification of landslides was presented, and specific examples of slides along rivers, on seashores, and on mountain slopes, together with the remedial measures used, were discussed.

The site of foundation investigations for a prestressed concrete TV tower 500 meters high and weighing 29,000 tons was visited. Load tests were being conducted by a novel procedure. The reaction for a jack is obtained from the passive pressure of the soil on the sides of the pit. By means of a system of cables and pulleys, the deflections of the plate could be read at the ground surface.

Research Institute of Frost Studies, USSR Academy of Sciences, Moscow

Director Prof. N. A. Tsytovich presented the delegation with a two-volume monograph of recently published work performed by the laboratory. It is of interest to note that approximately half of the land surface of the USSR is covered with permafrost.

The laboratory consists of two major sections: (a) a section to investigate physicochemical phenomena in the freezing process, and (b) a section to study the mechanical properties of frozen soils. Emphasis is placed on basic research. Numerous field laboratories to conduct in-situ studies under the direction of the central laboratory are distributed throughout the country.

Dr. S. S. Vialov, assistant director of the laboratory, is working on the properties of ice. Horizontal displacement of ice lenses under foundations have been observed.

Studies are being conducted on the possibility of reducing the rate of frost heaving by replacing divalent ions (such as calcium) in the soil water with monovalent ions (such as sodium). An apparatus has been constructed to determine localized volume changes due to changes in pressure by means of a narrowly focused beam of gamma-rays. Theoretical studies of the shape and movement of glaciers are in progress (see section on Universities and Engineering Institutes).

An extensive investigation to evaluate the stability and deformation characteristics of frozen ground is in progress. The strength-deformation relationships are dependent upon the ice structure in the frozen ground, temperature, soil type and time. Long-term creep studies, with measurements of axial and radial deformations, were being conducted at temperatures as low as —60° C. Properties of frozen sods during and after thaw are also being studied. It was stated that the shearing resistance can drop as much as 80 per cent by alternate freezing and thawing. A "ball-cone" test is used as a measure of strength relaxation with time. The short-term reductions, as measured with a ball-cone, have been correlated with long-term creep tests to give a rapid measure of residual strength.

Some of the future work of the laboratory will be concerned with the problem of artificially freezing soils to assist in the sinking of mine shafts. Design characteristics of soils are to be determined for a shaft 700 meters deep.

Other equipment and studies in the laboratory included:

(a) A 30-ton press in a cold room with temperatures as low as —60° C for studies of creep.

(b) A cold box with temperature to —70° C.

(c) A study of the change in density of soils during thawing and under load. Density was being determined by an apparatus measuring the absorption of gamma rays. It was stated that the sensitivity was 1/100 gr per cc and that the density was measured over a 5 mm depth.

(d) A nucleonic field apparatus for measuring density had been developed, useful to depths of 6 meters or more with a stated precision of 0.025 gr per cc.

(e) A study of the vertical and lateral strains in hollow cylindrical specimens. This work is a start on the study for mine shafts. Mixtures of 3.5 per cent paraffin, 68 per cent sand, and 28.5 per cent mica are being used rather than soil in the preliminary tests.

(f) Studies of the use of ultra-sonic waves for determining the extent of frozen soils either from the ground surface or in bore holes.

City Trust of Geological Engineering and Mapping, Moscow

Chief Engineer Muskalov welcomed the delegation and reviewed the work of the Trust, which is charged with the responsibility of: (a) making plans for the city of Moscow and its suburbs, (b) calculating and laying out boundary lines for buildings and roadways, (c) determining the location of pipe lines and utilities, (d) investigating soil conditions and soil properties, (e) making recommendations concerning desirable types of foundations, (f) examining foundations of existing buildings to determine if additional stories can be added, and (g) investigating causes of reported differential settlement and making recommendations regarding best methods of correction. For this purpose the trust prepares 1:500 and 1:2,000 scale maps and in addition compiles two documents for each building area. The first of these includes:

1. The decision of city authorities concerning the disposition and use of land.

2. A statement of architectural features of the building, which is also decided by the city authorities.

3. The requirements concerning utilities —size of pipes, connections to manholes, etc.

4. A statement concerning type and extent of landscaping to be provided.

5. A brief statement of the geological conditions.

The second document presents the detailed results of the investigation of the soil profile, the results of soil tests, settlement analyses and recommendations concerning the foundations to be used.

For the preparation of these documents the Trust makes about 430,000 lineal feet of boring a year. Almost all of this work is done by the vibratory method of soil exploration—a pipe forced into the ground by a combination of a light static load together with vibrations. Equipment is now available for making borings by this method to a depth of 140 ft although investigations for apartment building foundations usually extend from 25 to 50 ft below the ground surface. The borings are started using a diameter of 5 in. and then reduced to 4 in. or $3\frac{1}{2}$ in. at larger depths. The rate of sinking of the sampling tube is about 1 meter/minute. Allowing time for equipment set-up and sampling, a single boring rig drills between 150 ft and 300 ft per day depending on the type of soils encountered.

Samples obtained by the vibratory boring method are considered to be undisturbed. Initially there was concern that the vibrations would disturb the soil but comparisons of samples obtained by this method with those obtained by driving sampling tubes into the soil show similar results.

A demonstration of vibratory soil sampling was conducted for the delegation. Two sizes of vibrating machines are used depending on the anticipated soil conditions and depth of borings. The smaller unit is held by a truck-mounted crane, weighs 120 kilograms and vibrates at a frequency of 1,400 cycles/min. or some fraction thereof. The desirable frequency is selected during the boring operation. Sampling tubes have a vertical cut along their length, the size varying up to about 1/5 of the circumference of the tube *(Fig. 5)*. This prevents plugging of the soil in the tube during penetration into the ground. The desirable size of cut is selected on a trial and error basis. The vibrator for the larger unit weighs 450 kg., with a power supply of 7 kw.

For deep borings in hard soils, vibratory equipment is unsuitable and percussion drilling is used.

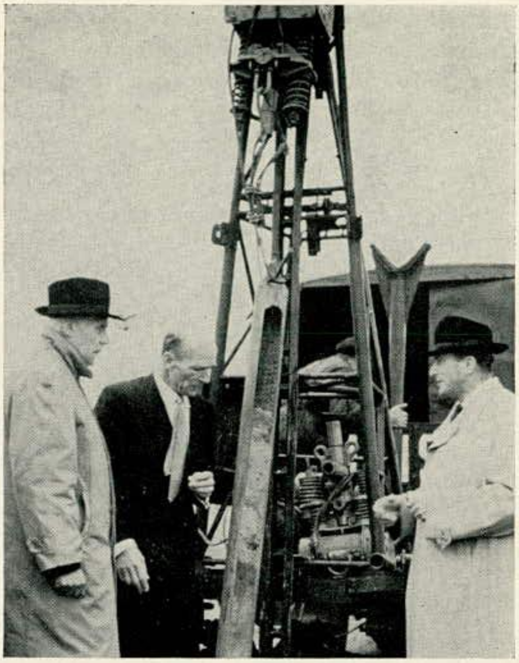


FIGURE 5
Vibratory method of soil sampling.

A machine for drilling test pits with a diameter of 32 in. to a depth of about 30 ft also was demonstrated; this machine can drill at the rate of 6 ft to 8 ft/hour. The entire unit is enclosed in a small truck and is thereby protected against inclement weather.

Ukrainian Academy of Construction and Architecture, Kiev

The delegation was welcomed by President A. M. Komar.* Academician I. M. Litvinov, secretary of the Academy, described its structure and its research and experimental works in soil mechanics and foundations. Formerly a branch of the USSR Academy, the Ukrainian Academy of Architecture was formed separately in 1946 and its activities were broadened to include construction in 1956.

The Academy is now comprised of 14 research institutes, located mainly in Kiev but with small branches in areas of concentrated construction activity. The present staff totals 3,500 of which approximately

* The delegation noted with deep regret the untimely death of President Komar shortly after its return from the USSR.

200 are at the doctoral level, 900 are graduate engineers and scientists and the remainder are technicians. The main problems currently being studied by the Academy are:

1. Methods of reducing the weight of buildings through the development of varitypes of lightweight aggregates.

2. The development of methods for utilization of local materials for construction work.

3. The introduction of new industrial elements (precast and prestressed concrete units) for building constructions.

Problems of mass construction of apartment buildings are now considered to have been solved but the Academy conducts a continuing search for improved construction methods and techniques.

To provide the delegation with a survey of the studies being conducted, the Academy arranged a special exhibition at which representatives of the various institutes and organizations under its jurisdiction presented brief reports on their activities *(Fig. 6)*. Features of the reports are summarized.

A detailed classification of landslides developed in the Ukraine was briefly reviewed.

Problems resulting from differential settlements in areas of mining subsidence were discussed. Of special interest was the use of wedge-shaped footings which were reported to have minimized differential settlements in some areas.

Current studies of the Railway Institute at Dniepropetrovsk were described as follows:

(a) Investigation of the orientation of clay particles due to shear. Studies have been conducted using kaolinite, and photomicrographs show clearly the increase in degree of orientation (parallelism) of the particles along the slip plane.

(b) Development of pore-water pressure gages for use in the field. Three types of piezometers were studied: (1) a counter-pressure pneumatic gage, similar to the Goldbeck cell, (2) a gage

FIGURE 6
Technical presentation at Ukrainian Academy of Construction and Architecture, Kiev.

in which the water pressure deforms a membrane, the deformation being measured with either a vibrating wire or an induction type strain gage, and (3) an improved Casagrande type gage in which the plastic tube was replaced by a copper tube. The latter gage was being favored due to its greater stability for long-term measurements.

(c) Studies of the density and susceptibility to liquefaction of hydraulic sand fills. Hydraulic fills of fine sand are frequently used for dam construction in the USSR, and it has been necessary to determine the danger of liquefaction of these materials. For this purpose different methods of placement have been tried during the construction of small test dams, 15 ft to 30 ft high, and the danger of liquefaction determined by exploding small charges in the dams. It has been found that the density of the hydraulic fill varies considerably depending on the slope of the "beaches" and that utilization of a desirable slope results in a sufficiently dense fill that blasting causes no evidence of liquefaction.

Mobile boring equipment and field laboratories used in the Kiev area were displayed.

The portable soil testing apparatus* developed by Academician Litvinov and used extensively in the Soviet Union was demonstrated *(Fig. 7)*. This equipment, which can be carried in two small suitcases, includes consolidation and direct shear apparatus, an oven, and apparatus for performing classification tests. A paper describing this apparatus was presented by Mr. Litvinov during the visit of the Soviet delegation to the United States. Ten thousand sets of the apparatus have been produced to date.

The method of thermal stabilization of loess soils developed in the Ukraine was described. As about 80 per cent of the area of the Ukraine is covered by loess, there has been considerable research on methods of construction on this type of material. Early attempts at thermal stabilization by injecting hot gases under high pressure in the loess were not effective, but satisfactory results are now obtained by burning gas in a tube in the ground. It has been found that the temperature should not exceed 1,000° C, otherwise the soil grains adjoining the tube will melt and the hot gases cannot penetrate the soil mass. It is necessary, therefore, to provide a proper combination of air and fuel to produce a high temperature but one that will also enable the hot gas to diffuse through the soil.

The present procedure consists of injecting, through pipes in the ground, a controlled mixture of liquid fuel under a pressure of 0.3 atmosphere. The fuel is fired for about 10 days and produces a cylinder of solidified soil, about 9 ft in diameter, around each pipe. The largest depth of the stabilized zone appears to be about 40 ft.

The method has been used to date on about 30 large jobs including foundations for buildings, machinery and smoke stacks. It has also been used for remedial measures in areas where loess has settled due to wetting. The cost of stabilization is about 20

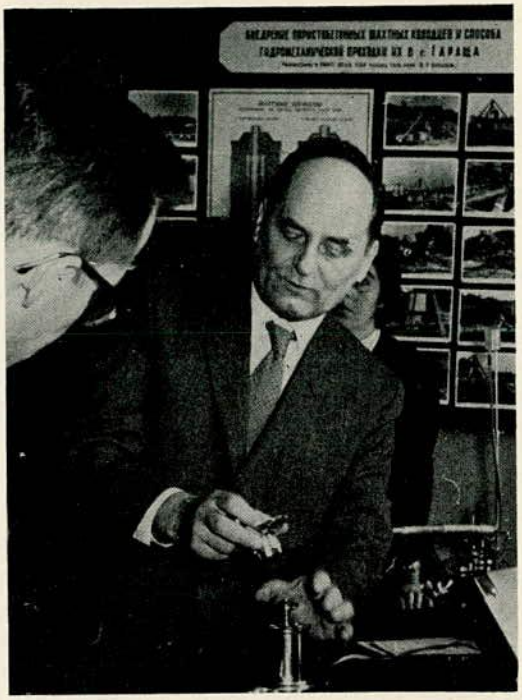


FIGURE 7
Demonstration of portable soil testing apparatus by Academician Litvinov, Kiev.

* See "Equipment for Field Geotechnical Investigations of Soils."

rubles per cubic meter of soil, enabling the method to compete economically with pile foundations. However, its use is limited to dry or partially saturated soil.

Pavement design procedures developed by the Auto Road Institute at Kharkov (Director Dr. A. K. Berulia) for use in the Ukraine were described. The design method is based on the principle that a sufficient thickness and quality of base and surfacing must be provided to limit the surface deflection of the pavement to a tolerable amount. This permissible deflection varies from 1 to 1.6 cm depending on the quality of construction.

Computation of the deflection of a given pavement structure is based on an empirical relationship between deflections caused by repeated loads and by static loads and on the deflection computed by elastic theory utilizing a stress distribution pattern determined by applying suitable correction coefficients to the Boussinesq theory. In the Ukraine, moduli of deformation for substitution in the analyses are determined from a correlation obtained from a large number of field studies between the initial composition of a soil and its subsequent modulus of deformation.

Photographs and diagrams illustrating the use of "camouflet" piles were exhibited. The term "camouflet" is used to describe cast-in-place, end bearing piles with an enlarged base produced by exploding a small charge at the bottom of a bored shaft partly filled with fluid concrete.

The method appears to have been first used in England around 1870. The development of the method in the USSR was started by an engineer named Romanov. A hole is made in the ground below the bottom of the pile. The gas of the explosion partly goes up through the concrete, the remainder cools and contracts to form a partial vacuum. The vacuum plus gravity causes the concrete to fall into the hole. The size of the bulb created is indicated by the amount the top of the concrete drops in the pipe. The soil surrounding the tip of the pile is damaged during the explosion.

Camouflet piles have been widely used in the Soviet Union. The greatest depth utilized thus far was for a bridge foundation where the piles were 30-33 meters long. Due to the explosion, the soil in the vicinity of the bulb generally compacts although this is not always the case.

Tests indicate that the unit load which the soil in contact with the bulb can carry is less than the unit load it could carry before the explosion. This decrease in unit load capacity is caused by the cracks which develop during the explosion. However, the large area of the bulb more than compensates for this loss in strength and the capacity of the pile is much greater than if no bulb were used. By using a semi-fluid mortar in the lower portion of the pile, the effective radius of the bulb can be increased about 50 per cent.

Local Branch, Academy of Construction and Architecture, Leningrad

Only one morning was available for a visit to the Academy, which was represented by B. V. Muraviev, vice-director of the Scientific Department. It was devoted to reports on recent developments in vibratory pile driving equipment (for a discussion of applications, see section on Construction Jobs).

Dr. O. A. Savinov reported that the vibratory method of driving piles could be used for all kinds of conditions, but for efficient sinking the parameters had to be properly selected. To overcome point resistance, considerable static loads or impact forces are required, as illustrated *(Fig. 8a)*. Moreover, an optimum amount of surcharge exists for a given set of conditions *(Fig. 8b)*. For high point resistance and heavy piles, as much as 15 tons of surcharge is needed. This involves complicated equipment, although advantage can be taken of the weight of the vibrator and housing.

Vibration at resonance is found to increase efficiency, but requires low frequencies. With vertical vibrations only, there are two instants when the actuating forces are zero (unless two out-of-phase vibrators are used, which decreases efficiency). This permits the soil to set up. It is thought that by applying torsional vibrations 90° out of phase with the vertical vibrations that this difficulty can be cor-

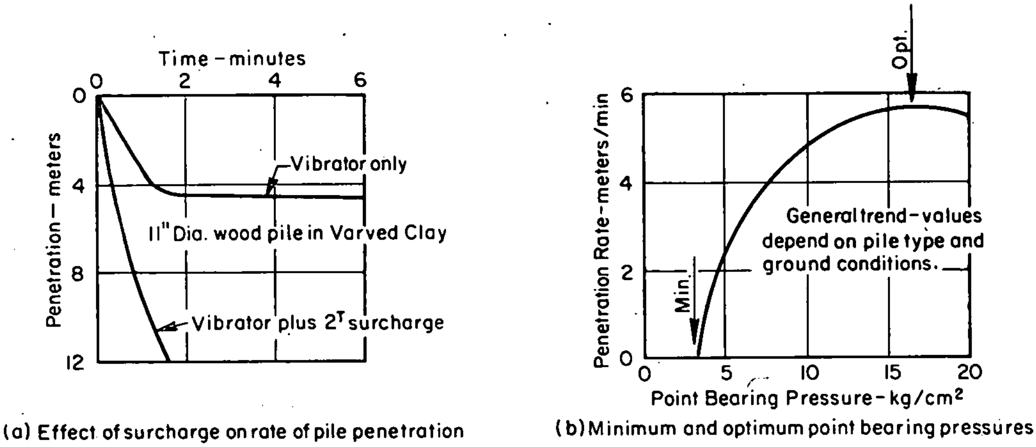


FIGURE 8
Parameters affecting rate of vibratory pile driving.

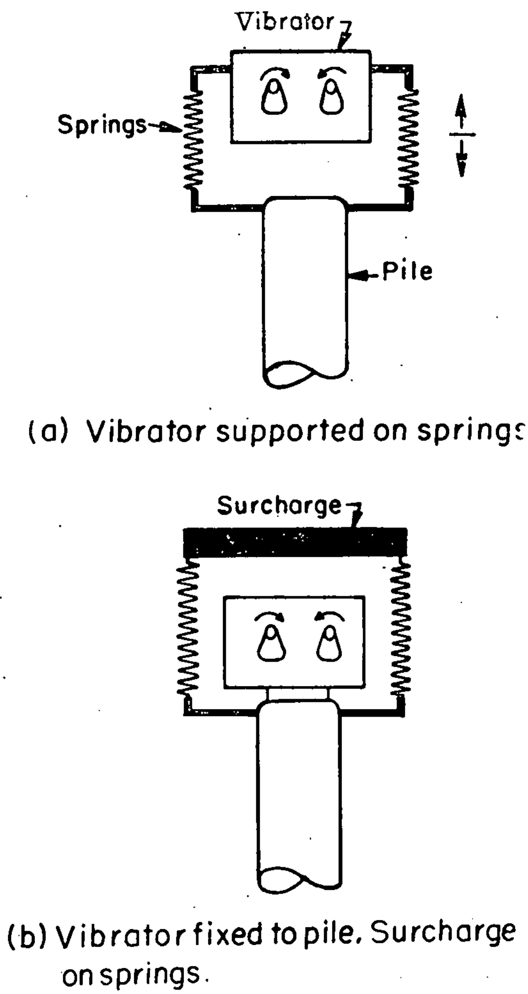


FIGURE 9
New designs for vibratory hammers.

rected. Some powerful vibrators based on this principle are now being designed.

Experiments are being conducted with equipment that combines impact with vibration. The successful development of such vibrators would greatly extend their range of applicability. A vibrator of this type is illustrated *(Fig. 9a)*. It was found, however, that it was difficult to control, particularly in the initial stages of driving; did not permit low frequency vibrations; and precluded controlled application of surcharges. Consequently this approach has been abandoned. Experiments are currently under way with a type of vibrator shown schematically *(Fig. 9b)*. This vibrator is attached to the pile and can operate at low frequencies. The magnitude of the surcharge can be varied independently.

The vibratory method of pile driving has also been adapted for other uses, including:

1. Sinking of casing for wells.
2. Vibratory borings and soil sampling.
3. Installation of horizontal conduits without trenching.
4. Mining and earth excavation.
5. Installation of thin-shell caissons.
6. Installation of piezometer pipes.
7. Piercing through frozen soil crusts.
8. Installation of sand drains.

IV — Universities and Engineering Institutes

In the USSR the vital role played by higher education in the military, economic, and social development of the country is apparently fully appreciated at all levels of society; consequently it is treated with the utmost seriousness.

Entrance to the university or engineering institute is considered a privilege accorded only to those who have demonstrated the highest level of academic proficiency. Furthermore, the student's opportunity to select a curriculum of his choosing, his stipend and status as a student, and the possibilities for employment upon graduation are largely determined by academic accomplishments. Accordingly, the eagerness to learn, the desire to excel, and the seriousness of purpose which pervade the Soviet university scene are probably unequaled anywhere in the world.

From the standpoint of efficiency, one cannot help but admire the directness and obvious effectiveness with which the Soviets are going about the business of providing higher education for virtually all of their best minds.

The delegation had the opportunity to visit one university, two polytechnic institutes, and two civil engineering institutes. From these visits, and the ensuing discussions, it is believed that a reasonably clear picture was developed of the Soviet approach to education in civil engineering, and particularly to soil mechanics and foundation engineering. In general, the philosophy is to begin with a strong background in mathematics and the physical sciences, followed by immediate specialization in some aspect of civil engineering, including extensive study of practical design details. A factual account of the conditions encountered by the delegation follows, but no attempt will be made herein to appraise the comparative value of the Soviet educational system.

Moscow University

Moscow University is by far the most impressive building to be constructed in the Soviet Union since the Revolution *(Fig. 10)*. From the 32nd floor, a majestic view is obtained of the surrounding botanical gardens, of the meanders in the Moscow River, and

FIGURE 10
Moscow University.

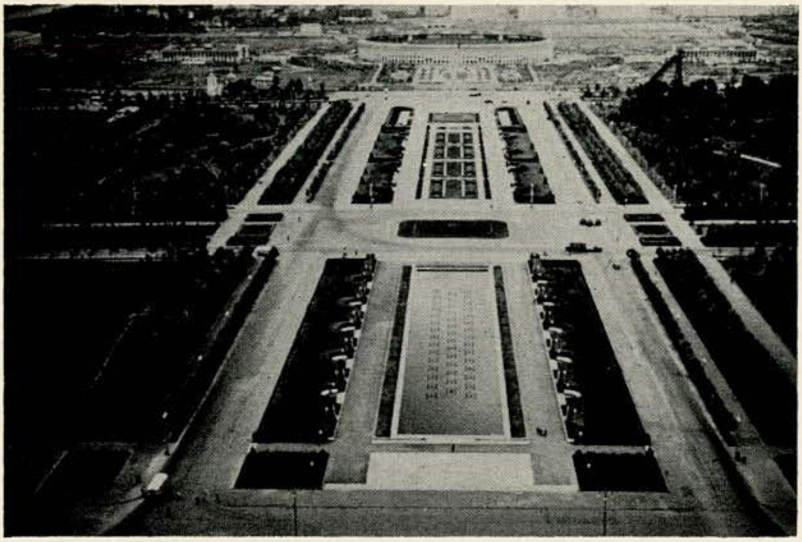


FIGURE 11
View looking north from 32nd floor of the University.

of the city of Moscow *(Fig. 11)*. Mr. Khrushchev's residence is nearby. Muscovites are justly proud of this fine edifice, which is the major seat of learning in the USSR.

The University has an enrollment of approximately 22,000 students of whom about 15,000 are regular day students. About one-half of the students are girls. Natural sciences, consisting of mathematics and mechanics, physics, chemistry, geology, biology and geography are taught in the new building which also houses the museums of anthropology, astronomy, geology and zoology. Approximately 40 per cent of the students are studying the humanities, consisting of languages, literature, history, philosophy, psychology, law and economics, which are taught in old buildings near the center of the city. It is planned to construct a new humanities building in the near future, in order to bring the whole university to one campus.

To enter the University, a student must have a high school diploma and must pass a rigorous, competitive examination. The only exceptions to the examinations are "Gold Medal Students" who enter directly from high school. Only one out of six who take the examinations passes. If a student fails he then goes to the factory or the army for two years. He may then take the examination again, and is given some degree of preference. He may keep trying once a year until he is 35. The average entrance age is 20 years; the limits are 18 and 35.

Ninety-five per cent of the students who start at the University are able to complete the course in due time. Those who do not finish generally drop out for illness or reasons other than lack of ability.

Instruction is free, as in all other Soviet educational establishments. Besides this, the Government provides grants to about 85 per cent of the students. The 15 per cent who do not get fellowships are those who do not need them, e.g., the children of professors or scientists. The fellowship pays for board, room, clothes and similar expenses. Top students get an additional 25 per cent.

Engineering is not taught at the University but the Geology Department includes a Division of Engineering and Hydro-Geology, in which a Chair of Geology and Soil Mechanics is established headed by Prof. N. V. Ornatsky. During intermission between the morning and evening seminars, the delegation made a brief inspection of the geology museum and of the soil mechanics laboratories. The museum contained an outstanding collection of rocks and minerals; the soil mechanics laboratories, used primarily for instruction, contained excellent equipment, all of which was of Soviet design and manufacture.

A direct shear apparatus was fitted with a device which could vibrate the bottom of the shear box horizontally at frequencies ranging between 300 and 3,200 cycles per minute; an unconfined compression device was fitted with a lever along which a weight could be moved by a Selsyn motor, thereby applying continuous loading at a constant rate; otherwise, the equipment was of conventional design. Triaxial compression apparatus was not in evidence.

The general course in soil mechanics is taught in the third year. In addition to the usual material on soil properties (including laboratory experiments) and theoretical soil mechanics, considerable time is devoted to discussing the physico-chemical properties of soils. Elective courses are available in the fourth and fifth years; these consist primarily of special projects, individually assigned.

Moscow Civil Engineering Institute

The Civil Engineering Institute in Moscow prepares students in seven different specialties such as hydraulics, industrial and civil construction, reinforced concrete and sanitary engineering. All students follow a common curriculum for the first two years. Included are 410 hours of mathematics (lectures 200 hours, exercises 210 hours), 133 hours of chemistry (lectures 80 hours, laboratory 53 hours), and 291 hours of physics (lectures 161 hours, laboratory 94 hours, problems 36 hours), as well as courses in freehand drawing and drafting, descriptive geometry, surveying and foreign languages (English, French and German).

Thereafter courses vary with the specialty, but all students receive instruction in theoretical and structural mechanics, strength of materials, theory of elasticity, theory of structures, construction engineering, foundations and soil mechanics.

Instruction in soil mechanics and its applications is provided by the Chair of Soil Mechanics and Foundation Engineering headed by Prof. N. A. Tsytovich, assisted by Dozent P. G. Kouzmin. The course in soil mechanics and foundations is given in the seventh and eighth semesters of the fourth year, and consists of. 98 hours of instruction (lectures 84 hours, laboratory 14 hours) plus a design project.

Each student is given an individual assignment for his project; generally, a geologic cross-section, the results of soil tests, and the general plans for a structure are provided. The student is required to design the foundations, make a settlement estimate, and defend his project before the faculty. About 600 students, divided into 23 separate classes, take the soil mechanics course each year.

After completing a six-year program that includes one year of full-time work in industry, the successful student graduates with the degree of engineer. He must then work at least two years in industry before he can apply for graduate study; if he is accepted, he becomes an aspirant for the candidate degree. Upon completion of one and one-half years of course work he can begin experimental work on his thesis. On the average, another one and one-half years is required to complete the thesis for the candidate degree. Before the thesis is presented to the chair it must first be published either in a book or as a technical paper.

A considerable amount of graduate work in soil mechanics is being conducted at the Institute. Prof. Tsytovich presented five of his aspirants for the candidate degree who described their research projects and answered questions posed by the delegation. They were: Engineer, Mr. Baranov, who was investigating the distribution of contact pressures beneath footings including theoretical and experimental studies of the effects of membrane stiffness on the performance of earth pressure cells; Engineer, Mr. Veronsky, who was developing improved methods for measuring soil density, both from the ground surface and in bore holes, by means of gamma rays; Engineer, Mr. Uskov, who was conducting field investigations on the use of prefabricated reinforced concrete retaining walls constructed at the Kuibyshev dam; Engineer, Miss Doroshkevich, who was investigating the distribution of soil stresses in groups of friction piles subject to static loads—models of pile groups in gelatin are being studied by means of photelasticity; Engineer, Mr. Lukin, who was conducting theoretical and experimental investigations of moisture distribution in partially saturated soils. For analysis, the soil is replaced by a capillary model with an equivalent "suction capacity" (pf). Predictions of the accumulation of moisture under slabs in dry climate are being checked in the field using equipment that measures neutron scattering.

Following the presentation by the five aspirants, Prof. S. S. Vialov briefly discussed the main topic of his forthcoming book which deals with the deformation of ice and the movement of glaciers. Using optical methods, Prof. Vialov has shown that the orientations of ice crystals are aligned in the direction of shear deformations. Measurements of crystal orientations in ice from continental glaciers show alignment that is approximately horizontal; hence it was concluded that shear deformations in such glaciers must also be approximately horizontal. Measurement of stress-strain-time relationships in ice led Vialov to the conclusion that the equation

$$\gamma = a\ \tau^{\alpha}$$

where, γ = rate of change of shear strain with time

τ = applied shear stress

a, α = empirical coefficients that are approximately constant for a given type of ice

adequately describes the shear stress-shear strain rate relationship for ice.

Using these two basic assumptions and a knowledge of precipitation, temperatures, and ground profiles, Vialov has developed a theory to predict the shape of the glacier surface as well as the stress and velocity distributions in the ice mass. Schematic diagrams illustrating his results are shown *(Fig. 12)*. It was stated that the results predicted from this theory were in agreement with field measurements.

Kiev Polytechnic Institute

The Kiev Polytechnic Institute has eleven "faculties" or departments—electrical, radio, heating, machine construction, chemical machinery construction, chemical technology, mining, metallurgy, engineering for the movie industry, evening education faculty, and correspondence education faculty. Within this framework the Institute prepares engineers in 36 specialty areas. Originally the Institute also included a faculty of civil engineering, but because of its size and importance this was separated in 1930 to form the Kiev Civil Engineering Institute.

The present total enrollment of the Polytechnic Institute is 13,000 students. Admission is on the basis of an entrance examination; however, for those students near the boundary line for admission, other factors are considered, such as previous practical experience. For the last academic year, 2,770 students were admitted from about 7,000 applicants.

Under the new plan for engineering education which went into effect in September 1959, students will be educated under a cooperative system combining academic training with practical experience, with four days of study and one day of practical work each week. A half-year of full-time work is also required. To facilitate practical training the Institute has its own factory where a variety of appliances and instruments are manufactured. A practical diploma project must be worked out (problems are assigned by industry) and each student must defend his thesis. Under this system a student will spend six years before graduating with the degree of engineer.

The minimum requirement in mathematics is 300 hours of lectures; the maximum requirement is 450 hours for radio engineers. All students receive 200 hours of instruction in differential and integral calculus, including differential equations. The remainder of the time is spent on topics of particular interest to the various specialty departments, and includes work on the theory of complex variables, operational calculus, vector analysis, partial differential equations and statistics.

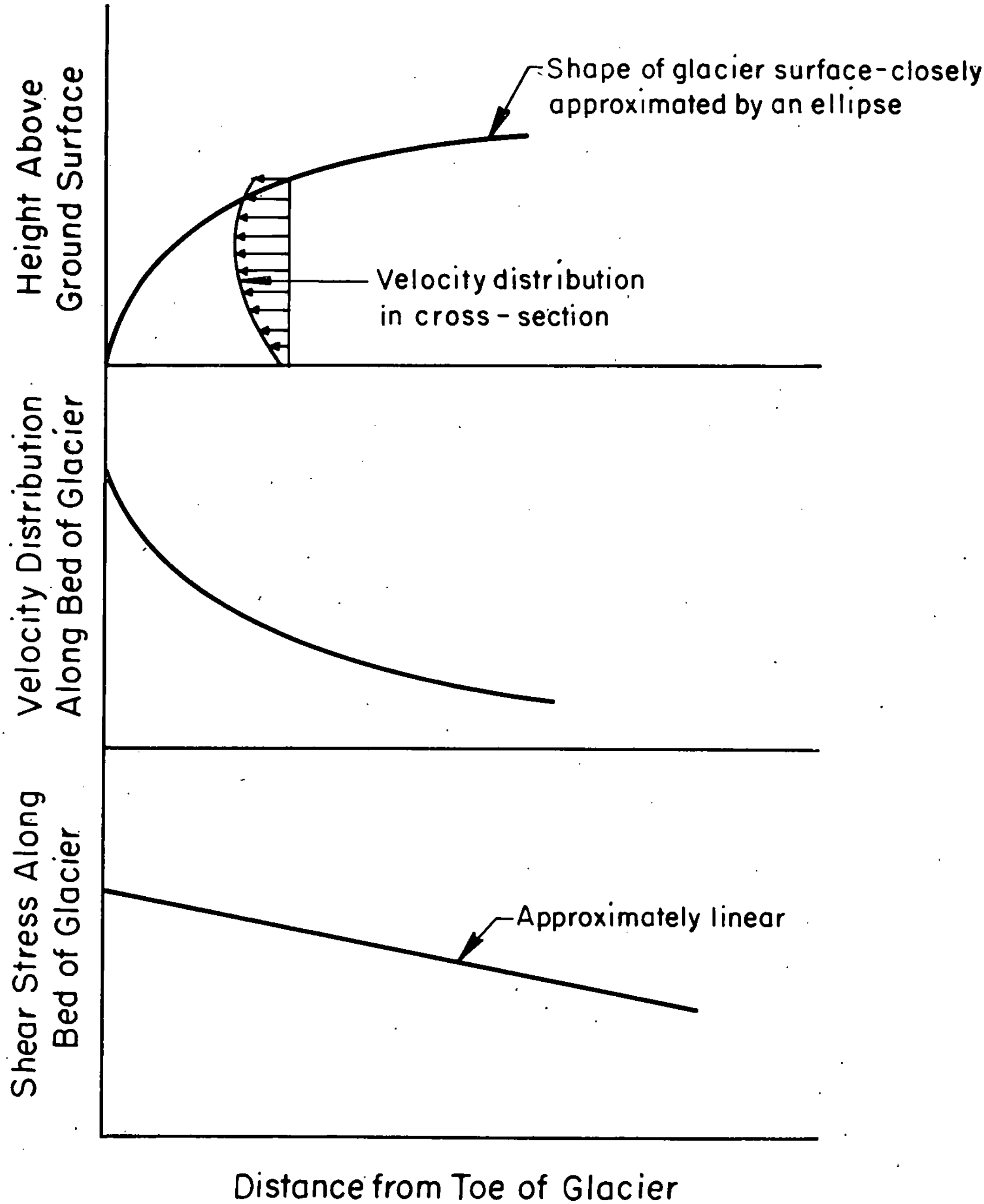


FIGURE 12
Schematic diagrams showing results of Prof. Vialov's theory of glacier movement.

On graduation, students are assigned to positions by a special state commission. A list of available vacancies is sent to the Institute and the professorial staff makes recommendations for the assignment of students based on their performance records. Students disliking their assignments can appeal to the special commission and, if sufficient justification exists, can get the assignment changed. The starting salary of graduates is about 1000 rubles per month.

As at other universities throughout the

USSR, students admitted to the Polytechnic Institute receive considerable financial support. Students from families with incomes less than 500 rubles per month per member of the family receive a monthly stipend of 300 rubles. The better students receive the same stipend regardless of the financial standing of their families, while top students get a 15 per cent bonus. Dormitory space is available for out-of-town students. Typical living costs per student are 220 rubles per month for room and board.

Kiev Civil Engineering Institute

The Civil Engineering Institute also engages in daytime, evening and correspondence instruction. The total student enrollment is 4,500, comprising 2,500 day students and 2,000 in evening and correspondence courses. Areas within which students may specialize include:

- Industrial and Civil Construction
- Sanitary Engineering
  - (a) Water supply and sanitation
  - (b) Heating and ventilation
- City Planning and Construction
  - (a) City economy and organization
  - (b) Engineering geodetics
- Architecture
  - (a) Architectural engineering
  - (b) Interior decoration
- Reinforced Concrete

The same cooperative system of education is followed as at the Polytechnic Institute, but the civil engineering students obtain their practical work at construction sites. During the first two years a student does trade work and is expected to achieve a specified rating in at least three trades. Beyond this stage practical training is more professional in character.

As at the Polytechnic Institute, admission is determined by special examination. On the average there are six applicants for each vacancy, but in certain areas the competition is keener; for example, in the architecture department there are about twelve applicants for each vacancy. About 20 per cent of the total enrollment is female.

Student-faculty ratio in the daytime classes is about 11 to 1 and about 22 to 1 in the evening and correspondence instruction. Daytime students have about 36 contact hours of instruction per week. The total number of contact hours required for graduation is 4,564.

Under the new plan, students will receive 410 hours of instruction in mathematics, 380 hours in physics and 133 hours in chemistry, in addition to technical courses. Each student also will be required to study a foreign language for four years and pass a state examination on completion of the course *(Fig. 13)*.

Soil mechanics instruction at the Institute is provided by the Chair of Foundations headed by Prof. A. M. Drannikov. Two courses, engineering geology and soil mechanics and foundations, are given to students in all departments except heating and ventilation. However, the subject matter is varied somewhat depending on the specialty area of the students.

The course in engineering geology emphasizes the applications of geology in civil engineering construction; it involves 70 to 150 hours of class work depending on the specialty area of the students involved.

The course in soil mechanics and foundations includes lectures, laboratory work and exercise classes. It involves 120 to 190 hours of classwork, with the time being devoted approximately equally to soil mechanics and foundations. Every student is required to complete a series of laboratory assignments, including direct shear and consolidation tests, and an individual design project incorporating some aspect of such topics as strip footings, pile foundations, bridge foundations, anti-seismic design, permafrost, slope stability, quicksand, foundations on fills, etc. The numbers of students run about 50 to 70 for lecture classes, 25 for exercise classes and five to 12 for laboratory classes.

The soil mechanics laboratory was adequately equipped for instructional purposes, although triaxial compression apparatus was not available. Equipment was of Soviet design and manufacture and was of excellent quality.

In addition to student instruction, the soil mechanics staff also engages in research activity. Areas of concentration include: stability of earth masses, including waste

FIGURE 13
U. S. delegation with faculty of Kiev Civil Engineering Institute.

piles and earth fills; economics of precast concrete foundations; utilization of inexpensive explosives for densification of soils; and compaction and lateral pressures of soils along retaining structures. This research is closely related with problems encountered in engineering practice. Subjects for investigation are solicited from practicing engineers, and the research conclusions are tested in practice on completion of the studies.

Leningrad Polytechnic Institute

The Leningrad Polytechnic Institute is one of the distinguished engineering schools in the USSR. It has "faculties" or departments in electrical, mechanical, metallurgical and hydrotechnical fields, and an enrollment of about 4,000 students.

The delegation regrets that an overcrowded schedule did not permit any discussion of curricula. The Soil Mechanics Laboratory, which is headed by Prof. W. A. Florin, is a part of the Hydrotechnical Department whose dean is Prof. P. D. Glebov. The laboratory is apparently used primarily for demonstrations and research.

It is also regretted that time did not permit a visit to the Vedeneev All-Union Research Institute for Hydraulic Engineering (Director, B. V. Proskourakov; Deputy Director, N. N. Maslov), where it is understood significant research is being carried out in soil mechanics, especially in its applications to hydraulic structures. The few available hours were occupied in hearing short reports by Prof. Florin on his current research and a brief visit to his laboratory. Following is a summary of Prof. Florin's discussion:

1. Distribution of Contact Pressure for Footings and Slabs on Ground

It was stated that the assumption of an elastic half-space is to be preferred over Winkler's assumption of a modulus of subgrade reaction if the slab or footing is resting on hard ground, but that Winkler's assumption gives better results in the case of soft, compressible foundations. Solutions have been developed which take into account tangential stresses at the contact surface. It was found that these stresses have little effect on the distribution of normal stresses in the ground, but they do have an important influence on the stresses that develop in the slab or footing.

It is recognized that the use of a viscoelastic half space would be a distinct improvement, and work is proceeding on such analyses.

2. Consolidation of Clays

Prof. Florin referred briefly to his earlier (1937 and 1948) mathematical analyses of two- and three-dimensional consolidation problems. The theory of consolidation needs to be modified to take into account the physical properties of real soils. Among the factors currently being studied are: (a) the influence of entrapped air; (b) the effect of changes in permeability with changes in effective stress, including the variations in permeability due to effective stress gradients; (c) the effect of the compressibility of water and soil particles on the over-all compressibility; and (d) the effect of creep (or secondary compression) during primary consolidation, as well as after primary consolidation is completed.

Prof. Florin is of the opinion that a specific hydraulic gradient is required to initiate the flow of water through clay soils. The results of one particular test were quoted where the magnitude of this initial gradient was about 15 (details of the test such as soil type, degree of saturation, etc., were not given; however, references to work done by S. A. Rosa and B. F. Reltov were supplied). Accordingly, two zones exist in a consolidating mass: in one zone there is flow, and in the other there is not; and the boundary between the two zones is time-dependent. Work is proceeding on mathematical solutions for these conditions.

It was stated that initially a suddenly applied load may be carried entirely by the pore water, or entirely by the soil structure, or partially by both, even in one-dimensional consolidation. Thus, the ratio of the initial excess pore pressure to the applied normal stress may vary between zero and one. Measurements to date to confirm this hypothesis have been confined to partially saturated soils, but the opinion was expressed that it was also valid for saturated soils.

3. Liquefaction of Sands

Reference was made to a slide at a dam site on the Svir River due to liquefaction of sand caused by an ordinary construction blast. At another site, a 5-kilogram charge exploded at a depth of four meters caused a pipeline for hydraulic filling to settle and break. At Gorki Dam a similar explosion resulted in a dish-shaped settlement about 15 meters in diameter, an average settlement of 30 centimeters, and a maximum settlement of 70 centimeters.

The relative density is only one of several factors that influence the susceptibility of a sand to liquefaction: the severity of the vibration, the magnitude of the effective confining pressures, and the shapes of the grains are considered to be of great importance. Susceptibility to liquefaction can be minimized by using surcharges that permit free drainage, as well as by densification. Explosives have been used successfully for the latter purpose. Probes have been inserted in the ground and the changes in conductivity between probes were used as a measure of porosity changes during the explosion. Liquefaction caused by an explosion begins at the surface (where confining pressures are low) and works its way down as more and more overlying material becomes liquefied and loses its confining effects. Densification of the sand, on the other hand, starts from the bottom and progresses upward.

The surface settlement pattern resulting from the detonation of a 5-kg charge at a depth of four meters has been correlated with the susceptibility of sands to liquefaction and design requirements are based on this correlation. However, no details of the correlation were given.

After hearing these reports, the delegation made a brief inspection of Prof. Florin's laboratory. A "quicksand" tank was available that could be rotated on an axis through a measured angle so that slope stability under upward seepage could be demonstrated. A model pile is used to demonstrate electroosmosis. The soil is sufficiently stiff to support the metal pile and a small load. By means of a battery, a difference in potential could be applied between the pile and the container, with the pile being the negative electrode. When the current is switched on excess pore pressures develop around the pile causing it to sink; when the current is turned off the pile comes to rest.

An apparatus to illustrate the effect of varying the normal and shear stresses on the shear strain of granular soils, employing a vibrator mounted on a plate, was shown. The vibrator was capable of applying both normal and shear stresses, which were measured along with the deformations.

Shown is a model embankment *(Fig. 14a)* that can be subjected to shock loading with simultaneous measurements of pore pressure. Typical isochrones of excess pore pressure after 1.5, 3, 6, and 30 seconds are shown *(Fig. 14b)*. Note the negative excess pore pressures near the top of the embankment after three sections.

The delegation was shown a concrete tank (about 10 ft x 10 ft x 10 ft) that had recently been constructed for use in studying bearing capacity under eccentric and inclined loads in both two and three dimensions. The effects of underlying discontinuities will also be investigated.

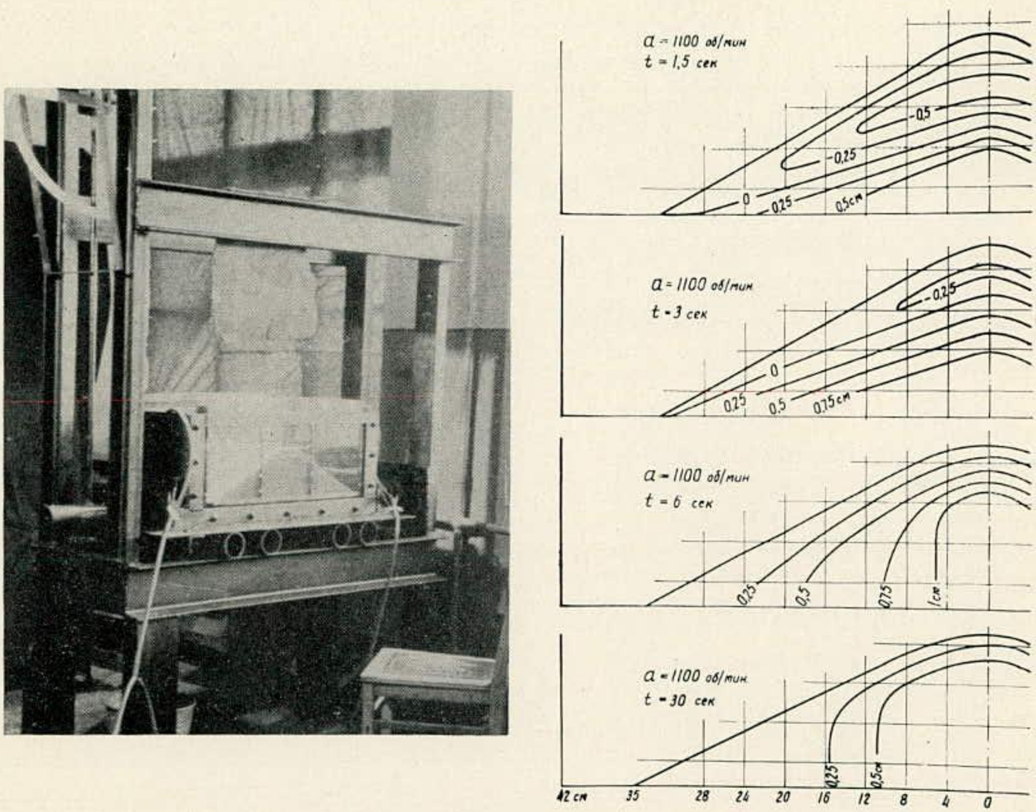


FIGURE 14
Apparatus for measuring excess pore pressures in embankment model caused by shock loading.

V — Construction Jobs

HIGHWAY CONSTRUCTION

The delegation had two opportunities to see highway and pavement construction work: A major inspection of concrete pavement construction and of two highway interchange bridges on the outskirts of Moscow and a small street construction project in Stalingrad where asphaltic concrete was being laid.

It would appear that in past years little emphasis has been placed on highway construction in the Soviet Union. However, with the increasing use of truck transport highways are taking on a status of greater importance, and undoubtedly highway design and construction will be studied and advanced with accelerated efforts in the immediate future.

The visit to highway construction in the Moscow area was conducted by A. M. Sitzky, head of the Moscow Direction of Road Construction, and V. B. Zavadsky, chief engineer of the same organization.

The principal highway system in the vicinity of Moscow consists of 16 main roads radiating out from the city, together with a loop road around the outside of the city, called the Moscow Ring Road. The latter is newly designed.

The delegation first visited a recently finished portland cement concrete pavement on one of the main roads leading out of Moscow, the road to Riazan. The highway has been built on a new location parallel to the old road, which carries a heavy volume of truck traffic. The new highway has a divided section; the pavement slabs are each 7 meters wide, and the dividing strip of grass is 4 meters wide. The slab is 22 cm thick (24 cm is used on some highways). On the outer edge of the slab there is a 30 cm wide strip of white concrete and the outside shoulder, about two meters wide, is surfaced with 12 cm of broken stone. A section of this highway constructed on fill across a marsh has been temporarily paved with stone blocks; it was stated that vertical sand drains had been used here, and that final paving would not be done until the settlement was complete.

Another section of this highway, 800 meters long, is paved with an experimental prestressed concrete slab, 17 cm thick. It was explained that during construction the wires were prestressed the full 800 meters, but that a 2-ft open section was left in the concrete every 100 meters. The wires were cut at these openings after 20 days, and the open sections filled with concrete. Thus the prestressed slabs are 100 meters long. A second experimental section is paved with a 17 cm thick slab of continuously reinforced concrete.

The delegation then visited a field laboratory used for evaluation of highway bases and pavements by means of plate loading tests. The laboratory, which is a wheel-mounted trailer, can apply a static load of 15 tons or a dynamic load of 10 tons to plates of various sizes and record the resulting deflections of the plate and adjacent ground surface. Plate sizes used are: 50 cm diameter for tests directly on the soil, 34 cm diameter for tests on flexible pavements and 34 and 17 cm diameter for tests on concrete pavements.

Seven rods passing through the floor of the laboratory are used for deflection measurements; six of the rods have angles at the ends so that a pattern of deformations can be determined by rotation of the rods.

For dynamic tests, loads are applied to the plates at the rate of 12 per minute and the resulting deflections at seven points are automatically recorded by means of an oscillograph mounted in the laboratory.

Concrete pavement construction was observed on a section of the Moscow Ring Road. A sand base course, 35 cm thick on fill sections and 50 cm thick in cut, was being used; this was compacted by a vibratory compactor traveling on the paving forms.

Density determinations for compaction control were made by a novel procedure. A sample of the base sand of known volume was taken and placed in a chamber of a

FIGURE 15
Density test on compacted subbase.

large hydrometer. By placing the hydrometer in water the technician determined directly the total unit weight of the sample. Next the sample of sand was thoroughly mixed with water, placed in the hydrometer which was now open to the surrounding water and another reading taken. This determination gave the buoyant unit weight of the soil. From these two measurements, and a known specific gravity of solids, the dry unit weight and water content can be calculated. This rapid method would appear to give results accurate enough for field control when soils containing no large particles and possessing little cohesion are encountered.

The pavement slab itself was 24 cm thick and had mesh reinforcement plus two longitudinal bars along each edge and dowels at expansion joints *(Fig. 15)*. The concrete was hauled to the site in trucks without agitators; it was very stiff with a slump of about 1.5 cm. The finishing procedures appeared to be comparatively incomplete; no final longitudinal and horizontal floating was being accomplished. The finishing operation was made more difficult by the ex-

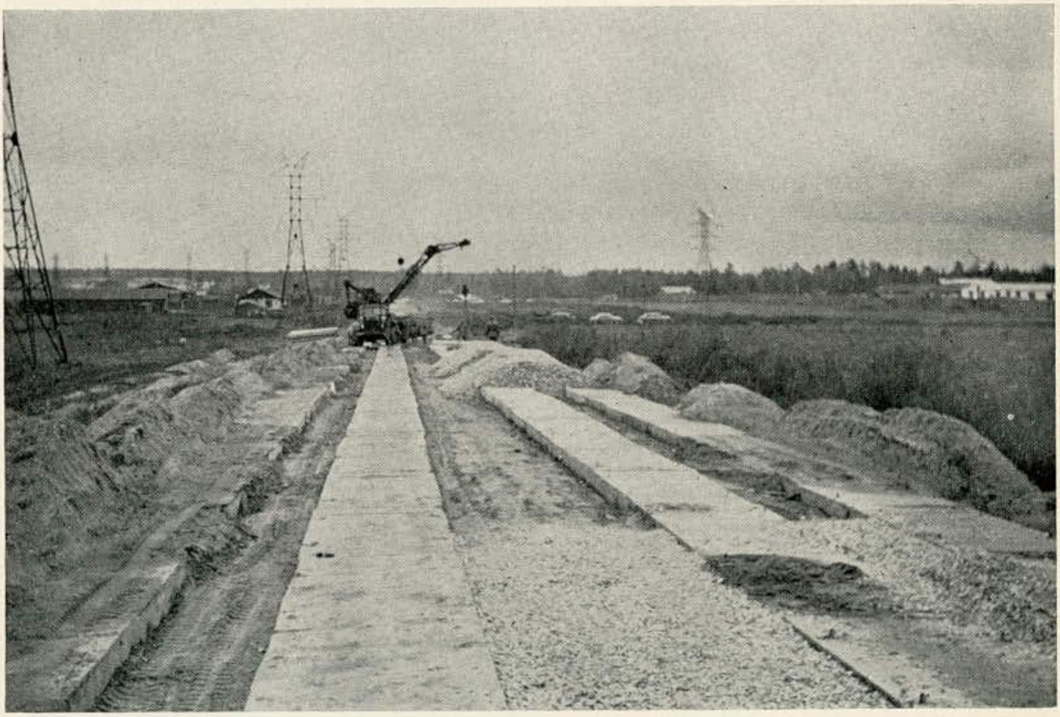


FIGURE 16
Construction of experimental road. Pavement for four wheel tracks has been precast.

tremely dry, harsh mix being used. Curing was by bituminous seal plus 1 cm of sand. Progress was reported to be 220 to 250 meters per day with two shifts.

An interesting feature of the highway inspection was a visit to an experimental track road which was under construction *(Fig. 16)*. The road was being paved with four strips of concrete, each 80 cm wide, and placed to correspond with vehicle wheel tracks. Trials were being made with different types of slabs though all were 18 cm thick. Precast units were about 9 ft long. One portion had the slabs cast in place. Gravel and a light bituminous surfacing was to be placed between the concrete strips. After completion the test road was to have traffic of 4,000 vehicles per day, but it was stated that such construction would be considered for roads with up to 10,000 vehicles per day.

The inspection also included visits to two highway grade separation bridges which were under construction. One of these was the overpass structure carrying the highway to Riazan over another road. The bridge, which was nearly completed, had a good general appearance but on close inspection it showed relatively rough surface finish and roughness at the joints of the precast concrete members. The fill slopes at the spill-through abutments were paved in a neat manner with square precast concrete blocks; other slopes were sodded and presented very good appearance.

The other bridge inspected, crossing the Moscow Ring Road, was being fabricated from precast prestressed units. The delegation saw one of the 22-ton precast segmented members forming a portion of the decking being hoisted into place. The method of post-tensioning these members and grouting the wires was demonstrated on the job, using jacks at both ends of the member. A unique feature of this project was that final grouting of the wires could be continued through the winter thus causing no shut-down of the work; this was accomplished by introducing an electrical current into the wires and maintaining low heat for a sufficient time for the grout to cure.

The only asphalt paving observed by the delegation was on a short section of highway crossing a hydraulically filled gully in Stalingrad *(Fig. 17)*. The section of this pavement consisted of 3½ cm of hot-mix asphalt surface course, 4½ cm of hot-mix asphaltic binder course, 5 cm of slag, 22 cm of crushed rock up to about 8 in. in size, and 5 cm of sand on the compacted subgrade. The asphaltic concrete was being placed and raked by hand. The engineers explained that on larger projects mechani-

FIGURE 17
Construction of asphaltic concrete pavement, Stalingrad.

FIGURE 18
Donwstream view, powerhouse section, Stalingrad Hydrolectric Station.

cal spreading machines are used. A medium-weight three-wheel roller was being used to compact the asphalt producing a reasonably smooth but undulating surface. The side drainage was by curb and catch basin.

STALINGRAD HYDROELECTRIC STATION

The Stalingrad Hydroelectric Station across the Volga River *(Fig. 18)*, just a few miles outside Stalingrad, was the most impressive construction project seen by the delegation in the USSR. The station, construction of which was begun in 1953, consists of a combination of several earth-fill dam sections, concrete overflow gates, a hydroelectric plant, and lock sections.

It is difficult to visualize the structure as an earth dam because of its great crest width and because about 30 per cent of its length is composed of the various concrete hydraulic structures. Beginning at the right abutment, the dam consists of an earth-fill section approximately 1,400 meters long, then the hydroelectric plant and overflow gates with a combined length of about 1,450 meters, then an earth-fill section approximately 900 meters long, then two lock sections occupying a length of about 100 meters and finally an earth-fill section about 1,300 meters long to the left abutment. A channel about 4½ kilometers long with an average depth of 10 to 12 meters, but with a designed minimum depth of 8 meters, has been dredged below the locks.

A harbor above the lock section protects shipping entering the lock. The extension of the left abutment upstream forms one side of this harbor and a dike section about 1,500 meters long forms the other side. It was stated that 10,000-ton ships can pass through the locks; however, the allowable draft was not given. On the basis of observation, it was estimated that a ship with a draft of about 7 meters could be accommodated.

The basic problems in connection with the construction of the dam were: (a) regulation of the discharge of the Volga, (b) production of electrical energy, (c) guaranteed navigation depth for 600 kilometers upstream, and (d) furnishing irrigation water on the Trans-Volga Steppes. The area of the initial irrigation project is one million hectares. The average annual rainfall in the Stalingrad area is about 8 in.

The useful storage capacity of the reservoir is 33 billion cubic meters. The surface area at normal water level is 3,500 square kilometers. The anticipated wave height is 3⅓ meters, which is the reason why the harbor dike mentioned above is required.

The reservoir level was 8 to 9 meters below operation level, but it was intended to completely fill the reservoir in the coming spring.

Foundation. It was difficult to obtain details concerning the foundation materials, but a map in the office of the chief engineer indicated that, basically, the foundation consisted of fine to medium sand 40 to 50 meters in depth. The dry density of the sand was about 94 lb per cu ft, and the dam was constructed directly on this sand without benefit of compaction either on the surface or at depth. In certain areas of the valley the sand was underlain with stiff clay layers at rather shallow depths. Advantage was taken of one of the clay beds in construction of the powerhouse, as the footings of the powerhouse rest in clay.

One particularly interesting feature of the dam was that while consideration may have been given in the design to construction with long piling, all structures were built without piling except the mooring wall adjacent to the locks. This mooring wall is supported on concrete piles. Sheet-pile cutoff sections were used in front of the gate and lock structures; however, it was inferred that these sheet-pile sections did not extend completely through the sand.

Earth Dam Section. The earth-fill portion of the dam was constructed hydraulically; the section ranges from 20 to 40 meters in height and has a crest width of 102 meters. It was understood that this great width of crest was built to accommodate the double-line railroad track, a highway, and appurtenant power-line structures rather than to provide increased stability of the dam.

The approximate downstream slope from the crest downward was 1 on 3½ to 1 on 5, with a flat berm section at the toe of 1 on 18. The upstream slope began at 1 on 3 and graded into 1 on 4, with the slope of the flat shallow berm at the toe being 1 on 18. It was understood that the 1-on-18 slope was the natural hydraulic beaching slope of the sand. Berms were placed on the downstream slope every 8 to 10 meters in vertical elevation.

At maximum operation, as many as six hydraulic dredges were used in constructing the dam. The maximum capacity of each dredge was 1,000 cubic meters of fill per hour. The total volume of material pumped by the dredges was 145 million cubic meters; however, only about half of this was pumped in the dam section proper.

The hydraulic fill material contains very little gravel particles larger than the No. 4 sieve. Delegate Willard Turnbull stated that the sizing in the hydraulic fill material reminded him very much of that in the shells of Sardis Dam, Mississippi.

Apparently the material in borrow was so clean that no trouble was experienced in disposing of the fines. The material was pumped on the fill with the water being allowed to drain laterally over the side slopes and longitudinally between the shoulders of the dam. The slopes were maintained by shear boards.

The closure of the dam was effected in the hydraulic fill section on the right abutment by dumping gravel, stone and concrete tetrahedrons from a pontoon bridge floated across the closure gap. The materials which were dumped were basically of three sizes. The small size, which was dumped first, consisted of coarse gravels and medium-size cobbles; the next-size material was fairly large broken stone; and the dike was finally topped out with heavy tetrahedrons. The first two materials were dumped until the velocity of the current carried the material out about as fast as it was dumped.

After the tetrahedrons were brought above water, the dredges discharged the sand immediately upstream; the sand was forced by the flowing water into the crevices of the stone, and a complete cutoff was effected. It was stated that the closure of the dam was accomplished in one day.

The dry density of the sand in the fill was between 93 and 95 lb per cu yd, which is about the same as that of the foundation material. The problem of liquefaction was considered in the design; however, no danger was indicated.

A figure was not obtained on the amount of settlement under the dam or under any of the hydraulic structures as the result of volume changes in the foundation. However, a statement was made that such settlement as had taken place had in no way been of sufficient magnitude (differentially) to affect the operation of the gates or the eight turbines presently on the line.

It was noted at the abutment of the spillway structure and the hydraulic sand fill that two lines of vibratory driven steel sheet piling extended from the structure abutment into the sand fill as seepage cutoff walls. It was not determined how many of these lines existed across the transverse section of the dam.

Hydroelectric Plant. As indicated previously, the foundation of the power plant rested directly on clay strata. No upstream cutoff was used.

The rating for each turbine is 123,500 kva, 68.2 rpm, 13,800 v, 50 cycles. The capacity of each unit is 600 cubic meters per sec of water at an average head of 20.6 meters, and a maximum head of 26 meters. The total rated capacity of the plant is 2,563,000 kva, which is the largest in the world, followed in order by the Soviet Kuibyshev plant and the Grand Coulee in the United States. The turbine blades, which were built in Leningrad, have variable pitch.

Eight turbines were in operation at the time of the visit, four more were to be completed and cut in on the line later during the year, and the remainder were to be completed and put in operation in 1960. Normally, 12 to 15 units will be in operation at a time.

Two main transmission lines will radiate from the plant, one to the Moscow area at 500,000 v and one to the southwestern regions at 220,000 v. Presently an experimental line of 700,000 to 800,000 v direct current is planned. If this experiment is successful in keeping transmission losses to an acceptable low value, probably all the hydroplants in Siberia will be interconnected, and possibly many more plants in other areas of the Soviet Union will be included.

In addition to the discharge through the turbine, bottom openings below each turbine will accommodate 15,000 cubic meters per sec total. The total discharge capacity of the entire system is approximately 61,000 cubic meters, made up of discharges of 15,000 cubic meters through the bottom gates, 13,000 cubic meters through the turbines, and 33,000 cubic meters through the spillway gates.

Trash grillage protection gates are located in front of the turbines but at a short distance above the intake opening to each turbine rather than directly at the intake. The purpose of this is to minimize head losses.

Many features of construction were observed on the tour of the hydroelectric plant. As indicated, eight turbines were operating; however, the housing over these turbines is temporary, but it will be made permanent when all turbines are installed.

In other areas, early stages of construction were noted. It was observed that the concrete of the main supporting columns for the powerhouse as well as the supporting columns and cantilevers for the railroad and highway had been poured in place. This concrete appeared to have a reasonably good surface finish and was quite free of surface voids and exposed aggregate. Some of the floor slab members were also being poured in place, and placement of reinforcing steel was observed. Many of the connecting girders, beams, and wall slabs were precast concrete. The precast concrete members were inferior in surface finish to the cast-in-place members.

Spillway Gate Structure. The spillway gate structure rests directly on sand. Some of the spillway sections had been completed and the gates were in operation. The spillways are being constructed from the bottom up, in segments, in such manner that flow can be taken over the spillway before it reaches final height. The gates are ordinary slide gates and are operated from an overhead traveling crane. Most of the gates seemed to fit well in that leakage was at a minimum. Each two adjacent gate sections are constructed monolithically. Each monolith is approximately 60 meters wide.

The ordinary flood which has to be accommodated by the plant and system of gates is 40,000 cubic meters per sec, while the anticipated maximum peak flood is about 56,000 cubic meters per sec (10,000-year flood).

Lock Structure. The locks consist of two structures. Each structure has two chambers—the upper chamber upstream and the lower chamber downstream. In other words, the transition in elevation is accomplished in two steps rather than one. The upper lock chamber in each structure rests on sand. Clay and sand were excavated in the area for the lower chamber, which allowed the lower chamber in each structure also to rest directly on sand. Each lock is about 75 ft wide and, as previously stated, will probably pass a boat with a draft of about 7 meters. The mooring wall extends immediately upstream of the lock entrance. The locks are provided with radial gates.

A unique system was used in designing the lock section *(Fig. 19),* which consists basically of heavy concrete walls with half of the base integral with the wall. At the centerline point where the base sections meet an expansion joint is provided with water seals top and bottom. It was understood that no reinforcing exists across this section or transversely between monoliths. At some distance above the base, heavy reinforcing steel connects the two lock walls. This reinforcing steel is securely anchored in each wall but is not encased in concrete.

As the walls are constructed and built up, there is a tendency for greater settlement to take place under each main wall section and a resulting tendency for the wall sections to spread apart. This is resisted by the heavy reinforcing steel of the future lock floor. When a predetermined stress (as determined by its measured elongation) is developed in this reinforcing steel, concrete is placed around the steel, abutting solidly against the inside wall faces. The concrete-encased steel acts as the floor of the lock.

As the steel was in tension when the concrete was placed, the floor is in a sense prestressed. As the backfill is placed behind the concrete walls, the walls tend to tip inward; this force is resisted by the concrete in the floor around the pretensioned steel, which is then placed in compression.

The fine point of the design is that the walls are supposed to tend to come back into the vertical position. There is an open area between the base of the chamber and the floor of the lock, the latter being supported by concrete diaphragms.

Protective Dike to Mooring Basin. The protective dike was constructed by hydraulic sand fill, and at the time the dele-

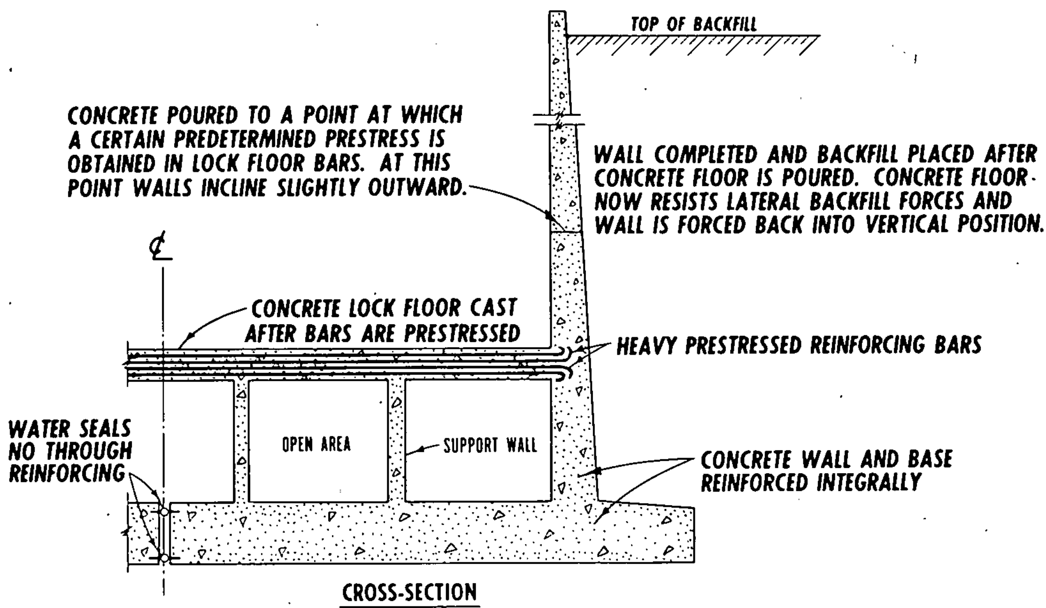


FIGURE 19
Design principle, lock walls, Stalingrad Hydroelectric Station.

FIGURE 20
Hand placement of concrete in protective dike facings, Stalingrad Hydroelectric Station.

gation observed it, the dike was being faced with concrete slabs about 8 in. thick *(Fig. 20)*. The slabs were being placed on a filter bed of gravel. Reinforcing mesh was used in the slabs and preformed expansion joints were constructed around the slab sections, which were about 18 in. by 18 in. The concrete was being placed by hand, and the finished surface was rough and undulating. There seemed to be no continuity of location in placing the slabs on the dike face; rather, it appeared that the completed and unfilled sections were placed in random order. Placement of reinforcing steel and expansion joints, and the alignment of slabs, were not being carefully executed.

Volgski City. An interesting sidelight on the construction of the dam is Volgski City which has been constructed almost in its entirety since 1953. The purpose of the city was to accommodate the workers on the dam. Initially there were about 20,000 workers, and this number gradually grew to 35,000; presently the number is down to about 15,000.

The city is completely self-supporting and independent of Stalingrad and is on the opposite side of the Volga River. It has its own civic and school centers, including libraries, athletic fields, etc. In the libraries it was noted that a few translations of English books were available, among them being books by Jack London, Upton Sinclair, Mitchell Wilson and Mark Twain. One of the conspicuous things about this city was the almost complete absence of passenger automobiles.

When the employment at the dam began to taper off, it was determined that some measures should be taken to provide employment for the inhabitants. As a result, the government began to introduce independent industries into the city. Ten new industries have been introduced and additional people have been brought in to provide a working force for these industries. At the present time the city has a population of 65,000. A general impression concerning the city, and of most of the housing and new buildings being constructed in the USSR, was that the buildings look much older than they actually are.

Impressions. The general impression of the Stalingrad Hydroelectric Station project was that it was of the highest type of construction seen by the delegation in the Soviet Union. In spite of the rather "helter-skelter" appearance, it was understood that construction is approximately on schedule; and it was particularly noticeable that the distribution of personnel about the dam was normal in that there were no unusual concentrations at any one point.

VOLGA-DON CANAL

The Volga-Don Canal, with a minimum water depth of 5 meters, furnishes a waterway for transportation between the Volga and Don Rivers. It is approximately 101 kilometers long, connecting two points which are only about 50 kilometers apart as the crow flies. The designers of the canal utilized natural depressions such as sloughs, channels and lake areas to cut down on the excavation quantities; however, in spite of this, total earthwork was about 194,000,000 cubic meters.

The canal begins at the Tsimlyanskaya reservoir impoundment on the Don River. There are three pump stations between the Don and the high point in the canal between the two rivers, with three pumps at each station, each with a capacity of 45 cubic meters per sec. From the Don River to the high point of the canal there are four locks, representing a total height of about 44 meters. Between the crest and the Volga River there is a drop of about 88 meters through nine locks. The Volga-Don Canal is a very important link in the waterways system of the USSR.

The soil profile along the line of the canal consists of diverse soil types of the Quaternary period. Some of the soils are relatively watertight, while some are pervious. The leakage tends to be offset by relatively high water tables.

Some of the major features considered in the development of the canal were navigation, fisheries, irrigation and power. The power is developed in one plant which has a capacity of 160,000 kva.

Lock No. 2. The delegation visited Lock No. 2, which is typical of the several locks in the system. Eight minutes is required to fill the lock, which is 18 meters wide and 500 ft long. The lock is equipped with radial gates and is capable of transporting 3,000-ton barges with a 15-foot draft. It is intended to increase the barge capacity to 5,000 tons. Materials transported are lumber, coal, oil, oil products, and various types of grain. Passenger ferryboats also use the system. The lockage time ranges from 12 to 15 minutes, depending on the type of boats.

In the excavation for most of the locks, ground-water lowering was required. This was accomplished either by shallow wellpoints or deep wells. The lock is constructed in seven longitudinal sections with nothing in the expansion joints between sections other than water seals.

Each longitudinal section is divided along the centerline of the lock into two monolithic sections. The monoliths rest directly on the soil without pile support. The centerline section between the two monoliths is not reinforced—only water seals are incorporated in it.

It was interesting to note that this relatively simple foundation is performing satisfactorily. About the only detrimental effect noticed around the lock system was a slight slumping of the outer slopes of the backfill behind the lock wall chambers. Some seepage flow was noticed in the ditches at the toe of these slopes.

Canal. The canal has a bottom width of 38 meters and side slopes from bottom upward of 1 on 6 to 1 on 3 at the top. In cut sections no sealing of the canal is used in any of the soil types. In the more pervious soils in the cut-fill sections, a clay blanket approximately 2 ft thick was used. It is considered that the main losses from the canal are due to evaporation because of the generally high water table. In more erodible materials the sides of the canal are protected by rubble stone and at some points by concrete revetments resting on a three-layer filter blanket.

DRIVING OF BEARING AND SHEET PILES AND CAISSON SHELLS

The first reports concerning Soviet vibratory driving techniques attracted considerable attention in the United States. As a result, an impression was created in some quarters that vibratory driving was the only one used in the Soviet Union. No statements to this effect were either made or implied by any Soviet engineer during the entire exchange. Pile driving equipment seen by the delegation on various construction jobs included several types of vibratory drivers as well as drop hammers and single-acting and double-acting steam hammers.

The various types of vibratory hammers in use in the Soviet Union, as well as those under further development, have been described by a member of the Soviet Delegation.* The delegation was taken to see three construction sites where vibratory pile driving was in progress.

The first vibratory driving job visited was in Leningrad, where U-shaped steel sheet piles were being driven for the excavation of a sewer trench on a new housing project. A VP-2 type vibrator was used for the purpose. The ground appeared to be soft and the vibratory driving proceeded easily.

Next, the delegation visited an old pier in Leningrad Harbor which was being re-

* See "The Use of the Vibratory Method for Sinking Piles and Pile Shells in Bridge Construction of the USSR" by M. M. Levkin.

habilitated by driving in front of it a row of U-shaped steel sheet piles and a row of precast reinforced concrete piles which were to support a relieving platform.

Most of the piles and sheet piles had been driven by means of a VP-2 type vibrator. This vibrator develops a centrifugal force of 9.2 tons and is designed to drive piles with not more than 50 tons limit resistance. At one end of the pier, a layer of stiff clay was encountered which could not be penetrated by this type of vibrator. A 6-ton single acting steam hammer was then employed, but not all the precast concrete piles could be driven down to grade as was evidenced by their condition in place at the time of the visit. The heads of the steel sheet piles driven by the 6-ton hammer evidenced considerable distortions.

In spite of these unfavorable conditions, an attempt was made to demonstrate the action of the VP-2 vibrator available on the site by driving a U-shaped steel sheet pile specially set up for the purpose. This sheet pile, however, could be driven down only about half way.

On the same site a large unit was exhibited consisting of two synchronized VP-160 vibrators which were stated to have been used to drive precast reinforced concrete cylindrical shell dolphins in another part of the Leningrad Harbor *(Fig. 21)*. Vibrators of this type are said to develop up to 320 tons downward force, and are now used for sinking caissons for bridge foundations consisting of cylindrical precast shells up to 18 ft diameter.

FIGURE 21
Unit with VP-160 vibrators for driving reinforced concrete cylindrical shell dolphins, Leningrad Harbor.

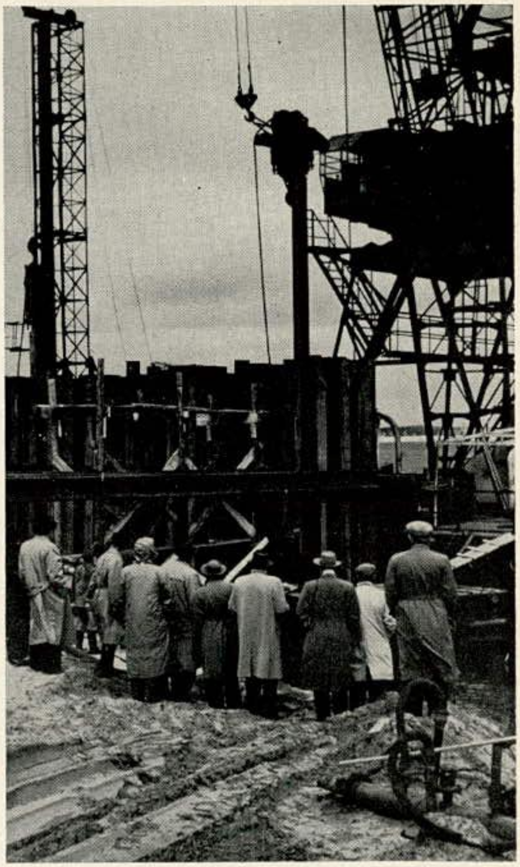


FIGURE 22
VP-2 vibrator driving sheet piling. Cofferdam construction on Volga River, Stalingrad.

In the Stalingrad area, the delegation visited a site where a double-walled steel sheet pile cofferdam for the construction of a landing pier was being installed *(Fig. 22)*. A VP-2 vibratory driver was used most of the time but a double-acting steam hammer finished the driving when the pile resistance exceeded the capacity of the VP-2 vibrator. The river portions of the cofferdam were already completed at the time of the visit and the wing sections were being installed to make a junction with the Volga River banks. These banks had old protection mattresses below their surface.

The delegation observed a 68-ft U-shaped steel pile driven down to grade by a VP-2 vibrator. About half way down it encountered some obstruction and the penetration was slowed appreciably. Vibratory driving was then interrupted for about four minutes every three minutes in order not to overheat the motor. The delegation was informed that the vibrator was not designed to run longer, since in sandy soils with no obstructions it took about 2½ minutes to sink a sheet pile of that length.

Vibratory driving of sheet piles is of particular advantage in dense saturated sands and gravels. The organization for construction work in the Soviet Union is on a regional basis, which facilitates extensive use of vibratory drivers by the same construction thrust whenever favorable soil conditions are encountered.

APARTMENT BUILDING CONSTRUCTION

One of the main efforts in building construction in the Soviet Union today is in the field of housing. The concerted activity on apartment building construction was very obvious in all the cities visited, and the delegation inspected construction sites in Moscow, Leningrad and Stalingrad.

In order to provide some idea of the magnitude of this construction program, the delegation was informed that 90,000 flats were being built in Moscow in 1959, providing about 2,800,000 square meters of "living area" (i.e., living and bed rooms). Kitchens, bathrooms, hallways, and stairways are additional to this area, and would increase it by about 30 per cent.

In Leningrad, it is planned to almost double the existing housing by 1965; in 1959, about 600,000 square meters of living space was being produced. In Stalingrad which now has a population of 600,000 and has about 3,5 million square meters of living space, present plans are for a growth to 800,000 persons, with living space to be increased to 9 or 10 million square meters.

Most of the apartment buildings which the delegation saw under construction were five-story structures. The buildings were about 10 meters wide and 64 meters long and were of wall-bearing design. There are 60 flats in such a building and four stairways; some buildings have 80 flats. Most flats consist of two or three rooms plus kitchen and bathroom with about 35 square meters of "living space". Living space is allocated at about 9 square meters per person. Utilities such as gas, electricity, water and central heating are provided.

The field construction of these apartment buildings is essentially an assembly process. Precast reinforced concrete footings, wall panels, floors, stairways, bathrooms, etc., are made up in plants, hauled to the sites, and hoisted into place with a tower crane. Connections between the panels are made by welding. Pictured is a view of this construction in Moscow *(Fig. 23)*.

Plants which fabricate wall panels were visited in Moscow and Leningrad. The Leningrad plant was one of five in that city

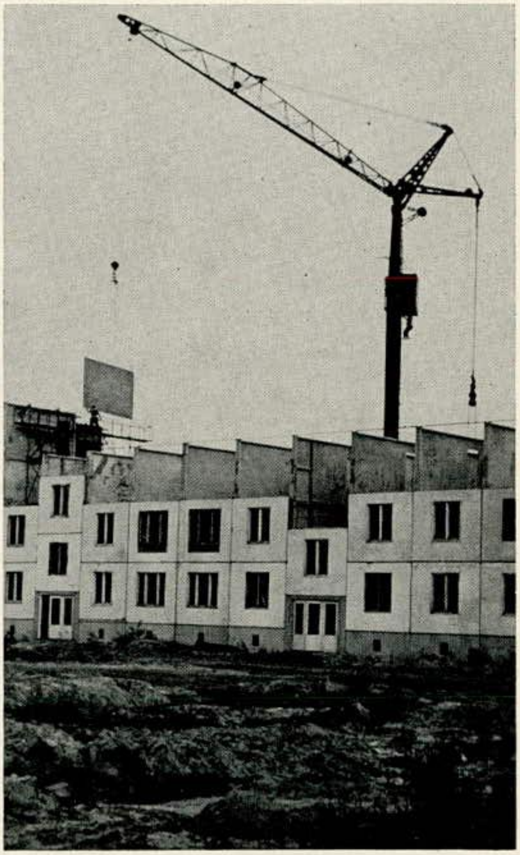


FIGURE 23
Apartment building construction, Moscow. Precast units being placed by tower crane.

each of which produces all of the panels for a particular apartment house design with the exception of the footings. The plant visited has a capacity for producing enough living space for two 80-flat buildings per month. Another plant in Leningrad was reported to have a capacity of 170,000 square meters per year.

Concrete panels produced at the plant were steam-cured for 12 hours and those for exterior walls were provided with a foam concrete insulation. They were then finished to a point of maximum readiness for incorporation into the apartment structure; windows and doors were included in wall panels and plumbing was installed in the bathroom units before delivery to the construction site. As a result of this high degree of prefabrication, an apartment building with 80 flats is constructed in 25 working days (three shifts per day) after completion of the foundation; the building is completely finished in 3½ months.

The delegation was particularly interested in the foundation aspects of these structures and in the methods of designing for settlement. Individual footings for columns and strip footings for the bearing walls were all of precast concrete *(Fig. 24)*. The size of these varied according to the bearing value of the soil. In Moscow it did not appear that there had been any special treatment of the soil before the footings were placed. In Leningrad the foundation conditions are generally quite poor and deposits of organic silt or peat are frequently encountered.

In the past some housing units have been constructed over such poor soil deposits and have settled as much as 40 centimeters resulting in considerable damage. Consequently efforts are now made to conduct more careful foundation investigations and to provide adequate foundations. It was stated that preliminary borings are made at each building site at spacings of 50 to 150 meters and to depths of about 10 meters. Where necessary, pile foundations are being used.

Another measure taken with the object of minimizing differential settlements is the provision of a ring of cast-in-place reinforced concrete just above the foundation wall blocks and below the first floor. The ring has the same width as the foundation wall and is about a foot thick; this was the only poured concrete observed by the delegation during the several visits to apart-

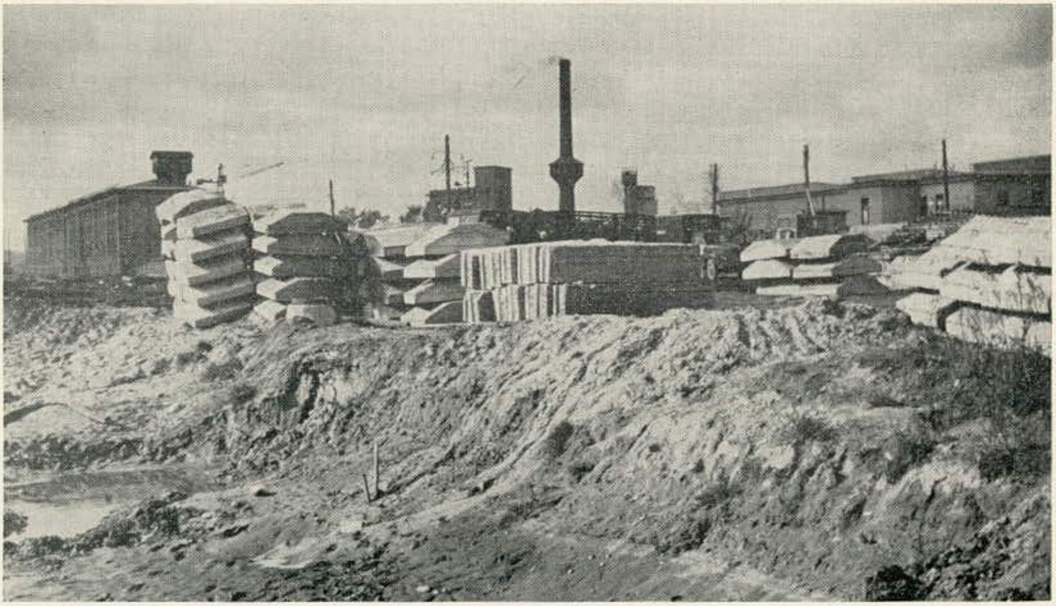


FIGURE 24
Precast footings for apartment buildings, Leningrad.

ment building sites. It was also stated that buildings are sometimes divided into two or three sections to minimize the effects of differential settlement.

At the Leningrad site visited by the delegation several feet of sand were being spread on the bottom of the excavation before the precast strip footings were placed. Precast blocks were set on top of the strip footing to form the foundation walls.

The use of short piles for the foundations of apartment buildings was discussed at the Moscow Institute of Foundation Design and was observed at construction sites in Stalingrad. The piles were about 8 ft long and were spaced at 80 centimeters. A precast reinforced capping beam about 20 in. wide and 12 in. high was placed above the piles.

Another feature of the apartment buildings seen at Stalingrad was the use of silicate concrete in the precast wall slabs. These were made of lime and sand heated to a temperature of 140° C under eight atmospheres of pressure. This material gave a more pleasing surface appearance than the regular concrete slabs.

Efforts are also being made to reduce the amount of settlement of structures by keeping the weights of the structures as low as possible. The use of light weight aggregate aids in accomplishing this purpose.

The delegation visited a plant producing Karamzite, an expanded clay, at the city of Volgski. The clay is heated in rotary kilns to 1000° C. The final product has a specific gravity of 0.4 to 0.45 and concrete produced with it has a unit weight of about 94 lbs per cubic foot. It was stated that the use of this concrete makes the total weight of a building about 25 per cent less than that of similar structures constructed of concrete with regular aggregate.

DEPARTURE

The American delegation's 21-day visit to the USSR came to a conclusion on October 5 when at 9 a.m. the visitors took off from the Moscow airport for the return flight to the United States.

At a formal dinner in Moscow the evening before the visitors from the USA again expressed their thanks and appreciation to the Soviet Host Committee and the associated engineers, soil scientists and interpreters for the many useful presentations made available to the American engineers and educators, and the warm hospitality that marked the exchange mission.

It was indicated that mutual exchanges of Soviet and American specialists could well result in good, reliable and desirable relationships between the engineers and scientists of the two great countries.