

# INTERNATIONAL SOCIETY FOR SOIL MECHANICS AND GEOTECHNICAL ENGINEERING



*This paper was downloaded from the Online Library of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE). The library is available here:*

<https://www.issmge.org/publications/online-library>

*This is an open-access database that archives thousands of papers published under the Auspices of the ISSMGE and maintained by the Innovation and Development Committee of ISSMGE.*

# SECTION V

## EARTH PRESSURE; STABILITY AND DISPLACEMENTS OF RETAINING CONSTRUCTIONS

### SUB-SECTION Va

#### EARTH PRESSURE AGAINST RIGID VERTICAL WALLS

V a 2

#### SOIL MECHANICS IN RELATION TO THE DESIGN OF LARGE DRY DOCKS

Mr. D.H. LITTLE, B.Sc., A.M.I.C.E.

Civil Engineer in Chief's Dept., Admiralty, Great Britain

#### SUMMARY AND CONCLUSIONS

Large dry docks have become massive civil engineering structures in themselves and as a dry dock usually requires a wharf as a complementary structure (and the wharf may be nearly as costly as the dock) the two together can comprise an undertaking amounting to many millions of pounds.

Docks must be located on or near the sea coast or by an extensive waterway so that water is usually the most important feature of the design and constructional problems.

The excavation for a large dock may be 1,500 feet long by 200 feet wide by nearly 100 feet deep and with the water effect playing such an important part in the problem it is hardly surprising that almost every aspect of Soil Mechanics is involved. A short paper, therefore, can only be very general in character and no attempt has been made to refer to any special works nor can any special points be mentioned in much detail but some of the facts given have arisen out of definite projects.

Most civil engineering undertakings require the designer to bear in mind to some extent the problems of construction but with large graving docks construction can even be the dominant factor. Accordingly two broad divisions that immediately suggest themselves for this paper are (1) design and (2) construction. To these can be added (3) the practical techniques of soil mechanics and (4) a general introduction.

The actual order of these four sub-divisions is

- 1) Introduction
- 2) Completed Structure (Design)
- 3) Construction Problems (Construction)
- 4) Stages in Soil Mechanics (Practical Techniques)

Future developments are dealt with under individual considerations and while any development in the whole field of soil mechanics is likely to have some bearing on large graving docks the more important are (a) assessment of earth pressures on walls (b) distribution of such pressure (c) hardening of silts and soft clays by electro osmosis and (d) expansion of clay foundations on the removal of the weight of deep excavations.

The main conclusion to be drawn is that soil mechanics although not known by that name, has always been used by the designers and builders of dry docks, and in its modern form will continue to be of even greater significance. But the range of conditions is so wide in these structures that more than ordinary care and judgment must be exercised in its use.

## II. INTRODUCTION.

A properly designed dry dock once it is built seldom gives rise to any trouble. If troubles do occur they usually consist of the floor lifting under hydrostatic uplift. Settlement is unusual in a finished dock unless there happens to be a sudden change of strata along the length i.e. change from relatively soft yielding ground to relatively hard unyielding rock. Uplift, too, is usually local and due to the top surfacing of the floor consisting of an almost impervious layer of granite or of stone setts laid on a thick and somewhat pervious bed of concrete.

As a rule the amount of earth excavated away to form a dock weighs more than the completed structure - even when the dock is flooded. Approximate figures for an actual site are:

Weight of Excavated Earth	900,000 Tons
Weight of Concrete in Walls & Floor	500,000 "
Weight of Water in Full Dock	200,000 "

It follows, therefore, that such a dry dock can be said to float in the ground just as floating docks float in the water.

In the design stage it is of course imperative to prepare a design that will be strong enough in itself to behave in this manner but very often stability considerations during construction and the practicability of actual construction are of even greater importance in their effect on the design. A designer cannot be expected to be a specialist in construction but the contribution of soil mechanics, in the case of large graving docks, is probably more important with respect to construction problems than to the completed structure.

### III. COMPLETED STRUCTURE.

Although it has been emphasised that construction problems must be continually borne in mind in the design, the completed structure, nevertheless, is the ultimate aim of all the work and design must at least commence with a consideration only of the complete dock. As the design proceeds construction problems will undoubtedly modify first idea.

Soil mechanics deal with the following aspects of the completed structure.

- a) Assessment of Pressure on the back of the Wall. While water may be a major constructional problem it helps to simplify this design problem. It is always safest to assume that the ground behind a dry dock wall will be saturated and, as a allowance for surcharge, it can be taken as saturated from coping level. This means that full fluid pressure at 64 lbs./c.ft. will act and as even the best of ground must add something to this it follows that the minimum equivalent fluid pressure must exceed 70 lbs./c.ft. - say 75 lbs./c.ft. The worst of ground would be a silt near its liquid limit. Such a soil would weigh about 110 lbs./c.ft. and assuming a fluid factor of 80% the equivalent fluid pressure becomes say 90 lbs./c.ft. Thus the range for good to bad ground is only 75 to 90.

When the soil constants are known this assessment can be checked by the sliding wedge method. In effect this is a graphical solution of the Bell or the Rankine analytical method but is recommended as being of more general use since it is applicable to cohesive and frictional soils and to surcharge or relieving banks.

While these methods enable the total earth pressure to be calculated with some degree of accuracy there is, as yet, no accepted means of finding the point of application. As dock walls are subjected mainly to fluid pressure the usual assumption of triangular distribution is not likely to be far wrong but this can hardly be regarded as a satisfactory state of affairs and further full scale research is necessary.

Under certain conditions of arching in the floor it may be necessary to assess the passive resistance of the ground behind the wall. Again the total capacity can be estimated accurately enough but some doubts always exist as to how much movement is necessary to develop fully this resistance and further research is needed on this.

- b) Capacity of Soil at Foundation Level. As has been stated the gross weights imposed by a properly designed (completed) dry dock, on the foundation soil are usually less than those existing in the ground prior to construction. At first glance, therefore, there would seem to be no foundation problem to solve. But during construction if the walls are built ahead of the floor - as they often have to be - high too pressures may be induced. The effect of these can be considered on the basis of shear failure but in deep excavations of the order of 75 feet the expansion of cohesive soils due to the removal of the overburden pressure may be of over-riding importance. Little is known yet about this phenomenon and it offers considerable scope for fundamental research.

- c) Possible Settlement Under Various Conditions of Loading. The conditions of loading induced by a graving dock are more variable than for any other type of large struc-

ture. When flooded the loading is almost completely uniform: when empty and with no ship being docked there may be local concentration of loading near the walls; and when empty but with a ship being docked there may be additional local concentrations in the floor at the line of docking blocks. Where hydrostatic uplift exists under the floor and the latter is not vented against it, then most of the dead weight of dock and ships resisted by the uniform uplift, and as this is usually less than the weight of excavated material, it follows that even after completion there may still be a tendency in cohesive soils for the foundation soil to be swelling due to release of loading. And, of course, during construction the actual rate of swelling due to load release may be rapid and the amount quite appreciable. Finally the condition of loading is continually changing as ships enter and leave the dock and the dock is flooded and dewatered so that the time factor as an element of settlement cannot be given a value.

Because of these many variable factors no firm estimate of settlements can be made but by exercising careful judgement a good guide to limiting values can be suggested. Extreme caution is necessary, however, when making use of the results obtained.

- d) General Piling Considerations. Although a completed dry dock may be regarded as floating in the ground, piles are often used where the ground is poor. Probably the actual function of the piles is to provide a firm foundation during construction, but the decision to use them is usually based on the assumption that they are essential to carry the loading on completion. As the value of the first ship to use the dock will certainly far exceed the cost of the dock it is obviously uneconomical to risk undue settlements for the sake of saving the expense of piling. But if piling is used on this account then it must be designed to carry everything - dead weight of concrete, weight of water when dock is flooded and weight of ship when docked. It then becomes very extensive and besides being costly may add many months onto construction time. As yet, soil mechanics can offer no positive solution to this problem but the question of construction time will undoubtedly compel more consideration to be given to it and as advances are made a better understanding will develop. Of all the problems in dry dock this is perhaps the most complicated and full scale experience will have to lead theory for a long time.

### IV. CONSTRUCTION PROBLEMS.

Final details of these must be the concern of the construction engineer and as most large dry docks are built by constructors with special experience of such work the design engineer can only deal with construction problems in a general way. This is especially so where work is put out to tender and the successful contractor cannot be known during design because no two contractors will tackle problems in the same way. But even with the greatest attention to construction in the design stage tenders should always be invited in such a manner as to allow contractors to put forward suggestions of their own. And it must be recognised that the most experienced of contractors may yet employ specialist subcontractors for such works as ground water lowering or chemical consolidation.

Soils mechanics deals with the following aspect of construction.

a) Assessment of Pressure on Timbering to Trenches for Walls. This differs from the pressure on the completed wall in accordance with what effect the "draw down" of the water in the soil is likely to have. During construction the water must be kept down by pumping and in granular soils the soil pressure is likely to be considerably reduced. Such reduction is an important consideration with regard to the stability of the walls before the floor support is completed, but it must be remembered that pressure on open trench timbering may relieve itself more than against the solid concrete of a wall. Also, when pressure relief is due to water "draw down" the point of application of the pressure is less likely to be as for triangular distribution.

b) Stability of Slopes. Large slopes can exist in the "dumpling" excavation between the two walls if the latter are taken out in trench; or if the whole excavation is in "open cut" then the two main sides, at least, form slopes. In either case these slopes may be 100 feet high and while they are only temporary their stability is important from the point of view of carrying plant and providing access to permanent construction. Also, "dumplings" between walls are used for back strutting while wall concrete is being placed. Stability assessments can be readily made by slip circle methods.

c) Capacity of Soil to Carry Construction Plant. Except for important developments in electro-osmosis and for the consideration of especially heavy items of stationary plant by shear failure methods, this aspect of construction is likely to continue to be a question of experience.

d) Rate of Flow of Water into Excavations. This is always a possible major construction problem but if an adequate soil analysis has been made complete with particle sizes and distribution a good assessment of the risk is possible.

e) Possibility of Artesian Water Pressure, Developments of "Quick" Sand Piping and "Blows". These may well prove to be sources of major disaster but given an adequate soil survey can be foreseen and provided for and in many respects this constitutes the most important contribution of soil mechanics to dry dock engineering.

f) Feasibility of Ground Water Lowering. This is the corollary to the preceding paragraph and if in the design stage it appears likely to be a major consideration it is better to have specialist advice before tenders are called for so that the matter can be fully specified in the contract documents.

g) Feasibility of Chemical Consolidation or Electro-Osmosis. Chemical consolidation is only likely to be used for local problems e.g. in the deep sumps of the main pump house or in the construction of main culverts. But electro-osmosis even though a temporary expedient may have far reaching effects. Temporary strengthening of weak slits and clays permits plant to be used that might otherwise be impossible; relieved pressure on trench timbering or sheeting factor in eliminating the use of piles at what are now regarded as bad sites. Especially if it is accepted as a basic assumption that "completed dry docks float in the ground"

## V. STAGES IN SOIL MECHANICS.

Once economic or strategic factors have

resulted in a decision to build a dry dock on a particular site the detailed technical works may be said to commence with soil mechanics in the form of borings. Quite often borings are taken in two stages, the first being of a confirmatory nature only i.e. to confirm that the desired site is a practical one from the Civil Engineering aspect. The second on which detailed design and construction will be based may be deferred even years. In such cases modern methods of classifying and testing soils are an important advance on older methods since they enable the soil properties and potential effects to be properly assessed irrespective of the time interval; and visual inspection of samples is almost unnecessary.

The stages in the Soil Mechanics approach are:

a) Siting and Taking of Bores: All geological maps and records of other works near the site should be consulted to give an indication of what may be expected and these with the preliminary lay-out plan will fix the actual siting. For a first investigation some fifteen holes should suffice spaced at 200-300 feet in both directions. Accurate recording of all different strata, of the type of tool used and of water levels must be made. Ultimately for design purposes a "simplified soil profile" will have to be agreed upon, but during actual boring it is far better to record too much than run the risk of missing something.

b) Sampling in Bores. The main results will be obtained from "undisturbed" samples and these samples are the backbone of modern soil mechanics. Improvements in methods of taking undisturbed samples are continually being made and it is important that engineers keep in touch with them. This aspect of soil mechanics is so fundamental, however, that no improvement should be adopted as such unless accepted by a recognised research specialist. If the latter can be a state or public authority this also provides a central body to which engineers can refer generally for information.

In addition to "undisturbed" samples, auger parings etc. should be taken in the usual way at frequent intervals for check visual inspection.

c) Testing of Samples in Laboratory. Preliminary tests can be made on site but the main testing must be carried out in a properly equipped laboratory manned by experienced staff. In the end the designer will mainly make use of (1)  $\phi$  the angle of internal friction (2)  $C$  the cohesive strength and (3)  $w$  the density, but the full range of testing should include for Mechanical Analysis, Liquid & Plastic Limits, Unconfined and Triaxial Compression, Shear and Consolidation.

d) Interpretation of Laboratory Tests. The extensive data produced from the boring records and from the laboratory tests is formidable and in itself unwieldy as a design tool. It has to be broken down into a "simplified soil profile" with simplified soil constants and considerable experience is needed to do this. Obviously such simplification might be dangerously misleading and all through the design it must never be forgotten that it has only been drawn up as a matter of convenience. For special localised problems reference back to the detailed boring records and laboratory tests should always be made.