THESIS

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CANALS AND CANAL CONSTRUCTION

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INTRODUCTION.

I

In selecting the subject of Canals for our thesis, we did so in view of the fact that the Government of the United States has undertaken the gigantic task of linking the Atlantic and Pacific Oceans. This together with the increased importance which is being attached to irrigation opens a field of wide promise and vast possibilities to enterprising intelligent engineers. Owing to the limited time given to Thesis writing and lack of opportunity for original research we have endeavored to investigate and study only those principles of construction which are deemed fundamental by our best engineers.

As the Panama Canal question is one of immediate and vast importance, a brief outline of the intended plan of work is given.

CANALS

The question of canal construction is one with which engineers -ancient and modern- have had to deal. Early Historians give meagre accounts of this work showing that to the ancients is due the conception of the advantages accruing from canal work or traffic.

The more recent conception and construction of such canals as Suez, Corinth, Caledonian and Panama project show conclusively that the problem of canal work is yet in its infancy, yet it demands engineers possessing clear farseeing ideas.

II A canal is: "A passage for water; a water course; an excavation in the earth for conducting water and confining it to narrow limits".

There are three heads under which canals may be classed.

1 Navigable Canals

2 Irrigation Canals

3 Drainage Canals

Navigable Canals may be most advantageously treated under the two following heads:

1 Barge or Boat Canals

2 Ship Canals.

Barge and Boat Canals are now largely superseded by railways,but the number of them in use and the recent large expenditures justify an investigation.

The fundamental principles underlying their construction:
The first and most important consideration in the construction of any canal whether it be barge,irrigation or ship,is the water supply and the maintenance of the same.
In some canals,notable Barge and Irrigation,vast dams and reservoirs must be constructed for storing water necessary to supply leakage,lockage and evaporation. In all climates and especially in hot, dry climates the question of evaporation is an important one. It is probable that the average daily loss from a reservoir of moderate depth from evaporation alone through the three warmer months of the year is about $\frac{3}{10}$ of an inch and $\frac{1}{10}$ during the nine cold months in the U.S., Southern States excepted. By trials in the Tropics it is found to be $\frac{1}{8}$ inch per day.
In leading the water to canal,feeders are used and these feeders must oftentimes go through hills by means of tunnels,span valleys by aqueducts or cross them by huge embankments and in all this work great care must be taken to prevent overflow and consequent damage to water works themselves and the surrounding country. Moreover,the necessity of surmounting elevations by means of locks or inclined planes often restricts the engineer.

The following principles are found applicable in most cases:
Obviously a canal cannot be of any marked advantage or importance unless it has a necessary supply of water throughout the entire year. If there is no natural lake or supply available for storage the engineer must select suitable sites for the building of immense reservoirs. These reservoirs must command drainage of sufficient area to supply the losses mentioned above viz: Leakage,Lockage and Evaporation due to the canal length,the number of locks and the probable amount of traffic. The offlets or branches from the storage dams must be of such elevation as to command sufficient head to convey the water to the summit head of the canal. These embankments for retaining the water must be erected on sites offering possibilities for a sure,firm foundation and if possible in such places

that an embankemnt of small height and length may dam up a large amount of water. Another consideration of vast importance is the subsoil of the valley forming reservoirs.This of course must be retentive enough to prevent leakage since,thereby water is lost and there is a great danger of undermining the foundation. Of course wastewiers are necessary for the discharge of water in time of flood. It is readily seen that in cases where the natural supply is small that the loss of water from the deficient workmanship and lockage must be reduced to a minimum.Barge Canals are usually from four to five feet in depth and in some cases more. When soil is porous, clay puddle is often introduced though the advantage of this is a question of discussion among engineers. Quoting from Mr. Ranking,the depth of water and sectional area of water-way should be such as not to cause any material increase of the resistance to the motion of the boats beyond what it would encounter in open water. The rules are given by him:

Least breadth of bottom = 2X greatest breadth of boat

Least depth of water $= 1\frac{1}{2}' +$ greatest draft of boat.

Least area of water-way = 6X x greatest mid-ship section of the boat.

A canal engineer has to also consider road traffic and has to provide for same by means of fixed or movable bridges.

An essential feature to a canal is the construction of a sufficient number of waste-wiers necessary to discharge the surplus water arising from floods as mentioned above. The number and disposition of these wiers necessarily depends on the nature of the country through which the canal passes.

When a canal crosses a stream a waste-wier must be provided in the aqueduct and the engineer must also consider at what points large influxes of water may be expected and in this case not only wiers but even artificial courses must be provided for the discharge. The waste-wiers are placed at the water level of canal so that they may relieve the banks when the flood comes. Stop-gates are necessary at intervals of a few miles for the purpose of dividing the canal into isolated reaches so that in event of a break in the wall the gates may be shut thus prementing the discharge extending throughout the whole line of canals. In case of large canals the gates may be formed like those in the Kanawa River or two pair of gates may be formed shutting in opposite directions. In small canals simpler methods may be used. When repairs have to be used stop-gates permit the water to be run off for a short distance and then be restored without very much interruption to the traffic. When water has to be drained off to admit of repairs - the stop-gates being closed - off-lets which are pipes placed at the bottom level and fitted with valves are required. The preservation of the banks at the water-line is also an important matter. Stone-pitching is sometimes used and brushwood facing if well executed forms good protection both from an economical and an effectual standpoint. In the formation of the bed leakage must be provided against by puddling.

Irrigation Canals

In irrigation canals the principles already stated in regard to dam and resevoir construction as well as in construction of the main channel are applicable. The question of bank formation is the important one. The height of these range up to 50-feet and various forms of cross-section and character of construction are used. Simple filling masonry wall,masonry face-wall,masonry revetment-wall,puddle face and core banks. The following conditions should be satisfied before the bank can be classed as a good one.

1 The greatest possible leakage must not remove material from the bank.

2 A creek or burrow right through the bank must be impossible.

3 The impervious part of the bank must be so secured so that neither settlement can breach nor leak through cracks carrying the material out of place.

4 The impervious part must be encouraged to settle or sink so that it closes any cracks that may occur in it.

5 It must be easy to detect and overhaul any bad puddle.

The question of placing the puddle on the face or in the body of the wall to prevent leakage is one in which engineers differ. On ordinary irrigation canals either construction will satisfy every purpose. The conveyance of the water over valleys and rivers in flumes is much the same as the previous mention of aqueduct.

SHIP-CANALS.

There are in general three classes of ship-canals:-

1st Canals which on their route from ocean to ocean traverse high districts surmounting the elevation by locks supplied by natural lakes or artificial resevoirs, such as; Lanquedoc, in France, the Caledonian, in Scotland.

2nd Canals in low lying districts which are carried on from end to end in a uniform water level and are protected from the inroading of the sea at high tide by double acting locks which also retain the canal water at low tide. An admirable example of this class is canals of Holland and other low flat countries.

3rd Canals without locks at either end communicating freely with the sea from which it derives its water supply.

Ex: Suez Canal.

A brief description of a canal of each of the above classes.

1st The Caledonian Canal of Scotland is a good representative of the first class. The length of this Canal is about 60 miles, but this length embraces a chain of fresh water lakes which materially lessened the actual construction which was necessary as only about 23 miles is of canal construction. The summit level is at Lagan between lock Oich and lock Locky whence the drainage flows to the eastern and western seas. The area of eastern discharge embraces about 100 sq-miles, chiefly mountanous country, intersected by streams and lakes which flow into locks Oich, Ness and Doughfour and are then conveyed by the Ness to the Moray Firth, Lock Oich, the summit level of the canal has an area of 2-sq miles and its elevation is about 102-feet above the level of mean high water of Map tides in Beanly Firth.

The drainage of the western district of the country including lake Arkegg finds its way into Lock Locky which is about 10 miles long and thence by the river Locky to the western sea at lock Eil. The two locks in lock Beanly at the northern entrance to the canal are 170-feet long,40-feet wide and have a lift of about 8-feet. At Muirtown are four locks of 170-feet in length,40-feet in width and having a rise of 30-feet raising the canal to the level of Lock Ness which it enters at Bond.Westward of this lock are seven locks communicating with loch Loich. It is then carried on to Locky by two more locks. At the south end of Lock Lochy is a regulating lock and from this point on it descends 64-feet by 8 connected locks. The canals are about 120-feet in width at the top water level 50-feet at the bottom and 20-feet in depth. Total cost of this canal was about 4,000,000 Sterling.

A specimen of the 2nd class is the North Holland Canal. It is about 16½ miles long.

The harbor in which the Canal terminates in the North Sea is formed by two piers built of concrete blocks having a foundation of rough Basalt. The piers are about 5000-feet in length and enclose an area of 260 acres. From its commencement at the harbor passes by deep cutting through a number of sand hills which protect Holland from the sea,there are two sets of locks,one at each end. These locks have three passages. The central one is 60-feet wide and 390-feet long and has two pairs of gates at each end pointing in opposite directions and one pair in the centre. The northermost one is for barges,has three pairs of gates and is 30-feet long and 34 feet wide. The one to the south has five pairs of gates,is 227-ft. long and 40-feet wide. In constructing the canal the material proceeding from the cutting was made to form two banks 443-feet apart through the lakes on each side of the main canal. The length of these banks is 38½ miles. The bank is formed of sand with coating of clay and protected during the progress of construction by fascines. The lock-gates at the ends of the canal pointing seaward are of ~~valuable~~ malliable-iron. Those pointing inward are of wood. The cost of constructing 2,275,000 Sterling.

Of the 3rd class the Suez is probably the only example. It has nothing in common with other canals such as locks,gates,resevoirs or pumping engines. The whole length is 88 miles,66 miles being formed by actual cutting. The canal was intended to have a depth of 26-ft for a width of

72-feet at the bottom, the size at the top varying according to circumstances. At the places where the cutting is the deepest the slopes are 2 to 1 with a water line width of 197-feet. In the less elevated portion where material is softer the slopes are increased, giving a surface width of about 325-feet. Total cost was 2,000,000 Sterling.

Panama Canal.

For Generations the Panama Canal has been the dream of men of bold imaginations and for half a century it has been the object of various engineering, financial and diplomatic efforts.

The Panama railroad built by Americans is only a forerunner of the ship-canal. It is the Isthmus of Panama in the narrow sense which is to be crossed by the canal. It affords a shorter route than that of Darien and while the central cordillera does not sink more than 980-feet in the Isthmus of San Blas it is rather less than 290-feet at Culebra Col. The ship-canal is to follow very much the same route as the railroad. It will keep closer to the bed of the Chagres which it is to cross several times and on the Pacific slope it will descend the Valley of the Rio Grande. The two great difficulties connected with the undertaking are caused by the mountain and the river. The Culebra Col will not be tunnelled therefore it will be necessary to cut an open channel through this which will vary in depth from 300 to 350-feet, however the rock is of the soft schistose character.

The work of constructing the Panama Canal will naturally be separated into three grand divisions. First is the comparatively simple matter of completing the excavation along the level stretches and including the above mentioned Culebra cut which though a big operation is not at all difficult. The second is the building of Bahio dam which is to create a fresh water lake. This is one of the most important features of the Canal construction. Third there will be the construction of the locks and the harbor and pier at the ocean ends of the canal. In addition to all of this is the task of disposing of the flood-waters of Chagres, the sanitation of the entire district, the drainage of vast marshes, the effort to mitigate mosquito pest and danger and the introduction of an ample supply of fresh water.

In adopting the old line from Colon to Panama the length is about 47 miles from deep water to deep water & is to have four locks on each side with summit level at 98-feet. There is to be a large storage reservoir constructed at Alhajula. On the upper Chagres 12 miles from the sand line and feed water from the reservoir to the summit level will be supplied by aqueducts. The radius of curvature of the Panama Canal is 8200-feet.

The bottom of the Bay of Panama consists largely of semi-liquid mud in which the regular steamers always sink at low tide without injury and the considerable amount of dredging will be necessary for the proper maintenance of channels through it.

The structures as planned are of a permanent nature and would succumb to violent earthquake, only.

The next step since the return of the Canal Commission from South America where they have thoroughly investigated all conditions is to dig; about $\frac{2}{5}$ of the canal is already cut, including 14 miles on the Atlantic Coast and 4 miles from the Pacific Coast. The sections will have to be made somewhat deeper than they are at present. This leaves about 36 miles of the most dificult part to be cut. It is estimated that the construction of the canal will require 50000 men for eight years. The great dam built at Bahio will make a lake 52 ft above the Alantic into which vessels will be raised by means of locks. The level reached by this means will continue for 22 miles then vessels going toward the Pacific will descend by locks about 65-feet, further on they will perhaps descend 30-feet more to the Pacific level. The dam will supply the power that will be used in excavating and the work under American direction is expected to go forward rapidly, thence it is fair to conclude that within a few years the Continents of North and South America will be separated and one of the greatest feats of modern engineering will have been achieved. The value of the canal to commerce in time of peace will be inestimable. In time of war the enormous advantage of the canal can best be illustrated by the Battleship Oregon, having to go all the way around by Cape Horn in in order to reach Santiago.

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Respectfully submitted