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River Navigation

25.1. Introduction

There shall be no exaggeration, if we define water as something which is a necessity, a comfort and a luxury too. There cannot be two opinions about water being a necessity, as there can be no life without water. Men, animals and even plants can never survive if there is no water. Besides the basic necessities for existence, water provides us various comforts and luxuries, and makes our lives easier. Besides the various uses of water, water provides us cheap* means of transport. Before the inventions of rail-road transport, water was the only means of communication between distant places. Even today, cargo – too heavy to be packed on wagon trains or trucks, is lifted and transported through big ships. In the modern affluent living, towing through water is not only required for transporting purposes, but is also required for recreational boating. However, boating and floating of ships through the natural rivers is not always safe. Rapids and sandbars may create problems, and may require considerable time to be passed. Isolated rocks, fallen trees, debris and other obstructions may create constant hazards, and may damage or even wreck the boats, steamers, or ships being towed through such waterways. It is, therefore, absolutely essential that all the waterways through which the boats or ships are to be towed, must be made completely safe.

The chief requirement for navigating through a waterway is the availability of sufficient water depth in the waterway. A minimum water depth of about 2.7 metres is generally required for navigating safely and economically ; although a depth of about 3.7 metres is generally aspired in the final development of a navigable waterway. Availability of lesser depth in the rivers may completely eliminate the possibility of towing the ships through such rivers or may cause increased unit cost of transport.

The cost of water transport is generally expressed in Rs. per tonne per kilometre. The total cost per kilometre of travelled distance divided by the transported tonneage, gives us the cost per tonne per kilometre. The total cost consists of fuel charges, wages of crews, etc., and other operating and incidental charges. The wages and other operating charges depend only upon the time of transit ; while the fuel consumption charges depend on one more factor *i.e.* the available draft. *The consumption of fuel decreases as the depth of water between the bottom of the ship and the bottom of the river increases.* This is because, when the clear depth between the barge and the river reduces, an increased drag force is developed which increases the consumption of fuel. So much so, that the fuel consumption can be reduced by about 25%, if this clear space is increased from 0.6 m to 1.5 m or so. In order to maintain this minimum depth available, the ship will have to be loaded only to such an extent that a certain minimum clear space remains available between the bottom of the ship and the bottom of the river. Hence,

* Water transport is cheaper because on water, the coefficient of friction being small, one horse power can pull 4 tonnes ; while on road and rail, it can move approximately 0.15 tonne and 0.5 tonne, respectively.

the amount of loading of the barge is dependent and limited by the availability of sufficient water depth at the shallowest point in the route. From this discussion, it can be easily concluded that a certain minimum depth depending upon the type and extent of traffic is always required to be maintained in the river, so as to keep it fit for shipping or towing of barges. When this available depth or draft is not sufficient or if the channel width, channel alignment, locking time, current velocity, terminal facilities, etc. are not adequate, engineering measures are undertaken so as to increase the available draft and to improve other requirements. By undertaking more and more measures, and thereby spending more and more money on improving a waterway for navigation, we can make heavy and heavier transport feasible through that waterway. A compromise between the money invested on these technical works and corresponding advantages likely to be obtained by way of better and cheaper water transport, must be weighed against each other while working out a financial justification for such works. Besides the direct tangible benefits such as increased and cheaper communications for commerce and trade, etc. ; the intangible benefits such as recreational boating and better defence facilities for carrying military equipments, during war times, should also be given due importance, while working out the economic justification for such improvement works.

25.2. Various Requirements of Navigable Waterways

There is no rigidity about the requirements of a good navigable waterway, since it all depends upon the extent and type of traffic likely to pass through it. However, the various general requirements are enumerated below :

(1) Sufficient water depth is available so as to pass the more heavily loaded barges cheaply and economically.

(2) The width of the waterway is sufficiently more than the width of the tow itself.

(3) The radii of the bends should not be sharp and should be high enough to allow the maximum length of the ship to pass through them.

(4) The alignment of the waterway should be as straight as possible, because a highly irregular alignment increases the circuitry or length in excess of air-line distance which the barge tow must travel. The existing channels generally have a length about 50 per cent greater than the air-line distances.

(5) The flow velocities should not be high, as they may cause substantial reduction in the true speed for tows moving upstream and thereby increasing the time of transit and the cost of transport per kilometre. The speed of most of the barge tows in still water is of the order of 2.8 m/sec. The flow velocities of the order of 1 m/sec may, therefore, cause sufficient reduction in true speed (*i.e.* $2.8 - 1.0 = 1.8$ m/sec) and hence, should not exceed such a value.

(6) In order to minimise the transit time, the time required for the tow to pass through locks should be minimum. In certain cases, where the lock is not large enough to accept the entire tow, the tow is generally broken and taken through the lock in portions. This increases the time lost in locking, and thereby increasing the transit time and the cost of transport. Hence, sufficient sized locks should be ensured for economic and better transport.

(7) Efficient and adequate terminal facilities for unloading the barges for transferring the cargo effectively, must be ensured for economic and better navigation.

25.3. Various Measures Adopted for Achieving Navigability

There are three basic methods which are generally adopted for improving a river for navigation. They are :

(1) *Open channel methods*

(2) *Lock and dam arrangements* ; and

(3) *Canalisation.*

They are described below :

25.3.1. Open Channel Methods. In the open channel methods, the existing waterway is improved to such an extent as to make navigation possible. This improvement in natural waterway is possible only if the following conditions are satisfied :

(*i*) Sufficient discharge is available in the river throughout the year or at least for a reasonable portion of the year.

(*ii*) The existing river is having a satisfactory alignment without excessively sharp bends.

(*iii*) The river bed slope is reasonably flat so that the flow velocities are not excessive (*i.e.* they are within 1 m/sec or so).

(*iv*) The river width is not too small and is such that it can be improved economically for the modern barge tows.

(*v*) The material of the river bed and banks should permit satisfactory treatment by one or more of the open channel methods.

If the above requirements are approximately satisfied, the channel can be economically improved and made fit for navigation. But if the available conditions are far too short of requirements, open channel methods may prove to be highly uneconomical, and, therefore, should not be considered. However, these requirements and factors may be controlled to some extent by some suitable measures. Say for example, if the discharge in the river during lean periods is very low, while the average annual flow is adequate, reservoirs may be constructed so as to store water and augment the supplies during lean weather flows. Similarly, very sharp bends may be eliminated by cut off channels, provided the resulting channel slopes remain within limits.

The **various works and techniques** that may be involved in improving the channel by the Open channel methods are :

(*a*) *Constructing and Regulating the flow through Storage reservoirs.*

(*b*) *Excavation and Dredging.*

(*c*) *Contraction works.*

(*d*) *Bank stabilisation.*

(*e*) *Straightening the waterway by artificial cut offs.*

(*f*) *Removal of snag, debris and other obstructions.*

These techniques are generally required together as one of them may rarely provide the necessary required improvement. These techniques are described below :

(*a*) **Storage reservoirs.** The storage reservoirs generally store water during high flows and can release the required amount of water during lean-flows, so as to make downstream navigation possible even during periods of low weather flows. However, the construction and planning of storage reservoirs for navigation alone is not generally justified economically. Hence, reservoirs are mostly planned under Multipurpose projects, where navigation may be one purpose of that project. Moreover, the storage reservoirs can augment low supplies for navigation, only if the reservoir is situated at the head of a relatively short navigable reach. This is because ; *as the distance from the reservoir to the navigable river-reach increases, reservoir-releases have to be increased so as to allow for transit losses due to seepage, evaporation, etc. The releases must also be made much in advance so as to allow for travel time to the navigable reach and their quantity has to be sufficient even after reduction due to channel storage.*

(*b*) **Excavation and dredging.** Huge amounts of excavations are generally required for clearing sand bars and filled channel sections in order to make it fit for navigation. Besides the basic initial excavations, continuous desilting and proper maintenance is required in order to keep the waterway fit for navigation. These excavations from the bed and banks of the waterway are generally carried out by *dredging* by means of dredgers. Three types of **dredgers** are generally used. They are :

(*i*) *Dipper dredgers.* They are merely floating power shovels and are used on small projects.

(*ii*) *Ladder dredgers.* They have an endless chain of buckets for bringing the excavated material upto the surface. The cuttings carried by buckets are discharged on a *belt conveyer* which are disposed of through a *stacker conveyor* at the rear of the dredger. Since the stacker conveyors (generally called *spoil stackers*) are limited in length to about 100 metres or so, ladder dredgers cannot be used when the excavated materials (*i.e.* spoils) are to be discharged at a considerable distance from the dredge.

(*iii*) *Suction dredgers.* In these dredgers, the cuttings and water are collected in suction pipes, and the mixture is then discharged by pumping through a pipe supported by floats (called spoil pipe) into the desired spoil area. A line diagram of this operational process is shown in Fig. 25.1.

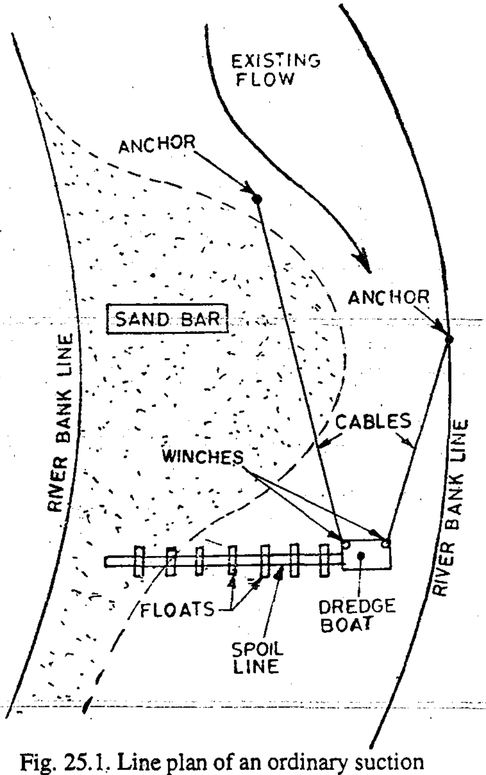

Fig. 25.1. Line plan of an ordinary suction dredge called Dust pan dredge.

A suction dredge cannot operate in rocky or boulder river reaches. The suction head of these dredges is provided with jets or rotating blades so as to cut or loosen the bed material, and also with suction openings through which the soil and water mixture enters into the suction pipe. These dredges can make cuts of about 10 m width through sand bars, and various such parallel cuts can be made in order to achieve a wider channel.

(*c*) **Contraction works.** Contraction works are those engineering works which are constructed in order to change a wide shallow river into a narrow deep river ; or to close off the river creeks (small branches) and thus to divert the entire water into the main the material of bed and banks of a river is coarse grained with little shallow wide channel, or a number of coarse channels at low waters, will develop... ch situations may be corrected with the help of spurs or groynes. Under the process, rivers carrying huge sediment loads can be corrected with the help of properly placed permeable spurs called sal balli spurs made of sal ballies, driven at some suitable distance centre to centre in rows across the river current and braced at top. The function of permeable sal balli spurs is to slow the current and thus promote silting in the dyked area. The concentration of flow in the narrower section also encourages deepening of the channel. Several years are allowed for the effect of the structures to develop.

Similarly, the rivers carrying a little sediment load can be corrected by properly placed impermeable spurs or jetties which shall divert the flow, thereby confining the entire water in a smaller width and thus deepening the same.

(*d*) **Bank stabilisation.** A good navigable channel must have stable banks. When the river banks are not stable and start caving, the river starts meandering, creating bends, which may obstruct the path of longer barge tows. Moreover, scouring at concave banks and silting at convex banks take place due to meandering (as explained in chapter 8). Hence at bends, sufficient depth will prevail at least near the concave side. But the tangents, *i.e.* the crossings joining the two successive bends, will definitely develop shallower channels with cross bars by the deposition of sediment scoured from the upstream bend. *It is in these crossings that the controlling depths for navigation occur.*

Spurs or groynes, when suitably and intelligently placed, may prove to be useful in bank stabilisation ; because a spur placed along the concave bank shall promote silting. Banks may be protected more easily by *pitching* or by *rivetments.* The entire concave bank is generally protected by pitching. The loosely dumped stone called apron or riprap is generally used, and it is extended from top of bank to beyond the toe of the underwater slope. This extension of rivetment in the bed is essential so as to avoid the failure of rivetment due to scour and consequent undermining of the underwater edge of the rivetment. The rivetment must be flexible so as to adept itself to the surface on which it is placed. Moreover, the rivetment must be relatively impervious so as to avoid, the washing of fines through it. It must also be strong enough to resist the flow currents. Various types of rivetments are used. Concrete mattresses in the form of concrete blocks placed in wire meshes may sometimes be used, when ordinary stone dumping over a graded filter is not provided due to non-availability of stone in the nearby areas. Uncompacted asphalt paving is also finding a use in developed countries, and is under serious investigations. Compacted asphalt paving and monolithic concrete paving are not generally used, as they are liable to be cracked and damaged by uplift pressures.

(*e*) **Straightening by artificial cut-off.** It was explained in chapter 8, as to how and when a cut off develops in a meandering river. Since the development of a cut-off eliminates sharp bends which are undesirable for navigation, artificial cut-offs may sometimes be used advantageously. A pilot cut is made and allowed to develop (Fig. 25.2). These cut offs have been used with

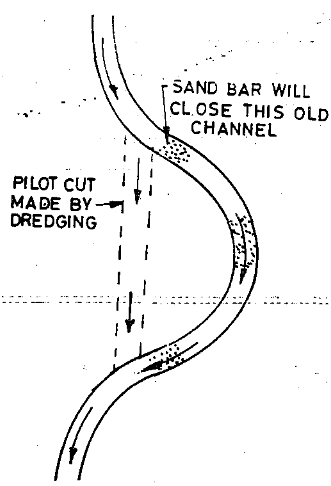

Fig. 25.2.
Development of a cut off.

success at various places, provided the banks are stabilised to avoid future caving and meandering.

(*f*) **Removal of snag, debris and other obstructions.** Presence of debris, trees, isolated rocks, and other obstructions, not only pose a direct hazard to the barge tows, but also promote the formation of sand bars. They must, therefore, be removed effectively in order to ensure safe and economical navigation. Different methods and equipments may be used in different cases, depending upon the circumstances of each case. Tractors, winches, derrick barges, explosives, etc. may be required in the process of clearing the waterway of these obstructions.

25.3.2. Lock and Dam Arrangements. The arrangement consists of dams which create a series of slack water pools through which the traffic can move with locks to lift the vessels from one pool to the next. Lock and dam construction may be adopted where existing site conditions are not favourable for adopting open channel methods described earlier. *This arrangement is a second choice to open channel methods.* In this arrangement, water is required for lockages, sanitary releases, evaporation, percolation, etc. This requirement of water is much less than that required for open channel procedures. Hence, when the available water is less, these arrangements may have to be adopted.

The slack water pools behind the dams, will submerge the rapids and channel bends, and thus overcoming those problems. Further, because of their relatively large areas of cross-sections, the velocities in these pools shall be low enough as to cause lesser reduction in true speed of the barge tow moving upstream.

Lock and dam arrangements are suitable only on rivers bringing only a little sediment load. Because, highly silt laden river-waters shall fill up the pools rapidly. Moreover, suitable sites for construction of small dams must be available for providing such arrangements. Further detailed descriptions of these arrangements are beyond the scope of this book.

25.3.3. Canalisation. A totally new channel-cut is provided artificially around an otherwise impassable obstruction or between two navigable rivers. Such a cut is generally economical only when a short length of new channel opens a large length of existing waterways. Construction of a new channel connection between two existing waterways is also sometimes adopted, so as to ensure a continuous traffic way. However, canalisation is a costly process, as the per kilometre cost of canal, capable of passing modern barge tows, is normally very high, and are adopted when very short lengths are required.

25.4. India's Navigable Waterways

Unfortunately, there is no river in India running from North to South or *vice versa*. Most of the Indian rivers run from West to East or from East to West. This is the major handicap in the development of navigation in this country. Although there are about 15,000 kilometres length of navigable waterways in India, but most of them are in very bad conditions due to silting and poor maintenance. Most of these waterways are fit only for boating except for about 2,500 kilometres length, in which the steamers can ply. Out of the total navigable lengths of about 15,000 km ; about 8000 km is on rivers, and 7000 km is on canals and backwaters. Most of these navigable waterways exist in Ganga and Brahmaputra rivers and their tributaries. On account of its inherent advantages, the water transport has been widely developed in various countries (especially in U.S.A.), but a lot of work remains to be done in India. Let us hope that as soon as our Government finds some free investment, the same will be invested in improving our navigable water-ways. Although the initial investment may be high, but the advantages obtained shall be tremendous, as it will not only provide us cheap transport, but would relieve the burden upon our rail and road transport.

PROBLEMS

1. (*a*) What do you mean by 'River navigation'? What is the importance of river navigation in modern system of transport ?

(*b*) What are the requirements of navigable waterways, and what measures are adopted to satisfy these requirements ?

2. (*a*) Discuss the importance and necessity of improving India's waterways.

(*b*) Enumerate the different methods which are adopted for achieving navigability in a river. Discuss one of these methods in details. Also discuss the pros and cons of different methods and their use for a particular project.

3. Write a descriptive note on 'River navigation'.