特 別 寄 稿

水路의 機械化 施工의 必要性

The need for mechanization in todays canal building program in Korea and overseas

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〔이 原稿는 林迎春 會長께서 ICID 第30次 理事會에 參席時 ICID 建設技術委員會 委員長(Chairman of the Committee on Irrigation and Drainage Construction Technique)인 Mr. Gordon. P. Hawkins에게 特別히 要請하여 받은 것임.〕

要 約

옛날에는 人力으로 水路를 만들었으나 機械의 發達 및 賃金의 上昇에 따라 機械化 施工이 經濟的으로 有利하게 되었으며 앞으로 이런 현상은 더욱 加速될 것이다.

水路의 機械施工은 굴착, 整理, 鋪裝으로 나누어지며 굴착은 水路의 斷面을 대략적인 形態로 만드는 것이고 整理는 鋪裝을 할수 있게 水路의 斜面과 바닥을 정확한 모양으로 다듬는 것이다. 整理의 精密度에 따라 鋪裝用 材料의 量이 크게 左右된다. 自動整理機는 종래의 것이 20～40mm의 表面 凹凸이 생기게 하나 現在는 ±6mm의 程度까지 可能하다. 現在의 自動機械는 1人의 運轉員이 1日 1.000～2.000m^3까지 굴착 整理를 할수 있다.

콘크리트 鋪裝은 人力비빔으로 할때 1日 2m^3/day의 量도 어렵고 로타리 믹서를 써도 20m^3/day 程度이나 콘크리트 뱃치 푸랜트로 하면 100～500m^3/day가 가능하다. 그러나 大型 鋪裝機를 使用하면 1日 大型 水路 300～1.000m를 鋪裝할수 있다.

水路의 機械施工은 콘크리트 鋪裝 두께를 均一하게 하므로써 콘크리트 費用을 最大로 節減하며 鋪裝의 品質을 좋게한다.

水路의 機械施工外에도 많은 새로운 機械들이 使用되고 있으며 이러한 機械의 活用이 技術發展에 크게 기여하게 될 것이다.

Introduction

The old societies of the world knew the importance of reclaiming land to sustain their population, but being limited in the power sources available they did all their works of construction with large forces of manual labor, supprted at times with animals. Until this century, the art of construction and the design of systems changed little; however, in the past 75 years a complete revolution has taken place in the application of energy tools for completing construction works without the need for massive labor forces. Today one large earthmoving machine can do the work of 1,000 men-cheaper and usually more effectively.

In years past, consideration was given first to provide employment to the most people in developing nations. The theory that in low cost labor markets work could be done cheaper by hand than by machines, was at times valid. However, inflationary rates in labor have all but destroyed this theory. Now it appears to be more politically important for governments to feed their people and bring agricultural lands into production as rapidly as possible by the most efficient systems. This concept has led to a rapid move toward mechanization in most countries.

Evolution of Mechanization

Although the turn of the century saw the Industrial Revolution beginning to make inroads into the construction industry, the first machines used were generally heavy and cumbersome. Steam operated machines were among the earlier developments, but the diesel engine and gasoline engine had to come of age before real advances could be made in mechanization.

By 1925 effective construction machinery was operating in most fields. Diesel and gasoline engines had now reached a good stage of development. The crawler tractor was proving itself in all areas of construction. Trucks abounded on all projects. Early scraper models were in evidence. Cranes and draglines were meeting many of the contractors needs. Shovels were in evidence everywhere. The post war era of World war I was now in full swing.

Although the early 1900s saw the introduction of some of the most basic construction tools, World war I advanced the cause of construction. The depression of the Thirties proved to be a dampening influence on rapid growth and it was not until World war II that really strong emphasis was placed on increasing the capability of the construction trade. War time development overflowed into post war activity for the construction industry and growth continued at a rate not imaginable during earlier years. It was only natural after the war that rapid advances were made in all fields of construction machinery to make the period 1945 to 1975 truly a golden age in construction.

After World War II, whole nations were rapidly rebuilt and the demands placed upon the construction industry were enormous. Horsepowers of machines were increased at rapid rates-sizes and capacities of machines took great strides upwards. Automation of machinery became commonplace. Old machines were modernized-new machines were introduced. The Golden Age of Construction left little to the imagination.

Manual Labor versus Machine Labor

With the great expansion required of machinery systems, it was only natural that during the past 25 years, many evaluations would be made of hand labor versus machine labor. There never seemed any question that in countries of high labor rates, mechanization was becoming an increasing necessity to combat higher labor costs—but how about the countries with low labor costs.

One of the most interesting stubies made during this period was by the United Nations. Here an attempt was made to evaluate the productiveness of hand labor and thus make comparisons with mechanization.

The field of study encompassed earthmoving which would include digging, loading, and transporting of earth as found in a wide variety of countries and soil conditions. The results of this evaluation showed that productiveness varied greatly from one part of the globe to another and from one material to another. In general it was found that an individual could dig from one to four cubic meters per day, average closer to two cubic meters per day.

When wages were $0.10 per day, such production could be very Competitive; however, as wages increased to $0.50 to $1.00

per day in the low income areas, the true costs of excavation began to become unreasonably high, especially when excavation by machines could be done for \$0.20 to \$0.40 per cubic meter (U.S.). Today, wages for laborers have risen even more, going up to \$3.00 or even higher, raising the cost per cubic meter past \$1.50. The use of massive amounts of hand labor necessitated extensive housing, feeding, and supervising problems. These problems which were once considered normal and a part of any constructin project has become increasingly harder to handle in the same manner they were years ago. Labor problems have become increasingly more involved as each of our societies developed.

Today there are many jobs that can still be done only with manual labor. The construction of special types of canals is still a manual job, The construction of structures is still a manual job, but mechanization is making a healthy inroad in these areas.

Excavation and Trimming

Rough excavation of canals is defined as that part of excavation involving the excavation of the primary material from the canal profile. Rough excavation of a canal can be carried on months ahead of a trimming or paving operation with little damage that can be due to erosion caused by windstorms, rainstorms, etc. Rough excavation should leave sufficient material on the canal profile to protect the canal from the elements.

Trimming of canals is defined as the final excavation of the canal profile that prepares the canal for paving. This is normally limited to the last 0.2 to 0.3 meter of dirt removal. Originally, this work was done by hand. Later it was done in a mechanized manner with sloper attachments for crawler tractors with draglines or with backhoes. However, in each case the degree of tolerance was limited by the capability of the machine operator. Eventually, automated trimming machines were designed to excavate to a very close tolerance automatically and independent of the capability of the machine operator.

The cost of hand trimming has increased extremely rapidly during recent years and has proven to be very slow and limited in accuracy. The cost of trimming with standard construction machines is likewise much higher than most people visualize. Where a machinery operator moves large volumes of material in rough excavation, when he begins to come to the limits of the profile, his speed of operation and productive work diminishes very rapidly. At this point the unit cost of excavation becomes exorbitant, and production is greatly limited by his capability of keeping ahead of the paving train.

The automated canal trimming machine can trim at a fixed cost per cubic meter, which is normally considerably less than that achieved by conventional excavation machines. Automated trimmers can leave a finished surface on the bottom and slopes of a canal to a tolerance of plus or minus six millimeters (controls are designed for accuracies for plus or minus three millimeters). Conventional construction machinery will rarely achieve accuracies greater than 20 to 40 millimeters.

When hand trimming is done, one laborer trimming 15 centimeters in depth may excavate and trim no more than two cubic meters of material and unless extremely close supervision is maintained, uneven grade results. With automated trimming machines, a single operator could excavate, trim, and load out material to a spoil pile at a rate of 1,000 to 2,000 cubic meters per shift.

If a contractor places concrete ten centimeters thick and his placement of concrete could be plus or minus two or three centimeters, because of poor tolerance in trimming he could end up with an error or overrun of concrete amounting to 25 to 30 percent. Where a large volume of concrete is used this overrun can be very costly. Where close tolerance trimming is done before paving, the overrun of concrete can be maintained below a five percent figure.

As with any type of excavation machinery, the production of an automated trimmer is highly dependent on the material being trimmed. Where the toughness of the material causes low production or excessive maintenance costs, the contractor should consider excavating past the canal profile and placing a thin layer of trimmable material on the surface. This layer is then compacted and trimmed to the required specifications.

Trimming should be done directly ahead of the paving operation (normally no more than two days). If a minimum of four to eight hours of operation separate the two machines then any slowdown in trimning will not seriously affect the paving. Conversely, if the trimmer is directly ahead of the paver, any action that slows trimming will also slow the paving. The trimmed surface should be kept moist so it will not absorb water from the concrete after it is placed, causing improper curing.

Table 1 **EXCAVATION-CANAL CONSTRUCTION**

MANUAL	FARMMACHINERY	HEAVY--DUTY CONSTRUCTION MACHINERY TOTAL MECHANIZATION	
		Heavy-duty Constrion Machines, Cyclic-type	Specialized Construction Machines, Continuons-type
Man	Farm Tractor	Crowler Tractor Wheel Tractor	Trencher
Pick	Plow	Motor Grader	Trapezoidal Excavator
Shovel	Dicher	Sctaper	Automatic Trimmer
Plow	Land Plane	Backhoe	Mass Excavator
Wheelbarrow	Farm Scraper	Shovel	Belt Conveyor
Bullock	Pickup	Front End Loader	Dredges
Cart	Backhce Loader	Dragline/Clamshell	Wheel Excavator
Basket		Compactors	
		Truck-End Dump	
		Truck-Bottom Dump	
	HP RATINGS OF MACHINES	HP RATINGS OF MACHINES	
No machines used	10 HP to 100 HP	50 HP to 500 HP	50 HP to 500 HP
EXCAVATION 1 to 4 cu m/man/per day	PRODUCTION EXCAVATION 50 to 200 cu m/man/per day	PRODUCTION EXCAVATION 200 to 2,000 cu m/man/per day	PRODUCTION EXCAVATION 500 to 2,000 cu m/man/per day
HAULING	PRODUCTION HAULING	PRODUCTION HAULING	PRODUCTION HAULING
1 kilometer	1 kilometer	1 kilometer	Normolly not required
1 to 4 cu m/man per day	50 to 200 cu m/man per day	100 to 2,000 cu m/man per day	Materlal backfilied or deposlted on bean

Concrete Placement

Table 1 illustrates graphically the changes in production being obtained. Equally dramatic are the changes taking place in the handling of concrete for canal lining. A man with a mixing trough will produce from one-half to two cubic meters of concrete per day; with a small rotary mixer, production is increased up to 20 cubic meters per day. Large, mobile, concrete batch plants will increase production anywhere from 100 to 500 cubic meters per day. Using contemporary slipforms and truck unloaders, daily production of 300 to 1000 lineal meters of large canal can be achieved. Table 2 illustrates the achievements in this area.

table 2 **CONCRETE & ASPHALT PAVING FOR CANAL CONSTRUCTION**

MANUAL	MINOR	MAJOR MECHANIZATION	
Mixing Hauling & Paving	MECHANIZATION Mixing, Hauling, & Paving	Mixing & Hauling Continuous Type	Trimming & Paving- Continuous Type Automated Machines
Man	Mixer, Small	Dry & Wet Batch Plants	Full Section Slipform Pavers
Basket, Bucket	Paving Boat	Transit Mixers	Slope Pavers
Wheelbarrow	Simple Screeds	Crushing Plants	Convertible Slope to Flat Pavers
Mixing & Troweling	Concrete Buggies	Bituminous Plants	Workmans Jumbos
Tools		Concrete Mixers	Joint Jumbos
		Dump Trucks	Curing Jumbos
		Compactors	Automatic Trimmer & Profile Machine
Quality Control Very Difficult	Quality Control Difficult	Quality Control Good	Quality Control Good
No Machines Used	0 to 10 HP	30 to 300 HP	30 to 300 HP
PRODUCTION, CONCRETE	PRODUCTION, CONCRETE	PRODUCTION, CONCRETE	PRODUCTION, PAVING
1/2 to 2 cu m/man per day	2 to 20 cu m/man per day	100 to 500 cu m/man per day	25 to 100 cu m/man per day
PAVING 1/2 to 2 cu m/man per day	PAVING 2 to 20 cu m/man per day	HAULING 25 to 100 cu m/man per day	

Mechanization of concrete placing, with it's ability to maintain close lining tolerances, has two important advantages over manual placement. If the concrete thickness is greater than the required project specifications, the contractor has spent more money than necessary for lining. If the concrete thickness is less than the required project specifications, the lining is weakened and damage to the canal is more likely, and is very expensive to repair. Inspectors locating a thin area will require the contractor to remove that section of canal, and re-line it. This greatly increases the cost of canal construction.

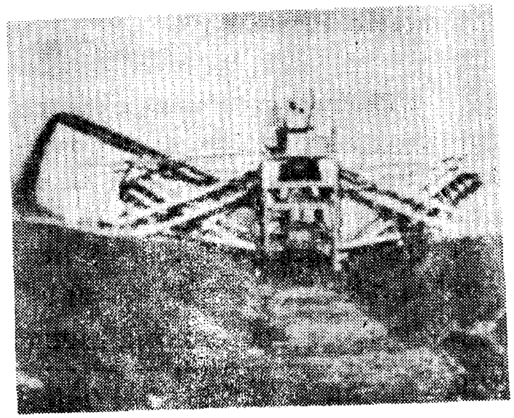
Summary

Canal construction is not the only area in which mechanization has advanced with great strides. All phases of the construction industry, including earthmoving, land clearing and levelling, road construction, and drainage and water control projects, have benef ited from today's technological advancements.

Lasers, an excellant example of advanced technology, have been refined for use as guidance systems for construction machinery, increasing accuracy and the speed of operation. The use of explosives by contractors is becoming more commonplace. One of the most valuable modern tools available today is the two-way radio. On today's sophisticated projects a single machine being down can frequently stop the progress of the entire project, delaying hundreds of men and machines from completing their assigned work for the day. The use of two-way radios in all the pickups and cars being used on a project facilitates communication so that emergency repairs can be effected immediately, and costly down time on any project can be reduced to a minumum.

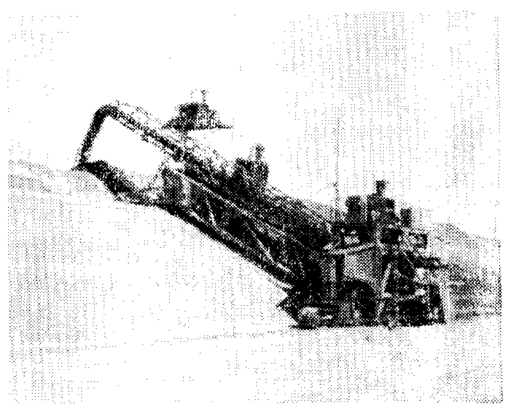
Not every construction project is suitable to mechanization. However, on the majority of projects mechanization has a great deal to offer the Korean contractor, and all contractors, in savings of time and money. Each and every project being considered by a contractor, should be closely examined for the most effective and efficient machinery application available.

The International Commission on Irrigation and Drainage (ICID) has formed a committee on construction techniques being used in canal construction today. Two publications are now available describing the advances made in recent years. Standards for construction have been established for mechanized systems and this information is being distributed worldwide.



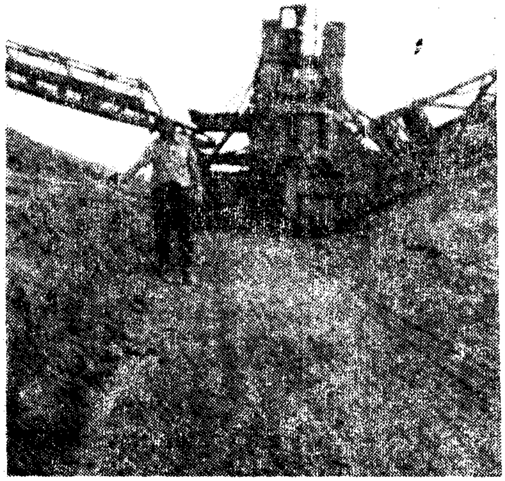
PROJECT: ARGENTINA

This canal Trimmer is enlarging a smaller canal. This machine uses rotary slope cutters and a central bucketwheel to excavate the canal profile. The excavated material is discharged to one side of the canal by a conveyor belt attached to the machine.



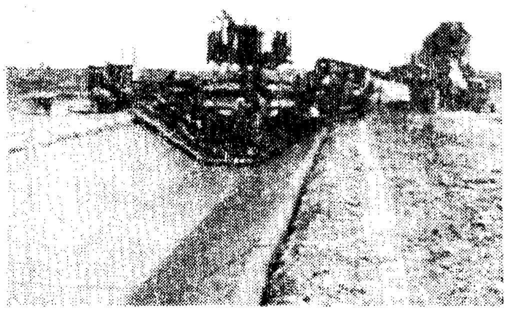
PROJECT: USSR

This half-section Trimmer is shown completing the final finish of the canal slope. In a multiple-sequence operation, this machine trims first one slope; in a second operation it trims the opposite slope; and then after being converted to a flat configuration, completes the bottom in as many passes as necessary. Canal projects which were prevoiusly too costly to attempt, are now made feasible, thanks to the developement of canal construction machinery such as this.



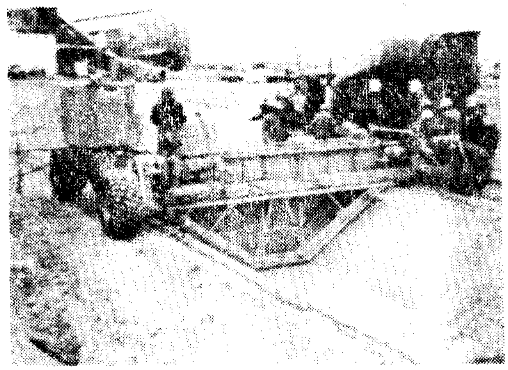
PROJECT: USSR

The Soviet Union purchased canal construction machinery designed and fabricated by the R.A. Hanson Company, "RAHCO", of Spokane, Washington, USA. Here the operator is pointing to the depth of cut which is possible with this half-section Trimmer. This Trimmer excavates one entire slope and half of the bottom in the first pass, and then completes the canal profile by trimming the opposite slope and remaing portion of the bottom in a second pass.



PROJECT: IRAQ

Canal construction machinery systems have been designed, fabricated, and tested at the factory by R. A. Hanson Company, "RAHCO". Their machines have been shipped to over 35 countries. The use of automated machinery has enabled developing nations to speed up their construction process, completing projects in record times.



PROJECT: YUGOSLAVIA

This full-section Concrete Placer paves the complete canal profile in one pass. The lining requires little finish work and unlike hand labor, the cost of this canal construction process is relatively inexpensive.