(Paper No. 3479.)

“Aerial Suspension-Cableways.”

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IN the execution of engineering works, and in the conduct of manufacturing and other processes, where large quantities of materials have to be moved from point to point, the cost of such transport is often a large factor in the total cost of the works, or of the article produced. To meet present-day conditions, labour- and time-saving devices must be employed wherever practicable; and the demands made upon the engineer to improve upon mechanism already constructed are increasingly exacting and difficult of fulfilment.

In this Paper the Author proposes to follow, generally, the development of the cableway; to indicate the various forms in which the machine has been constructed, in order to suit different situations and kinds of work; and to refer to some undertakings whose execution has been, and is being, aided by its use. What are known as aerial tramways, shootways and wireways, are used for conveyance only, having no provision for hoisting and lowering the loads; they will not be dealt with here.

The cableway may be defined as a machine in which a fixed cable, suspended between supports, acts as a rail for a carriage provided with suitable grooved wheels, which is free to be moved backwards and forwards on the cable, and from which depend a hoisting-block and hook. By means of wire-ropes, worked by a winch or winding-gear, led over pulleys, and connected with the carriage and block, a load may be hoisted, lowered, and conveyed to and from any point between the supports of the cable.

History of the Cableway.—Inclined cableways, worked by means of a winding-engine having a single drum, have been used in the Welsh slate-quarries for many years, and more recently in those of Pennsylvania and Vermont. A cableway of this type is illustrated in *Fig. 1*. The hoisting-chain is doubled between the carriage and the load, and the minimum slope of the cable must be such that the resistance to drawing the carriage up the incline is greater than the effort involved in hoisting the load. The carriage, resting against a stop on the cable, does not, therefore, begin to ascend until the hoisting-block comes in contact with it.

Fig. 1.

Provision is made for the block to collide with the carriage without either being injured. When the carriage has been drawn to the upper end of the cable, a sliding platform overhanging the edge of the quarry is pushed under it, and the load, on being lowered by paying out the chain slowly, is caught on the platform. After unloading, the hoisting-block is raised, the carriage is hauled up the cable sufficiently to clear the platform, the platform is pulled in, and the hoisting-chain is paid out until the carriage reaches the stop; continuing to pay out the chain, the hoisting-block is lowered to the floor. These cable-inclines are frequently worked in pairs; the carriage on one cable descends while that on the other

is ascending, the two carriages being worked by the same drum. The travelling-speed of these machines is not more than 80 feet to 100 feet per minute: the hoisting-speed is 40 to 50 feet per minute.

The first great advance in the development of the cableway was made by Mr. John Fyfe, a granite-quarry owner. The depth of his Kemnay Quarry, Aberdeenshire, had become so great that some more expeditious means of hoisting than by a derrick was essential to its profitable working. Owing to the small area of the quarry-floor, inclined railways were out of the question. The first machine, designed by Mr. Fyfe, and constructed in the quarry workshop, consisted of two chain-cables suspended parallel to each other between timber supports on the top edge of the quarry. Each cable was provided with means for adjusting its length, so that both should have the same amount of sag. On the cables was placed a four-wheeled carriage, from which hung the hoisting-block and hook. After working for a short time it was found to be impracticable to maintain the catenary of both cables alike. Recourse was then had to a single wire-cable, with a two-wheeled carriage, and success resulted immediately. The winch-gear had two independent drums, one for hoisting and lowering the load, and the other for travelling the carriage along the cable. The speeds adopted by Mr. Fyfe were, approximately, hoisting, 100 feet per minute, travelling, 200 feet per minute.

Forty years ago wire-ropes had not attained to extensive use for mechanical purposes, and the advance in the design of cableways rendered possible by the adoption of such ropes did not take place until a more recent date. In Wales, it is still quite usual to employ chains for both the fixed and the movable cables.

In America the cableway appears to have come into general use about 30 years ago. The Author has been unable to find any record of the use of chain-cables on any of these machines; available data and illustrations of the earliest inclined cableways in the United States, which are those already mentioned as having been installed in the slate-quarries of Vermont and Pennsylvania, indicate that wire-ropes were employed from the outset. Subsequently, an American contractor named Locke constructed a horizontal cableway, in which the motion of the carriage along the cable was effected by means of an endless rope. In Locke's apparatus, chain-connected carriers were used to prevent the hoisting-rope from sagging unduly between the load-carriage and the head support. These carriers consisted of a series of blocks, having 8-inch or 10-inch wheels, running on the main cable,

spaced at intervals of about 50 feet, and connected by $\frac{1}{2}$ -inch chains. These heavy hoisting-rope carriers are said to have been a source of considerable trouble. The span of this cableway was about 750 feet.

On a cableway erected for the construction of the Sodom Dam, thirty-two chain-connected carriers at intervals of about 20 feet, were used, *Fig. 2*. The span of this cableway was 667 feet. The hoisting-rope does not require to be supported at smaller intervals than 100 feet, but with chain-connected carriers the chains themselves have to be supported, necessitating a larger number of carriers. The weight of the chain and carriers used on this plant

Fig. 2.

was about 2 tons. The chains were found to give trouble by becoming entangled with the hoisting-block and with one another; they also limited the speed of the carriage, and caused excessive wear of the cable.

Modern Developments of the Cableway.—Long-span cableways and high speeds were found to be impracticable with the chain-connected hoisting-rope carriers, and the first departure therefrom is illustrated in *Figs. 3*. An auxiliary rope, about $\frac{5}{8}$ inch in diameter, is suspended above the main cable, and is held in position, parallel to the main cable, by passing under wheels in the load-carriage. On this rope a series of buttons are secured, the diameters of which

increase with the distance from the head tower. Slots in the heads of the carriers, corresponding with the diameters of the buttons, allow each of the carriers in passing down the incline to be stopped at his proper button. These carriers have small wheels which roll on the auxiliary or button rope. Thus the heavy chains were dispensed with, and these hoisting-rope carriers, spaced by buttons, and weighing about 100 lbs., were found to meet all the require-

Figs. 3.

ments of chain-connected carriers weighing, with the chain, about ten times as much. The original carrier was of wood and iron. The development of a few years has brought the carriage and carriers to a standard form, shown in *Figs. 4.* The load-carriage is built with two, three or four main-cable wheels. When three or four wheels are used, they are so carried on articulated levers that the load is borne equally by all the wheels. The horn in front of the carriage picks up the carriers as it travels towards the head

support, and also carries them out as the carriage recedes; the buttons on the button rope take the carriers from the horn and leave them spaced along the main cable at proper intervals for supporting the hoisting-rope.

A standard cableway winding-engine, having two cylinders 12 inches in diameter by 20 inches stroke, is shown in *Fig. 5*. The drums are 5 feet in diameter, one to carry the hoisting-rope, and the other, turned with a curved surface, to carry the endless travelling-rope. The travelling-rope is coiled four or five times round the drum in order to obtain sufficient friction to keep it from slipping in the opposite direction to that in which the drum is

Fig. 4.

turned; the ends of the travelling-rope are passed over the grooved pulleys on the towers, and made fast to the front and rear of the load-carriage. The drums are independent of each other, and each drum has a separate band-brake. The reversing-lever, friction-clutch and brake-levers are all brought to a convenient position in front for the operator.

The method of leading the ropes on a long-span horizontal cableway is illustrated in *Fig. 6*. The endless rope serves to hold the load-carriage in position during hoisting and lowering. For travelling horizontally, the hoisting-rope is drawn in, and the endless rope is paid out at the same speed. The load may be hoisted or lowered at any point under the line of the cable, and

the horizontal motion may be given to the load at any height to which it may be raised.

Applications of Cableways.—The applications of cableways in this country, and in works abroad controlled by British engineers,

Fig. 5.

are very comprehensive. The conditions to be complied with in designing cableways are more or less different in each case; the site, the area to be covered, the load to be carried, the capacity or output required, and the nature of the work to be

Fig. 6.

performed, are all factors to be taken into account, as well as commercial considerations. For this reason it has not been possible fully to standardize the machine. Certain prominent features of the various arrangements of the cableway have evolved

distinctive names for different types, namely, "inclined," "fixed," "horizontal," "travelling," and "radial." These will be dealt with as they occur in considering the different classes of work to which cableways have been applied.

The cableway having been devised primarily for use in stone-quarries, particulars of a few typical machines employed in such work will first be given. One of the early inclined cableways used by Mr. Fyfe in his Kemnay granite-quarry, is shown in *Fig. 7*. The height of the trestle-support was about 65 feet, and the span, from the top of the support to the anchorage in the quarry about 450 feet, the diameter of the cable being $1\frac{3}{4}$ inch. The engines had two cylinders, each 10 inches in diameter and 21 inches stroke, and the drums were 4 feet 6 inches in diameter. The load handled was about 2 tons. The trestle-staging abutting on the support carried the wagons on which the loaded skips were lowered. From the staging the loaded wagons were run to the paving-set makers' berths, to the breaking-machine, or to the waste tipping-bank, as required. This method of distributing useful materials and disposing of waste is frequently adopted in quarries where cableways are employed.

A "horizontal" cableway erected in 1895 over the Enderby Hill Quarry, near Leicester, is shown in *Fig. 8*. This cableway is one of several used by the Enderby Company; the span is 525 feet, and the load 3 tons; an endless rope is used for travelling the carriage along the cable. The engines have two cylinders, 10 inches in diameter and 18 inches stroke. The quantity of material handled is about 300 tons daily, all of which is deposited on the platform and thence fed into breaker-hoppers. Another cableway, working under conditions similar to those at Enderby, is that over Messrs. A. and F. Manuelle's Longue Hougue granite-quarry, Guernsey. It has a span of 480 feet and handles a load of 4 tons, which it conveys straight to the machinery for crushing (a distance of fully 120 yards), thus dispensing with horse-labour. The last example of a cableway for quarrying which will be mentioned, is that over Messrs. John Mowlem and Company's Vale Castle Quarry, also in Guernsey. The span is 550 feet and the load 4 tons. The cableway reaches right across the quarry, and carts laden with 2 tons or more of stone are lifted from three or four different levels to the depot, where the stone is broken by machinery, or to the rubbish-tip, a height of 60 feet above the highest working-level of the quarry.

Particulars of a few typical cableways used for bridge and viaduct construction are given in the following Table :—

CABLEWAYS ON BRIDGE AND VIADUCT CONSTRUCTION.

Name and Location of Bridge or Viaduct.		Clear Span.	Height of Supports.		Load.	Engine-Cylinders.		Diameter of Drums.	Type of Boiler.
Name.	Location.		Head.	Tail.		Dia.	Stroke.		
Vauxhall	Westminster	Feet. 904	Feet. 76	Feet. 72	Tons. 4	Ins. 11	Ins. 21	Ins. 66	Vert.
Kew Bridge	London	525	60	50	4	10	18	66	Loco.
Viaduct	Kirkcaldy	430	45	35	2	8	12	48	Vert.
"	Co. Durham	900	62	58	3	8	12	48	"
"	"	835	60	57	3	8	12	48	"
"	Devon	1,000	72	60	2½	8	12	48	"

Special mention may be made of the cableway over the Thames at Vauxhall Bridge. It was intended to carry out this work by means of overhead travelling-cranes spanning the bridge transversely and running on gantries reared from the bed of the river. Tenders for the cranes had been invited, and arrangements were far advanced for having them built, when the advantages of the cableway were made known to the contractors. Not the least of those advantages is the great saving in cost of the cableway-plant over that of cranes; the very high and long gantries which would have been required for overhead travellers were, of course, entirely dispensed with. A cableway erected over the Cannington Valley, Devonshire, for the building of the viaduct of that name on the Axminster and Lyme Regis Light Railway is illustrated in *Fig. 9*. By aid of the cableway the contractors were able to proceed with the concreting of any one of the piers while the concrete elsewhere was setting. The ribs for centering were lifted into place and set by the cableway, and the viaduct was built without the use of staging.

The cableway has been used extensively on reservoir-dam construction. As already mentioned, the Sodom Dam near New York was built by means of a cableway between 1888 and 1892. The first application in this country was on the Talla Dam of the Edinburgh Waterworks, in Peeblesshire, in 1899 (*Fig. 10*). The span of this cableway was 1,450 feet, the load handled 6 tons, and the capacity about 550 tons per working-day of 10 hours. In 1900 two cableways were placed over the Howden Dam, Bamford,

Fig. 10.

Fig. 11.

Fig. 12.

near Sheffield, for the Derwent Valley Water Board. These machines have the head ends fixed and the tail ends movable. Each tail tower and loading-stage is carried on wagons which are free to move on rails laid in a curve with its centre at the head support. The movable end of one cableway and the fixed end of the other are placed on each side of the valley. This allows every point in the foundation of the dam-wall, which in this case is very wide, to be reached without pulling the hoisting-block out of plumb. The span of the Howden cableways is 1,360 feet, and the load handled is $6\frac{1}{2}$ tons. Twelve months later, two similar cableways were erected over the Derwent Dam, situated 3 miles lower down the valley, and part of the same water-scheme. The span of the Derwent cableways is 1,520 feet, and the load handled is the same as at Howden, namely, $6\frac{1}{2}$ tons. Particulars of some cableways used in waterworks construction are given in the following Table:—

CABLEWAYS ON WATERWORKS.

Name and Location of Waterworks.		Type of Cableway.	Clear Span.	Height of Supports.		Load.	Engine-Cylinders.		Diameter of Drums.	Type of Boiler.
Name.	Location.			Head.	Tail.		Dia.	Stroke.		
Edinburgh	{ Peebles-shire }	Fixed	1,450	28	25	6	11	18	66	Loco.
Howden Dam	{ Near Sheffield }	{ Two radial }	1,360	{ 40 50 }	{ 30 20 }	$6\frac{1}{2}$	11	18	61	„
Swansea	{ Brecon-shire }	Fixed	1,250	70	65	4	10	18	61	„
Ilkley	Yorkshire	Fixed	1,000	55	52	3	8	12	50	Vert.
Harrogate	„	{ Travelling }	1,028	60	50	$6\frac{1}{2}$	10	18	61	Loco.
Derwent Dam	{ Near Sheffield }	{ Two radial }	1,520	{ 50 40 }	{ 30 30 }	$6\frac{1}{2}$	11	18	61	„
Motherwell	Scotland	Fixed	950	35	25	$3\frac{1}{2}$	8	12	50	Vert.

One of three fixed cableways used on the Harbour Works at Gibraltar is shown in *Fig. 11*. The span of each cableway is 655 feet, the load handled is 4 tons, and the quantity of material handled in 10 hours by each machine is 840 tons. Two graving-docks, running nearly parallel with each other, and forming part of the Admiralty dock-extension scheme now in progress at Malta, are being built with the aid of three travelling cableways. One of these is shown in *Fig. 12*, and the arrangement of the three

cableways is shown in plan in *Fig. 13*. The span of each machine is 750 feet, the head travelling-tower is 60 feet in height, the tail travelling-tower 50 feet in height, and the load handled is 5 tons. These machines are fitted with an automatic arrangement for tipping the skips. An auxiliary wire-rope for tipping is passed from the hoisting-drum of the engine round a smaller block attached to the rear of the flat skip. The hoisting-rope carries the whole of the weight, the tipping-rope running out slack. When the skip is to be emptied, the tipping-line is passed on to a part of the drum of larger diameter, and, being thus drawn in at a higher speed, the skip is tipped and the load is discharged. The

Fig. 13.

load is tipped while the carriage is in motion, and as there is no delay, a large capacity is obtained. The full output has not yet been obtained from the Malta plant on account of difficulties due to water in the excavation, but it is estimated that 1,400 tons of material per day will easily be handled by each machine. The Table on p. 200 gives particulars of some cableways in use on dock-works.

A large portion of the excavation of the Chicago Drainage Canal was removed by means of travelling cableways designed by the Lidgerwood Company of New York. The requirements

CABLEWAYS ON DOCK-WORKS.

Name and Location of Dock.		Span.	Height of Supports.		Load.	Engine-Cylinders (two).		Diameter of Drums.	Type of Boiler.	Capacity per 10 Hours.
Name.	Location.		Head.	Tail.		Dia.	Stroke.			
H.M. Dock-yard	Malta	750	60	50	5	11	18	58	Loco.	800
„	Gibraltar	655	75	25	4	10	18	58	Vert.	840
Hongkong	Hongkong	1,100	40	40	5	11	18	54	Loco.	400
Simon's Bay	S. Africa	500	55	50	3	8	12	50	„	150

specified by the purchaser of the original cableway for work on the canal called for a machine to handle 300 cubic yards per day, which should move along the canal at a rate of $2\frac{1}{2}$ to 5 feet per day. It was found by trial to be possible to fill into the skips or trays as much as 500 to 600 cubic yards per day, especially where the material broke favourably on blasting. Consequently, the improvements required to be made on the first machine were all in the direction of increasing the speed of the whole machine,

Fig. 14.

so that it might travel rapidly along the tracks, thereby increasing the number of trips per day. The improved machine was made and the number of machines was increased, until finally twenty cableways were in use along the canal. The first plant erected had a span of 623 feet and towers 80 feet in height; in the more recent plants the span was increased to 700 feet, and the height of the towers to 90 feet. Usually one cableway was at work on the first lift, a second following on the second lift, and a third on the last lift (*Fig. 14*), thus completing the canal as shown in *Fig. 15*.

The records of the output of a cableway on these works are interesting. In 1 month one cableway handled 10,821 cubic yards, or, during the actual working-time 57·86 cubic yards per hour, an average of almost 600 cubic yards per 10 hours. On another section, the largest day's output from one cableway was 363 skip-loads. With this cableway, during 1 week's running 1,854 skip-loads were removed in 60 hours, with only 20 minutes' delay, of which 15 minutes was due to a signal-wire having been broken by a blast, and 5 minutes to a rope being caught in a sheave. During night-work the average output on a 5-hour run has been 41 skips per hour, and 43 skips are recorded for a single hour's work.¹ A travelling cableway was used by Messrs. S. Pearson and Son on the Mexican Drainage Canal. The cableway was arranged to work with either hand-filled skips or a mechanical grab, the latter being used mainly, as the canal was full of water. A travelling cableway with a self-filling bucket would appear to be about the limit of cableway development for canal-construction.

Fig. 15.

Cableways are employed in shipyards for dealing with materials. One of these machines, at the works of Messrs. Swan, Hunter and Wigham-Richardson, at Wallsend-on-Tyne, has a span of 695 feet, and handles a load of 3 tons. This cableway is driven by an electric motor suitably geared to the winch and having a controller for regulating the speed. The whole of the plates, bars, angle-bars, etc., composing the fabric of a vessel are brought in railway-wagons to a siding at the head end, and are thence conveyed by the cableway to the stacking-ground, plating-shed, straightening-rolls, and drilling-machines, and on to the covered building-berth as required. A second electric cableway for a 6-ton load will be at work shortly in the same yard. The span will be similar to that of the machine described, and the operator will travel with the load-carriage, controlling the motions of hoisting, lowering and travelling from his seat on the carriage.

Cableways have been installed in many factories for handling

¹ The figures quoted in connection with these cableways are taken from a pamphlet issued by the Lidgerwood Company.

such articles as paper, paper-pulp, cotton-yarn. These machines differ from the cableways already described only in that the cable is usually carried between, and is supported by, the factory-buildings, instead of by the steel or wooden towers. For driving these factory-cableways power has invariably been taken from an existing source. The load dealt with has never exceeded 1 ton. Particulars of some cableways installed in factories are given in the following Table:—

Name and Location of Works.		Span.	Height of Supports.		Load.	Diameter of Drums.	Motive Power.	Capacity per 10 Hours.
Name.	Location.		Head.	Tail.				
		Feet.	Feet.	Feet.	Cwt.	Inches.		Tons.
Paper Mill	Sheffield	220	{ Fixed on buildings }		12	39	Electric	95
" "	Fifeshire	210	20	60	12	39	"	50
Cotton "	Oldham	320	{ Fixed on buildings }		7	36	Belt	30
Biscuit Works }	Reading	260	{ Fixed on building }		6	36	"	20

Cableways have been largely applied in America to sewer construction, for which purpose they are built as light as possible; the head support and winding-gear are carried on a platform mounted on wheels, or arranged to be easily skidded on battens; the cables and other parts are capable of being quickly taken down and re-erected. The whole plant is therefore portable, and appears to be well suited to the work. About 500 lineal feet of trench is open at a time, and the whole of this length is under the cableway. After a start has been made, the operations are performed in regular stages, the excavation being cut to the required depth, the sewer built, or the pipes laid and jointed, the trench filled up, and, where required, a roadway laid. The facilities afforded by the cableway for carrying out such work are now receiving consideration in England.

A modification of the cableway is used in America for "logging," or dragging felled trees in the forest. A light cable is stretched between a stout unfelled tree and the saw-mill; the trees which have been cut are hauled to the mill by means of a wire-rope led over a carriage running on the cable, and pulled in by a winch fixed in the mill.

Other uses to which cableways have been put are clay- and

sand-digging, alluvial mining, and loading and unloading vessels either lying alongside a wharf or moored in mid-stream. A variety of inclined cableway is extensively used on the Californian and Hawaiian coasts for loading vessels riding at anchor in the open roadstead.

The coaling of a fleet at sea is a question of growing importance to every great naval power, and is a problem to which at the present time considerable attention is being directed. The practical solution of it is no longer hypothetical, but is only awaiting the pleasure of naval authorities to take the matter up on a sufficiently comprehensive scale. Actual trials carried out for the Admiralty by the Temperley Company have given results from which it may be assumed that, from a suitable vessel specially equipped, coal can be transferred to a war-vessel on the open sea at the rate of 100 tons per hour, with safety. The coal, which is in bags, is conveyed to the battleship by a travelling carriage, hauled to and fro on an aerial cable stretched between the foremast of the transport and the mainmast of the battleship. This cable is kept uniformly taut by means of a specially-designed compensating winding-engine, which automatically pays out or hauls in the cable exactly as may be required to suit the relative movements of the two vessels. Under no conditions can the stress on the cable exceed that which is just requisite to sustain the load. The traveller is hauled to and fro by two ropes—an inhaul-rope and an outhaul-rope—operated by two winches, one of which is automatically compensating, as in the case of the main cable winding-engine. The bags of coal are assembled at the foot of the collier's mast and are thence hoisted by an ordinary winch to the mast-head, where they are automatically transferred to the traveller, which conveys them to the battleship, and automatically deposits them on the deck. The distance between the vessels is 300 to 400 feet; and the time occupied by the traveller in taking the load from the mast-head of the collier, delivering it on the deck of the battleship, and getting back to the starting-point ready for another load, is 45 seconds, the traveller attaining a speed of 2,000 feet per minute. In a test of the gear, operated by men who had had no previous experience of its working, the actual rate of coaling varied between 30 tons per hour and 60 tons per hour, according to the conditions under which the operations were conducted. The whole of the ropes were rigged between the ships, and the first load was delivered, within 20 minutes after the transport was taken in tow. On receiving the order to cease

coaling, the whole of the gear was taken in and stowed within 15 minutes.

The hoisting-speed of the cableway is about four times that of an average fast-working crane, and its travelling-speed is much higher than that of a locomotive crane. The dead load in the cableway is small. A derrick is adversely affected in its working, often seriously, by windy weather, especially if the jib be long; the cableway is unaffected by even the most boisterous weather; it is out of reach of floods, and is not affected by snow and frost. The cableway is also out of reach when blasting. A derrick stands close to its work and is often in the way; a locomotive crane requires rails for its path, and these constitute an obstruction, while the work of laying and removing them costs time and money; the cableway causes no obstruction in the working-area. A derrick commands the area within the radius of its jib, whereas a cableway commands a rectangular area 40 feet to 80 feet in width and up to, say, 2,000 feet in length. A locomotive crane having a jib with a radius of 15 feet commands an area of, say, 35 feet in width, less the width of the road; the travelling cableway operates over an area having a width equal to the length of span—say, up to 2,000 feet—and in length equal to the length of rails laid for it, as in the case of the locomotive crane.

The Paper is accompanied by photographs and drawings, from which the Figures in the text have been selected for reproduction.