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MADRAS RECORD OFFICE.

Government of Madras.

Public works **DEPARTMENT.**

G.O. No. 46	Press / Mis.
89-90	
Dated 6. 1	1870.

Not to be folded or roughly handled

Proceedings of the Madras Government, Public Works Department, 6th January 1870.

No. 89. Read the following Proceedings of the Government of India in the Public Works Department.—

Forwarding copies of further letters and enclosures from Mr Bridges Adams on the subject of "Railway requirements of India in reference to Commercial and Military uses and purposes of Government." } (Here enter 9th August 1869, No. 1,092-R.)

No. 90. ORDER THEREON, 6th January 1870, No. 46.

RAILWAY, No. 14.

COMMUNICATED to the Consulting Engineer for Railways in continuation of G. O., No. 3,869, of the 11th December 1868.

(True Extract.)

Colonel, R E,
Secretary to Government.

No 1692 R.

GOVERNMENT OF INDIA.

PUBLIC WORKS DEPARTMENT.

RAILWAY.

SIMLA, AUGUST 9, 1869.

Mr. Bridges Adams on "Railway requirements of India"

Read again :—

Public Works Department Resolution Nos 1256—60 R, dated 26th October 1868

Read also the following :—

No 40, dated 8th July, 1869

From—The Secretary of State for India,
To—The Government of India

With reference to my predecessor's Despatch of the 16th September last, No. 75, I transmit herewith copies of further letters* and enclosures from Mr. W. Bridges Adams, in which he discusses the subject of "Railway requirements of India in reference to Commercial and Military uses and purposes of Government."

* Dated 29th May and 16th June 1869

Dated 29th May, 1869.

From—W BRIDGES ADAMS, Esq,
To—Under Secretary of State for India.

I send you the paper† and diagrams, going logically into the mechanical and consequently economical question of the Indian Railways, Main Lines, Branches, Suburban and Military I think you will find that Mr Burton Wright agrees with the propositions therein laid down, and I shall be glad to compare notes with him, as to his own experience, confirmatory or otherwise, of my paper, for he has, I believe, been the most economical amongst the mechanical workers of Indian lines

† Sent a number in the packet

I will send you a full-sized model of the rail and sleeper, showing that with the ordinary weight of metal the strongest rail is produced, with the fewest types and the smallest number of parts per mile

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Dated 16th June, 1869

From—W. BRIDGES ADAMS, Esq,
To—Under Secretary of State for India.

The object of my paper is, first to call attention to the industries yet to be developed in India by the aid of and combination with machinery which has produced such large results in Europe, without possessing the advantage of the indigenous population in India, so peculiarly adapted for the production of textile fabrics, and next to the wide extension of transit by more economical processes than have yet obtained, and the adaptation of improved Railways to the purposes of defence and military police, as well as the prevention of distress in cases of periodical famine, by the removal of unemployed labour to other sites where it may be in demand

My pamphlet on Railway practice and improved rolling-stock, which you were kind enough to transmit to India, has produced the effect of inducing one Railway Company to commission their Engineer here to examine into my system. I have been applied to on the subject, and have referred the Engineer, Mr Burton Wright, to the paper, diagrams and model I forwarded to you, because, as a Director of all the Companies on behalf of the State, you of all men hold the most important office in the Railway Department

I should be glad to have the paper, diagrams and model brought before the Secretary of State for India, with a view to the application of the system on the Punjab and other State Lines that may be constructed, on account of the greater economy in first cost, as well as economy in making

Railway requirements of India in reference to Commercial and Military uses, and purposes of Government

Rapid transit in the power of the State is synonymous with making a comparatively small body of troops do the work of a large number, by the power of rapid concentration, and at a comparatively cheap rate, inasmuch as the troops may be lodged in healthy localities and cool temperature when not wanted for actual service

Transit of troops

The only means of rapid transit, in the modern sense of the term, is the Railway Rivers in India, over the wide flat plains, will ultimately be all absorbed for the purposes of irrigation, and an enormous increase of produce for commercial purposes, and for the sustenance of a much larger population than yet obtains Transit by animals in a hot climate may be regarded as altogether out of the question.

River transit.

Animal transit.

On the whole, the condition of the people of India has been better under our rule than under that of their Native Princes, and when we leave India,—if ever we do so,—the probable result for many years would be long wars and misery, and loss of life, till the strongest and fiercest attained the mastery Our claim to rule India, apart from our power, is that the sense of justice predominates over power, and that we seek to enforce law and order and progress in the interests of mankind, and not of a caste The institution of caste in India was simply that of gradation of slavery, from the poorest peasant up to the tyrant ruler The gradual decline of caste is the best evidence of our beneficent rule We may be yet very far from being the best possible government, but we are assuredly amongst the best existing governments of the world

English rules in India

Caste

With the extension of rails and roads in India, and free transit, commerce will continue to stimulate production, and many useful arts, now practised on a small scale, will grow up into national importance India is essentially the country of textile fabrics, and especially of cotton Time was that all our cotton fabrics were brought to England, not in raw bales, but spun and woven by Indian fingers But the metallic spinning jennies of England, steam worked, were as thousands compared to scores of Hindoo maidens, and beat them out of the market manifold by competition; and so the manufacture changed its site And now it must go back to its original site by the laws of political economy. India will be largely the seat of manufacture, while England will be the sale emporium

Textile fabrics in India

To produce cotton cloth there is needed, *first*, the growth of the cotton, *secondly*, steam power, *thirdly*, spinning and weaving machinery, *fourthly*, a climate naturally or artificially adapted to the process, *fifthly*, and abundant population of work-people with delicate fingers, and as regards cost the last is the most important consideration of all. The cotton can be grown in India and brought to England In England the steam-power is cheap, and the machinery the best in the world The artificial climate can also be produced in the mills, and an artificial population with delicate fingers can be selected and aggregated from Ireland and elsewhere Under these circumstances, India is out of the market save for the raw material But other European countries are our competitors The southern populations of Italy, France and Spain, Greece and Asia Minor, have a population of indigenous delicate fingers They can buy cotton as well as ourselves, and make or import machinery, and erect steam-engines They can get their work-people at a cheaper rate, they have a better climate, and therefore we shall be less and less able to compete with them But we can manufacture the best machinery and steam-engines, and if we send them to India, the advantages—cotton, climate, steam machinery and labour—will all be combined and produce the cheapest result Under such circumstances no other country can compete with India in the open market, the labour being the cheapest of all. The manufacture, therefore, will be transferred from English subjects in Lancashire to English subjects in India, and the largest sale shop will be in England Our mill-people in England work in an unhealthy artificial climate, and need much more and better food than the Indian races And it will be no disadvantage to us to lose a trade which tends to deteriorate a portion of our population, and more or less convert them into a caste So also with silk and jute and other fibres wherever they may be adapted to Indian work, India will go on increasing her manufactures The United States will not be our competitors in spun and woven-cotton, for the reason that the abundance of free soil will prevent them obtaining labour at a cheap rate as in India for a long period to come The time may come that in a portion of the United States analogous to India cotton may be both grown and worked by indigenous fingers, but we need not take present note of it

Elements of cotton manufacture

In England, and elsewhere

Transference to India

Not to the United States

Meanwhile, the great want of India is cheap transit by steam or other heat power, for animal transit on a large scale is hopeless A mule in the temperate climate of Chili can carry 400 lbs In the hot climate of Venezuela the limit is 100 lbs, and there the prime cost of the mule is multiplied by ten The only roads for India are rail-roads of the maximum and the

Mule transit in hot and temperate climates

minimum gauge, for it is a fallacy to make a large road for a small traffic A large road means a heavy engine, and a small road a light engine, with wear and tear in proportion The tram-road proper, *i e*, with a flat wheel on a flat surface is simply a very inferior and quite as costly a road as the rail-road proper The edge rail gets rid of the dirt and a large quantity of friction It is not the mere numbers of transit that are needed, but cross and intermediate roads also, feeding, and *cheap* feeding lines, not *suckers* Having these, commerce will grow, and with commerce products of all kinds will increase There is a Spanish proverb which says,—

Tram road

"With water and sand and sun and seed,
Paradise making's an easy deed"

If we look at the raised map of India, we find the snowy range of the Himalaya sweeping like a huge dam in a giant course from sea to sea, enclosing the Indian Peninsula on almost one low flat level, and keeping back the elevated table-lands of Thibet and China From every rill and stream at the very sources of the great rivers, Ganges, Indus, and others, we should hem in and utilise the waters for irrigation, planting great trees to overshadow them and lessen the amount of evaporation, while serving to attract rain With abundant irrigation and abundant railways the whole of India may become one universal garden

Indian irrigation

As the State is now entering upon the construction of Government Railways, it is worth while enquiring how far the existing Railways of private Companies comply with the requisite conditions, how far, at a given cost, they attain the maximum of strength and capacity of transit, what is their durability, mechanically and chemically, and what is their daily cost of maintenance in proportion to the work done, how far it is imperial and wasteful, or in consonance with mechanical laws?

Private and State Railways

Use and economy

If a Railway be required to traverse a given distance between two points in the shortest possible time, regardless of cost in outlay, the best structure would be apparently a line horizontally straight, but it is by no means certain that a dead level would really be the best In horse traction it is well known that a dead level tires the animal more than alternating slopes up and down hill, which varies the action of their muscles And so also an engine which has exhausted its steam in arriving at a summit level, may blow up a fresh fire, and attain greater steam pressure on running down an incline

Levels and gradients

The liking for a straight line has grown up to suit the rigid structure of the engines and carriages, and the increasing length of wheel tires to induce steadiness, and prevent oscillation while carrying a larger load. But a practically straight line is imaginary Saying nothing of the curves necessitated by points and crossings and sidings, the rail surfaces vary from one side of the rail to the other, as any one may observe, and the effect of this on the coned surfaces of the wheel tires is equivalent to a succession of small sharp irregular curves, over which the wheels do not roll, but slide The wear and tear of both wheels and tires give practical evidence of this, true rolling of the tires on the rails without sliding should involve no wear unless by a superincumbent load of crushing weight The amount of wear in common practice may be judged of by the double-headed rail and cast-iron chair common in England The object of the double-head is to be enabled to reverse it upside down, changing the top table for the botton when worn When reversed, a number of notches are commonly found in the lower table corresponding to the seats in the chairs, varying from one-eighth to half an inch in depth, according to the softness of the rail metal and the weight on the driving wheels To ride over these rails when first reversed is a painful operation like that of a new corduroy road in Canada The notches in the rails are at first square indentations In a few days the square edges are worn away, and the notches become short curved indentations As time wears away and running goes on, the short curves become longer and larger, and finally they disappear altogether, leaving the rail a plane straight on its surface

Imperfection of rails

Double head rails

Waste and wear

In this process a thickness of metal has disappeared equivalent to the depth of the notches If the process of the wheels travelling over it had been rolling, the result ought simply to have been a continuation of the curves, but the process has been sliding, and the engines and trams have acted as rough planing machines to remove the metal And whether the rails are notched or smooth, this same process of grinding away the rail surfaces is continually going on, re-acting on the wheel tires

Demonstrated

Therefore the first consideration, after determining the course of the line, which for economy should follow the natural curves of the country and the convenience of bridge structures, should be to settle the best form of rail The ordinary double head is usually applied on a chair of cast-iron spiked down on a transverse wooden sleeper, and has many defects

Best form of rail

Sheet 1—In order to form a comparison, a Tabular Statement is given, with sections of four different classes of rails. No 1, the double-headed rail, with cast-iron chairs spiked down on cross-sleepers, and secured by wood-keys driven in between the rail and chair join. The sleeper is 5 inches deep and 10

Sheet 1

inches wide, the chair 1½ inch wide and 5 inches deep This gives a leverage of 11½ to 10 on the lengthway direction of the rail, tending constantly to rock the sleeper fore and aft on the ballast by the tugging action of the driving wheels on their peripheries, and tending to spring the sleeper, and unsettle it transversely to the rails by the lateral action of the wheel flanges The sleepers are usually 3 feet apart, centre to centre, and the chairs each about 5 inches wide, so that the unsupported space of the rail between the chairs is 32 inches, the rail being only 5 inches deep and 2½ inches wide, continually springs both vertically and laterally in the chairs, and grinds away the wood-keys, loosening the rails in the chairs, so that they spring up and down with loose knocks, and add to the displacement in the ballast, caused by the leverage elevation of the rails above the burr This leverage and loosening of the upper structure allows rain to percolate to the burr, and causes rolling To put the road in order, it is necessary to remove the superincumbent earth or ballast a depth of some 12 inches, in order to be enabled to pack below the sleepers. And if the line needs packing in rainy weather, it cannot be done, so the evil must go on and get worse, till dry weather comes The opening out of the surface makes it loose like a garden bed, forming dust in hot weather, and mud in wet

Structure

Disadvantages.

The joints of the rails are what is called "fished," *i e*, the side channels below the rail tables on each side are filled up with an iron-bar rolled to fit the section of the rail, 18 inches in length, and bolted together by four cross-bolts ⅞th inch diameter, passing through holes 1 inch diameter, through rails and fishes Now as the depth of the rail is 5 inches, that multiplied by the square will give 25 inches But each fish being only 2½ inches in depth, the square is only 6¼ inches, or 12½ inches the pair, one-half the strength of the rail, and that strength lessened by the bolt holes The space between each side of the joint is 24 inches, and whoever watches an engine passing over the joints will see them bending vertically and horizontally under the passing load The fishes depending merely on the bolts to keep in position, strain and loosen them, and most superintendents know how fruitful a source of expense this is

Fish joints

Defective strength

The sectional form of rail required to prevent the head from breaking down, is an obtuse angle between the head and vertical rib But though this is the best form for the head, it is the worst form for the fish The best form for holding the fish firm, would be nearly square side channels, in which case the fish would hold in with little strain on the bolts, but in such a case, the rail head would rapidly break down, and if the angle be made at 45 degrees, it is simply making both rail and fish inefficient The fish has never yet been made as it should be, and the principle has been constantly allowed from the sheep-like propensity to follow in a given track

Years back, Mr John Chapman, one of the earliest Railway Surveyors in India, detected the fallacy of timber sleepers, and recommended iron Practical experience has confirmed his view, and considerable quantities of what are called pot sleepers, made of cast-iron, have been used They get rid of timber sleepers, but they retain the wood-keys, and the hollow bowl form will not permit the use of hard stone ballast, but only of soft material. To prevent all tendency to split open, they would require to be much heavier, a serious evil, when freight has to be considered (*See* No 2, Sheet 1)

Iron sleepers

In addition to the other defects of the double-headed rail, there is another important consideration By the running of the wheels on the upper table, when not crushed it has a tendency to become granular, and when turned over, it is found to have lost so much of its tensile strength as to be very liable to break Moreover, it is impossible to fit a worn top tightly into a newer chair, and the break is greatly increased

Rail vibration

What then should be the form of the rail? Some Engineers have taken to the foot rail using the metal, of one of the tables expanded to a flat foot resting on the sleepers, and held down by dog spikes Formerly, these rails had holes punched through the flat part to take the spikes, but this was found to weaken them and cause them to bend

The foot rail is now made usually five inches in height, and five inches broad in the foot, and this being apt to tilt laterally with the pressure of the flanges, six inches are found more desirable, and seven to eight inches would be better, but as the foot requires to be very strong and heavy to prevent bending upwards, the weight becomes greater than that of the double-headed rail, and with the width of the foot the difficulty of rolling increases (*See* No 3, Sheet 1)

Foot rail.

What is really wanted is, first, vertical strength in the rail to resist vertical flexure. Secondly, breadth of head or table to resist lateral pressure Thirdly, depth of head or table to resist crushing under the load of the driving wheels By applying the metal as a single head instead of a double head, and dispensing with the foot, a very efficient form may be obtained without exceeding in weight A rail 75 lbs per yard, 7 inches deep, 3 inches wide in the head and 1½ inches deep, would be double the vertical strength, and one-half stronger laterally than the double-head of the same weight.

Requirements of rails

Depth

Width

As regards durability against wear, hard granular iron is the best, better than what is called steel. Steel is a treacherous materials unless under one of two conditions, difficult to attain—equally hardened and tempered throughout, or equally annealed throughout If varying in hardness the rails break, it is, therefore, generally recommended to "keep them soft," which means to take out the carbon required for the original smelting, and reduce them to the condition of iron, and, be it observed, homogeneous iron without scale But as it is softer, it is not so well adapted to resist the action of the brakes till it gets hardened by the rubbing of the wheels, and in most cases it is apt to become brittle

Hard iron or steel

Having obtained the best form of rail, the next question is how best to secure it on the ground or ballast, how to give it the most continuous support, how to keep the head of the rail with as little elevation as possible above the bearing surface on the ballast, how to lessen the number of types and parts to the minimum, how to pack it easily and without disturbing the surface, and lastly how to arrange the fastenings to be out of the reach of pilferers

These conditions are attained by the diagram form No 4, Sheet 1, wherein the deep rails before described are placed in a succession of iron grooves, the rails bearing beneath the head or upper table along the upper edges of the grooves, each sleeper being 2 feet long and 12 inches wide, with a space of 12 inches between, thus the rails are supported through two-thirds of their whole length They are keyed down to each sleeper by a single parallel key of round iron, driven in the mode technically called "draw bore," so that the rail cannot rise from its seat The opposite sleepers are locked together by a tie-bar clipping them and fixing the gauge without bolt, or screw, or key The rail joints meet in the middle of a sleeper, and are secured by four parallel keys, so that fishes and fish bolts are dispensed with Thus, then, the system is reduced to four types or parts, and fishes, screw-bolts, wood keys, timber sleepers, spikes, and trenails are all dispensed with The keels descend about seven inches deep into the ballast, forming a nearly continuous keel, keeping the gauge with perfect accuracy, but permitting lateral bending when laying on, to form accurate curves as sharp as may be desired. The bearing being on the surface of the ballast, any subsidence beneath the rails is restored with the minimum of labour, being at once perceived, and the elevation of the rail being only three inches above the bearing, twelve inches wide, the angle of stability is at the maximum Sheet 2 shows a section of the rail and sleeper full size, with the tie-bar and round iron key, and also a half plan and side elevation on a smaller scale, placed in position on the ballast The system is then shown as applied in ordinary ballast, which may be earth or broken stones

Iron groove sleepers

Joints

Four types

Adapted for curves

Angle of stability
Sheets 2 and 3

But there are conditions of land requiring other provisions, notably boggy ground, and what is called black earth, which in rainy weather becomes a species of quicksand To meet these conditions, the bearing surface supporting the rails must be extended, and made buoyant Sheet 3 shows how it may be done by placing broad flat longitudinal sleepers of creosoted timber beneath the wing bearings, keeping them *in situ* by lengthening the iron keys and turning them down at the ends The plan is shown to a scale one inch to the foot, the section full size Brushwood can also be used beneath the timber still further to increase the surface A full-sized model of a piece of rail and a sleeper, with key and a portion of the bar, showing the mode of fastening, accompanies the diagram sheets

Boggy ground and black earth

Sheet 1, showing four systems of permanent-way including that last described, gives tables of particulars for comparison The last, No 4, has only four types against eight types or parts, the maximum It has only 9,936 parts per mile, as against 22,888, the maximum Elevation above bearing surface, 3 inches to 12 inches, as against 11½ inches to 10 inches No timber sleepers or wood keys Rails 7 inches deep, with 3 inch head, as against 5 inches deep and 2½ inch head Bearing surface of rails or sleepers 587 square feet, as against bearings in chairs 244 feet per mile Length of bearing, two-thirds, as against one-seventh Bearing area of sleepers on ballast 7,040 square feet, with angle of stability 3 inches to 12 inches, as against bearing area of 8,000, with angle of stability 11½ inches to 10 inches Fastening all secured out of sight of pilferers, as against exposed fastenings Depth of ballast required 6 inches, as against 15 inches Vertical strength of rail 49, as against 25, the weight per yard being equal.

Comparison
Four systems

Parts per mile

Rails
Bearing surface

Ballast

Strength

The system is well adapted for bridges, the keel descending between parallel beams, while the bearings rest on their surface. And the form of the sleeper is a strong one as against breakage.

By the facility of forming curves, what are called turn-tables—a piece of costly machinery, with costly foundations—may be dispensed with, and a great saving of time obtained in reversing the engine and train If a turn-table be used on a Main Line, the loose parts are a great source of destruction of run over at speed, and, if placed on a siding, involve extra expense of rails, sufficient to form curves and dispense with the turn-tables altogether

Turn tables.

Gauge of way

The gauge of way has been wisely settled at 5 feet 6 inches, an immense advantage and economy as compared with the narrow gauge which has unluckily become the standard in England for our Main Lines There are circumstances, as for towns and suburbs, wherein gauge, if less than 4 feet, becomes a useful and important economy, but with large traffic, a narrow gauge involves waste in transit

Gauge of vehicles

The gauge of way being settled at 5 feet 6 inches, the next question is, what should be the gauge of trains as to their carrying capacity The wider the vehicles can be made, the shorter may be the train, and other things being equal, the shorter the train can be kept, the less will be the difficulties involved in the manipulation. Therefore it is desirable that the vehicles should over-hang the wheel base to the greatest extent consistent with safety against tilting Practically the vehicles may be

Double the width of gauge

safely made double the width of the gauge, and probably double the width of the spring base, which may be about 8 feet, and this would give an inside width of vehicles of 11 feet 6 inches, equal to 7 third-class passengers, 6 second-class, and 5 first class abreast In the ordinary mode of construction the usual limit of width would be 8 feet 6 inches

Length of vehicles

With regard to the length of vehicles, there must be a certain proportion of length to breadth, to ensure steadiness of wheel base and freedom from oscillation Three breadths to a length would be a convenient proportion for four-wheel vehicles, say 16 feet The points of support should be direct from the handstocks, to prevent the vehicle from "hogging," and the springs should be sufficiently long, and wide and flexible, to prevent blows The springs and supports would therefore extend the length of the body to 25 feet The frame supports would therefore be divided into four

Sheet 4

equal lengths, of about 6 feet each, with a floor area of about 260 square feet The diagram, Sheet 4, shows a diagram elevation of a wagon so constructed, with self-acting brakes

Radial "caster" vehicles

Mechanically considered, a vehicle with a 16 feet wheel base must of necessity involve much flange friction, not merely on special curves of small radius, but also on the multiplicity of small curves caused by irregularities of the rails The cones of the wheels are supposed to compensate for their irregularities, but that is fallacy To accomplish this, lateral movement of the wheels is needed, and lateral movement, fulfilling the required conditions, can only be attained by a "caster" movement of the wheels at either end, permitting the axles to take radial lines corresponding to the centres of the rail curves With this arrangement, the vehicles may run without flange friction, round curves as sharp or sharper than one chain radius In such case, the headstocks of the vehicle should be formed with curved buffers, so that the thrust will always be true to the frame centres, without risk of getting off the line This class of vehicle will

Sheet 4 *a*.

be well adapted for goods or passengers for ordinary use Sheet 4 *a*

Eight-wheel radial "caster" vehicles.

But supposing a very large traffic, vehicles of double the length will be more advantageous, as involving fewer openings in the length of a train, and to enable them to traverse sharp curves the wheels should be disposed in two groups of four each group, one near each end The vehicles should be built in two parts, to couple together by bolts to form one frame, thus affording facilities for removing them from the line in case of repairs Wagons for bulky goods built in this

Inside measure, 50 feet by 11 feet 6 inches.

mode will afford much more stowage space With 50 feet of length and 11 feet width, a floor area of 550 feet superficial may be attained

Sheet 5

This general construction is illustrated in Sheet 5, where the Diagram No 1 shows a double carriage with an under-frame at each end, suspended by springs with long swinging shackles, so that the wheels can diverge to right or left, true guidance being given by central pivots fixed to the upper frames, which rise and fall through corresponding holes in the spring frames To the spring frames brakes are attached, revolving round the central bars, and which brakes can be worked

First second, and third class, 324

by gravitation levers pressing the blocks on to the wheels Thus every wheel can have a block, without any jar or motion being communicated to the body of the vehicle, and without the need of supplementary brake-vans No. 1 represents a second class with 10 separate bodies for 12 passengers each, total 120, No 2 shows a third class, with 10 bodies for 140 passengers,

Sheet 6

No 3, a first class, with 8 bodies, 8 passengers each, 64 total Sheet 6 shows this in cross-section

Saloons for long journeys Sliding doors

There are conditions in which it is not desirable to divide the vehicle into separate compartments all alike The double carriage can be divided into two parts, separation by sliding doors, one-half for ladies, the other half for gentlemen Each half can have a saloon, a kitchen, a bath-room, two private compartments, a close lobby, and an open lobby at the end, with two entrances and communication throughout All the doors are made to slide instead of to hinge, which gives a facility for keeping them open during a journey, a most important consideration for coolness and ventilation And this sliding arrangement is very important in avoiding risk at station platforms and saving space

Transport of Troops.

It is of the utmost importance that large many-wheeled carriages should be employed, and that the wheels should be radial to enable them to run round sharp curves, because independently of their advantages on the low flat country, it is essential to the easy surmounting of the steep and curvilinear roads giving access to the slopes and elevations of the healthy hill country And the same vehicles that serve the purpose of the low country will be perfectly adapted for the transport of troops to and from the hills And such vehicles will be equally adapted to the transport of troops to

Artillery batteries moving

and from the hills and to the transport of batteries of Artillery of considerable size and weight, capable of being used on the large wagons in pursuit of an enemy, with abundance of ammunition, if need be, under armour shelter

6,000 troops, one train

Each eight-wheeled third-class could carry 140 soldiers, weighing say 10½ tons, with the vehicle, say 20 tons Forty-three vehicles would thus take a load of 6,000 soldiers, and saying 10 extra for luggage, making 53, would be equal to about 1,100 tons

Engines. Twin engines, 20 miles per hour Gradients 1 in 50

An engine with cylinders 24 inches in diameter could haul such a train up and down gradients of 1 in 200 at a speed of 20 miles per hour, and a pair of such engines radially coupled, up and down gradients of 1 to 50, with an ample supply of fuel and water for a considerable distance

Sheet 6

Sheet 6 shows, in cross-section, the wheels, springs, frame, and body of a four-wheel or eight-wheel passenger carriage as before described

Sheet 7

Sheet 7 shows a pair of coupled engines with true radial movement to roll freely without flange friction round curves of 2 chains radius

Twin engines

Each engine is carried on eight driving wheels, 3 feet 6 inches in diameter, worked by a pair of cylinders 24 inches in diameter, and 24 inches stroke The total wheel base is 21 feet 6 inches, and the four central drivers are without flanges The fire-box is about 8 feet long, and the height from the rails 7 feet 6 inches

Steam brakes

A pair of wedge brake blocks, one on each side, actuated by a pair of small cylinders, put a retarding force by steam on all eight wheels, at the will of the driver, and of course on 16 wheels to the two engines

Armour covered engines

Sheet 8.

As these engines are contemplated to be used for war purposes, they are shown provided with an armour covering, denoted by the blue lines, 1½ inch thick, capable of glancing or resisting musket shot, or anything less than cannon Sheet 8 shows the whole or cross-section, boiler, cylinders, frame, bearing, springs, wheels, axles, boxes, and ammunition Everything is covered to within 3 inches of the rails, and the driver or drivers, if two for security, are sheltered by rising armour hoods The armour can be lifted on or off by a crane at pleasure The total weight of each engine, armour and water tanks inclusive, would be about 55 tons, or 7 tons per wheel, a weight excessive for ordinary purposes, but not damaging if hoops of spring steel be applied between the wheel and tire, of which there has been ample practical demonstration

Separating twin engines to form two

With the armour taken off, these engines may be separated and used apart, each can have a tender, with radial wheels bolted to the fire-box end, making two complete engines for ordinary use, running with perfect steadiness round sharp curves

Inside and outside cylinders.

There are two classes of engines in ordinary use, those with inside and those with outside cylinder, the latter are the simplest and the easiest kept in repair The advocates of inside cylinders claim as their advantage that the cylinders placed close together on the smoke box can be kept warm to prevent condensation, and that the pistons being near together inside the wheels do not cause the engine to oscillate so much as when the pistons are outside But to set against this, it sometimes happens that the cylinders in the smoke box get too warm, so as to roast the oil

Crank and straight axles

on them, and, again, the inside cylinders require a crank axle not needed for the outside, for which a straight axle suffices And, moreover, the smoke box can be made to cover outside cylinders, and keep them warm without the risk of burning And there is a serious disadvantage in the crank axle, that it causes the boiler to be carried a foot higher to get out of the way of the cranks, elevating the centre of gravity, and this crank axle, if straightened out, would be found to be four feet longer than the straight axle with four outside cylinders, and, therefore, it is a weak axle, and constantly subject to a transverse and tortional strain, which is a frequent source of accidents Again, a certain amount of oscillation is produced by the inside cylinder engine, owing to its high centre of gravity and its short wheel base The advantage of the inside cylinders is that they can be placed nearly close to the leading axle, being within the wheels, whereas the outside cylinders must be projected beyond the wheels, causing overhanging But in the arrangement of the coupled engines, shown at Sheet 7, the overhanging of the outside cylinders is counterbalanced

Length of wheel base

by the length of the wheel base, which is 38 feet, against 13 feet, the ordinary base of the inside cylinder engine If the straight axle, measuring 4 feet 6 inches between the wheels, be 7 inches in diameter, the crank axle measuring 8 feet 6 inches between the wheels, should be 14 inches in diameter

These coupled engines, Sheet 7, are well adapted to draw heavy trains on steep inclines and sharp curves, such as the ghâts on the slopes of the Himalaya But for working steep inclines with heavy trains, it becomes a very important consideration how to prevent accidents The radial system before described prevents all risk of the wheels getting off the rails, but there is the question of couplings breaking away or slipping In such case, a portion of the train may get loose and run back, without the driver being aware of it It is possible, by a fitting arrangement of self-acting brakes, to prevent this Sheet 4a, shows this The brake-holders, forged on the ends of long levers, are suspended from the axle-boxes in such mole that the weight of the lever, acting as a steelyard by gravitation, brings the blocks in double contact with the wheels, and if two levers be used, all four wheels may be braked Thus the normal condition of these brakes is to be always pressing on the wheels when not taken off The weights of the blocks pressing on each pair of wheels is 1,120 lbs, or one ton per wagon on four wheels The weight at the lever end is 80 lbs, or 160 lbs per wagon By the sheeves in the lever ends this weight is reduced to 80 lbs Second sheeve in a snatch-block reduces it to 40 lbs, and this again, by the multiplying winch in the guard-van behind, or in the engine in front, may be reduced to 13 lbs. to lift the weight of one ton at the wheels A thin rope working over rollers will suffice to put on or take off brakes from any or every wagon in the train. Any wagon can have the brakes put out of use by a hand winch

Self acting continuous brakes

Now supposing a heavy train, ascending a steep incline, to separate into two parts by the breaking away of a coupling, the lifting rod will break at the same time, and every brake block will drop in succession on the wheels, not only on the hinder part, but also on the part remaining attached to the engine, thus calling the driver's attention The workmanship of these brakes is all of the commonest kind, and they are not liable to get out of order

Safety in case of a coupling breaking on an incline

With regard to the spring tires before alluded to, an accompanying reprint from two papers, by Mr Cross on locomotive engines, for sharp curves, and myself on impedimental friction between wheel tires and rails may be referred to, in which the questions were discussed at the Institution of Civil Engineers, showing the increased durability of spring tires and their greater amount of adhesion There is a diagram sheet, illustrating the plan, attached to the paper

Spring tires to wheels

Papers Institution of Civil Engineers

Sheet 9 shows an engine with a 29 feet wheel base, six drivers, 4 feet 6 inches in diameter, and four radia trailers 3 feet 6 inches in diameter, outside cylinders, one frame, in two parts, bolted together by inch clamps, to separate when needed or to take out the wheels Water in tank 2,000 gallons, 22 inches cylinder, 30 inches stroke, small steam cylinders to lift wedge brakes between drivers, brakes to radial trailers attached to the axle-boxes, pulling off by gravity, and put on by chain and capstan on foot plates This engine is adapted for drawing heavy trains

Sheet 9

Goods engines.

Radial.

Sheet 10 shows a similar engine in elevation, and plan for greater speeds. It has four coupled drivers 5 feet 6 inches in diameter, and four trailers 4 inches diameter The trailing wheels are connected by side frames to the axle-boxes, and by a cross curved frame working between horn plates to right or left, and placing the wheels and axles in a radial position, equivalent to a curve of four chains radius. Two sides springs bearing on the axle-boxes, and with central slide bolts passing through the axle-box frames, the springs being firmly connected by a cross bar support the hind end of the engines on their buckles, sliding beneath the upper frame, which is rigidly bolted together, but capable of separation by unbolting the coupling plates Thus the length of the frame steadies it against the crushing of the cylinders The breaks are steam-worked to the driving wheels The brakes to the trailing wheels fall off by gravity, and are applied by a chain worked by the stokers with a small capstan sunk on the foot plate The tank holds 2,000 gallons of water

Sheet 10

Radial speed engine

Radial engine structure

This engine is similar to 37 radial engines now working on the Great Northern and Chatham and Dover Lines, with the exception that instead of two trailing wheels with radial axle-boxes and 1,000 gallons of water, it has 4 trailing wheels with ordinary boxes and a curved cross-bar, and carries 2 000 gallons of water The buffers are radial, and the traction hooks have side movements on bars to suit curves

Great Northern and Chatham and Dover Lines

By the rapid application of brakes to all the wheels of the engine and self-action gravitation brakes to the whole of the wheels of the train, the retarding power can be so distributed as not to damage the wheel tires by sliding

Brakes to all wheels, engine and train

The brake blocks are not of timber, but of cast-iron studded with copper in perforations, giving good adhesion without requiring constant replacement, as when wood is used

Metal brake blocks.

The question of axle friction should be well considered, and to this end easy springs are essential, as well as ample friction bearings To ensure perfect lubrication, an abundant cushion of oil or grease should be interposed between the axle-arm and the bearing If a viscid unguent like soap be used, the adhesion will increase the resistance to traction unless in a correspondingly warm atmosphere, and if oil be used, it will require a more ample bearing surface With the wheels made radial to move with freedom laterally, and with easy springs, the resistance may be reduced to one-half that which a rigid system involves

Axle friction and lubrication.

Branch lines and four lines may be worked on the same gauge with lighter rails if heavy engines be kept of them But if engines of too great weight get on light rails they will destroy the line

Branch lines

Practically, for suburban purposes, a 3 feet 6 inch gauge would suffice, giving vehicles of 7 feet in width, equivalent to 50 passengers inside and out, accessible from the ground level, like ordinary omnibuses, and the question is now springing up of heated air engines, which, found to be quite practicable for stationery purposes still, ere long, become locomotive also These engines involve no risk whatever, as they have no magazine of power like a steam boiler, but only create their power as they use it, and no faster Needing no water and no skilled workmen, and being very economical in fuel, they will, though with a small power per square inch, be very valuable as a motive power for light transit, and also for stationary purposes And these engines needing no skilled labour, but only the most ordinary kind, will be found especially valuable for the production of artificial cold and ventilation in dwellings, so all important in a hot climate when a clear brain is requisite for thought in the processes of science and for judicial trials

Suburban lines, gauge 3 feet 6 inches.

Hot air engines.

Steam-engines weighing less than eight tons on four wheels would be equivalent to the transit of 200 passengers up gradients of 1 in 30, and round sharp curves at 10 to 15 miles per hour, or 700 to 800 on the level

Sheet 11

The general condition of dry rails in India is very favourable to the adhesion required for traction, but in hilly districts moisture prevails, and then it becomes needful to use sand to increase the adhesion But this adhesion is only useful for the engine-driving wheels. As regards the train wheels, it is a mischief But with the radial system, the engine can be made to propel the train up inclines from behind, without any risk In this case, the carriage wheels are not impeded, while the sand can be freely used to the engine, and the maximum result of load may be greatly increased. And the flanges of the driving wheels may be formed into cones fitting corresponding angles of the rails, in which case the adhesion may be still further increased

Adhesion of driving wheels

Working up hill, engine behind train

There is yet one important question, fuel for locomotion Whether the power be steam or heated air, we must have fuel Coal exists, and so does liquid coal or petroleum, both in Rangoon and the Punjab, and boring is about to be tried Fuel which is most easily disintegrated to form gases is the best, mixing the gases with atmospheric air for the purposes of combustion, and that which gives out the greatest volume of flame is that which produces steam most rapidly, by impinging on the largest amount of heating surface Anthracite coal or coke is only steam making in the ordinary way by the amount of surface that comes into contact with its red heat The hot air evolved passes rapidly away by the chimney, without imparting heat to the boiler Petroleum blown by compressed air in the form of fine spray on to a small fire flashes into a large mass of flame rapidly, and developes a corresponding mass of steam If petroleum be found in abundance, as in the oil wells of America, locomotive engines may run without smoke, or dust, or dirt, or labour, or annoyance to the drivers or passengers, and also without risk of sparks communicating fire to the lands along the Railway The Punjab Railway, running to the sources of the Indus, may probably be worked in this mode, and will open up to English colonisation as healthy sites as any in Europe, and will civilise Affghanistan by constant contact with commercial profits without the processes of war, possibly converting it into an Indian Switzerland Along the boundaries of the Punjab, the English race, looking upwards to Thibet and Cashmere, may become a permanent offshoot of our nation, and a future land of freedom, setting a type to the strong men of the warlike tribes around them to work by, till they shall grow into the conviction that has obtained in England, that commercial peace is more profitable than spoliatory war

Fuel.

Petroleum

Flame

Punjab Line

Hill Lines

There is yet another consideration connected with this question, our shortest route between England and India What is in the future of ships along our ocean highway we have not yet worked out, but our possibilities therein are yet far from having culminated Meanwhile, when we get to channel steamers large enough to abolish sea sickness, our route will probably lie from the Thames through Belgium, Germany, Switzerland, and Italy, till we are again on board of a non-sea-sickness steamer at Brindisi, and, passing by Cyprus, land at the sea-port of Aleppo, and thence by rail pass down the shores of the Euphrates to the Persian Gulf, whence steamers again land us near the Indus, on the route to the healthiest neighbourhood in India The Euphrates route lies through Turkish territory, and assuredly English capital may be quite as safely vested in them as in Russian Railways And it is more than our mere transit that is concerned It is the re-civilisation of the ancient eastern countries, it is the reclamation of the Arabs, with all their natural commercial skill and aptitude, from the occupation of mere camel drivers to that of servants of the rail

Euphrates Railway

Arab civilization

It is the reclamation of the desert, winning another portion of the world from the wilderness, by economising the waters of the streams and rivers to yield a tribute of green harvest before they pass into the ocean, making the Euphrates into another Nile, with a world's commerce passing around it And with the awakened spirit that grows with the perception of new knowledge, it is more than probable that a new spiritual life will arise, when the Crescent will subside into the Cross As the Americans have a Far West, so have we a Near East fallen into savagery by despotism, and only to be reclaimed by the advent of freedom

Sheet 11 Small locomotion

Sheet 11 shows a small steam locomotive for suburbs Four drivers, 3 feet 6 inches diameter, one trailer, radial, 3 feet diameter, 9-inch cylinder, 18-inch stroke Steam brakes 380 gallons water Radial buffers and traction bars For one-chain curves

Conclusions

The conclusions arrived at on the subject of rail transit in India may be thus summed up —

1 That timber, by reason of its rapid destruction, not merely by insects, but by alternations of hot sun and heavy rain, is an unfitting material for the construction of permanent-way, unless on boggy ground or quicksands, as a mere float, and on small rises

2 That the iron now used on permanent-way in India is not so used as to produce by its mechanical structure the greatest strength and durability in reference to its carrying capacity

3 That the carriages and wagons by reason of their non-flexibility and want of elasticity prevent the economic use of curves, the wheels being placed in parallelograms forming tangents with the curves, grinding out both tires and rails, and involving great risk of getting off the rails

4 That the carriages are hereby kept much shorter and much narrower than need be the case were the mechanism so arranged as to keep the wheels parallel with the rails, instead of at tangents

5 Properly constructed, the width of the carriage bodies made should be at least twice the width of the gauge of the rails.

6 That with bulky goods, not very dense, the greater the floor area in each wagon, the larger may be the proportionate amount carried

7 That, by means of bolting two carriages together endwise, greater steadiness can be obtained, with facility of structure and repair, and a greater number of passengers can be carried with ease and comfort And that for long journeys such carriages may provide every convenience for eating, sleeping, bathing, and recreation, and, by submitting sliding doors for hinged doors, coolness and ventilation may be attained while travelling, and greater convenience and safety at stations

8 That the rigidity of existing vehicles involves at least one-third more resistance than would be the case were they flexible and elastic, in which case one-third more passengers or goods might be carried with the same engine power

9 And that, with flexibility and elasticity, curves of two or three chains radius might easily be worked on steep inclines, when ascending mountain slopes, a very important consideration on laying out lines, to save cost in construction

10 That by flexible construction of locomotive engines, a greater number of driving wheels can be used, and the tender connected in one frame with the engine, so as to run either end foremost, without the necessity of reversing And by the number of driving wheels the load may be more distributed, with an ample supply of water and fuel, and thus a much more powerful engine may be obtained

11 That such an engine would be capable of transporting a small army of six to eight thousand Infantry on the level, with baggage up gradients of one in two hundred, at a speed of 20 miles per hour And two end engines, twin coupled, would work the same train up gradients of one in fifty

12 That with such vehicles, batteries of Artillery could be mounted and protected by armour with ample ammunition under safe cover

13 That the engines could be covered with armour formed to glance shot, and with the skirts of the armour reaching nearly to the rails, to prevent all chance of oversetting

14 That such appliances being easily obtained and used by the State, and not by revolters or uncivilised people, would give immense advantage in case of outbreaks

15 That advantage could be taken of ordinary roads to lay down rails on them when requisite for multiplying communication.

16 That a cheaper class of lines of narrow gauge, to be worked by light engines, could be constructed for about 2,000*l* per mile, capable of carrying 500 passengers per train on the ordinary gradients, and that there is a strong probability that level lines may use hot air as a motive power, simplifying structure, and greatly lowering cost, while absolutely free from all risk of explosion, while needing no water, such lines needing no platforms, the vehicles being accessible from the level and not requiring skilled labour

17 That, if procurable, the best fuel for locomotive engines, whether used for steam or hot air, will be of the liquid fuel, such as petroleum, and that when solid coal is used, it will be desirable to make it chemically more available by artificial preparation.

18 That the advantages to be gained by widening the carriages are so great as to outweigh all considerations of the cost of widening the stations of existing lines

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ORDER.—Ordered, that copies of these papers be forwarded to the Local Governments and Administration noted in the margin, with the intimation that spare copies of the pamphlet on "Locomotive Engines for Sharp Curves" and "Friction between Wheel Tires and Rails" will be subsequently supplied, if obtainable.

Madras. Bombay | Bengal Punjab Chief Commissioner of Oudh

In Secy's No 1250/160 R, 20th Oct 1868

A. Alexander, C. E., Asstt Secy

for Offg. Secy. to the Govt. of India.

To

The Secretary to the Govt of Madras in the Public Works Dept (Ry)

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