(*Paper No. 3342.*)

“Federated Malay States Railways, Perak and Province
Wellesley.”

By CHARLES RASTRICK HANSON, M. Inst. C.E.

PREVIOUS to the opening of the Larut Railway, in the State of Perak, the principal port in the north of the State was Teluk Kertang, on the Larut River, which was connected, by a metalled cart-road about 6 miles in length, with Taiping, the chief town of the State, Fig. 1, Plate 9. Frequent outbreaks of cattle disease, causing interruptions to cart traffic, demonstrated the necessity for a more reliable means of transport between the port and the mining district of Larut than was afforded by bullock-carts. In 1884 a railway came to be looked upon as a requirement which could no longer be dispensed with, and construction was commenced as soon as a suitable position for a new port, easier of access than Teluk Kertang, was determined upon. The Larut Railway, $8\frac{1}{4}$ miles in length, from Port Weld, on the Sapetang River, to Taiping, was opened for traffic in 1885, and has proved a financial success, earning between 6 per cent. and 10 per cent. per annum on the capital expenditure, after deducting the cost of working and maintenance; it was extended in a northerly direction for a distance of $8\frac{3}{4}$ miles in 1889–1890.

In May 1891, the construction of the Kinta Valley Railway, a line 50 miles in length, was commenced. The construction of this line from the port of Teluk Anson on the Perak River, in the south of the State, through the district of Lower Perak, Batang Padang and Kinta, to Ipoh, the principal town of the Kinta district, was undertaken with the same object as that in the Larut district, namely, to cheapen the cost of transport to the mining districts of Perak, to obviate the inconvenience caused by periodical interruptions to cart transport, and to aid in the general development of the State. Until this line was opened for traffic, all supplies for the mining district of Kinta were conveyed from the port by the laborious poling of flat-bottomed boats up the Kinta River (a journey occupying 6 days to a fortnight), to

villages on the river-bank, whence they were carted to the trade centres and mines; goods had sometimes to be unloaded on the banks of the river, as in dry seasons boats could only ascend the higher reaches of the river with half-loads. Consequently there was always great uncertainty as to when a cargo would reach its destination, as well as risk of damage and loss. This line also proved a financial success. It was opened in sections, as these were completed, the final section being opened in May, 1895; the profit earned on the first year's working was equal to nearly 9 per cent. on the capital expenditure; it was extended for a distance of 13 miles in 1896.

It having been decided to connect the two Perak railways, and to extend the Larut Railway through the Krian district and Province Wellesley to the Prai River opposite the Island of Penang, and also to connect the Perak railways with that under construction in the neighbouring southern State of Selangor, surveys were commenced in 1896; and in the following year, as soon as the surveys were sufficiently advanced, construction was commenced at several points on the new lines. The total length of the Perak and Province Wellesley Railways, as finally decided upon, is 213 miles 64 chains, of which, at the end of 1901, a length of 147 miles 31 chains was open for traffic, 29 miles was completed ready for opening, and 37 miles 33 chains was still under construction. Of the total length, 188 miles 62 chains forms part of the main trunk-line running down the Malay Peninsula, the aggregate length of the two branches, from Taiping to Port Weld and from Tapah Road Station to Teluk Anson, being 25 miles 2 chains, Figs. 2, Plate 9. The northern terminus of the railway is at Kuala Prai, in Province Wellesley, and communication is maintained between the railway terminus and George Town in Penang by a service of ferry steamers running in connection with the trains; the time occupied in crossing is 20 minutes. In Penang a steel screw-pile jetty has been constructed, running out to the $1\frac{1}{2}$ -fathom line, with a timber superstructure roofed with corrugated iron; a tee-head, 97 feet by 30 feet, is being constructed at the end of the jetty, also on screw-piles, placed at an angle to suit the set of the current in Penang Harbour, with suitable arrangements for the landing of passengers from the ferry steamers; provision for the warehousing of goods transported by rail is also to be made.

The ferry steamers, which have a draught of 6 feet and carry four hundred passengers, were built by the Hongkong and Whampoa Shipbuilding Company for the Federated Malay States Railways;

they are twin-screw steamers, maintaining a speed of 11 knots, and have proved well adapted for the purpose for which they were built, being easily handled and navigated through the shipping which crowds the Port of Penang; the captains and crews are Malays. Passengers only are carried by these steamers, but they are also fitted up for the conveyance of horses and carriages. Goods carried by rail and intended for transport to George Town are shipped into lighters at Kuala Prai, which are towed across the channel between the mainland and the Island of Penang by the ferry-steamers in the intervals of the passenger train-service; goods for transport by rail are dealt with in a similar manner.

From Kuala Prai the line runs, for the first 36 miles (of which 23 miles 19 chains is in Province Wellesley), through cultivated land, with sugar, cocoanut, and tapioca plantations intermingled with padi or rice-fields of considerable extent. Numerous canals used for the transport of sugar-cane are crossed on bridges of 15 feet span, several unimportant rivers on spans of 40 feet to 80 feet, and, at the 21st mile, the Krian River is crossed on a bridge of two spans of 150 feet and two spans of 100 feet. Between the 36th mile and the 42nd mile the country is low-lying, thickly-wooded, and swampy. The impounding reservoir for the Krian irrigation-works is crossed on an embankment 12 feet in height, through which there are bridges of 40 feet and 65 feet span for the Tengah and Merah Rivers, and at the 46th mile the Kurow River is crossed on a bridge of 150 feet span; the line then runs almost due south and through the mining district of Kamunting till it reaches Taiping, at the 59th mile. On this section the line is principally in embankment; there are thirteen bridges of 40 feet span and upwards, eighty-two bridges of less than 40 feet span, and forty-two culverts. The aggregate length of the curves is 10 miles 50 chains, of which $6\frac{1}{2}$ miles consists of curves of greater radius than 28 chains. The sharpest curves are of 15 chains radius, with the exception of a curve of 12·22 chains radius, in Kuala Prai station-yard. The steepest gradient is 1 in 150, but of this there is only 23 chains length, and there is 32 miles of level line. The short lengths of 1-in-150 gradient were introduced to raise the line at the Krian River crossing, in order to give greater headway for tongkongs and junks passing up and down the river. The earthwork averages 31,000 cubic yards per mile.

On the next section of line, Taiping to Kuala Kangsar, a length of 19 miles 13 chains, the character of the country changes

completely ; for one-half of the distance the line is of the type of a mountain railway with heavy works, steep gradients, reverse curves, tunnels and retaining-walls. There are 7 miles 76 chains of 1-in-80 gradient, 1 mile 45 chains of 1-in-200 gradient, and only 2 miles 61 chains of level line ; there are fifty-nine curves, having a total length of 7 miles 66 chains, of which twenty-nine curves, having a length of 3 miles 5 chains, are of 10·86 chains radius. There are six bridges of 40 feet span and upwards, five bridges of less than 40 feet span, and eighty-three culverts. The four tunnels on this section have an aggregate length of 869 lineal yards, and there are 112 lineal yards of cut-and-cover work. The earthwork and rock-excavation is estimated at about 80,000 cubic yards per mile.

Leaving Kuala Kangsar the line crosses the Perak River at the 83rd mile on a bridge of seven spans of 150 feet, and then rises with a gradient of 1 in 150 for a distance of 3 miles 60 chains as it emerges from the Perak River valley and crosses the watershed into the Kinta River valley ; Ipoh, the principal town of the Kinta district, on the banks of the Kinta River, is reached at the 112th mile. From Ipoh the line is continued down the Kinta River valley, crossing the Pari, Kinta and Kampar Rivers ; it then rises with a gradient of 1 in 200 for a distance of about 2 miles, and descends into the valley of the Batang Padang River ; Tapah Road Station, the junction of the Teluk Anson branch, is at the 145th mile. This section of the line is of much the same character throughout ; the earthworks are moderately heavy, averaging about 50,000 cubic yards per mile, but the amount of bridging is considerable. The aggregate length of the curves between Kuala Kangsar and Teluk Anson, a distance of 83 miles 51 chains, is 12 miles 49 chains, the sharpest curves being of 15 chains radius, but for a total length of 13 chains only. The gradients in general are easy, there being 27 miles 21 chains of level line, 16 miles 22 chains with easier gradients than 1 in 400, and 21 miles of gradients between 1 in 150 and 1 in 200. There are twenty-one bridges of 40 feet span and upwards, seventy-five bridges of less than 40 feet span, and seventy culverts.

Between Tapah Road Station and the junction with the Selangor Railway at Tanjong Malim, a distance of 43 miles 76 chains, the line is almost entirely through heavy forest ; it crosses several rivers requiring spans of 150 feet and upwards, and the earthworks are heavier than in the preceding section, averaging 58,000 cubic yards per mile. The ruling gradient is 1 in 100, and of this there are 5 miles 42 chains ; of gradients steeper than 1 in 250 there are

altogether 22 miles 17 chains, and there are 12 miles 28 chains of level line. The aggregate length of the curves is 11 miles 12 chains, all the curves being of greater radius than 20 chains except one, which is of 14.47 chains radius for a length of 20.46 chains.

Branch Lines.—The Port Weld branch-line, constructed in 1884–1885, is 8 miles 24 chains in length, and is practically a straight line, there being only two curves, having an aggregate length of 32 chains, outside station limits; the steepest gradient is 1 in 300, but a length of 4 miles 38 chains is on the level. This line is chiefly in low embankment, and for more than half its length through swampy ground; there are five small bridges not exceeding 15 feet span, and five culverts.

The Teluk Anson branch-line, 16 miles 58 chains in length, runs through heavy forest throughout its entire length; for the first 4 miles from Tapah Road the country is gently undulating, after which the line is through a perfectly flat country with one long low continuous embankment till Teluk Anson is reached. The steepest gradient is 1 in 225, and the sharpest curve is 25 chains radius; there are several long straights, the longest measuring $4\frac{1}{4}$ miles; there are three bridges, the principal one being that over the Bidor River.

Earthworks (Figs. 3, Plate 9).—The width of the embankments at formation-level is 16 feet, the slopes being $1\frac{1}{2}$ to 1; cuttings in general are 18 feet in width at formation-level, but in cuttings over 1,000 feet in length the width has been increased to 20 feet to facilitate drainage, and in rock-cuttings the width has been reduced to 16 feet. The usual slope of the cuttings is 1 to 1, but in some cases it has been found necessary to flatten them to $1\frac{1}{2}$ to 1; rock-cuttings are excavated with $\frac{1}{4}$ to 1 slopes. It has not been found necessary to turf the embankments, although this has been done in one or two cuttings with flat slopes, to prevent erosion, but all banks have been planted with grass, which grows readily in the tropics. Most of the embankments were made up from side cuttings, all excavation from cuttings, with the exception of a length of 2 chains at each end, being in general taken to spoil; but in places where the line crosses swamps, and borrow-pits alongside the line were impracticable, earth for the embankment had sometimes to be transported for long distances by train, and afterwards carried forward by hand in baskets. Light rails and tip-wagons, holding about $\frac{2}{3}$ cubic yard, were extensively employed, but most of the earthwork was done by baskets with Indian (Tamil) and Chinese labour. Rates of pay vary considerably and are dependent on the

locality, higher rates being always paid for work away from towns, and in unhealthy or uninhabited districts.

BRIDGES.

With few exceptions the abutments and piers of the bridges are constructed entirely of brickwork in cement, the superstructures of steel lattice- or plate-girders. The more important bridges are—

Krian Bridge . . .	At the 21st mile	550 feet in length.
Kurow " . . . " "	46th " "	150 " "
Victoria " . . . " "	83rd " "	1,050 " "
Pari " . . . " "	114th " "	180 " "
Kinta " . . . " "	120th " "	200 " "
Batang Padang Bridge " "	144th " "	150 " "
Bidor Bridge . . . " "	154th " "	150 " "
Sungkai " . . . " "	162nd " "	150 " "
Bernam " . . . " "	189th " "	200 " "
Bidor Bridge on the Teluk Anson Branch.	550 " "	" "

Krian Bridge consists of two spans of 150 feet and two spans of 100 feet; it crosses a tidal river having a depth of 35 feet at high water of spring tides. The centre pier is constructed of two cast-iron cylinders built in segments, each cylinder being 8 feet in diameter, reduced to 7 feet in diameter at the top, sunk to a depth of 44 feet below the bed of the river, and filled with 6-to-1 concrete; these cylinders are connected from the top to a depth of 6 feet below low-water level by steel diaphragm-plates stiffened with angle-bars. The other two piers are built on brick wells, 12 feet in diameter and 3 feet in thickness, sunk to a depth of 64 feet to 67 feet below ground-level. The abutments are also carried on brick wells sunk to a depth of 34 feet to 53 feet below ground-level, and filled with 8-to-1 concrete. The girders of the two centre spans of this bridge were built on staging on the bank of the river, and were floated into position, each end of a girder being carried on a pair of 80-ton iron barges braced together; the end spans were erected on staging in position. The height of this bridge is 92 feet from the bottom of the centre cylinders to rail-level.

Kurow Bridge is a single-span bridge of 150 feet span; the abutments are on brick wells filled with concrete, sunk to a depth of about 20 feet below the bed of the river; the girders were erected on staging in position.

Victoria Bridge (Figs. 4, 5, and 6, Plate 9), over the Perak River, consists of seven spans of 150 feet. Each abutment is carried on circular brick wells, six in number, sunk to the rock and concreted.

The piers are founded on double-octagon brick wells 34 feet in length by 17 feet in width (Figs. 6, Plate 9). The brick wells rest on steel curbs 4 feet in height, of the same shape, and weighing $11\frac{1}{2}$ tons each. In sinking the wells, artificial islands of sand-bags and boarding secured to piles and filled in with sand were formed in the river, and on these the steel curbs were pitched and riveted together. Brickwork was then commenced, and was carried up to a height of about 15 feet, bolted throughout with heavy iron bolts connecting the curb to the brickwork. The wells were then sunk by excavating the sand in the centre. As the wells sank, brickwork was added, and this process was continued until the rock was reached at a depth varying between 14 feet and 21 feet below the bed of the river. The rock was then chiselled off to secure a level bed for the curbs, and the central portions of the wells were concreted. The wells were finished off at a level of 6 inches above ordinary water-level, and varied in depth between 18 feet 6 inches and 25 feet. The piers are 34 feet in height, and measure 32 feet by 11 feet at the bottom, reduced to 30 feet by 9 feet at the top, with semi-circular ends. The brickwork is set in 3-to-1 cement-mortar, and the pointing is in neat cement. Machine-made bricks of standard size were used, special plant being erected for making the bricks. The superstructure, of lattice-girders 14 feet 4 inches in height, with overhead bracing, and having cross-girders at intervals of 10 feet to carry the rail-bearers, was erected on staging in position, by Chinese and Indian workmen under the supervision of a European foreman. One end of each girder is carried on a fixed bearing, and the other end on a frame containing six hardened steel rollers, $3\frac{1}{4}$ inches in diameter, to admit of expansion and contraction. A 6-foot pathway is provided at one side of the bridge for foot passengers. This is carried on prolongations of the cross-girders, Figs. 5, Plate 9. The Perak River is liable to heavy floods in the rainy season, and trees of over 100 feet in length and 4 feet to 5 feet in diameter are sometimes brought down by the flood. The height of the bridge is fixed so that there is a clear headway of 8 feet at the highest known flood-level—that of 1897. This gives a height of 41 feet from the bed of the river to the underside of the main girders. The cost of the bridge was \$454,320 (about £45,000).¹

¹ The constant fluctuation in the sterling value of the dollar during the time these railways were under construction renders it impossible to give the exact equivalent in pounds sterling of dollar figures; those figures given in pounds sterling must only be considered as approximate.

Pari Bridge consists of one span of 100 feet and two spans of 40 feet. The abutments and piers are in brickwork in cement on beds of concrete, put in in open founds. The 100-foot girders were erected on the river-bank and swung into position by derricks, the 40-foot spans being launched into position.

Kinta Bridge has two spans of 100 feet each. The abutments and pier of this bridge are on brick wells sunk to the rock at a depth of about 27 feet below the bed of the river, and afterwards filled in with concrete. The wells for the pier, 12 feet in diameter, were built on hardwood curbs pitched on an artificial island formed of sand-bags and piling, and were sunk in the same manner as those of the Victoria Bridge. The wells were corbelled over below ordinary water-level to carry the pier. In the case of the abutments the corbelling was just below ground-level. The girders were erected on staging in position.

Batang Padang Bridge is a single span of 150 feet; the foundations for the abutments are cast-iron cylinders 6 feet 6 inches in diameter, sunk to a depth of 18 feet below the bed of the river, and concreted. On the tops of the cylinders, which are pitched 1 foot 6 inches apart, a bed of concrete 4 feet in thickness was laid, and on this the brickwork was commenced; the girders were erected on staging in position.

Bidor Bridge (Figs. 7 and 8, Plate 9) consists of five spans of 100 feet and two land-spans of 25 feet; the piers are each composed of a pair of cast-iron cylinders, 6 feet 6 inches in diameter, connected by a steel diaphragm, sunk to a depth of 35 feet to 56 feet below the bed of the river and filled with concrete; the abutments are of brickwork on piled foundations. As the bridge crosses a tidal river with a bottom of soft black mud, any attempt at the erection of staging was impracticable; the girders were therefore erected on the bank of the river, and as each pier was completed a pair of girders was hauled out on to two wooden pontoons and floated into position. The pontoons were then anchored, and as the tide fell the girders dropped into their places. The time occupied in the erection of this bridge was 18 months, and the cost of the bridge was \$107,591 (about £18,000). The principal difficulty experienced was in procuring materials; stone for concrete had to be brought from the island of Penang, a distance of about 130 miles by sea and 39 miles by river, and bricks for the abutments were brought from Province Wellesley, about the same distance. Only Chinese workmen were employed, under a European foreman. Of the smaller bridges, the foundations of those between 100 feet and 40 feet span are chiefly on brick wells or iron cylinders filled

with concrete, it having been found impracticable to make use of open founds, except for some bridges not exceeding 40 feet span, on account of the sandy or peaty nature of the sub-soil, which is generally saturated with water. This, and a rainfall of over 160 inches a year in some parts of the country, necessitated extensive pumping arrangements where open founds were adopted, and the country being covered with jungle or heavy forest, the transport of boilers and pumping machinery was a matter of extreme difficulty. All girders of 100 feet to 65 feet span are of the lattice type and were erected on staging, with the exceptions already mentioned. The 40-foot, 25-foot, 20-foot and 10-foot girders are all plate-girders, and were erected either by launching over a light scaffolding or were riveted in position on a staging supported on sleeper-cribs.

WORKS.

Culverts.—The culverts are of three types, viz., rail-openings, arches, and slab-topped culverts; a few pipe-drains were made use of through low banks where the catchment area was small. The rail-openings vary between 6 feet and 2 feet, small built girders being used in the former; the arches vary between 6 feet and 3 feet; the slab-topped culverts are all of 3 feet opening, but in some cases two or three openings have been placed side by side in place of building a 6-foot or 9-foot arched culvert. The advantage of using slabs of stone for covering culverts is that the embankment can be tipped as soon as the slabs are in position, there is no danger of collapse in the case of unequal settlement of foundations, and the risk of bad workmanship in arches is avoided. A few cast-iron cylinder-culverts, 6 feet 6 inches in diameter, were constructed from spare cylinders sent out for bridge piers; these were bedded in concrete.

Tunnels (Figs. 9, Plate 9).—There are four tunnels on the section between Taiping and Kuala Kangsar. The ordinary section of tunnel adopted has a width of 15 feet and a height of 17 feet from rail-level, but the lined portions at the ends of tunnel No. 2, and the cut-and-cover work, have been constructed with a height of only 14 feet 9 inches from rail-level, with the object of affording greater resistance to lateral pressure where there is no great height above the crown of the arch. In all cases the tunnels are through hard granite rock, except for short lengths at the ends, which were lined with brickwork set in cement-mortar, the greatest length of lining at the end of any tunnel being 45 yards. Work was commenced by driving a heading at the top of the tunnel, a narrow-gauge tramway being laid in the heading and extended as

the work proceeded. For tunnel No. 2 a shaft at the summit of the gradient was sunk in addition, so that work could be carried on simultaneously at four places. For the rock-work Schram "Optimus" compound drills were used, worked by air-compressors driven by a 12-HP. vertical cross-tube boiler. The greatest length of heading driven per month with one set of drills was 121 feet, and in breaking-down the greatest length completed in a month was 66 feet. Only Tamil labour was employed, under European foremen. Nobel blasting gelatine was almost exclusively used for work in the headings, and for breaking down, as it proved more satisfactory than dynamite.

Permanent-Way.—The gauge of the Perak and Province Wellesley Railways is 1 metre (3 feet 3 $\frac{3}{8}$ inches); the greater part of the road is laid with flat-bottomed rails weighing 60 lbs. per lineal yard, a standard section of that weight having been adopted since 1895 in the Federated Malay States. The Larut and Kinta Valley lines, constructed between 1884 and 1895, having a total length of 67 miles, are laid with rails weighing only 46 $\frac{1}{4}$ lbs. per lineal yard; on these lines the sleepers, which are of native hardwood, are 6 feet 6 inches in length, 9 inches in width, and 4 $\frac{1}{2}$ inches in thickness, the space between the sleepers being 1 foot 8 inches. On all lines constructed since 1895, rails weighing 60 lbs. per lineal yard have been used, and the sleepers are 6 feet 6 inches in length, 10 inches in width, and 5 inches in thickness, the space between the sleepers being 1 foot 10 inches. Rails are secured to the sleepers with dog-spikes, clip-bolts being used at the joints on curves. The line is ballasted for the greater part of its length with broken limestone, but in the mining districts washed gravel has been largely employed, and in some parts of the line, where no stone or gravel was procurable, river sand has been used. Sand was exclusively used on the Teluk Anson branch when the line was constructed, but after rails were laid into the district of Kinta all curves were packed and boxed in with broken stone ballast. In Province Wellesley and the Krian District the ballast used was to a great extent broken stone, brought in sailing-barges from the Island of Kra, off the coast, and trained out as the rails were laid. The width of the ballast is 8 feet 6 inches and there is a depth of 6 inches under the sleepers, the quantity of ballast used being 2,000 cubic yards to the mile.

Stations.—There are forty-two stations on the line at distances varying between 2 miles 33 chains, and 12 miles 25 chains apart. With four exceptions, sidings are laid at all the stations to provide for goods traffic and the crossing of trains. The crossing-sidings

have sufficient length for a train of forty-five wagons. The platforms are 300 feet to 400 feet in length, 16 feet in width, and, in general, are raised 1 foot 3 inches above rail-level; one or two of the earlier constructed stations have platforms raised to the level of the floors of the carriages; the unimportant stations have platforms raised only 6 inches above rail-level. The goods-sheds have platforms raised to the floor-level of the trucks, and are constructed of hardwood framing on brickwork foundations. They are usually constructed on a loop on the opposite side of the main line to the passenger building, as this arrangement enables shunting to be expeditiously carried out by trains running in either direction, and places the goods-yard under the close supervision of the station-master.

Workshops, &c.—The accommodation provided is at present of a somewhat temporary nature, as it is intended to establish the permanent workshops for the whole of the Federated Malay States Railways at Kuala Lumpur, in Selangor, as soon as the Perak and Selangor Railways are connected. The present workshops are at Ipoh and Taiping, in both of which sufficient machinery is provided for the general repair of locomotives, carriages, and wagons, and for the building of new wagon-stock. Locomotive- and carriage-sheds for running purposes are provided at Ipoh, Teluk Anson, Taiping, and Kuala Prai. Tanks and engine-turntables are also provided at these stations, and there are in addition eight watering-stations, situated about 20 miles apart.

Wharves.—In Penang, a light screw-pile jetty has been erected for the landing of passengers from the railway ferry-steamers. At Kuala Prai a floating wharf has been constructed for passenger traffic, and a dock 400 feet by 100 feet to be used by barges carrying goods to or from the railway. At Port Weld a wharf has been constructed of hardwood piles, and a wooden copper-sheathed pontoon with hinged gangways, providing berths for two steamers; and at Teluk Anson berths have been provided for three steamers by the construction of pontoon-wharves. The pontoons are constructed of iron cylinders, 5 feet in diameter and 16 feet in length, supporting a wooden platform, with hinged gangways at intervals, connected with the platforms of the goods-sheds. There is 20 feet depth of water alongside the pontoons at low-water of spring-tides, and the rise and fall of the tide is 8 feet.

ROLLING STOCK.

Locomotives (Fig. 10, Plate 9).—Three types of locomotives are in use on the railway, viz., tank-engines, for shunting purposes and for local trains; four-wheels-coupled tender-engines with side-tanks; and six-wheels-coupled tender-engines without side-tanks. Of the latter the cylinders are $14\frac{1}{2}$ inches in diameter by 20 inches stroke, the wheels are 4 feet 3 inches in diameter, and the gross weight of the engine and tender-loaded is 48 tons 14 cwt.

Carriages (Figs. 11, Plate 9).—There are two types of carriages in use, viz., four-wheel light stock, originally provided for the Larut Railway, and bogie-stock. For the latter the carriages are 45 feet in length over the end platforms, the bodies being 40 feet by 7 feet 6 inches in outside dimensions. They are entered from the end, and there is through-communication from end to end of all passenger-trains. The roofs are double, of the clerestory type, 7 feet 3 inches in height at the centre, and 5 feet 10 inches at the sides. The bodies are carried on bogies 29 feet apart, centre to centre, with wheels 2 feet in diameter on the tread; the under-frames are of channel steel with a truss-rod on each side, and they are fitted with radial draw-bars and central combined buffing and draw-bar gear with "Jones" hook-coupling. First-class carriages provide accommodation for thirty-nine passengers, composite carriages for eighteen first-class and twenty-seven second-class passengers, and third-class carriages for eighty passengers.

Wagons (Figs. 12, Plate 9).—Two types of covered goods-wagons, carrying respectively 5 tons and 7 tons, have been adopted. The bodies of the latter are 15 feet by 7 feet in outside dimensions, the wheel-base is 8 feet 6 inches, and the tare is 3 tons 18 cwt. The wheels of all the wagon-stock are 2 feet in diameter on the tread. The covered goods-wagons are roofed with corrugated iron. The following is the present equipment of the railway:—

22 tender-locomotives.	3 four-wheel vans.
11 tank-locomotives.	19 goods brake-vans.
69 bogie-carriages.	612 goods-wagons and other
18 four-wheel carriages.	vehicles.

The most recent prices paid for locomotives and rolling-stock, freight included, are:—

	£
Six-wheels-coupled tender-locomotive	2,625
First- and second-class composite carriages	1,340
Third-class carriages	820
Third-class and van composite carriages	890
Covered goods-wagons (7 tons)	94
Low-side iron ballast-wagons (7 tons)	68
Goods brake-vans (10 tons)	161
Horse-boxes	170
Cattle-wagons	135
Carriage-trucks	113

All wagons are fitted with hand-lever brakes; carriage-stock is at present fitted with the Clark continuous chain-brake, but it has recently been decided to fit all passenger-trains with the automatic vacuum-brake.

WORKING.

The line is at present worked in sections, the longest being Teluk Anson to Padang Rengas, 90 miles 44 chains; the other open sections are:—Port Weld to Pondoh Tanjong, 20 miles 40 chains; and Kuala Prai to Alor Pongsu, 36 miles 27 chains, but it is expected that all the extensions now in hand will be completed and the different sections joined up by the end of 1902. The estimated cost of the whole system is \$16,923,971, which is being provided from the surplus revenue of the State of Perak, it not having been found necessary to raise the loan authorized in 1897 when the works now in hand were sanctioned. In 1900 the total receipts from the sections then open amounted to \$1,017,618 (£101,761), the working expenses to \$514,108 (£51,410), or 50·5 per cent. of the gross receipts; the expenditure was divided thus:—

	\$	£
General management	23,339	(2,333).
Traffic department	161,518	(16,151).
Locomotive department	180,573	(18,057).
Way and works department	140,088	(14,008).
Stores department	4,075	(407).
Telegraph department	4,515	(451).

In the same year the number of passengers carried was 1,476,426, the receipts from passenger-traffic were \$531,844 (£53,184), from goods-traffic \$407,983 (£40,798), and miscellaneous receipts amounted to \$77,791 (£7,779); the goods carried amounted to 194,036 tons, and the total traffic to 349,319 train-miles. The longest section open in 1900, that from Teluk Anson to Kuala

Kangsar, contributed \$807,848 (£80,784) to the total receipts, with working expenses of 41·56 per cent.; the capital cost of this section to 31 December 1900 was \$5,061,054 or \$59,894 per mile, and the profit on the year's working was equal to a dividend of 9·33 per cent. On this section the expenditure in 1900 was \$1·44 (2s. 5½*d.*) per train-mile, the receipts were \$3·46 (6s. 5½*d.*) per train-mile, the total gross traffic was 23,578,065 ton-miles, or 233,567 train-miles. The expenditure per train-mile was divided thus:—

General management	7 cents (<i>7d.</i>).
Traffic department.	38 „ (<i>4¾d.</i>).
Locomotive department	56 „ (<i>6¾d.</i>).
Way and works department	41 „ (<i>5d.</i>).
Stores department	1 cent (<i>1d.</i>).
Telegraph department	1 „ (<i>1d.</i>).

Rates.—The passenger fares charged are, at the present rate of exchange, equal to rather under 2*d.* a mile for first-class, 1½*d.* for second-class, and ¾*d.* for third-class passengers. Return-tickets are issued at the rate of a fare and a half for the double journey.

Goods are divided into six classes, the rates varying between 2 cents per pikul (8·2*d.* per ton) per mile, and ¼ cent per pikul (1*d.* per ton) per mile; on the carriage of rice, tin, and tin-ore a special reduction of 10 per cent. is made for distances over 50 miles, with an additional 10 per cent. reduction for distances exceeding 150 miles. Goods-traffic inland from the ports consists principally of rice, figs, foodstuffs, and fuel; the outward traffic consisting almost entirely of tin and tin-ore.

Staff.—In the traffic branch, Chinese and Jaffna Tamil station-masters and clerks, locally trained, are employed, under the direction of European inspectors and a traffic superintendent. The porters and pointsmen are Tamils, and the loading-coolies are Chinese and Mohammedan Tamils. The locomotive branch employs, under European supervision, European and Eurasian drivers and Tamil firemen; and in the workshops, Chinese, Singhalese, and Tamil carpenters, blacksmiths, fitters, and turners, with some few Eurasians; the coolie labour is Tamil. The way and works branch employs Tamils as platelayers and masons, and Chinese as carpenters and blacksmiths. Platelayers are formed in gangs of ten to twelve coolies in charge of a tindal or head man, each gang having a section of line 3 miles in length; the work of the gangs is supervised by a European foreman-platelay, who has as a rule, a section of line 21 miles in length. The general

maintenance of the road is further supervised by a European inspector, who personally superintends the repairs of bridges, culverts, buildings, wharves, and signals, under the direction of a district engineer. The line, for maintenance purposes, is at present divided into two districts.

Conclusion.—The cost of construction and equipment has varied greatly. The cost of the 17 miles in the Laruk District (1884-1891) was \$45,717 per mile, and of the Kinta Valley Line (1891-95) \$50,905 per mile, while the average estimated cost of the extensions sanctioned in 1897 is \$93,744 (about £8,600) per mile. The cost of these extensions includes the provision of ferry-steamers, barges, and jetty in Penang harbour, and a landing-stage and dock at Kuala Prai. The estimated cost of the section between Taiping and Kuala Kangsar (19 miles 13 chains) is \$163,090 (about £14,900) per mile.

The dollar, which was worth 3s. 10d. in 1890 and 3s. 5d. in the year the Kinta Valley line was commenced, is now worth only 1s. 10d.; the fall in exchange has been accompanied by an increase in the cost of local labour and materials, and in the prices of materials purchased in England.

The construction and working of these lines have, since 1887, been in charge of the Author as resident engineer and manager; the consulting engineers are Messrs. Gregory, Eyles and Waring, who selected the European staff employed, and are responsible for the design of all the bridge-tops, locomotives, and rolling-stock, and to whom the Author is much indebted for advice.

The Paper is accompanied by six tracings, from which Plate 9 has been prepared.

Fig. 3.

Fig. 4.

Fig. 10.

Fig. 11.

Fig. 5.

Fig. 6.

Fig. 8.

CROSS SECTION.

Fig. 9.

CROSS SECTIONS OF TUNNELS.

Fig. 12.

7-TON LOW-SIDED STEEL WAGON.

PLAN.

7-TON COVERED GOODS WAGON.

PLAN.