



MINISTRY OF TRANSPORT

RAILWAY ACCIDENTS

**REPORT ON THE
COLLAPSE OF A FOOTBRIDGE
which occurred on
19th January 1952 at
KNOWSLEY STREET STATION, BURY
in the
LONDON MIDLAND REGION
BRITISH RAILWAYS**

LONDON: HER MAJESTY'S STATIONERY OFFICE

1952

2nd July, 1952.

SIR,

I have the honour to report for the information of the Minister of Transport in accordance with the Order of 22nd January, 1952, the result of my Inquiry into the accident which occurred at 4.39 p.m. on Saturday, 19th January, 1952, at Knowsley Street Station, Bury, in the Central Division of the London Midland Region, British Railways.

A large number of intending passengers were moving slowly over a covered wooden footbridge when the bottom booms and floor fell out, and about 200 people were dropped some 15½ feet on to the railway tracks below. I regret to report that two persons lost their lives and 173 others were injured of whom 136 were conveyed to the Bury General Hospital and 43 were detained there.

The collapse of the bridge was seen by the signalman in Bury West Junction box, and he immediately sent the 'Obstruction Danger' signal. The Station Master who was supervising the entrainment of passengers on the Down line also took prompt steps to stop traffic and to direct the relief work. First aid was given at once by railwaymen in the vicinity, and in a very few minutes police, fire brigade, doctors and ambulances began to arrive. The arrangements for attending to the many injured people were very well organised, and by 6.15 p.m. the last casualty had been conveyed to Bury General Hospital, where prompt and efficient steps were taken to deal with this emergency.

At the time of the accident crowds of spectators from a football match were returning to the station to catch special trains back to Blackburn. These trains were due to leave at short intervals from the Down side, and in order to reach it passengers had to cross by the footbridge from the booking hall on the Up side and descend a flight of steps to the platform. The gates at the bottom of these steps had been closed when sufficient passengers for the first train had assembled on the platform, and the crowd, which continued to arrive in large numbers, formed a queue across the bridge. The gates were re-opened as soon as the first train had left, and the passengers were moving forward again when the failure occurred.

The lines through the station were blocked by the debris, and traffic was diverted to Bolton Street Station about half a mile away; the remaining passengers left from there by special trains at 6.17 p.m. and 6.50 p.m. The debris at Knowsley Street was cleared quickly, and by 6.30 p.m. (less than two hours after the collapse) the station was re-opened for traffic. Owing to its unsafe condition, the remainder of the footbridge was removed during the early morning of Sunday, 20th January, the lines through the station being temporarily closed again from 12.40 a.m. to 11.5 a.m.

The weather was fine.

REPORT

Site.

1. Knowsley Street Station is on the Castleton-Bury-Bolton line, which runs roughly from east to west as indicated on the accompanying drawing (Plan A). The station comprises two main platforms and an Up bay line, all lying to the east of Knowsley Street, which runs north and south and crosses the railway on an overbridge. The four lines through the station are in a cutting, and the main access is down a flight of steps to the booking hall on the Up side. This concourse is about half way down the cutting, and gives direct access to the covered footbridge. Two other stairways lead to the Up platforms. There is a water column on the Down side directly underneath the footbridge.

The accident.

2. Mr. G. U. Gray, the Station Master at Knowsley Street, described the circumstances leading up to the accident. He said that four excursion trains had been arranged to convey about 3,000 passengers back to Blackburn after the match, and they were booked to depart from the Down side at 4.35 p.m., 4.40 p.m., 4.46 p.m. and 4.55 p.m. In addition, a number of the spectators were returning by the Up trains. Mr. Gray decided to regulate the flow of passengers by closing the gates at the bottom of the footbridge steps as soon as sufficient numbers had assembled on the Down platform for each train. His object was to ensure that there would be no overcrowding and that the trains could be despatched in an orderly manner. The same procedure had been adopted on previous occasions when large crowds were handled successfully after other football matches.

On this occasion the gates were closed when about 750 passengers were waiting for the first train and they were not re-opened until it left at 4.38 p.m.—three minutes late. By then the spectators had formed a queue from the Down side gates, up the steps, across the footbridge and booking hall, and back as far as Knowsley Street. They were moving forward slowly and in an orderly manner when the bridge collapsed. Mr. Gray was standing on the Down platform about 80 yards away when he heard the bridge timbers creaking and turned round just in time to see the bottom booms falling. He thought that they first gave way at about the middle of the bridge.

3. At that moment the second special train was due but prompt steps were taken to stop it. Mr. Gray ran down the platform towards the approaching train, Leading Porter D. Foulkes, who was on the Up side, promptly went to the foreman's office and telephoned the signalmen to block all lines, whilst Signalman W. Abbott of Bury West Junction box who had also seen the accident immediately sent the 'Obstruction Danger' signal. This message was received by the signalman at Bury East Junction box just in time to warn the guard, who made an emergency brake application, and the train stopped a few yards clear of the platform.

The action taken by Mr. Gray and his station staff and by other railwaymen was exemplary. As soon as the train had stopped, Mr. Gray ran back to summon help and met Foulkes who telephoned for the police, ambulances and medical assistance. The First Aid equipment from the station and the signal boxes was quickly forthcoming, and all members of the station staff did excellent work in helping the injured and in controlling the passengers.

4. Clerk R. Grunshaw of the Signal and Telecommunications Department who was off duty at the time, said he was returning to Blackburn after having seen the football match. He had to stand for about 10 minutes in the passage leading to the bridge before the queue started to move forward again. He had only taken about six paces when the bridge collapsed just in front of his feet; both ends seemed to fall together. He linked arms with others and by their exertions they managed to stop the crowd before anyone was pushed over the shattered end of the footway. Grunshaw, who was trained in first aid, then made his way down the steps to the Up platform and on to the line, where he rendered great assistance to the many seriously injured people.

5. Mr. F. Haythornthwaite, a resident of Blackburn who was also returning from the football match, said he joined the queue which was about six deep and stretched along the full length of the footbridge. After waiting for about 15 minutes the crowd began to move forward and thin out. Mr. Haythornthwaite was about a quarter of the way along the bridge when he felt it collapse under him. The far (Down) end dropped about a foot and then steadied for a second or so, after which the whole of the floor gave way and "went down just like a lift". Every one had been very orderly and there was no stamping, though a number of people gave a cheer when the gates were opened and the queue began to move again. Mr. Haythornthwaite was quite sure that it had thinned out at the time of the actual collapse because by then the people had spread out sufficiently for him to see the far end of the bridge.

6. Two other intending passengers, who were also on the bridge confirmed that the crowd had been closely packed just before the accident but it had thinned out a little and was moving forward slowly when the failure occurred. All witnesses agreed there was no stamping nor jumping which might have added to the stresses. It was also established that comparatively few of the persons on the bridge escaped uninjured, and from this it can be assumed that the load at the moment of failure was probably about 200, though as many as 250 people may have been standing on the bridge at one time before they started moving again.

The footbridge before collapse.

7. The footbridge is believed to have been built over 70 years' ago but no records nor drawings could be found. The Knowsley Street road bridge alongside it is dated 1848 but it is thought that the footbridge was not put up till some years afterwards. The details on plans A and B have therefore been prepared from measurements of the broken pieces. The bridge extended from the retaining wall supporting the booking hall on the Up side to the brick abutment on the Down side. Its total length was 72' 6" but the cast iron columns on the Up platform reduced the clear span to 60' 9"; it was this section of the bridge which collapsed. The main structure consisted of two timber queen post trusses carrying a 4" thick timber flooring on the bottom booms. The trusses rested on the cast iron columns on the Up side and were built into the brick abutment on the Down side.

The bridge was totally enclosed with boarding on the inside and outside of the trusses, and it had a glazed roof. The footway was approximately 7' 4" wide between the inside boarding and the clear head room was 9' 3". The overall length of the trusses was 64' 9" and they were spaced at approximately 8' 7" centres. They were made up of 14" x 7" bottom booms, and 12" x 7" top booms, queen posts and raking struts; cross members and minor verticals were 7" x 6". These were the nominal measurements; the actual dimensions as recorded after the accident are shown on the plan B drawings, to which reference is made in the paragraphs which follow.

8. Since the flooring was carried on the bottom boom, the queen posts were in tension, and the design provided for the load being transferred to them through wrought-iron straps which were originally 3½" wide by ¾" thick. Each strap passed around the bottom boom and was held to the queen post by an unusual fastening consisting of a key and two cotters (see joint B.). The minor verticals were held by similar, though smaller, straps. The diagonal members were housed at the base of each queen post in separate iron castings bolted to the upright (see joint C.). The main top joint was contained in one T shaped casting into which were fitted the tops of the queen post and the raking strut and one end of the top boom (see joint K.); the extension boom carrying the roofing to the ends of the bridge was also scarfed into this joint. A wrought-iron strap similar to the others transferred the stresses from the queen post to the top boom.

The original straps at the bottom of three of the four minor verticals had apparently been replaced by others which were held by bolts instead of cotters (see joints E, B.1 and E.1). Two of the main joints at the bottom of the queen post had also been reinforced with similar straps (see joints D and C.1). These newer straps were also made of wrought-iron and they had apparently been put up many years ago.

As will be seen from the descriptions which follow, the collapse of the bridge was due to the wrought-iron straps around the bottom booms having corroded to such an extent that they were no longer carrying any load. All these straps were completely covered by the boarding on the outside and partially covered on the inside, and both this and flooring would have had to be removed at the joints in order to examine them thoroughly.

9. The main truss bearings on the Down side consisted of large iron castings which fitted over the ends of the booms and also housed the bottom ends of the raking struts. A horizontal wrought-iron strap passed around each casting and was fastened to the boom by a key and cotters in a manner similar to the other joint; the raking strut was also braced to the boom by a wrought-iron strap (see joints A and A.1). These castings were built into the brick abutment.

On the Up side the bearings rested on the cast-iron columns and were of similar design, except that the castings were open ended so as to accommodate the bottom booms which extended through them as far as the booking office retaining wall. The horizontal straps were fastened to the timbers on either side of the casting as indicated (see joint F).

10. The timber in the trusses was second grade sawn red log pine of fair average quality. Large quantities of this timber had been used between 1840 and 1900, after which the forests were worked out; it is therefore reasonable to assume that all the truss members were the original ones. This timber is equivalent in strength to merchantable Columbian pine as supplied today. Details of its condition are given in para. 14.

11. The flooring was laid with good average quality 11" x 4" red deal planks, grooved and fitted with hoop iron tongues; it rested directly on the bottom booms to which it was fastened with 6" cut nails. The timber was in good condition and it had probably been renewed several times since the bridge was built.

12. The outside boarding was 7" x 1½", V jointed, machined, tongued and grooved red deal of good quality and in good condition; this boarding was fastened to 3" x 2" runners which were nailed to the top and bottom main booms with 6" cut nails. The inside boarding was also fastened to runners, which were fixed to the main boom at the top and to the flooring at the bottom. Both sets of boarding were also nailed to intermediate runners fastened to the truss members. Some of the runners were of red log pine and were clearly the original ones; others were of good average quality red deal of more recent date.

The footbridge after the collapse.

13. As already mentioned, the bottom booms of the trusses, together with the flooring, fell out, but the rest of the bridge stayed in position and was not removed until a few hours after the accident. Detailed drawings of the various joints as actually found are illustrated in plan B; all elevations have been taken from the inside of the bridge but an indication of the condition of the wrought-iron straps on the outside can be gauged from the cross sections. The actual thickness of the metal has been shown and where it has ended in a knife edge this has been indicated by the letters K.E.

The straps holding the bottom booms to the vertical members were in a deplorable condition; every one of them was badly corroded and none had been carrying any load; in some cases all that was left were two short lengths of wasted metal hanging from the vertical member. Both the horizontal straps on the Down side bearings were also corroded away; one of the raking straps was partially corroded and the other was missing. The straps on the Up side bearings were in better condition and were intact throughout although the bottom edges of the horizontal ones had wasted away in places. Straps for holding up a smoke plate were found on the inside of the booms at joints B and B.1; they were of steel and had probably been put in in 1945 (see para. 21); they had corroded in places from an original thickness of ½" to a minimum of ⅜".

14. The bottom booms had fractured as shown in the elevations on plan B. The timber appeared generally to be in good condition, except that the wood enclosed by the bearings on the Down side was in an advanced stage of decay, and the rot extended to a lesser degree as far as the slots for the cotters; the wood in the bottom booms had also split in places as it aged and some rot had begun where soot and water had seeped in. The outside runners had been torn away from the bottom booms and were found still suspended to the boarding. Many of the 6 in. nails holding these runners to the booms had pulled away from them, others had fractured and some had been completely corroded before the accident occurred. Some of the nail holes in the bottom booms were elongated, indicating that the wood had been crushed by excessive bearing stress.

15. A footbridge at Oldham with trusses of similar design and age to those at Bury, was also inspected after the accident. In this case, not only the sides but also the bottom of the bridge was enclosed. The underside boarding protected the trusses to some extent but even so it was found that the wrought-iron straps had corroded, though only to a maximum depth of about ⅜". These straps were removed and tested, and the material was found to be similar in composition and strength to the Bury bridge straps. Some of the timber at one of the bearings also showed signs of deterioration but not to the same extent as the Down side bearings at Bury.

Instructions for the examination of bridges.

16. Instructions for the examination of bridges on the London Midland and Scottish Railway had been issued in November, 1937. They provided for the annual examination of structures by a Works Inspector assisted by a Sub-Inspector or the District Foreman. One of the main objects of the annual inspection was the preparation of a programme of work for the following year. Special forms were used for the recording of the reports, and the inspectors were instructed to classify the condition of each part of the structure under the following headings:—

"G—good; U—urgent, to be done within three months of programme year; R—repairs required as soon as convenient; P—to be done if possible in the programme year."

The letters U, P and R were intended to represent the relative urgency of repairs in the programme year but the letter U though standing for "urgent" only meant that repairs could wait for six to twelve months according to the time of the inspection. Where defects were found which could not be deferred to the programme year the work could be put in hand forthwith but a special report had to be submitted. Owing to the outbreak of war and the emergency work which it entailed, it was found impracticable in many districts to make the inspections annually, and in the Blackburn District they were made at 5-yearly intervals in conjunction with the general repairs programme.

In October, 1950, the Civil Engineer, London Midland Region, issued new instructions to his District Officers. They were based on principles agreed by the Civil Engineer's Committee of the Railway Executive, and they laid down that bridges should normally be given a detailed examination every three years and a superficial examination every six months. A new inspection form was introduced, and the classification of condition was changed to "G—good; F—fair; P—poor". An extract from the instructions is given in the Appendix.

Bridge examinations.

17. Mr. A. Tims, the District Engineer, Blackburn, who had only been in charge of this District for 2½ months, said that during this period his attention had not been drawn to the Bury footbridge, which was one of the 1750 bridges in his District. The two previous Engineers had both retired and were not available. Mr. Tims produced records to show that the footbridge had been inspected by Works Inspector Halwood in 1944 and by Works Inspector Irving in 1948, but unfortunately both these men had since died. There had been another inspection in 1946 in connection with some repairs which were being undertaken at that time but no special report was made. An account of this inspection is given in paragraph 20 based on the evidence of Chargeman Wilson, who was present at the time. The bridge was repainted in 1949, but it was not inspected.

The only remarks in the 1944 report were:—

" Inspected 11th August.
Timber parapet, renew boards.
Rooflights and gutter renew; 180' 1". "

The report was marked E.I. which indicated it was referred to the District Engineer. He made his personal inspection on 19th September, 1944, and added the following note to the report:—

" A trussed beam type ' A ' girder—all timber boarding inside and outside both girders.
Ridged roof with skylights.
Obtain drawing if possible with a view to lean-to roof in Big Six asbestos sheets and place windows in sides, or alternatively consider Big Six rooflight special sheets. Drawing Office to first see what could be done. If above is not very practicable consider re-nailing outside boarding both sides of bridge—it would then last 5 years if patched now. Gutters to be renewed in any case."

The 1948 report was as follows:—

" Inspected 6th May.
Renew all outside boarding.
Renew gutters, drain spouts and 4 boards.
£110."

Neither of the Inspectors classified the condition of the bridge in accordance with instructions, nor had they nor the District Engineer made any comment on the condition of the wrought-iron straps, though these must have been showing considerable and increasing signs of corrosion throughout this period. The impression given by these reports is that attention was focussed on the superficial repairs and not enough care was given to the examination of those parts of the bridge on which its safety depended.

18. Mr. T. Buckley, the Assistant District Engineer, Blackburn, said he had held this appointment since 1946, but did not remember the inspection of the footbridge that year. He would have seen Mr. Irving's report in 1948 but there was nothing in it which would have caused him any alarm. The remark " renew all outside boarding and renew gutters " referred to the work which the Inspector considered should be included in the 1950 Structural Programme. Mr. Buckley explained that it had been customary to make inspections every five years in connection with this programme and that the detailed bridge examinations were made at the same time. In normal circumstances the bridge would not have been inspected again until 1949, but instructions were received from Headquarters that proposals for the structural programme had to be submitted a year earlier than usual and hence two years' inspections had to be completed in 1948. No additional staff was provided, and the sub-inspectors and foremen were called in to assist, so as to get through the work in time.

Mr. Buckley said that the periodical inspection should have included a thorough examination of the bridge members and joints in addition to the listing of the repairs and painting which might be needed. The inspector should have checked the underneath of the bridge from a ladder and he should also have taken off some of the boards so that he could see the joints properly. No special instructions had been given about these inspections but he thought that Mr. Irving should have had enough knowledge and experience to undertake this work, although he was a bricklayer by trade. Mr. Buckley agreed, however, that the inspector could not have made a thorough examination when he inspected the bridge in 1948 because if he had done so, he could not have failed to notice the bad condition of the straps.

19. Chief Works Inspector E. Lowe said he had been Chief Inspector of the Blackburn District for the last 10 years, and his experience of bridge inspections extended over the past 19 years. He was a bricklayer by trade, and, although he had never been given any special instructions, he had gained a lot of experience of bridge work in the course of his career. He remembered seeing the 1944 report and discussing it with Inspector Halwood; wood borings were taken on that occasion and the samples were sent to Headquarters, but Mr. Lowe could not recollect from which parts of the bridge they had been taken. He added that Mr. Halwood had been a good joiner before he was appointed inspector and he should have known how to examine a timber bridge. Mr. Halwood had told him that he had stripped some of the boarding on the inside and had also taken up some of the floor boards, but he had difficulty in taking off the outside boarding, probably owing to shortage of men in war time.

During the inspection of the station by the Chief Engineer in 1945 it was noticed that the roof of the footbridge was sagging. Instructions were given for its renewal and this work was done in 1946 under Mr. Halwood's supervision. Mr. Lowe did not see any inspection report on this occasion, nor did he remember Inspector Halwood saying anything about it.

Mr. Lowe said that Inspector Irving had only just arrived in the District when he carried out the 1948 inspection. Although a bricklayer by trade he should have been capable of undertaking this work because he should have picked up sufficient knowledge of the various branches of bridge work during the course of his duties. In any case, if he had to examine a wooden bridge he should have taken a joiner with him. Mr. Lowe did not give Inspector Irving any instructions about bridge examinations and did not tell him that he should strip off the boarding so as to inspect the joints of this particular bridge. He did not think that Mr. Irving did this, nor were any wood borings taken on this occasion because the 1944 borings had been excellent.

In conclusion, Chief Inspector Lowe stated that in his opinion the bridge was strong enough to carry a normal load of passengers quite safely in spite of the defective straps because the bottom booms were in good order. He thought the collapse was entirely due to the exceptionally large crowd which was allowed on to the bridge on that occasion.

20. Acting General Chergeman E. Wilson had held his present appointment in the Ramsbottom area which included Bury for nearly two years, and previously he had been Chergeman Joiner of the same area for six years. He remembered Inspector Halwood making an examination of the footbridge on 10th November, 1946, when the roofing was renewed. Wilson was in charge of this work and was present during the bridge examination. He removed internal and external boarding at the joints and also took up one or two of the flooring boards. He tested the timber in the trusses by hammering it and considered it was in sound condition. He also examined the straps on the inside above the flooring and found they were in good condition, but he did not look at the sections below floor level nor on the outside. The inspector examined the outside and the underside of the trusses from a ladder and he told Wilson that "the bridge was O.K.; it was fit to carry the roof and would last five years." The bottom booms of the bridge were thickly coated with soot and Wilson could not say whether or not the inspector cleaned this away from the straps, though he commented on the job being a dirty one. He thought the inspector had a hammer with him but he did not remember whether or not he tapped the straps. The inspection was continued on the next day and Wilson thought that the inspector had looked at all the joints but he could not be sure, as he himself was busy taking levels along the top of the truss in connection with the re-roofing.

Wilson stated he was not present during the 1948 inspection nor was he there when the bridge was repainted in 1949, as he was working temporarily in another area. He understood, however, that a few boards had been replaced on that occasion.

21. A smoke plate consisting of a wooden frame, with asbestos sheets, had been fixed with steel bolts to the underside of the bridge over the Down Slow line at the place where engines stood to take water at the column on the platform. Wilson thought that this smoke plate was put up in 1945 but it deteriorated quickly and was taken down again 18 months to two years later; all that was left when the bridge gave way were the bolts which were found in the positions shown on plan B, joints B and B.1.

22. Mr. F. Turton, the Bridge and Steelwork Assistant to the Civil Engineer, produced calculations of the strength of the bridge, and these are summarised in paragraphs 26 to 30. He said that if the bridge had been in good condition it would have been capable of carrying the full load which was put on it. The two bottom booms alone were, however, quite incapable of carrying this load which produced bending stresses equivalent to about double the breaking stress. He was sure that up to the moment of collapse some of this load must have been transmitted to the top boom through the 3" x 2" runners and the outside boarding which partially supported the bottom booms till the nails gave way.

Mr. Turton explained that it was very difficult to say for how long corrosion had been taking place in the straps because he did not know the actual atmospheric conditions, but he thought that it had been developing for 10 to 15 years. He would have expected Mr. Halwood to have noticed the defects when he made his examination in 1946. The straps may not have been completely eaten away by then but it is likely that they would have been very thin. The underside of the bridge was, however, thickly covered with soot, and it might have been difficult to see how far the corrosion had gone unless the timber and ironwork had been thoroughly cleaned. The inspector should have done this and then he should have measured the actual thickness of the straps.

23. Bridge Examiners, who were men specially selected by reason of their trade knowledge and maintenance experience, were appointed to each Engineer's District at the end of 1951, and before taking up their new duties they were given a special course of instruction at the School of Transport, Derby. This was organised by Mr. Turton, who gave them a few talks and two members of his staff gave a series of lectures. Examples of bridges in various conditions were shown to the examiners and the chief points to look for were explained to them. Attention was mainly concentrated on metal bridges but the essential features of wooden bridges were also pointed out, with particular reference to the joints and the condition of the timber in the bearings. Mr. Turton added that he hoped to hold a refresher course in a few months' time so as to deal with any difficulties which the examiners might have experienced in the course of their work and to touch on other aspects of inspection work which could not be covered in the first course, which only lasted for a fortnight. The Blackburn bridge examiner had only arrived in the District a few days before the accident occurred.

Strength of the materials

24. *Timber.* A number of sections were taken from the bottom booms near the points of fracture but considerable difficulty was experienced in selecting clear specimens as most of the wood had knots at approximately 2 ft. centres. Particulars of the relevant tests are:—

Type of Test	Number of Specimens	Ultimate breaking stress	
		Maximum lbs. per sq. inch	Minimum lbs. per sq. inch
Bending	13	6,740 (3.0 tons)	3,220 (1.44 tons)
Shear	10	356 (0.159 „)	198 (0.088 „)
Compression parallel to grain	24	4,660 (2.08 „)	4,050 (1.81 „)

It was not possible to take any specimens close to the fractures at the Down side end of the booms owing to the very poor condition of the timber. Some of the bending tests gave rather spurious results due to premature failure occurring at knots outside the inner loading points.

25. *Wrought-Iron.* The wrought-iron was analysed and a number of tests were made. The quality of the material was poor, laminations were visible on the machined surfaces of the test pieces, and there was an appreciable amount of slag in most specimens. The chemical analysis showed that the carbon and manganese contents were within the specification for grade C iron; the carbon content varied from 0.02% to 0.06%, manganese from 0.06% to 0.15%. The maximum and minimum results were:—

Chemical Analysis		Yield point tons per sq. inch	Maximum stress tons per sq. inch	Elongation	Reduction of area
Carbon	Manganese				
%	%			%	%
0.03	0.07	20.5	23.5	12.2	19
0.04	0.07	13.4	15.0	3.9	10

Calculations

26. As already stated, the original drawings of the footbridge could not be found, but it is assumed that it was designed in accordance with the rules in general use about 70 to 80 years ago. These laid down that footbridge loadings should be calculated on the following basis:—

- (a) Dead load. The weight of the superstructure plus snow load of 5 lbs. per sq. ft. on the roof.
- (b) Live load. 112 lbs. per sq. ft.

Footbridges are now designed for the following loads and stresses:—

- (a) Dead load. The weight of the superstructure.
- (b) Live load. 100 lbs. per sq. ft.
- (c) Wind and snow. No addition need be made to the sectional area of any member to meet the increased stress due to wind and snow over and above the dead and live load stresses, unless the actual stress in that member is thereby raised to more than 33½% above the working stress, in which case such additional material shall be provided as will bring the combined stress within that limit.
- (d) Working stresses
 - (i) Mild steel, in accordance with British Standard Specification No. 153;
 - (ii) Timber, tension and compression 1,120 lbs. (0.5 tons) per sq. inch for good quality woods, 896 lbs. (0.4 tons) per sq. inch for medium quality soft woods,
shear 150 lbs. per sq. inch.

27. About 80% of the persons on the footbridge were men and on this basis it is estimated that the average weight was 150 lbs. This would give a loading of 67 lbs. per sq. ft. for 200 persons and 84 per sq. ft. for 250, which was probably the maximum load carried by the bridge before the crowd started moving and thinning out. It will be immediately apparent that the actual load on the bridge was well within the designed limits, whether calculated under the new or the old rules.

28. With the bridge in good condition and the wrought-iron straps transmitting the load correctly, the stresses set up in the main members by the original designed loading of 112 lbs. per sq. ft. plus 5 lbs. per sq. ft. snow loading would have been as follows:—

- Bottom boom member CD, total bending stress 1,410 lbs. per sq. inch (0.63 tons)
- End Raker member FH, total compression stress 660 lbs. per sq. inch (0.3 tons)
- Top boom member HJ, total compression stress 490 lbs. per sq. inch (0.22 tons)
- End bearing at A, total shear stress 31.4 lbs. per sq. inch.
- Wrought-iron strap at D, total tension stress 2.58 tons per sq. inch.

The designed maximum stress in the bottom boom member is somewhat high and is due to the omission of the centre vertical tension member. The compression stresses in the rakers and top booms and the shear stress in the end bearing are well within the permissible limits, and the stress in the wrought-iron straps is also quite safe. With loadings of 200 and 250 persons the bending stresses would have been 985 lbs. (0.44 tons) and 1,165 lbs. (0.52 tons) per sq. inch respectively; these can be considered reasonable and would have allowed for a minimum factor of safety of 3 based on the ultimate breaking strength of the tested specimens.

29. As soon as the wrought-iron straps corroded, conditions changed entirely; the stresses were no longer transferred through these straps to the rest of the structure and the bottom booms became simple beams of 61' span except for such support as was provided through the outside boarding. Without such support, the bending stress in the bottom boom produced by loads of 200 and 250 persons would have been 9,200 lbs. (4.1 tons) per sq. inch and 11,000 lbs. (4.9 tons) per sq. inch respectively. These figures are greatly in excess of the ultimate breaking strength of the test pieces. It is clear, therefore, that part of the load must have been transferred through the nails and runners to the tongued and grooved boarding and thence to the top booms and that for a long time the safety of the bridge had depended on this inadequate means of support. The nails holding the runners to the bottom booms were the weakest link in this weak chain and when they gave way the booms collapsed.

30. Various witnesses stated that the two bottom booms and the floor dropped together without breaking in the centre, and the unbroken state of the flooring supports this view. If this were the case the final failure must have been due to shear and not to bending, and the fractures that were found in the middle sections of the boom probably occurred when they struck the rails. If the bottom boom had been acting as a simple beam the maximum shear at the ends would have been 163 lbs. per sq. inch with a load of 200 persons and 194 lbs. per sq. inch with 250 persons. This is somewhat less than the minimum breaking stress of 198 lbs. per sq. inch obtained from the test piece and bears no comparison with the heavy bending overload. The wood inside the Down side castings was, however, in an advanced state of decay which had extended to a lesser degree to the timber outside the bearing. Thus the strength of the bottom boom to resist shear at the abutment would have been very much less than that of the test pieces which had of necessity to be selected from timber in reasonably good condition. The support given by the outside boarding was probably irregular and the nails at the ends may well have given way before those in the centre. In these circumstances, it can be assumed that the bridge did not fail through bending, as might be expected, but the Down side end gave way first through shear failure, and as it dropped it struck the top of the water column, which checked its fall momentarily; after this the Up side ends must have broken so that the whole of the bridge fell as one piece.

CONCLUSION

31. I am satisfied that the footbridge, as designed, was strong enough to carry the heaviest passenger load likely to be placed upon it, and the failure would have been prevented if the bridge had been maintained in a proper condition. It should have been perfectly safe to allow the passengers to form a queue, and criticism should not be levelled against the station master, who was in no way to blame for the accident. The arrangements which he made for controlling the crowd of intending passengers were sensible, and the action which he took afterwards was most commendable.

The modern pedestrian loading figure of 100 lbs. per sq. ft. for railway footbridges is, I consider, conservative. A crowd of 300 persons would have been needed to produce this loading compared with my estimate of a maximum of 250. The witnesses who were on the bridge or its approaches just before it collapsed were unanimous that they were very closely packed and I doubt whether more would have crowded on to it except under panic conditions. In this case loadings up to 150 lbs. per sq. ft., the maximum obtainable in such circumstances, could have been carried without the bridge collapsing if it had been properly maintained, although its design was not in accordance with modern practice.

32. There are features in this design which call for comment. The ends of the Down side trusses were partially enclosed by a brick abutment so that damp seeped into the timber encased in the bearings and set up serious decay. This might have been avoided if the bearing had been left more open and the timber exposed to the air. The extension of the outside boarding so as to cover the straps around the bottom booms was quite unnecessary and made inspection more difficult.

33. As already described, the failure was due to the straps having corroded so badly that they were no longer transmitting any stresses to the rest of the structure. The bridge must have been in this dangerous condition for some years and it was only the precarious and fortuitous support given by the outside boarding which saved it from destruction for so long.

It is not possible to forecast with accuracy the rate at which the straps were deteriorating, but in view of their condition it is probable that they were getting dangerously thin some 10 to 15 years ago. Unfortunately neither the District Engineers nor the Inspectors who last examined the bridge were available to give evidence, but it seems from Chief Inspector Lowe's statement, that the 1944 and 1948 examinations were carried out in a cursory manner.

The special examination in 1946 appears to have been more thorough, but it is surprising, not to say disturbing, that the corrosion of the straps was not noticed on that occasion, when some of them must have been reduced to paper thinness or may even have been completely wasted away. I can only conclude that the Inspector did not remove the soot and dirt from the bottom booms when he examined the underside of the bridge. The sections of the straps above the flooring had been little affected by corrosion and Chargeman Wilson cannot be blamed for failing to observe their dangerous condition, a responsibility which rested on the Inspector.

By 1948 the corrosion would have been worse, but this time the bridge was examined by a newly appointed Inspector who had little experience of this work and who had not received any training for it. He may well have rushed the inspection on account of the double programme to be completed that year. Chief Inspector Lowe himself has little knowledge of the design or strength of bridges and he admitted that he did not give any instructions to his Inspectors about bridge examination. He cannot, however, be unduly criticised since he received no guidance in this important subject.

34. The failure to notice the serious state of the Bury bridge was not an isolated case, as is shown by the condition of a similar bridge at Oldham which was opened up and examined at my request. This reinforces the conclusion that not enough attention was paid to the bridge inspections in the Blackburn Division, where insufficiently trained staff were allowed to carry out this work under a Chief Inspector who appeared to know so little about the subject.

REMARKS

35. The regulations for the examination of structures had in the London Midland Region been revised before this accident occurred and specially trained Bridge Examiners had been appointed, but unfortunately the examiner in the Blackburn District had only just taken up his new duties. These men have recently been given a further course of instruction during which the lessons learnt from this failure were emphasised. Full particulars of this accident were also sent to all District Engineers and all timber footbridges of similar design were specially examined. A complete new code of practice has been prepared and will be issued shortly. I am also informed that in future one of the Engineers in each District will be directly responsible for supervising the work of the bridge examiners. These arrangements should ensure that a serious lapse in inspection procedure such as occurred in this case will not happen again.

36. The new instructions laid down a 3-year inspection cycle for bridges; this should suffice in the great majority of cases so long as the inspections are thorough and normally inaccessible parts are not overlooked. It is the responsibility of the Engineer to ensure that this is done and to see that more frequent inspections are made when necessary; this is one of his most important duties. The designer on his part should pay particular attention to accessibility especially of joints and those places where deterioration may be dangerous.

37. Many railway structures are getting old—some have been in existence for over 100 years—but there is no reason on this account to doubt their safety which has been generally assured throughout the years by careful and regular examination and by the prompt execution of necessary repairs. Very few failures have occurred, and the only other Ministerial Inquiry held during the last 50 years was concerned with the collapse of the Charing Cross Station roof on 5th December, 1905; a part of the roof of Sheffield (Victoria) Station also fell down on 24th September, 1951. The first failure was due to a hidden flaw in a tie bar and the second to concealed fractures in a cast iron gusset plate; neither of these could be seen in the course of normal inspections; in each case special steps were taken so as to ensure as far as practicable that there would not be a recurrence. This freedom from accident is evidence of the care which has been paid in the past to this vitally important inspection work and there is every reason to expect that it will be meticulously carried out in the future.

I have the honour to be, Sir,

Your obedient Servant,

C. A. LANGLEY,

Brigadier.

THE SECRETARY,

MINISTRY OF TRANSPORT.

APPENDIX

REVISION OF ARRANGEMENTS FOR THE NORMAL PERIODICAL EXAMINATION OF STRUCTURES

Extracts from Circular dated 18th October, 1950

* * * * *

General.

District Engineers are responsible for the periodical examination of all Railway Executive Structures within their Districts which are wholly maintained by the Civil Engineer, and all structures which the Civil Engineer maintains on an agency basis for other Executives, together with the examination of the appropriate parts of those structures for which the Civil Engineer is only partly responsible. Their responsibilities will only be varied to the extent shown in the Special Structures List.

The frequency of examination of structures will normally be as laid down in the enclosed schedule, but the District Engineer shall vary this as necessary in cases where structures are known to be generally or locally in such condition or subject to such deterioration that more frequent examination is necessary. Where structures are known to be in good condition, the normal interval between detailed examinations may be extended where it is reasonable to do so, provided that the authority of the Civil Engineer has been obtained.

District Engineers should endeavour to keep themselves fully aware of the condition of structures for which they are responsible by personal inspection when examinations are being made in accordance with the schedule, especially in the case of tunnels, viaducts, and harbour and sea defence works.

The new schedule for periodical examinations will be brought into force as from 1st January, 1951, and District Engineers must, in the meantime, set up the necessary revision of Records and Organisation to provide for this. They must consider, and report on, how the examination cycles for the different types of structures can best be planned to suit the lay-out of their Districts, and who should carry out the detailed and superficial examinations in all cases where this is not laid down in the schedule. A report and proposals covering these points should be sent to me by 1st December next, so that agreed proposals may be put into operation at the beginning of 1951.

SCHEDULE FOR THE NORMAL PERIODICAL EXAMINATION OF STRUCTURES

* * * * *

Viaducts, Bridges, Culverts and Retaining Walls.

Detailed examination of viaducts, bridges, culverts and retaining walls shall be made normally at intervals of 3 years.

Where possible the detailed examination of iron and steel bridges and viaducts should be carried out in conjunction with painting when scaffolding is available.

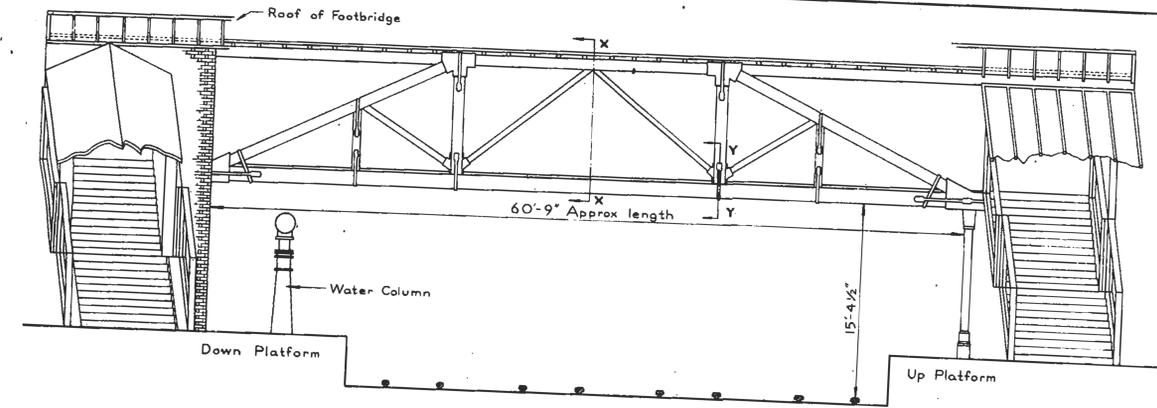
Superficial examination of all bridges and culverts, preferably under Traffic, and of all retaining walls, shall be made by the Permanent Way Inspector at least once in every six months. He will report forthwith to the District Engineer any development noted which might in any way affect the safe uninterrupted running of traffic.

In respect of all viaducts and certain bridges, culverts or retaining walls, where examination at six monthly intervals by the Permanent Way Inspector would be unreasonable, this duty may be waived and alternative arrangements for superficial examination at intervals not exceeding 12 months, made by the District Engineer, who will maintain a record of such cases.

KNOWSLEY STREET, BURY

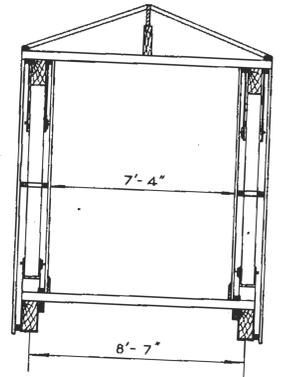
COLLAPSE OF FOOTBRIDGE

19th. JANUARY, 1952

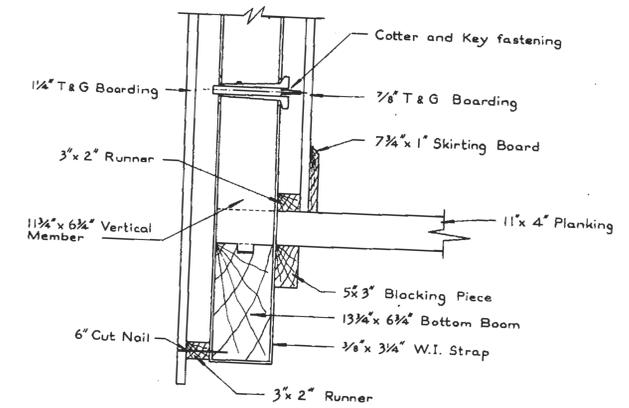


ELEVATION OF FOOTBRIDGE WITH BOARDING REMOVED
SCALE: 8 FEET TO 1 INCH

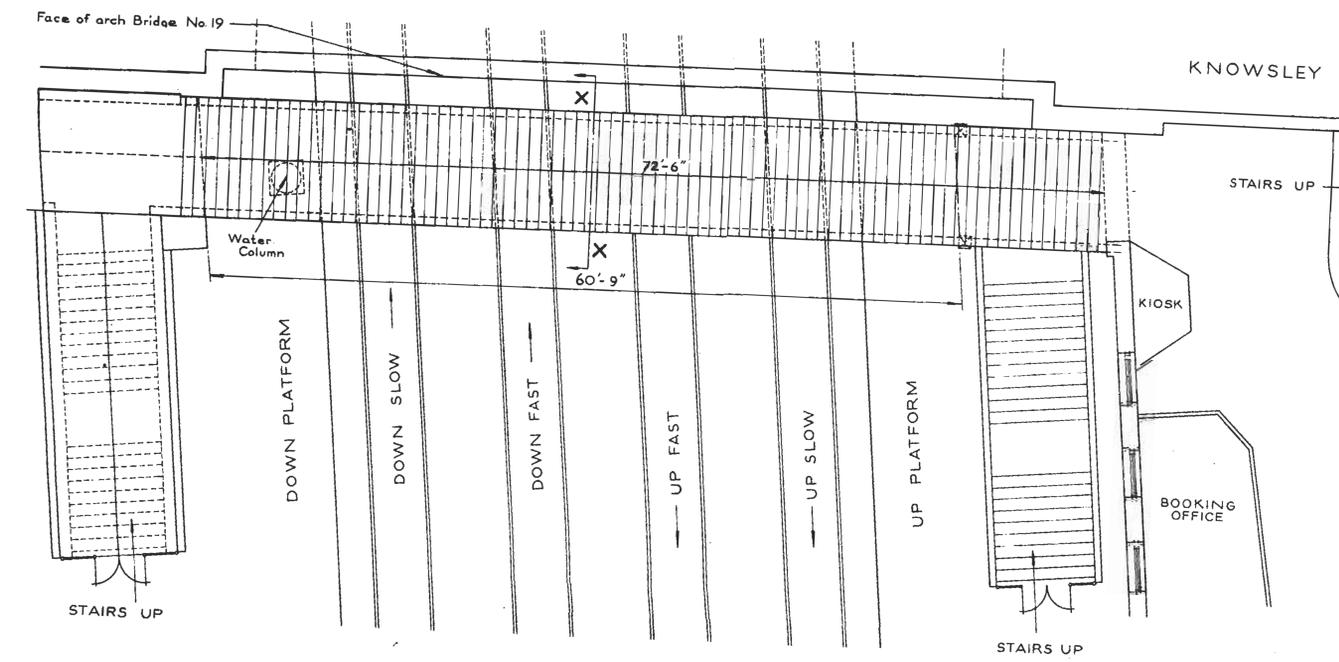
Note
Gates at foot of both
stairways are omitted



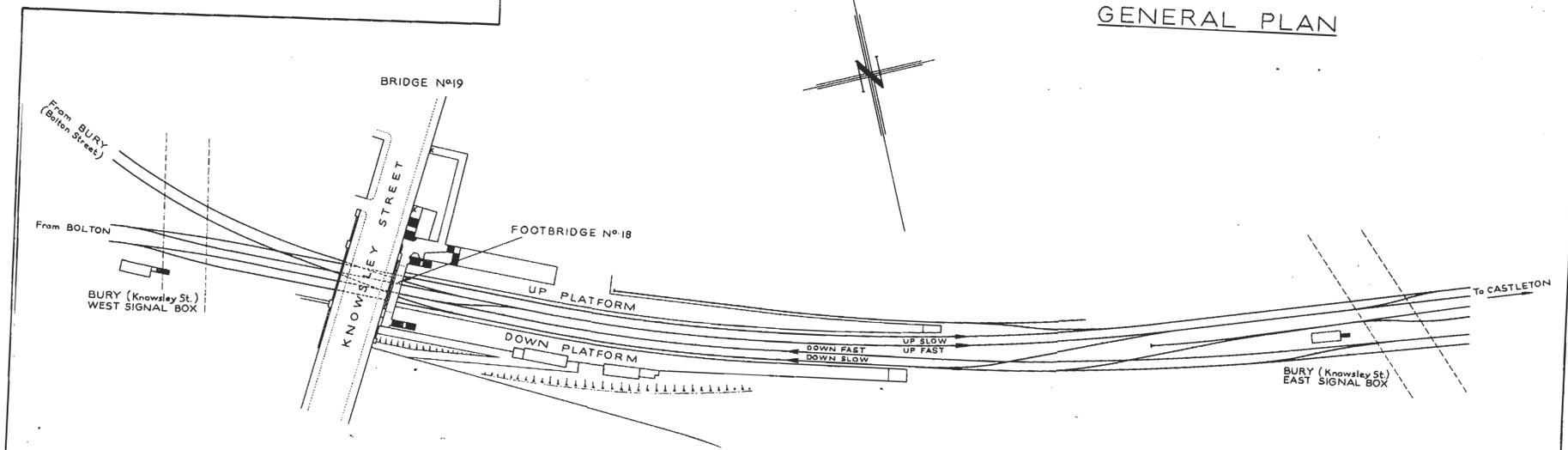
SECTION X-X
SCALE: 4 FEET TO 1 INCH



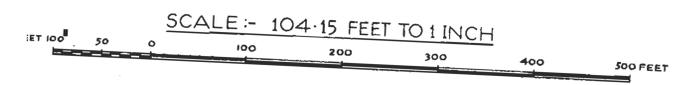
SECTION Y-Y THRO BOTTOM BOOM
AND FLOOR
SCALE: 1 INCH TO 1 FOOT



PLAN OF FOOTBRIDGE
SCALE: 8 FEET TO 1 INCH

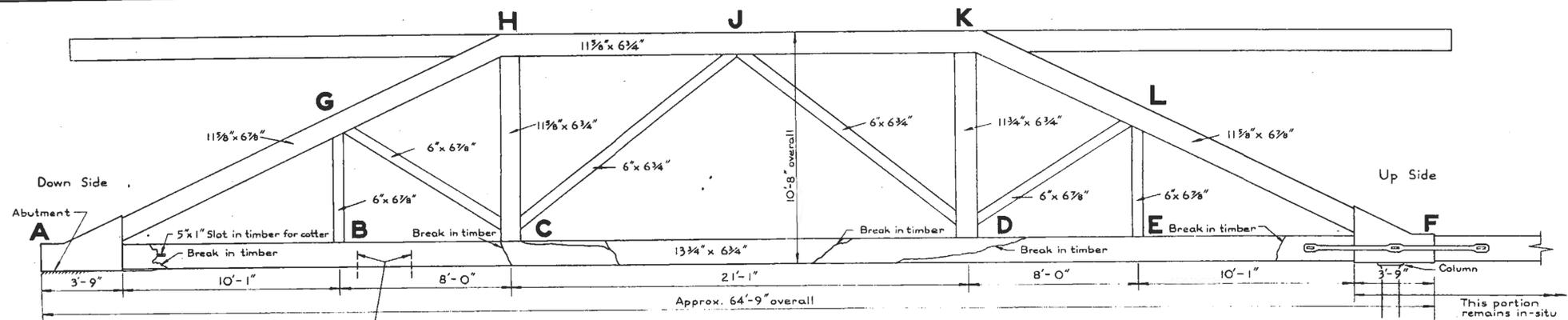


GENERAL PLAN

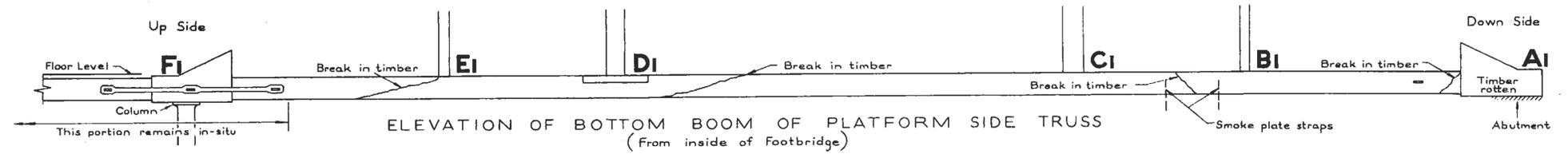


KNOWSLEY STREET, BURY — PASSENGER FOOTBRIDGE

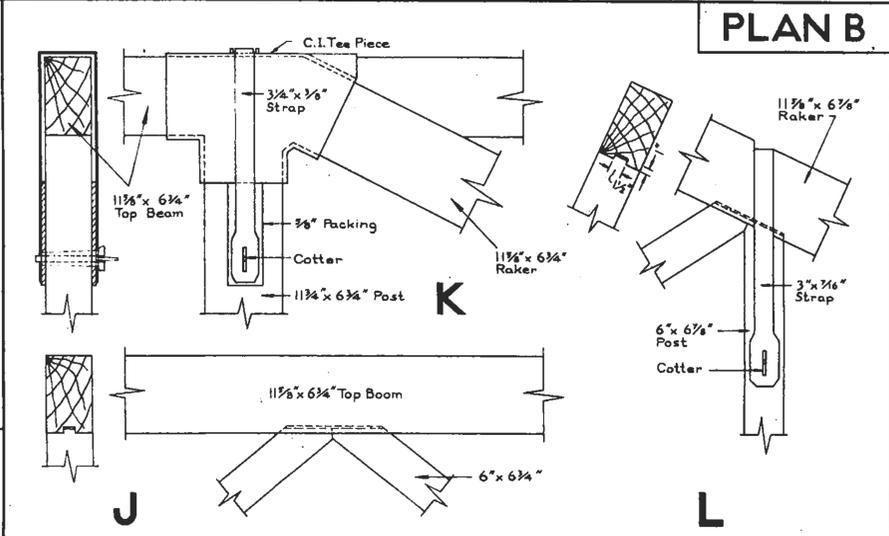
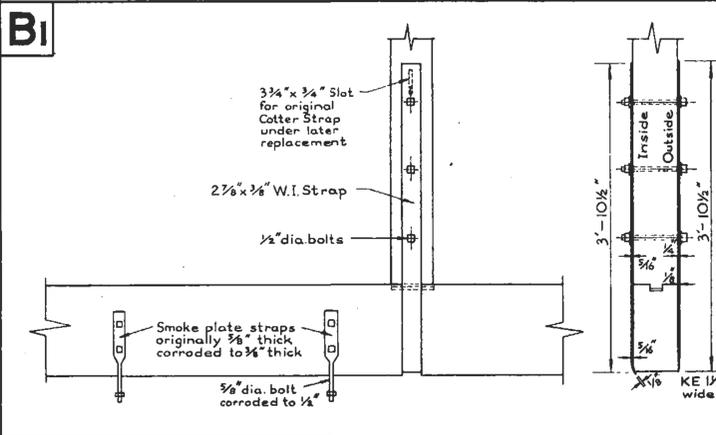
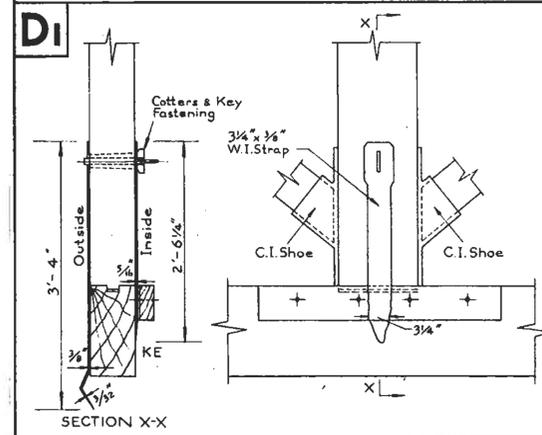
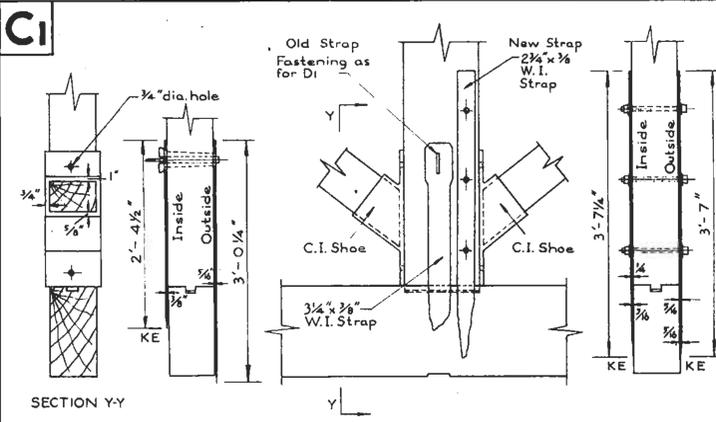
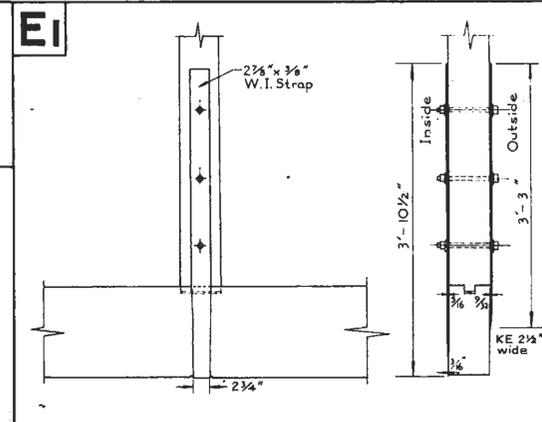
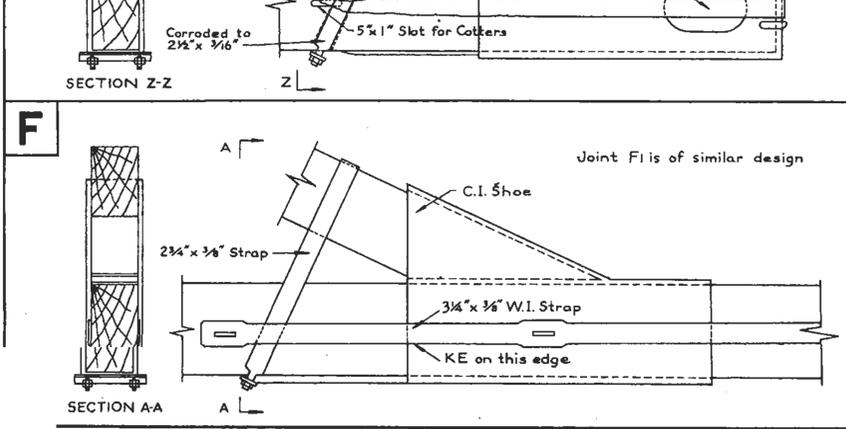
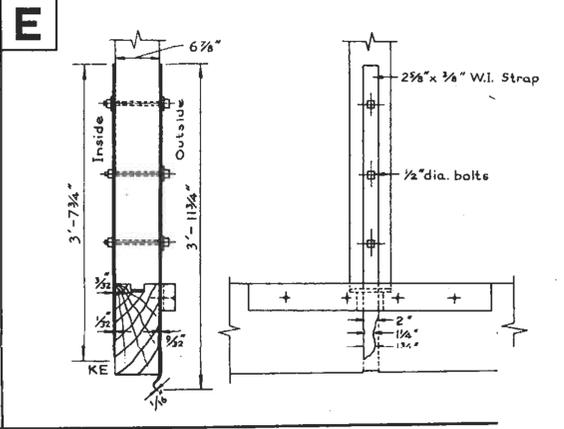
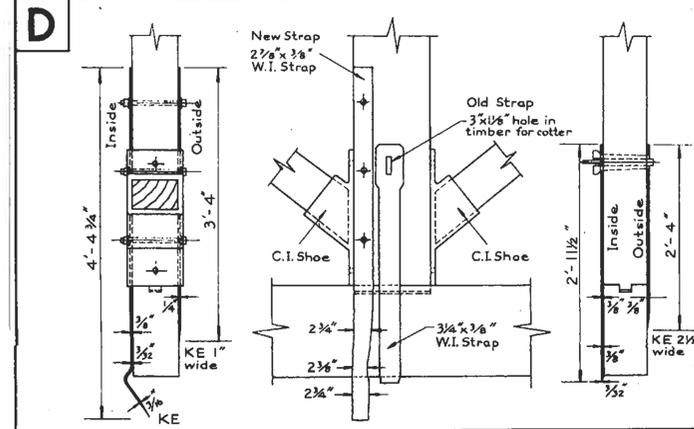
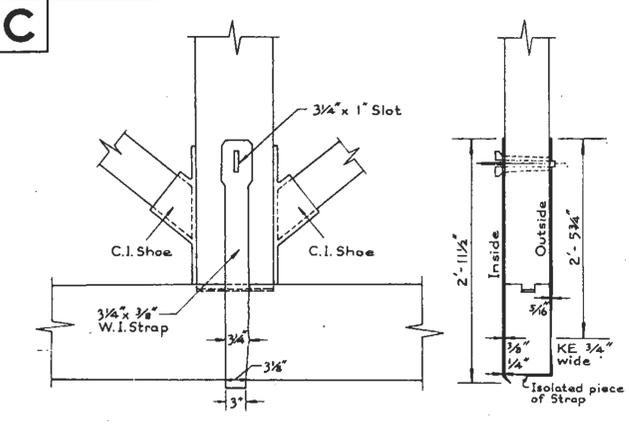
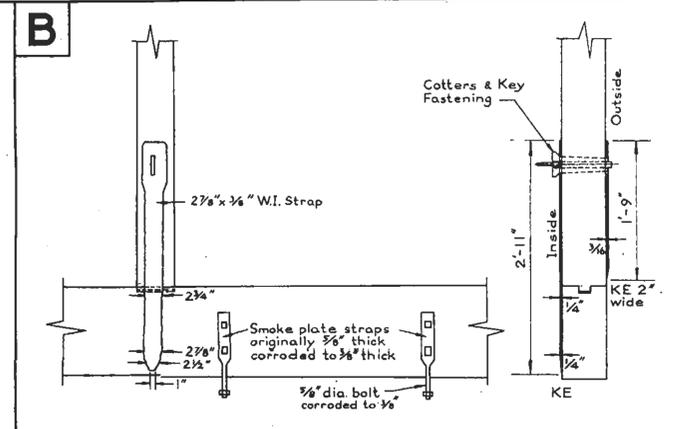
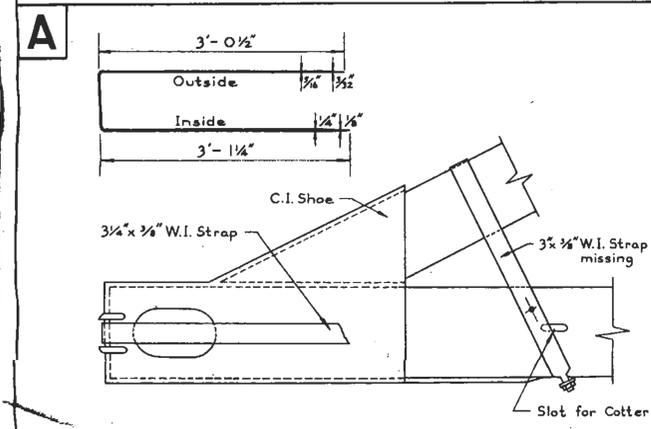
DETAILS OF THE JOINTS OF THE MAIN TRUSSES
 NOTE: - ALL THE ELEVATIONS HAVE BEEN TAKEN FROM THE INSIDE OF THE BRIDGE
 SCALES: GENERAL ELEVATION 1/4" TO 1'-0" DETAILS OF JOINTS 3/4" TO 1'-0"



ELEVATION OF ROAD SIDE TRUSS
(From inside of Footbridge)



ELEVATION OF BOTTOM BOOM OF PLATFORM SIDE TRUSS
(From inside of Footbridge)



PLAN B

