January 7, 1913.

The Director,

Bureau of Standards,

Washington, D. C.

Dear Sir:

I have the honor to report upon the failure of bridge No. 43 1/2, on the main line of the Pennsylvania Railroad, near Glen Loch, Pa., which occurred under west bound train No. 19, at about 11:40 P. M., November 27th, 1912.

This train was composed of a helper locomotive, a train locomotive, a mail car, a combined car, a day coach, and nine sleepers; all of steel construction. The total weight of the train was 2,327,780 lbs., made up as follows:

Locomotive No. 2426,	Engine,	183,100	lbs.
	Tender,	132,500	"
Locomotive No. 1618,	Engine,	183,100	"
	Tender,	132,500	"
Mail car, No. 6559,		123,900	"
Combined car, No. 4891,		125,800	"
Day coach, No. 1763,		115,700	"
Sleeper, Glen Rock,		148,500	"
" Silverton,		148,500	"
" Mansfield,		147,740	"
" Midway,		147,740	"
" Lambson,		147,740	"

Sleeper, Airey,	147,740 lbs.
" Economy,	147,740 "
" Westland,	147,740 "
" Allenport,	147,740 "

Each car had six-wheel trucks, excepting the day coach which had four-wheel trucks.

The axle loads were as follows:

Leading trucks of the engines,	16,850 lbs.
Forward drivers,	56,700 "
Rear drivers,	61,500 "
Trailers,	31,200 "
Tender,	33,125 "
Mail car,	20,650 "
Combined car,	20,967 "
Day coach,	28,925 "
Sleeper, Glen Rock,	24,750 "
" Silverton,	24,750 "
" Mansfield, and each of the other six sleepers,	24,623 "

The total length of the train was 1104 feet, 5 1/4".

The train was proceeding in a westerly direction on track No. 4, drifting on a down grade of 0.29%, when it reached bridge No. 43 1/2; the track on the bridge and east and west thereof being on a 2-degree curve, curving southward. The speed of the train when it reached the bridge was estimated to be about 48 miles per hour.

The failure of the bridge took place, apparently, when the leading locomotive was upon it, resulting in a partial derailment of the train, and causing the death of four persons and injury to forty-nine others. The middle part of the train consisting of the day coach and four sleepers left the roadbed immediately beyond the west end of the bridge, and were thrown down a 25-foot embankment. The two locomotives, the mail car, the combined car and the last five sleepers remained on the track or on the roadbed.

The track was destroyd, beginning at the west end of the bridge for a length of 369 feet.

The tender of the leading locomotive was uncoupled from the engine of the second locomotive. The leading locomotive ran a distance of about 2000 feet beyond the bridge, with forward driving wheels and No. 4 tender truck wheels off the track, each on the south side of the rails. The second locomotive broke loose from the train, the draw bar of the tender pulling out. No. 1 driving wheels and No. 2 and No. 4 tender truck wheels of this locomotive were off the track, on the same side as those of the leading locomotive; that is, toward the inside of the curve. The mail car was partially derailed, while the wheels of both trucks of the combined car left the track.

The day coach came to rest at the foot of the embankment, bottom side up. Four sleepers rested on the slope, forming a huge letter W; the forward one, the Glen Rock, coming into contact, sidewise and against its roof, with a steel hopper car which stood on track No. 7 at the foot of the embankment. This car was loaded with coal, the collision with which necessarily resulted in injury to the sleeper. Excepting at their ends the other sleepers, on the slope, were comparatively little injured. The last five cars of the train did not leave the track or roadbed and were in general good condition after the derailment. These steel cars showed superior structural qualities and to their strength the small list of casualties was without doubt due, while fire did not add to the disaster.

Bridge No. 43 1/2, an iron structure built in 1891, spanned the two tracks of the Trenton branch of the Pennsylvania R.R., and carried west bound tracks Nos. 3 and 4 of the main line of the road. These two west bound tracks are used for freight and passenger traffic respectively.

It is a skew bridge on an angle of about 15 degrees. There are two spans of half-through plate girders. The outer ends of the girders rest upon stone abutments, the inner ends upon a box girder which in turn was supported by eight latticed columns standing upon a center wall between the tracks of the Trenton branch. The latticed columns were made of two 12" channels each, and in height are a few inches over 14 feet. They were provided with base and cover plates, each 24" square, the base plates being anchored to the center wall by four 1" bolts, while the box girder was bolted to the cover plates by four 3/4" bolts at e ch column. The channels were connected with the base and cover plates by gussets and angles.

The main plate girders of the bridge were anchored to the abutments by means of two 1 1/8" bolts at each corner, eight bolts in all. Expansion was provided for at the west end of the bridge. Each main girder was provided with gusset braces, five each for girders designated by the letters A. B. and D, and six for girder C.

The floor beams, 15" I-beams, were at their outer ends in part riveted to the webs of the main girders, those however which reached to the abutments rested upon the masonry without attachment thereto. Shoes 8" by 10", of two 3/4" plates were riveted to the lower flanges of the I-beams and rested directly upon the abutment walls. The inner ends of the floor beams were bolted to the box girder.

Wooden stringers were carried by the floor beams, secured by angle irons, on which the ties were notched. The track, which was laid with rails of 100 pounds section, had steel guard rails inside, and wooden guard rails outside.

Concerning the derailment, the most easterly marks on the ties were found on the bridge about 66 feet west of the east end of girder B, and abreast column No. 8. They were located on the north side of the north rail of track No. 4, that is, the track on which train No. 19 was running. Figure No. 3, a floor plan of the bridge, indicates the places occupied by the main plate girders, designated by letters, the box girder and supporting latticed columns, and shows parts affected at the time of derailment.

These first marks on the ties were not numberous nor were they very deep. Since the derailed wheels of the two locomotives were found on the opposite side of the rails, that is on the inside of the curve, it is believed that these most easterly marks represent a secondary occurrence and not a primary one.

Near the middle of the length of the bridge there were flange marks on the south side of both rails of track No. 4. Between these two points, there was located a rail, a north one, which was very much bent. Measured after it was removed from the track, it was a middle ordinate of 6 1/2", concave on the gauge side. The middle ordinate for a rail 33 feet long, the length of this one, to conform to the curvature of a 2-degree curve, should be 9/16".

The middle of the length of this bent rail was nearly abreast column No. 3, where the depression of the track was greatest at the time of derailment. It was the only rail on the bridge which required to be replaced by a new one when the line was reopened for traffic. This rail probably played an important part in causing the several wheels of the two locomotives to reach a position on the south side of the south rail.

According to the report of the Committee of the Pennsylvania Railroad, appointed to investigate the cause of the wreck, the depression of the box girder over column No. 8 was about 13". The depression over column No. 7 was very much less, only a few inches.

Both locomotives dropped into this depression, which was lowest on the north side, received a rocking motion, and were then suddenly raised out of the hollow. The flanges of the derailed wheels on the south side of the locomotives apparently cleared the top of the south rail as the trucks came out of the depressed section, possibly having received an impulse in that direction from the bent rail. The rolling motion of the leading engine knocked the engineman off his seat toward the south. He felt the engine go down and then come up.

In the vicinity of column No. 8 and the bent rail the greatest depression and lateral displacement of the bridge both occurred.

The steel inner guard rails and the wooden outer ones kept the train in good condition until it cleared the bridge. The bridge ties were bunched but little. They were moved an inch or two.

From the west end of the bridge, proceeding westerly, the track was torn out for a length of 369 feet. Out of some place in this destroyed section the cars which were thrown down the embankment left the roadbed on the north side of the track. The locomotives, the mail car and the combined car, continuing along the track, marked the ties on each side of each rail. The marks farthest west, however, were on the south side only of each rail, these being made by the derailed wheels of the locomotives.

Prior to the time train No. 19 reached the bridge it is believed that the track on the bridge and vicinity was in a high state of efficiency, referring to the rails, guard rails, ties, stringers and roadbed. The track maintenance appeared to have been excellent, the injury to the track being the result of the failure of the bridge, track conditions not contributing toward it.

The condition of the bridge after the derailment showed that the chief injury to the structure occurred at the upper ends of columns Nos. 3 and 7, and to the section of the box girder which these two columns supported. Also that the part of the floor system which rested upon the east abutment was disturbed in its position while the two north main girders designated by the letters A and B were affected. The upper flange of girder A was buckled at the gusset brace near its end which rested upon the box girder. The west end of plate girder B was bent outward slightly. These bends made an outward bulge some fifty feet across.

Described in detail, girder A was straight from its west end to the third gusset brace. At that brace the girder was bent toward the north, reaching a maximum at the fifth gusset, where the top flange was buckled at the inside edge. Between the third gusset and the end which rested on the box girder the middle ordinate was 4 1/4", on a chord of 45 feet 8". The inner ends of both north girders were moved outward, girder A about 3" and girder B about 4 1/4", as measured after the bridge had been jacked up, and each had sheared the bolts which secured it to the top plate of the box girder. The bent rail previously referred to was located opposite this bulge in the main girders. Its position in the track is indicated by two short lines drawn across the line representing the north rail, on the plan of the bridge in figure No. 3.

For nearly one half its length girder A was tied across to girder D, being connected through the floor beams. The part thus reenforced remained straight. At the east end of girder D the angle iron connections of the first floor beam were fractured at the time of the derailment. The angles had previously been partially fractured by a blow which had been received by the girder, the rupture being completed on the present occasion. This floor beam, through its connections, afforded the first positive anchorage of the north girder against centrifugal forces tending to cause an outward lateral movement of the bridge during the passage of trains at high rates of speed.

The shoes of the floor beams had apparently worn smooth seats on the masonry of the east abutment, from which it appears that the frictional resistance of the beams at their ends resting upon the abutment wall was of uncertain value in resisting centrifugal forces. The floor beams moved on the east abutment at the time of derailment. Measured after the bridge had been jacked up, the maximum outward movement was about 4 3/4", which represents the displacement of the beam which reached across from the fifth gusset brace of girder A. This beam was also set backward toward the east one inch at its end on the abutment. The beams swivelled about some point along their length and while being moved outward their north ends were probably carried along in the direction the train travelled, causing their south ends to be set back toward the east. The shift in position of the floor beams diminished in extent toward the ends of the abutment where the anchorages of the main girders arrested the movement.

There was no evidence that the ends of the main girders were carried northerly on the occasion of this derailment but three of the corners showed the anchor bolts had been bent in a northerly direction, the result probably of successive impulses received during the period of time in which the bridge had been in service.

The bolts of girder B were partially withdrawn from the stonework.

At the southwest corner of the bridge, the bolts of girder C were not disturbed. This corner would not be called upon to resist centrifugal forces of trains rounding the curve at speed, on account of the reaction of the west abutment.

Although the destructiveness of the derailment owed its origin to the failure of the bridge, there was comparatively little evidence present until the west end was reached and passed. The damage to the track and to the train immediately resulted from conditions which affected the trucks about the time they left the bridge.

Below the floor beams the injury to the bridge was confined to the section of the box girder between columns Nos. 6 and 8; and to columns Nos. 7 and 8.

The initial line of rupture appears to have been the completion of a fracture which existed prior to this derailment in the cover plate of column No. 8, located near its south edge, and directly over the south vertical face of the gusset plate of this column. Figure No. 4 shows the details of the top of the column and indicates the location of this line of rupture.

The cover plate prior to the disaster was ruptured through the greater part of its thickness. It was 3/4" in thickness, planed on its upper face. The initial crack extended from the upper surface downward a depth of about 5/8" at the deepest place, leaving 1/8" thickness of unruptured metal. The completion of this line of rupture is believed to have been the immediate cause of the disaster. It permitted the box girder to drop down over the end of column No. 8, causing the sag of 18" in the bridge as noted by the Railroad Committee.

There was a bending moment at the top of column No. 8, which put the upper surface of this cover plate into tension. From outside to outside of the gusset plates the column measured 13", while the box girder which it supported measured 16 1/4" from inside to inside of its web plates, an overhang of 1 5/8" on a side. There was evidence of looseness at the joint between the cover plate and the web member of the box girder, at least at the south web, which was the ruptured edge of the cover. Repeated hammering of the web plate had indented and slightly grooved the upper surface of the cover plate. Figs. Nos. 5 and 6 show the appearance of this cover plate after removal from the bridge.

These conditions are believed to have started a progressive fracture in the cover plate, which was promoted by a deficiency in lateral stability of the bridge along its easterly half. Trains passing over the bridge at high rates of speed would tend to move it outward and exert an overturning tendency on column No. 8, such as it might be, while the floor beams would necessarily deflect under the weight of the train and further intensify the stress transmitted through the south web of the box girder. The load transmitted to column No. 8 by the main girder B would still further cause this to be a highly stressed member, and tend to rupture the cover plate. In addition the grain of the iron of the cover plate ran lengthwise the box girder, which caused the bending stress on the plate to be crosswise the grain - that is, it was stressed in its weakest direction.

The tendency of the bridge to shift its position in a no~therly direction under the influence of the centrifugal forces of the trains is shown by the bent condition of the anchor bolts at three of its corners. Whereas, ties well tamped in a well-ballasted track ordinarily have sufficient frictional resistance to keep the track from shifting outward on curves, in the present instance the ties as a group on the iron I-beams of the floor system did not have the advantage of such frictional resistance. Furthermore, the supporting columns of the box girder could easily be overturned by an outward thrust on the track. These columns were tied together in pairs by braces, but such bracing was not in the direction which would materially increase the stability of the bridge. The easterly end of the bridge was retained on its abutment chiefly by the resistance of the anchor bolts at the ends of the main girders, while they were bent in offering such resistance. Attending these conditions it would seem that the cover plate of column No. 3 had been repeatedly subjected to bending stresses both from the downward weight of the trains and from their outward centrifugal thrust, and that some looseness had permitted of a hammering action of the south web of the box girder upon the cover plate, all of which had resulted in the development of a progressive or detailed fracture. With such a fracture started it was only a question of time when rupture of the plate would be completed and the failure of the bridge consummated.

The formation of a progressive fracture is the result of occasional overloads, repeated a greater or less number of times according to their magnitude. If the overload reached a maximum at each application, rupture would soon take place, but such is not usually the case under service conditions. Doubtless it was an exceptional incident in the history of this bridge when all the conditions of loading conspired toward developing a maximum stress. In the interval of time since the bridge was built there has been a decided increase in the weights of rolling stock and concentrated loads on wheels, and higher stresses no doubt have been received by the bridge in recent years over those of former ones.

The length of time during which this fracture has been in existence cannot be told. As a matter of judgment it may have been in process of development for a number of years. It could hardly have been developed, however, to any great extent four years ago, the last time the bridge was painted, since paint had not run into the crack. It is not believed to have had its origin within a period of a few months.

The photographic prints figures Nos. 5 and 6 illustrate the appearance of the upper and lower surfaces respectively of this cover plate. There were two 4" by 6" angles riveted to the plate by five rivets each, the rivets being countersunk on the upper surface. The four bolt holes for the 3/4" bolts which secured the box girder to the top of the column are shown in figure No. 5.

The line of rupture was at a distance of 1 7/8" to 3" from the grooved or indented line on the upper face of the plate, the indented groove made by the south vertical web of the box girder. The rupture began at the top surface of the plate and extended downward. During its formation and development it would be visible in so far as not having been directly covered by any other member. Its accessibility for inspection or detection, however, was impeded by the double latticing of the vertical webs of the box girder.

There were other ruptured parts of the bridge below the level of the floor beams. The cover plate of column No. 7 was ruptured, the line of rupture occurring near the north edge, at a corresponding place to that of No. 8, only on the opposite side of the column. The appearance of the fractured surface showed the grain running in the same direction as that of column No. 8, that is both cover plates were fractured crosswise the grain of the iron. This fracture was not examined sufficiently early after the derailment to admit of a definite statement being made concerning the presence of an initial rupture preceding its final fracture.

When the failure of the bridge occurred the upper end of column No. 8 was tipped toward the north, that of No. 7 toward the south, each being carried over in a direction opposite the side on which their respective cover plates were fractured. The anchor bolts at the bases of the columns were disturbed on the sides opposite the directions in which the tops moved. Accompanying the movements of the tops of these columns there was a twisting of the box girder. The latter developed a longitudinal crack along the north vertical web, its angles were bent and cracked, the splice plates connecting this section of the girder with that next to it were injured, and the lattice bars quite generally bent.

The curvature, immediately east of the bridge, was taken out and the track straightened the length of a rail or two by reason of the northerly movement of the floor system and the rails thereupon.

The rules of the Pennsylvania R. R. company require a monthly inspection of its bridges by a Bridge Inspector, a semi-annual inspection by the Division Engineer and Master Carpenter, and an annual test for deflection. The monthly inspection is for the detection of detailed defects, if any are present. Recent inspections of this bridge were as follows:

Semi-annual inspection by the Division Engineer and Master Carpenter,	Oct. 7, 1912
Monthly inspection by the Bridge Inspector,	Nov. 18, 1912
Annual deflection test, by the Bridge Inspector,	" 26, "
The bridge failed,	" 27, "

The semi-annual inspection jointly made by the Division Engineer and the Master Carpenter "disclosed no imperfection affecting the integrity of the bridge". The Bridge Inspector reported the structure in good condition, giving it the highest mark provided for on the inspection report blanks, excepting the back wall was reported "fair", a condition not affecting the present accident.

The Bridge Inspector who reported upon the condition of this bridge stated that his monthly inspection included the examination of "rivets, connections and everything connected with the bridge".

The Master Carpenter of the Philadelphia Division, on which this bridge is located, testified that it was the custom to inspect every bridge every thirty days, that he had from five hundred to six hundred bridges under his care, and six inspectors for doing the work. From this testimony, it would appear that some twenty bridges per day would require to be inspected on his division by six men.

The test for deflection consisted of observing the deflection of the main girders during the passage of regular trains over the bridge, in this case there being two freight trains at speeds of 20 and 30 miles per hour and two passenger trains at 50 and 60 miles per hour, respectively. The deflection test "developed no conditions that would indicate weakness in the structure".

It further appears in the testimony taken before the Committee of the Pennsylvania Railroad that the Master Carpenter was cognizant of the fact that certain of the anchor bolts of the main girders had been disturbed and that both he and the Track Foreman were of opinion that the bolts at the east end of plate girder B were broken off down in the stone work of the abutment.

The results of chemical analysis and tensile tests of the fractured cover plate made by the Pennsylvania R. R., were as follows:

Chemical Analysis.

Carbon	.033%
Manganese	.025
Phosphorus	.252
Silicon	.115
Sulphur	.006

Tensile Tests.

Direction of grain.	Elastic Limit: Lbs. per sq. in.	Tensile Strength: Lbs. per sq. in.	Elongation in 2" %	Contraction of area %
Lengthwise	28,440	46,830	24.0	21.62
Crosswise	28,760	29,950	4.	1.45
"	29,200	29,460	6.	3.85

The Committee of the Pennsylvania Railroad appointed to investigate the cause of the wreck of train No. 19, in referring to the bridge said "the design of the structure prevented the disclosure of the rupture of the cover plate under the usual inspection, except at the front and rear ends of the plate where the accumulation of paint would tend to obscure the same. This detail fracture had no observable effect upon the stability or strength of the structure as is evidenced by the results of the deflection tests made the day before the wreck occurred."

The Committee concluded "that the failure of the bridge was occasioned by the rupture of the cover plate of column No. 8," which conclusion appears to be confirmed by the evidence presented.

This bridge had evidently been inspected at frequent intervals, none of which had disclosed the presence of a detail or progressive fracture in the fatal cover plate. It chanced that deflections were observed the day before the wreck, but such observations meant but very little. In this case nothing more than that an Inspector was at the bridge one day before the derailment, and general supervision of the structure given it. Beyond a reasonable doubt the progressive fracture was well advanced at that time and probably had been in an advanced stage for weeks and months. The Committee of the Railroad, remarked that this detail fracture had no observable effect upon the strength of the structure. This remark is accepted in its modified sense, meaning that the weakness of the plate did not produce an effect which the method of inspection revealed, and not that an important plate cracked nearly through its thickness and on the verge of complete rupture which wrecked a train the next day was not a source of weakness.

While it is desired to encourage and not discourage adequate supervision and inspection of so important a structure as a bridge nevertheless it is not clear just what information was expected to be derived from observations on the deflections of the main girders of this bridge under the weights of passing trains, at speeds ranging from 20 to 60 miles per hour.

The deflection of a girder depends upon the modulus of elasticity of the material which goes to make up the girder. That value appears to remain constant in a given structural member, unless there is a very decided overstrain, one in fact which would occasion such deformation as would throw the structure out of service. Overstraining would need be quite general to produce an observable effect on the deflection of a girder of this type, by reason of the lowering of the value of the modulus of elasticity of the iron. But the lowering of the modulus of elasticity by overstrain is not a permanent effect.

The metal recovers its normal value within a few days or weeks, as shown by laboratory tests, hence such indications would be effaced within a short time, and as applied to the deflection of a girder the test might be considered as lacking in exactness.

An overstrained girder would, however, assume a lower position with reference to its original level. To detect such a permanent set would require a careful determination of its original height and reexamination of that feature. Such a method of test or inspection does not appear to be prescribed, although the loss in camber of bridges of long span is a recognized feature.

These remarks are extended since it is desirable to inquire into the real value of current tests or methods of inspection on which reliance is placed to safeguard engineering structures. Tests, of course, should not assume a perfunctory character, nor lead to a fictitious idea of security, nor on account of the labor involved crowd out more effective and more efficient means of acquiring useful information.

Bridge No. 43 1/2 was certainly a very much inspected structure, but as the result has shown it was not saved from a disastrous failure. Reliance appears to have been confined to inspection for a period of twenty-one years to furnish assurance of the safety of this bridge for constantly increasing traffic and heavier rolling stock than in use at the time of its construction. At least, no evidence has been presented to show that any critical examination of the plans of the bridge were made during that interim leading to the discovery of defects in the structure which the wreck of train No. 19 clearly brought into prominence, details recognized as undesirable as they are now seen. In the fatal cover plate an unsatisfactory detail is recognized. The discovery or recognition of such a defective detail might properly have been expected by the custodians of the plans of the bridge. The Pennsylvania Railroad has from time to time had occasion to renew its earlier bridges and replace them with stronger structures. Such renewals may have been in part the result of inspection reports on their condition, but generally from engineering knowledge that the working loads were approaching too high limits. An inspector, can hardly take up matters of design in the performance of his duties nor questions of maximum stresses which result from heavy train loads; certain of the physical changes in the structure can only be passed upon by such inspection as ordinarily made.

It is well known that repeated stresses are competent to effect rupture of metals without the display of ductility which is witnessed in the usual laboratory test. When failure occurs under conditions of repeated loading little or no display of ductility may be witnessed. Such being the case it is obviously futile to look for reliable indications of impending rupture in the results of tests for deflection under passing trains. A more refined and careful analysis of the condition is needed to be serviceable to judge of the approach of danger. Track inspection and maintenance is wholly a different affair to that of bridge inspection in many details although the resemblance is close in some directions. A minimum amount of useful or relevant information results from a test for deflection under passing trains when not connected with other observations on the behavior of the structure. At 60 miles per hour, the rate of speed reported for one of the trains under the weight of which a deflection test was made on the day preceding the wreck of train No. 19, the duration of the test, under maximum load would hardly be two seconds of time. The interval of time during which any given part of the bridge would be exposed to maximum load would be only a small fraction of a second. The effect on the structure of such suddenly applied loads possesses very great interest, but the ordinary deflection test annually conducted supplies meagre information on important points at issue.

The progressive nature of the fracture of the cover plate afforded an opportunity to discover the weakened condition of the bridge, but as stated by the Committee of the Railroad the design of the bridge prevented its disclosure "under the usual inspection". It was inaccessible but in a comparative sense only, that is as respecting the usual inspection. The cover plate was a short one and easily reached for painting. The double latticing of the box girder prevented direct visual inspection of the plate along its most strained section, which part otherwise was exposed to full view.

Portable apparatus for the inspection of inaccessible surfaces has been in use for many years in other lines of inspection service, consisting merely of a mirror and lamp for illumination. It would doubtless be an innovation to introduce such an ap aratus in bridge inspection, but in a case like the present one it is a question whether the most vital part of the structure shall go uninspected because the inspector cannot get his head into position to view the critical part or to employ the necessary means to view the same. Vital parts, demanding careful inspection, should be pointed out to the bridge inspectors by the bridge engineers since the latter have the plans at hand and opportunity to judge by computation what parts are most strained, according to the design of the structure.

The bent shape of the anchor bolts at three of the corners of this bridge would suggest the kind of forces which were acting to strain the structure. The freedom of the floor beams to move laterally on the east abutment in response to centrifugal forces and leading to the bending of the cover plate of the end column under the box girder might reasonably have attracted attention. The evidence of hammering of the south web of the box girder on the cover plate suggests that some looseness existed at this place prior to the accident. It is believed that these forces led up to the rupture of the cover plate. While the final rupture of the cover plate precipitated the wreck, antecedent causes which occasioned the progressive rupture of the plate are thought to reside in the features just mentioned.

The grain of the cover plate was parallel to the length of the box girder, thus straining the iron crosswise the grain. The tensile tests showed low results, only 29,950 lbs. per sq. in. in that direction, with the elastic limit and tensile strength nearly coinciding. While iron plates would not be expected to be used in the direction found here there was no assurance that such would not be the case and both ruptured covers, of columns Nos. 7 and 8, were so oriented that the bending stresses strained the metal in its weakest direction.

Latticed column No. 8 made of 12" channels, 83.7 lbs. per yard should have an ultimate compressive strength of about 500,000 pounds total. The strength of the cover plate, unassisted by the 4" by 6" angles, assuming a maximum fibre stress of 30,000 lbs. per sq. in. would be 83,000 pounds total. The angles no doubt reenforced the cover plate still leaving, it is believed, a great disparity in strength of this detail over the strength in the body of the column.

The destructiveness to the track and to the train occurring beyond the bridge, attention is directed to conditions which prevailed during the interval which immediately succeeded the emerging of the train from the depressed part of the bridge. A drawbar was pulled out of the tender of the second locomotive. It would fall upon the ties, and this may have precipitated the disaster which befell the middle part of the train. Marks on the trucks of the mail car and the combined car showed some blow had been received at places on them over the middle of the width of the track.

It seems not improbable that the drawbar in question struck the blow, and that it caused destructive damage to the trucks of the cars of the train which followed the combined car. If this occurred the severity of the derailment was the result of a secondary cause and such is a probable explanation of the case.

In conclusion it appears that the derailment and wreck of west bound train No. 19 on the main line of the Pennsylvania Railroad, near Glen Loch, Pa. was caused by the failure of bridge No. 43 1/2.

That the immediate cause of the failure of the bridge was due to the completion of a detail or progressive fracture which existed in and finally separated the cover plate of column No. 8, which supported the east end of the box girder on which the floor beams of the bridge rested. The completion of this fracture allowed the bridge to sag to a depth of about 18" over column No. 8.

That the derailment was caused by the train dropping into this depressed section and its elevation therefrom.

Subsequent events pertaining to the destruction of the track and the wrecking of the train were incident to the breaking loose of the locomotives from the train immediately upon emerging from the depressed section of the track.

That the cover plate of column No. 8 was essentially a weak detail in the design and construction of the bridge.

That, as a matter of opinion, the cover plate had been in a state of partial rupture for a number of months, not unlikely extending beyond the period of a year.

That a number of inspections by the Pennsylvania Railroad, had been made in the interim and that none had disclosed the presence of this partially ruptured plate.

That a test for deflection of the bridge had been made the day before its failure, while a regular monthly inspection for detailed defects had been made nine days prior to the failure and also a semi-annual inspection about eight weeks prior to its failure, none of which disclosed any element of weakness in the bridge, although it is believed to have been in a weakened condition at the time of these inspections. In consequence of conditions found to exist at the bridge pertaining to its lack of lateral stability at the eastern end, the hammering effect of the box girder that had taken place over the cover plate, the bent condition of the anchor bolts of the main girders in an outward direction, these considerations make it appear that the bridge inspections as carried out were ineffectual and inadequate to reveal the condition of the bridge, and from their inefficiency would tend to give an erroneous and false feeling of security in the structure.

That while the line of fracture in the cover plate was inaccessible under the usual inspection accorded this structure, its position offered no insurmountable obstacle to discovery by methods of inspection in vogue in other lines of work.

That bridge engineers should acquaint bridge inspectors with a description of parts of bridges under their care which are likely to receive the greatest loads in service and that means should be provided for the inspectors to make proper and adequate inspection of all such parts.

That the easterly part of the bridge including the track, floor system, main girders, two supporting columns and a section of the box girder, was affected at the time of the derailment.

That the failure of the cover plate was promoted by the lack of lateral stability of the bridge which carried a track of 2 degrees curvature and was therefore exposed to an outward thrust by the centrifugal force of passing trains. Speeds of sixty miles per hour on the bridge were attained.

That the failure of the cover plate was accelerated by the weakness of the metal, from its being strained in a crosswise direction.

To guard against a recurrence of such accidents a critical examination of the details of other bridges in service would be expedient in order to ascertain whether or not any of their structural members are exposed to overstraining loads under present increased weights of equipment and not provided for at the time of construction of these bridges.

Respectfully submitted,

/s/ James E. Howard,
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