REPORT OF COMMITTEE ON CHARACTER AND USE OF ROAD MATERIALS

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REPORT ON GUARD FENCE RESEARCH

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The subject of Highway guard fence design has received very little attention until the last few years when the prevalence of high speed traffic with accompanying accidents has emphasized its importance

Many different kinds of guard fences are now in use throughout the United States These vary from the wooden planks and posts to the more elaborate designs of metal posts and rails, with springs or other attachments for the purpose of relieving the shock of impact on the car and occupant The selection of an efficient type must eventually be governed by service value and costs Under some conditions efficient service value can be accomplished by the use of a warning guard conspicuously marked to designate the limits of the highway This type of guard is not intended to resist the passage of the vehicle off the highway in case of accident, and from this standpoint is limited in use to sections where no serious damage will result if the vehicle leaves the highway In sections of rough topography where the damage might be serious if the vehicle should leave the highway, provisions should be made to construct a type of guard which will resist the impact and hold the vehicle This could be accomplished by the most rigid types, such as stone walls, etc , but impact reactions from such structures would probably cause serious damage The ultimate aim in designing for these conditions should be to hold the vehicle with minimum danger to the occupants and minimum damage to the car or truck

One of the research projects in the Pennsylvania Highway Department was to obtain data on the efficiency of the different types of guard fence for the purpose of establishing a standard design When preliminary work was started on this project in January, 1924, the type of guard fence in use consisted of two $\frac{3}{4}$ inch wire ropes threaded through wooden posts and anchored at both ends to concrete blocks imbedded in the ground This type was apparently first used in Pennsylvania on highways in the mining sections where the discarded mine cables were utilized as a road guard. Eventually special wire rope replaced the cable, and the type was adopted as a standard in many states.

The field tests started in 1924 [1] Different series were run in 1925, 1926, and 1927 The procedure was to erect about one hundred feet of guard fence and subject it to impact of a loaded five ton truck (ten ton gross load), and an average weight automobile striking the guard fence at varying angles and speeds In the 1924 series several types of guard fences were tested, but in the preliminary runs the wire rope with wooden posts indicated so much better possibilities than the other designs that the continuation of the series was confined to this type

From the experience and results obtained in the 1924 series, a more comprehensive program was laid out for the 1925 tests The original series demonstrated that two ¾ inch ropes would not hold the maximum

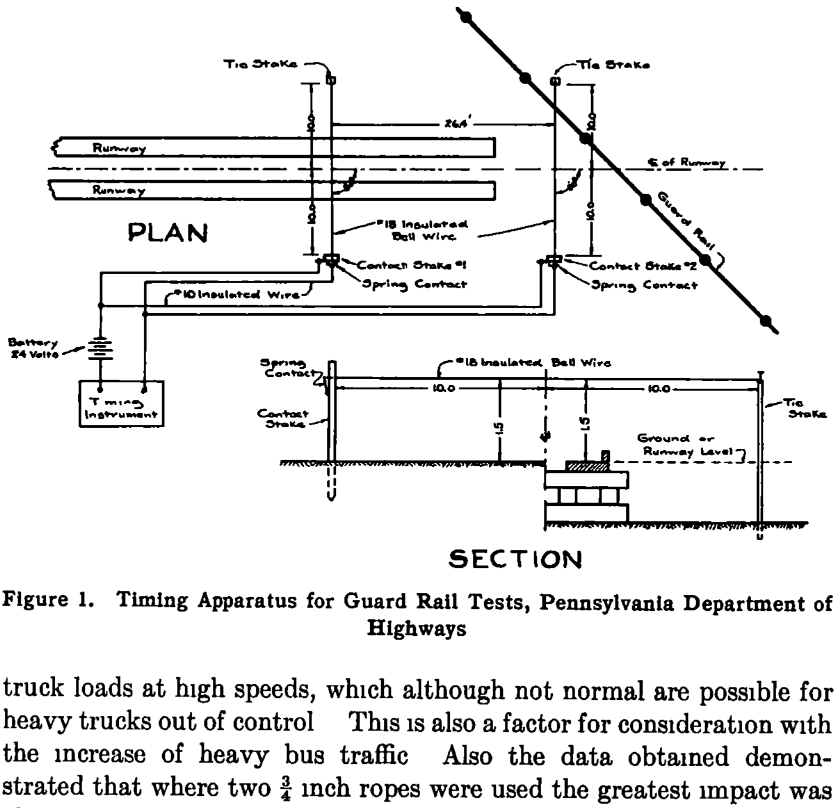


Figure 1. Timing Apparatus for Guard Rail Tests, Pennsylvania Department of Highways

truck loads at high speeds, which although not normal are possible for heavy trucks out of control This is also a factor for consideration with the increase of heavy bus traffic Also the data obtained demonstrated that where two ¾ inch ropes were used the greatest impact was obtained on the top rope, and in cases of failure the top rope always broke first The tests demonstrated that in more dangerous locations the use of a 1 inch top rope is necessary.

The main purpose of the 1925 series of tests was to ascertain the efficiency of the design of 1 inch top rope and ¾ inch bottom rope under

[1] The 1924 series of tests was a cooperative research project with the U S Bureau of Public Roads

actual field conditions. The 1924 tests were run on a flat field so it was decided to run additional tests to find the weakness of this new design under actual service conditions. The guard fence was constructed on a terraced fill with a total drop to the lower slope of 8.3 feet, as in the previous tests a five ton truck having a gross weight of ten tons and an average weight automobile were used. These traveled on a wooden runway constructed on an 8.5 per cent grade. An electric contact device was used to determine the speed of the truck (Figure 1).

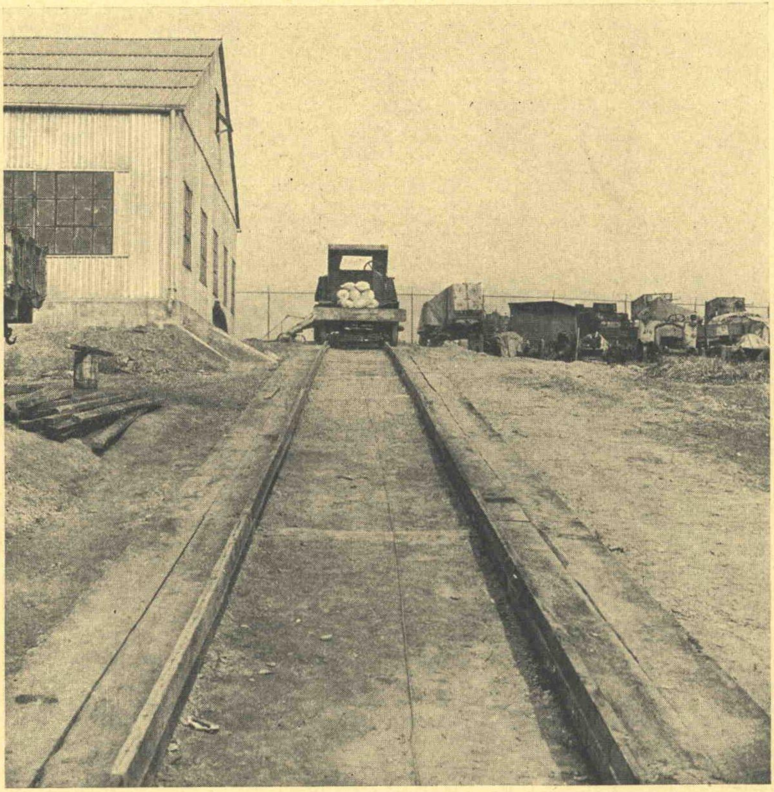


Figure 2

The data accumulated from this series of tests showed that the failures were caused by lack of careful construction and inadequate fixtures and attachments. For instance, after repeated stress the plain concrete block used as a deadman failed and relieved the anchorage, some of the fittings used to guy the fence to the deadman failed, and threading of the rope through holes in the posts weakened the post to such an extent that many of them split some distance away from the actual point of impact.

Figure 3

Figure 4

About one hundred photographs were taken during the 1925 tests for the purpose of illustrating the test conditions and the results of the

Figure 5

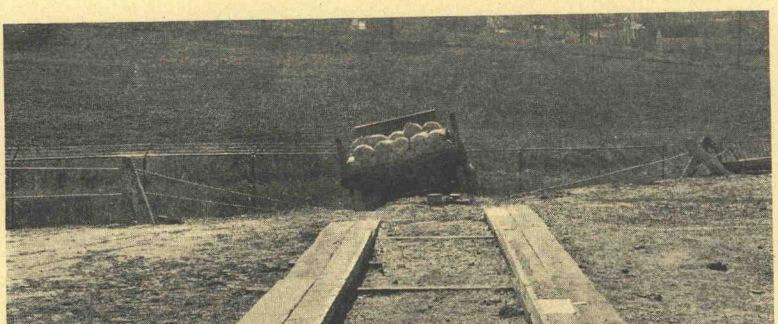


Figure 6

truck or car impact. The following plates selected from these photographs will demonstrate more clearly than written descriptions some of the main causes for failure under tests.

Figure 2 illustrates the truck on the runway prior to starting of a test.

Figure 3 shows the lower part of the runway and the guard fence before impact.

Figure 4 is an illustration of the guard fence after impact. In this test the truck hit the fence at an angle of fifty degrees, and at a speed of thirty-six miles an hour. The speed was greater than intended, and this phase of control was regulated in additional tests.

Figure 5 shows the position of the truck after having passed through the guard fence as illustrated in Figure 4. Note the concrete deadman which was pulled from the ground and hurled fifty feet as a result of the

Figure 7

impact. A detailed examination demonstrated that the back fill over the deadman was not properly compacted. This phase of construction has been corrected where possible by placing the deadman without disturbing the ground between the deadman and the end posts, as shown under Figure No. 5.

Figure 6 shows the failure of a fence. The truck in this case attained a speed of thirty miles an hour, and the failure was due to the breaking of the guy from the end posts to the deadman. This failure shows the necessity for larger size guy rope.

Figure 7 illustrates a failure due to the breaking of the eye-weld on

the eye bolt, connecting the top rope to the end post. In this test the speed of the truck was twenty-four miles an hour. This result demon-

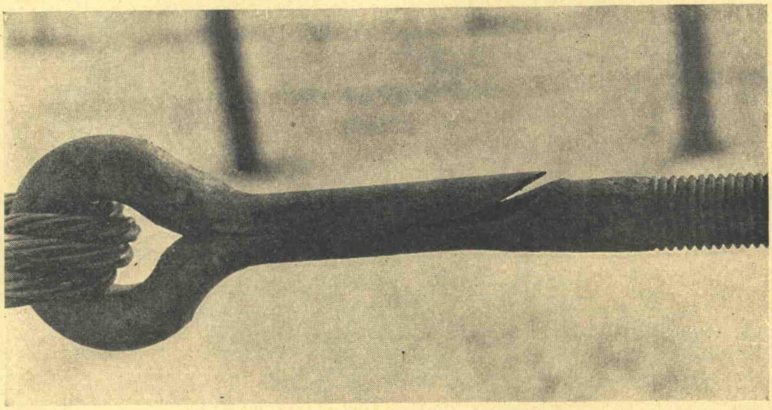


Figure 8

Figure 9

strates that safe construction requires drop forged eye bolts. The failure of the top eye bolt also shows the greatest stress on the top rope.

Figure 8 shows another failure in a welded eye bolt on the top rope connection. The speed of the truck was ten miles an hour.

Figure 9 illustrates the position of truck after impact. Note that the $\frac{3}{4}$ inch bottom rope had failed and the truck which had a speed of ten miles per hour was held by the top 1 inch rope.

Figure 10 shows a truck held by the guard fence. Note the destruction of wooden posts under frozen ground conditions; two posts were

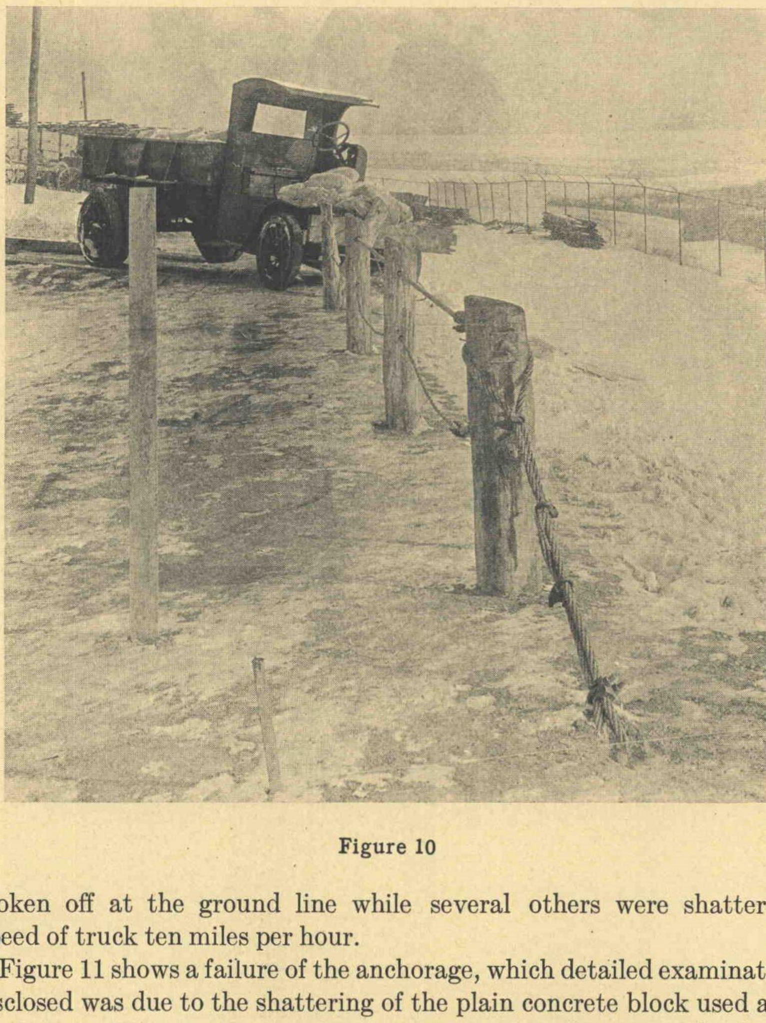


Figure 10

broken off at the ground line while several others were shattered. Speed of truck ten miles per hour.

Figure 11 shows a failure of the anchorage, which detailed examination disclosed was due to the shattering of the plain concrete block used as a deadman. This was corrected by using a reinforced concrete deadman, and also by increasing the size of the bearing plate in the eye bolt connection to the deadman, as illustrated in Figure 20. The speed of the truck was fifteen miles per hour.

Figure 12 illustrates the weakness of threading the wire rope through

the post line, and also emphasizes the safety feature of a 1 inch top rope. Speed of truck twelve and eight tenth miles per hour.

Figure 13 illustrates the guard fence now used as a standard. The basic principal of wooden posts and wire rope are the same as the original guard fence, but corrections were made to overcome the weakness found

Figure 11

as a result of the series of tests. Note that the rope is offset 4 inches from the post. This accomplishes two purposes; it gives the full efficiency of the post under impact, and in cases illustrated in other figures it prevents the hub of an automobile from coming in contact with the post, thus reducing the damage to the car and the tendency for the driver to loose control of the machine. See Figures 22 and 23.

Figure 12

Figure 13

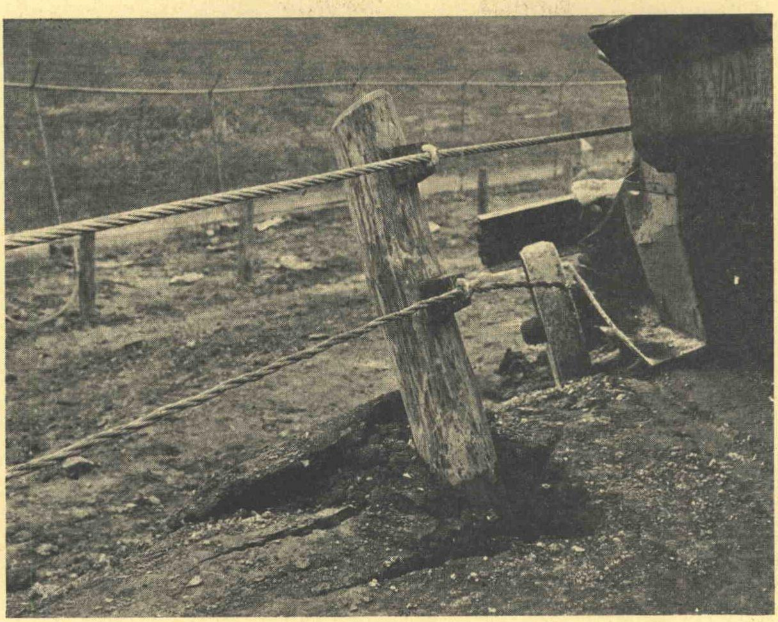


Figure 14

Figure 15

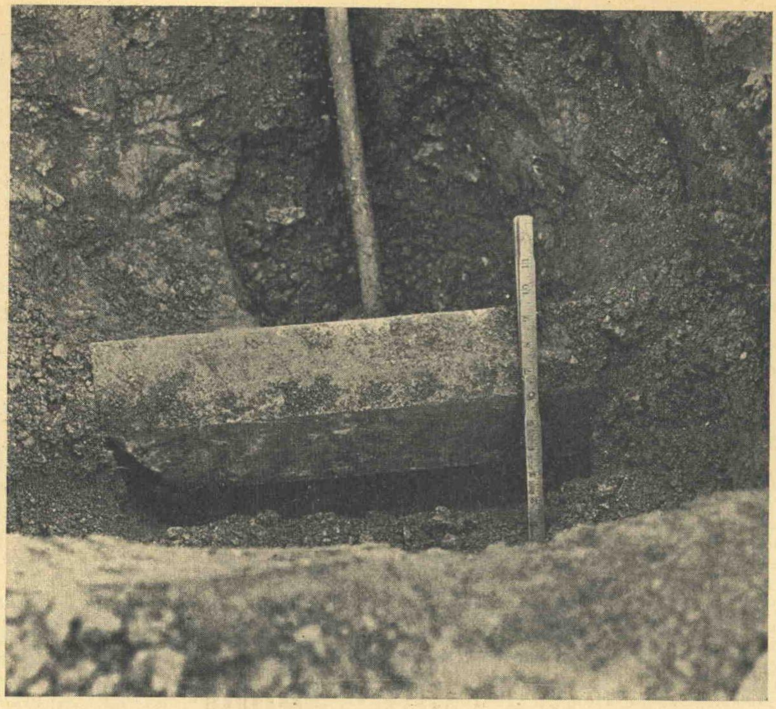


Figure 16

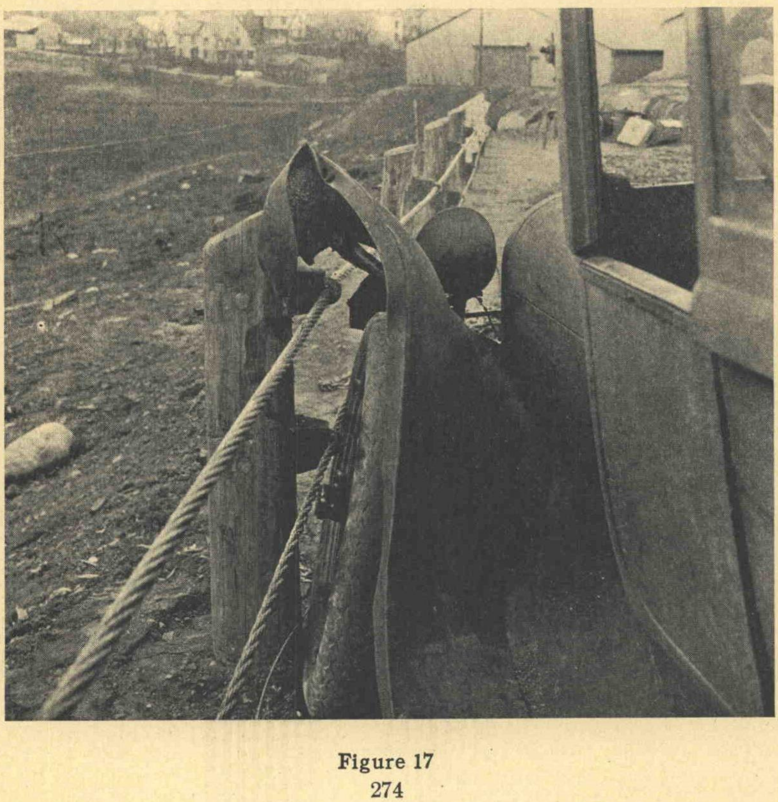


Figure 17

TABLE I

SUMMARY OF 1925 GUARD FENCE TESTS

Test number	Truck speed	Soil conditions	Kinetic energy	Damage caused to					Remarks
				1 inch rope	$\frac{3}{4}$ inch rope	Deadman	Posts	Fittings	
1	36	Fill not consolidated	866,000	None	Broke	East end pulled out West end moved $\frac{3}{16}$ inch forward	6 posts pulled	O K	Fence failed due to unstable fill Deadman pulled out
2	30	Fill well consolidated	601,200	None	None	East end moved $\frac{5}{8}$ inch forward West end moved $\frac{1}{16}$ inch forward	5 posts pulled	$\frac{3}{4}$ inch rope to deadman broke	Fence failed when cable to deadman broke
3	30	Fill well consolidated	601 200	None	None	East end deadman broke West end moved $\frac{1}{4}$ inch forward	6 posts pulled	O K	Fence failed when deadman broke
4	24	3 inch frost	384,800	None	None	East end no movement West end no movement	9 posts broken or split	Eyebolt on 1 inch rope failed clips on $\frac{3}{4}$ inch rope slipped	Fence failed when eyebolt holding 1 inch rope failed
5	15	$\frac{3}{4}$ inch frost	150,200	None	Broke	East end deadman broke West end no movement	3 posts pulled	O K	Fence failed when deadman broke
6	12 8	5 inch frost	109,400	None	Broke	East end no movement West end no movement	5 posts broken or split	Eyebolt on 1 inch rope failed	Fence failed when eyebolt holding 1 inch rope failed
7	10	11 inch frost	66,700	None	Broke	East end no movement West end no movement	2 posts broken	Eyebolt on 1 inch rope opened slightly	Fence held but eyebolt showed signs of failure
8	12 8	Fill well consolidated	109,400	None	Broke	East end $1\frac{3}{8}$ inches forward West end $1\frac{1}{8}$ inch forward	1 post broken	O K	Fence held
9	*	Fill well consolidated		None	None	East end no movement West end no movement	1 post out of alignment 2 inches	O K	Fence held Truck shunted back to road
10	15	Fill well consolidated	150,200	None	Broke	East end 1 inch forward West end $\frac{3}{4}$ inch forward	2 posts bent out of alignment	O K	Fence held Fence out of alignment 2 panels Maximum 1 foot 3 inches
11	22	Fill well consolidated	323 600	None	Broke	East end $\frac{1}{2}$ inch forward West end $2\frac{1}{2}$ inches forward	1 post split	O K	Fence held Fence out of alignment 5 panels Maximum 3 feet 6 inches

* Speed not determined

Figure 14 shows this new designed guard fence at the point of truck impact. Note that the shock was sufficient to dislodge some posts, but no shattering or breaking of the posts resulted, such as happened when rope is threaded through the posts. The speed of the truck for this test was twenty-two miles per hour.

Figure 15 illustrates the heave of the ground surface above the dead-

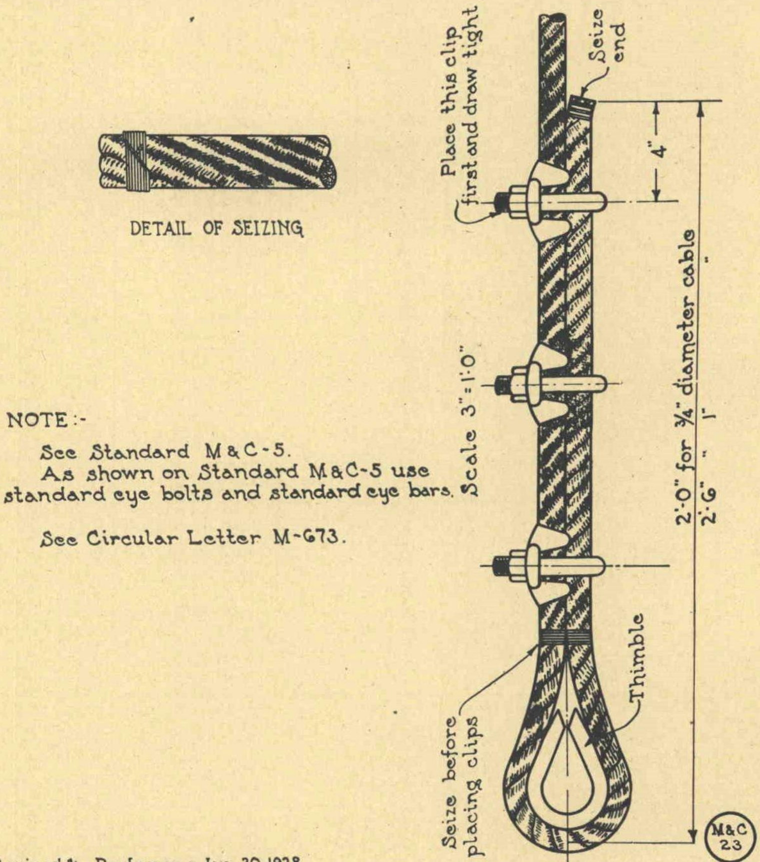


Figure 18. Standard Cable Fitting for Guard Fence, Pennsylvania Department of Highways

man after impact, the speed of the truck being twenty-two miles per hour. A more detailed examination indicated that the concrete deadman had moved to the extent indicated in Figure 16. In this test the deadman was installed as shown in Figure 21.

Figure 17 shows the efficiency of the offset on the guard fence. It will be noted that the hub of the wheel does not have an opportunity to

come in contact with the post. The main damage to the car after striking at a speed of twenty-two miles an hour was a destruction of the fender as illustrated.

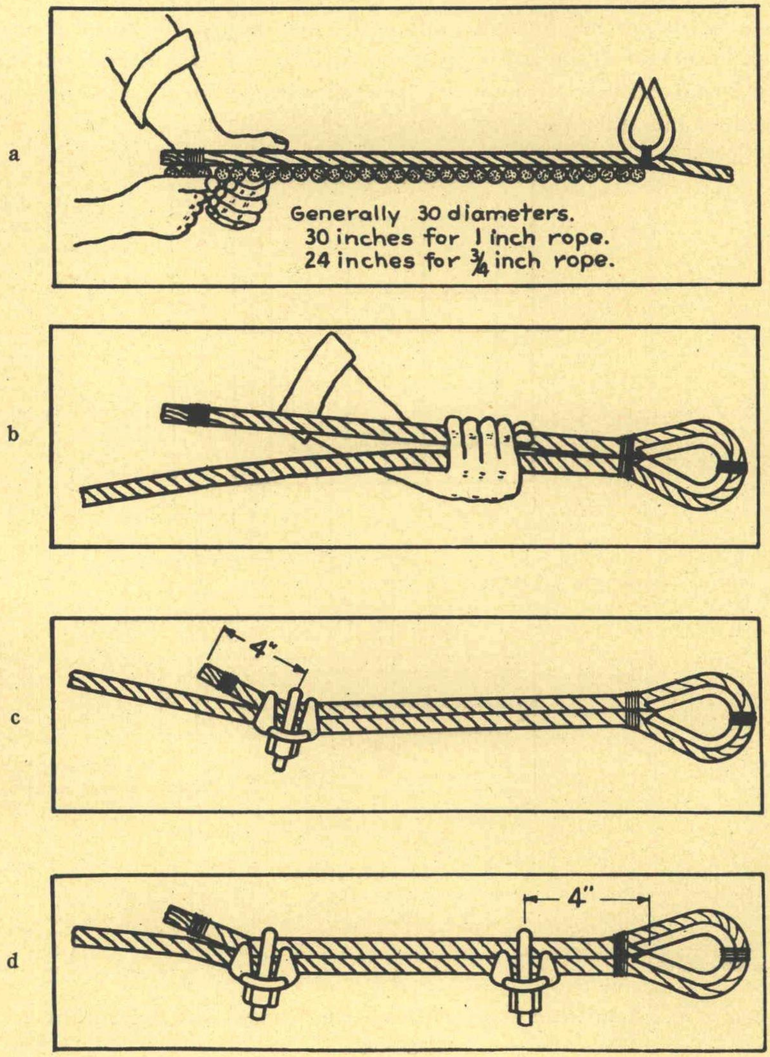


Figure 19. How to put Clips on Wire Rope, Pennsylvania Department of Highways a. Measuring to ascertain proper length of short end. b. Loop temporarily wired in place. c. First clip correctly put on. d. Second clip correctly put on.

(Third clip when used, to be half way between other two; see Figure 18)

The guard fence with both ropes offset 4 inches from the post lines, the present standard now used in Pennsylvania, has been found to be

very efficient in service. In the few cases where trucks or busses have been reported to have left the road through the guard, a detailed investigation has determined that this was entirely due to negligence in following the standard methods of construction, viz, improper form of splicing on a long line, or insufficient number of clips used at the connection of the end posts, or in the guy rope to the anchors It was also found that there is a tendency to connect these clips the wrong way Figures 18 and 19 illustrate the proper method of placing clips

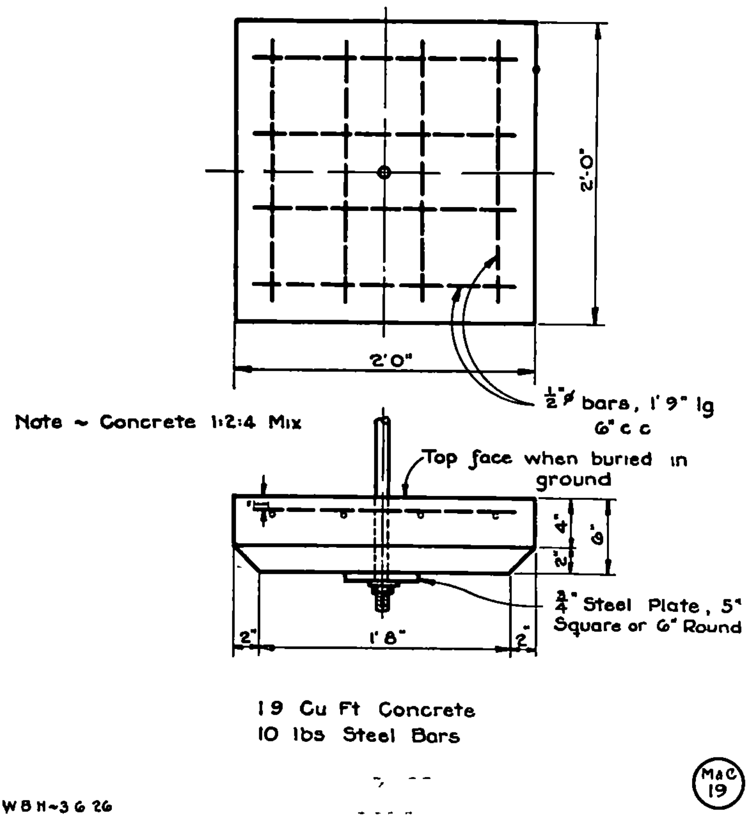


Figure 20. Reinforced Concrete Deadman, Pennsylvania Department of Highways

As a result of these series of tests it was found that the efficiency of the wire rope guard fence was improved to a considerable extent with a very slight increase in cost. This, with the added safety for the traveling public, more than justified the expense of such tests. Other types of guard fence tests which showed the same efficiency as the present standard guard, would be more expensive to install, and the tests indicated that no additional safety was secured.

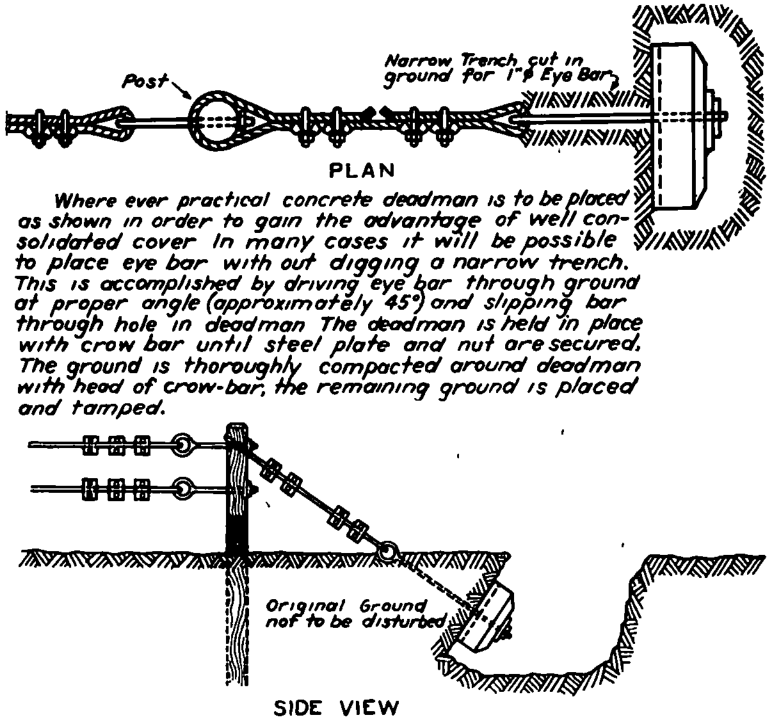


Figure 21. Method of Installing Concrete Deadman, Pennsylvania Department of Highways

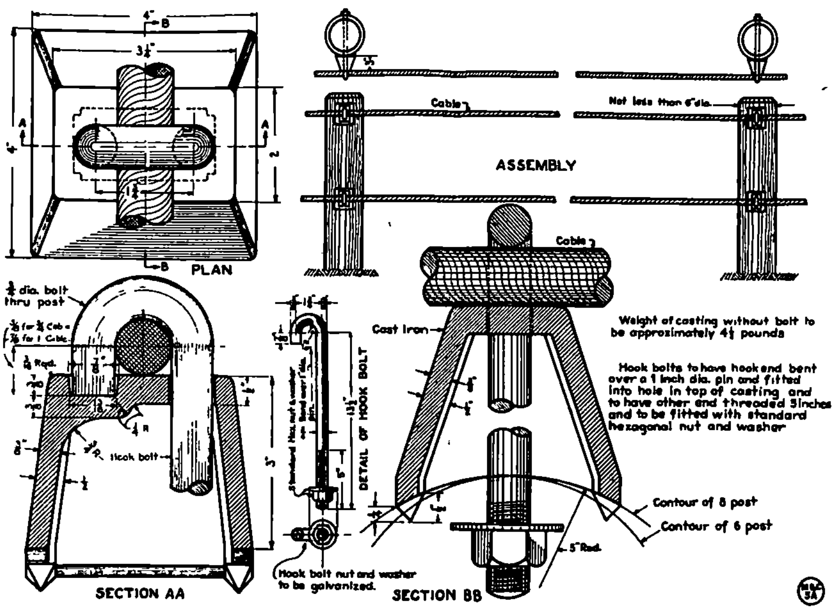
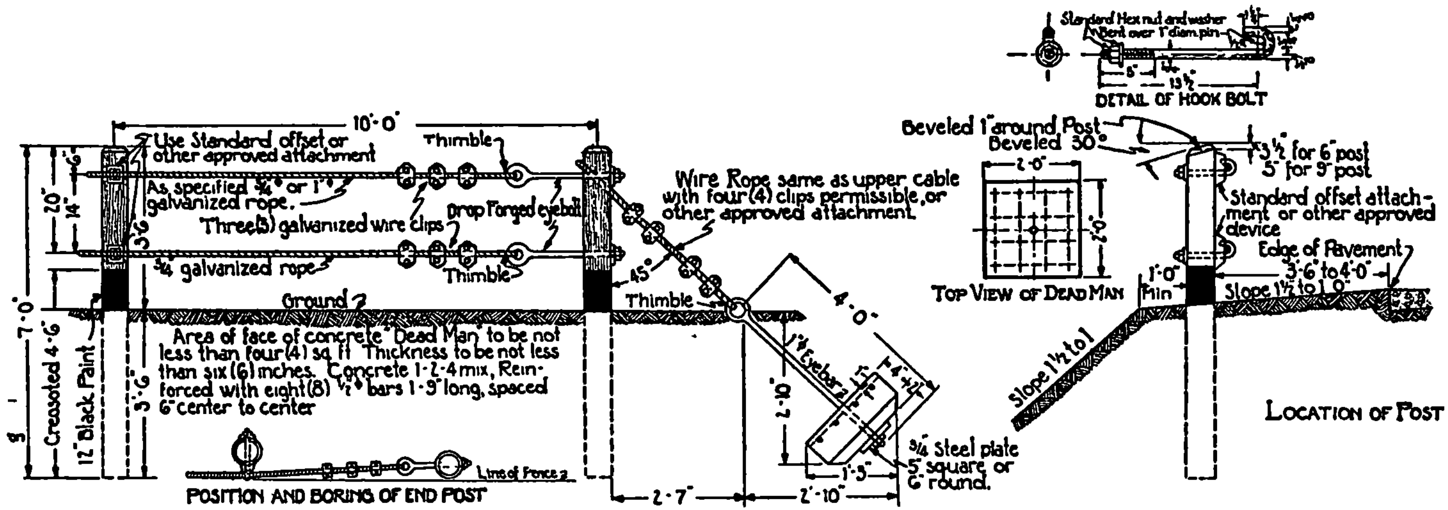


Figure 22. Offset Attachment for Standard Guard Fence, Pennsylvania Department of Highways



All posts to be of seasoned, straight, sound chestnut, locust or red cedar, at no place less than six (6) inches in diameter with bark removed, knots hewn flush with the surface and the surface shaved smooth. All posts shall be heavily brush-coated with creosote oil before being set. The creosote to be applied in a full free coating, covering the bottom end and extending up the sides four and one-half (4½) feet. No posts shall be treated until thoroughly dry. The creosoted portion of post above ground to be coated with shellac and painted with an approved black paint. After erection posts and all parts not galvanized to be painted with three (3) coats of the material as specified brushed in thoroughly.

All eyebolts to be one (1) inch in diameter, drop forged having a minimum tensile strength of 30,000 lbs. and with an eye having a minimum diameter of 1⅜ inches. They shall be double galvanized and have double galvanized steel washers and nuts attached. For each section of fence there shall be furnished four (4) eighteen (18) inch eyebolts, threaded for twelve (12) inches. All clips to be double galvanized and of approved design, double galvanized thimbles, of approved design, to be used where indicated on drawing. Hook bolts to be ¾ inches in diameter, and have steel washers and nuts attached.

Figure 23. Standard Wire Rope Guard Fence, Pennsylvania Department of Highways

It is estimated from the number of accidents occurring at dangerous locations that the protection by an adequate guard fence saves at least one hundred lives annually

The efficiency of the type of guard fence now used as a standard on Pennsylvania highways, Figure 13, depends on proper installation. Posts must be in stable ground, connections must be of adequate quality, and all connections and splicing must be done so as to give full effectiveness of the ropes

Included in the report are several detail standards for the placing of the deadman, the splicing of wire rope and cable connections, and the guard fence assembly

Figure 18 and 19 illustrate proper method of placing clips.

Figure 20 shows standard deadman

Figure 21 shows standard method of installing deadman.

Figure 22 shows offset attachment

Figure 23 shows standard wire rope guard fence

Table I gives a summary of the results of the 1925 series, showing the kinetic energy developed and the effect on different parts of the fence.

DISCUSSION

ON

GUARD FENCE RESEARCH

MR H L WHITTEMORE, *U S Bureau of Standards.*[1] Wire rope is widely used for guard rails for highways, the rope being secured at frequent intervals to posts The ends of the rope are anchored at each end of the rail

It should be obvious to anyone that the strength of the rail depends greatly upon the strength of the anchorage because the tensile load in the rope caused by vehicles striking the rail is transmitted in large part to the anchorage It is in all probability impracticable to secure the rope at each post so that loads are not transmitted to the anchorage

Assuming that the anchorages will not move under the action of forces which will break the rope, the strength of the guard depends very largely upon the strength of the fastening used to attach the rope to the anchorage rather than the ultimate strength of the wire rope. If the rope is socketed with zinc by skillful workmen the strength of the fastening may exceed the strength of the rope The tensile strength of wire rope is usually found by testing specimens having socketed ends

[1] Publication Approved by the Director of the Bureau of Standards of the U S Department of Commerce

Although this is the strongest way to fasten wire rope it does not seem to have been used to any extent for highway guards

It seems highly desirable for highway engineers to consider having the wire ropes socketed by the rope manufacturer and use turn buckles or equivalent devices in attaching the ropes to the anchorage

The ropes for many highway guards are fastened by passing the end of the rope around a thimble attached to an eye in the anchorage doubling the end back upon the standing portion of the rope and securing with clips

Although fastening wire rope with clips requires little skill and the fastening can be readily inspected, the rope is likely to slip, the clips frequently crush and bruise the rope and the strength of the fastening is usually less than 80 per cent of the strength of the rope

Information on the strength of these fastenings can be found on page 8 of Technical Paper No 237 of the Bureau of Mines "Safe Practice in Using Wire Rope in Mines" by Hood and Kudlich

The following table gives some of the results·

NUMBER OF CLIPS REQUIRED TO MAKE A FASTENING HAVING 80 PER CENT OF THE STRENGTH OF 6 BY 19 PLOW STEEL WIRE ROPE

Diameter of rope inches	Number of clips	Efficiency of fastening per cent	Efficiency of each clip per cent	Length of wrench inches
$\frac{3}{4}$	5	77 39	15 5	18
$\frac{7}{8}$	5	79 13	15 8	18
1	5	77 89	15 6	24
$1\frac{1}{8}$	5	80 00	16 0	24
$1\frac{1}{4}$	6	82 15	13 7	24

The distance between clips should not be less than 6 times the diameter of the rope For wire rope smaller than $\frac{3}{4}$ inch diameter, at least 4 clips should be used For wire ropes larger than $1\frac{1}{4}$ inches, it is preferable to socket the rope and avoid the use of clips

The clips should be inspected frequently and the bolts tightened, if they become loose, as the rope stretches Probably few highway guards receive the inspection and care that will maintain the efficiency of fastenings made with clips

Casual inspection of wire rope guards in some of the New England states, particularly Massachusetts, during the past summer leads to the belief that two or three clips are often used when double the number are required The cost of the additional clips would be a negligible percentage of the cost of an installation and should not stand in the way of making fastenings which are as near the strength of the rope as possible

There is a need for much more information on wire rope fastenings than is available at the present time

A wire rope clip consists of two parts, the U-bolt and the forged steel "roddle" or base When making a wire rope fastening the roddle should be in contact with the long end of the rope and the U-bolt in contact with the short end The catalogs of wire rope manufacturers emphasize this point by illustrating the correct and the incorrect way to attach clips One of these illustrations is shown in Figure 1 Probably most of those seen on our highways are attached incorrectly Apparently

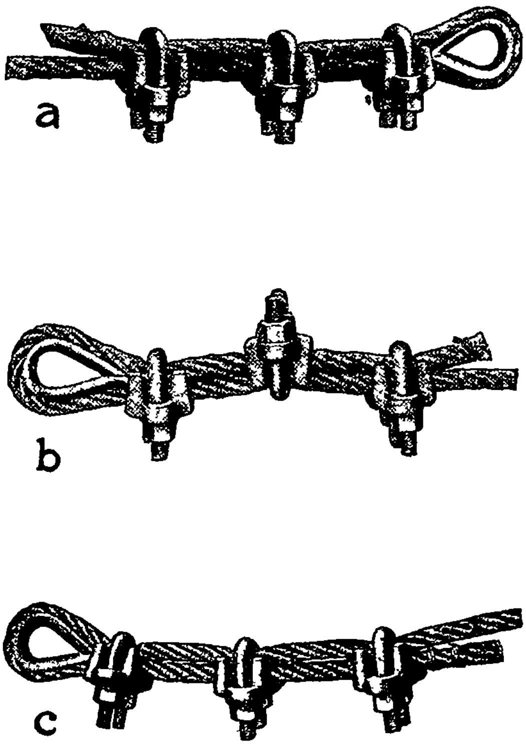


Figure 1. How to Attach Wire Rope Clips
A. Correct way. U-bolt of all clips on dead end of rope,
B Incorrect way. Do not stagger clips.
C Incorrect way. U-bolt of all clips on live end of rope.

the number of clips on highway guards and the way in which they are attached are left to the whim of the workman Even if for highway guards it could be proven that the way in which the clips are attached makes little difference, our highways are a great educational influence and should not be allowed to teach unsafe practices which it is impossible to counteract by the efforts of safety organizations If we are to be successful in our efforts to establish and maintain safe conditions in this

country each of us must make sure that he does not encourage unsafe practices by others.

It is believed that if the importance of attaching wire rope clips correctly is brought to the attention of highway engineers, the present situation will soon be remedied

THE BITUMINOUS SURFACE TREATMENT OF ROADS AND PAVEMENTS

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Director, Michigan State Highway Laboratory

Bituminous surface treatment is defined as the application of bitumen in fluid form to the surface of existing highways or pavements It may be employed on any of the standard types of construction, from earth roads through the several hard surface varieties The type of bituminous material, the amount of bituminous material, and the technique of treatment are dependent upon the nature of the surface to be maintained, and upon the results which are desired The elimination of dust, the waterproofing of the surface, and the prevention of disintegration through abrasion or displacement of weakly bonded surface materials are all objects of surface treatment In this report it is intended to review the objects of surface treatment on the several types of highway surfaces and to discuss briefly the requisite characteristics of the bituminous materials to give the desired results

I THE TREATMENT OF ROAD SURFACES COMPOSED PRINCIPALLY OF CLAY

Treatment of road surfaces of this type is undertaken for the purpose of (1) alleviating the dust nuisance, (2) waterproofing the road surface in order to render it less susceptible to softening during seasons of rain These objects are attained by the formation of a thin surface layer of bitumen coated soil particles

Ability to penetrate a fine grained, firmly packed, and often dusty soil is the most important quality to be possessed by a bituminous material for use on surfaces of this type One which dries or cures very slowly is also necessary as the bituminous surface layer must remain plastic in order not to break under traffic A high degree of adhesiveness is generally not a characteristic of materials possessing the foregoing properties and, in fact, is not a necessary property Successful treatment involves the formation of a surface layer which is mealy and plastic, rather than one which is tightly bound with highly adhesive bitumen

The state of Minnesota, during the last four years, has treated a considerable mileage of clay surface with oils which meet the above