GRADE SEPARATION

A THESIS SUBMITTED TO THE FACULTY OF

THE SCHOOL OF ENGINEERING OF

THE UNIVERSITY OF KANSAS

FOR

THE DEGREE OF CIVIL ENGINEER

BY

JAMISON VAWTER

1923

PREFACE

In this work the writer has endeavored to present the most important considerations that will be met with in grade separation problems, and at the same time to keep the body of the text in as concise a form as possible. The material here presented embodies the results of the writer's personal experience as well as an extensive study of the subject in the technical press. There is much material available on this subject (most articles being confined to certain definite problems or phases), consequently the greatest problem has not been to find the material, but to determine what could be properly omitted and still adequately cover the entire subject.

The problem logically divides itself into three parts: first, the general question of grade separation; second, the engineering phase; third, the application of these two to a specific problem.

Part I, of this work, consists of a general discussion of the grade separation problem, limited however to the economic and civic phase.

In Part II the general engineering problems that will be met with are taken up, together with the various methods of solution that the engineer might use. There is also given a comparison of these methods, which, with the experiences given of the various cities, will give an idea of the variety of conditions that will tend to make one definite solution the best for a given community.

In Part III the layouts and detailed estimates for a proposed grade separation are given. This layout was made in anticipation of an expected demand from the city in question, for a separation of grades in the not distant future. For that reason the names of the city and the railroad are not given in the text.

The writer has given credit in the body of the text where material has been borrowed directly. All publications that were consulted are listed in the bibliography at the end. He feels however that he should make special mention of the excellent work done by the Committee on Signs, Fences and Crossings of the American Railway Engineering Association, particularily their investigation of the laws of the various states and the bibliography they have prepared. Any one interested in this subject and desiring a more complete bibliography than the writer has given will find the same in volume 22, page 304 to 314 of the proceedings of the above association.

J.V.

Urbana, Illinois,
May, 1923.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Page

GRADE SEPARATION

PART I

THE GENERAL PROBLEM

The elimination of grade crossings, or grade separation, is a question that is becoming of greater importance each year, and is consequently assuming a more important place on the railway budgets. This is due to the increasing agitation for the elimination of such crossings. The agitation, as a general rule, comes from those who have little knowledge of the problems to be solved and little appreciation of the cost involved. Although their elimination can be justified in many cases there are many others where it cannot be justified, either from an economic standpoint or on the grounds of a public necessity.

Grade Crossings

The term "grade crossing" is used to denote the crossing of a railroad and a street or highway when both are at the same level. It is also applied to the crossing of one railroad by another at the same level. Only the first type of crossing, however, will be considered in this article as it is only in this type that the public is showing great interest at the present time. The crossing of two railroads at grade is a problem that concerns only the railroads interested directly, since such a crossing can be properly protected by an interlocking plant and thus be the cause of no danger or inconvenience to the traveling public. The highway or street crossing does concern the public directly; the former mainly on account of the danger caused by trains traveling over the crossing at a high rate of speed; the latter, since they are generally protected by gates or watchmen, on account of the delays they cause at busy crossings with the accompanying loss of valuable time and annoyance.

Grade crossings were a necessity at the time the railroads were built. There was no other solution at that time. For one thing the vehicular traffic did not justify any attempt to separate the grades. Also the expense of such separation would have been prohibitive, at that time, both to the railroads and to the towns - assuming that the towns would have borne their proportionate share of the cost of avoiding the grade crossings, which they probably would, as at that time they were willing to offer any reasonable inducement in order to obtain railroad connections. We may therefore take their present existence as a necessary evil; an evil in whose removal the public has as great a share of responsibility as the railroads themselves. The conditions under which the railroads were built were so radically different from those now obtaining that the public has an equal share in the solution of problems, in which it is primarily interested, and which were caused by a change in the former existing conditions, and for which changed condition it is equally responsible.

The history of the agitation for the elimination of grade crossings extends back to before 1880, but the subject was not considered of great importance until about 1900. The early efforts were, as a general rule, characterized by unreasonable requirements, but in the last twenty years there has been a greater tendency to approach the problem with the idea of making a more equitable solution. Also this same period of time has been marked by a great increase in the demand for elimination.

Causes Contributing to the Demand for Elimination

The great increase in motor traffic in the past few years is easily the greatest cause for this increased demand for grade crossing elimination. With our improved highways, along which sometimes will be found an almost constant stream of rapidly moving motor cars, and the congested traffic conditions of our city streets, it is readily seen why the public should so interest itself in the question. As mentioned above, it is undoubtedly true that this large increase in vehicular traffic is a menace to life where the highways cross railroads at grade and the motor car driver must be always on the alert so as to avoid being struck by a fast moving train. And no less important than the danger are the delays to congested city traffic caused by crossing gates being lowered to permit the movement of trains. Especially is this true in the vicinity of the larger terminal yards where the delay to traffic must of a necessity be comparatively long to allow the proper handling of the trains and switch engines.

Responsibility for Necessity of Elimination

It has been said that grade crossings were a necessity at the time the railroads were built and that the public is equally responsible with the railroads for the present changed conditions. To be more explicit, let us take two extreme cases. In the first case assume we have a railroad built through a new town with grade crossings. The existence of the railroad causes the city to grow up around it, with an increase in street traffic which becomes of a volume sufficient to require separation of the grades. But the railroad business has not increased in like proportion. In this case the railroad is not responsible for the necessity of elimination. In the second case let us assume the conditions reversed. Here the city has not grown to any great extent but the traffic on the railroad has increased in volume so that grade separation is required as a matter of safety and convenience. Here the railroad company is clearly responsible for the existing necessity.

These two cases are both extreme, however, and will seldom exist. Ordinarily the responsibility will be equally divided between the railroad and the public, since the street traffic and the railroad traffic will usually increase together and will together contribute toward the necessity for the separation. Priority of construction has been considered in the laws and decisions of some of the states. There they have thrown the greater responsibility for the separation of the grades on either the railroad or the community, depending on whether the railroad or the highway was there first. The writer does not believe in any such differentiation however. It appears to him that for existing facilities, where both the railroads and the highways are public necessities, and a grade crossing was justified at time of construction, that priority of construction should have no bearing on a separation necessitated by the traffic on both. In the case of new construction it is a different matter. Where a new railroad is being built across an existing highway the railroad certainly is the responsible party, and where a new highway is being opened across an existing railroad the public that is being served should bear the responsibility.

Benefits Derived From Separation

Robert H. Whitten, Librarian Statistician of New York, has made the following grouping of benefits derived from separation by the various parties interested.

Benefits to City.

1. Public safety, on account of decreased accidents at crossings.
2. Removal of cause of delay to street traffic.
3. Removal of cause of delay to fire engines and trucks.
4. Rapid transit - increased facilities for development of urban and suburban rapid transit lines.

Benefits to Property Owners in Increased Land Values.

1. Increased value to property in being made more accessible to the heart of the city. (It should be remembered, however, that there will be a decrease in the value of the property in the immediate vicinity of the crossing).

Benefits to Street Railways.

1. Elimination of delays at crossings.
2. Saving in installment of, and maintenance of, safety devices and crossings.
3. Saving of wear and tear of equipment on imperfect crossings and cost of stopping and starting.
4. Removal of the danger of accidents on crossings and the liability of the street railway to damages.

Benefits to Railroads.

1. Saving of expense of crossing protection.
2. Saving of expense due to accidents.
3. Relief from trespass nuisance. (This relief is not very noticable, however, except in the case of complete elevation or depression of tracks).

4. Increased speed and freedom of operation.
5. Chance for improvement in grade and alignment.
6. Chance to make increase in number of tracks.
7. Rapid transit - chance for development of suburban rapid transit lines.

From the standpoint of service rendered, the above listed benefits will apparently react more in favor of the public than the railroads, with the street railways worthy of some consideration. So that it can be safely said that the public derives most of the benefits obtained from grade separation.

From the standpoint of accidents alone it becomes the measurement of safety to pedestrian and vehicular traffic, on the side of the public, against the sost of flagmen and of damage suits, on the part of the railroad. It is easy to see there who derives the main benefit. Lives lost can not be brought back, and the money obtained as damages will not compensate for their loss. Their loss is not only a loss to the immediate family but also to the community at large, especially so in the case of the more influential citizens.

In the delays to traffic the public is necessarily the greatest sufferer. The railroad trains must of a necessity be run slower through the towns, but the public traffic will have to be held up at crossings to allow for the movement of trains and, as mentioned above, this delay will be excessive in some cases. To make a personal application, the writer himself will often drive several blocks out of his way to take advantage of an existing subway in order to avoid a busy crossing where the traffic is heavy and the delays sometimes long and vexatious, especially so when a long slow moving freight train is passing.

Responsibility for Crossing Accidents

As a matter of practice, the railroads are generally held responsible in the case of crossing accidents. Legally, they should only be held so when the accident is caused by negligence on the part of the employees of the company or from a failure by the company to provide the proper safeguards. As a matter of fact, most of the accidents that occur at grade crossings are due to the carelessness or negligence of the injured party. The following two illustrations will show that the great majority of people pay very little attention, if any, to the danger involved in crossing a railroad at grade, and that practically none obey the sign to "stop, look and listen".

Observations Made by Southern Pacific

The Southern Pacific Railway made observations as to the behavior of the drivers of 17,021 motor vehicles on approaching a railroad crossing. These observations were taken in a number of widely separated localities. 11,836 drivers, or 69½%, looked neither to right nor left before crossing tracks; 2.7% looked only one way and only 27.8% looked in both directions. 3,301, or 19.3% of the drivers, ran over the crossing at a reckless rate of speed, while only 35 drivers out of the entire number, stopped before crossing.

Observations Made by Baltimore and Ohio

The Baltimore and Ohio made the following observations at Uniontown, Pa., September 12, 1915. 729 automobiles crossed in 12 hours. Only 28 drivers stopped to ascertain whether a train was approaching or not, and 505 drivers did not even slow down. 135 drivers looked in both directions but 542 drivers did not even look at all before crossing.

Other observations have been made giving substantially the same results, which indicates that while the public is alive to the fact of the desirability of the separation of grades, the public is, as a general rule, still not willing to take upon itself the ordinary and sensible precautions that it should on the existing crossings.

Economics of Grade Separation

The elimination of only a few grade crossings can be justified from an economic standpoint, either for the railroads or for the public. In considering the public in an economic sense it is assumed that the public will bear its portion of the cost of such elimination. In case the municipality bears a portion of the expense, neither the city nor the railroad can expect to receive a financial return for the large amounts that must be expended, except in a few extreme cases. In this connection, however, danger to life and limb has not been considered. Human life cannot be measured in dollars and cents, so that when it is stated that the railroads or the city are not justified economically in expending the amount of money, account is taken only of the actual return in money for the money spent. The cost of maintaining the old crossing and the damages arising from its existence opposed to the interest on the new investment.

Chicago may be taken as one case in point. There has been more grade separation done in this place than in any other city in the country. Until about 1915 the railroads had expended around $75,000,000.00 on the work, with an estimated total of around $150,000,000.00 for completion. It was estimated that the actual amount that had been saved to the railroads would not do more than pay about 25% of the interest charges on the money expended. Compare with this the fact that in spite of the increased number of motor vehicles on the streets, the actual number of crossing accidents, in Chicago, has been steadily decreasing every year along with the progress in the grade separation. In 1905 there were 99 killed in crossing accidents and in 1914 there were 31, while in the same two years there were 34 and 143, respectively, killed on the streets by vehicles. Assuming that both crossing and street accidents increase in proportion to the number of vehicles, this last ratio can be taken as a fair example as to what could have been expected in the increase in crossing accidents if there had been no elimination.

The above can be taken as a fair case to prove the point that although figures may show no direct financial return, still when considerations of humanity are brought in we may find it well worth while. For it goes without saying that many people are walking the streets today who would not be doing so if there had been nothing done in the way of improvements. Added to that are also two other advantages brought about by this work, namely; saving in time in the use of streets, and the reduction of fire hazard due to the fact that the danger of the apparatus being held up at a crossing is eliminated.

Each problem requires a separate study as to advantages or the desirability of changing the crossing at that point. The railroad can tell very easily just what the grade crossing is costing it, both in cost of maintenance and damages - for although there may not have been any serious accidents at this particular crossing, each crossing does possess a potential damage liability that can be readily determined. It can probably be shown, in most cases, that the cost as determined is less than the interest on the new work; therefore the only other ground is that of danger to life, and service to the public. Prof. C.C. Williams, in his "Design of Railway Location", states that grade crossings have been eliminated with apparent justification when the chance of accident became about 1:200. He gives the results of a number of observations which tend to justify his figure.

The issue as to whether certain dangerous crossings should be eliminated has been somewhat clouded by the fact that at many places unnecessary work has been forced on the railroads causing them of a necessity to delay work on some of the more dangerous crossings, since there is a limit to the amount of such work that can be done in one year. The proper remedy for that is an equitable distribution of cost.

Apportionment of Cost

As mentioned before, the public derives most of the benefits from grade separation from the standpoint of service rendered. These benefits have been enumerated above. On the other hand, however, the traveling public has a right to travel the streets and highways and to do so in safety and comfort. The railroads are justified for the existence of the grade crossings on the original construction so that their elimination now should be a matter of mutual agreement on an equitable basis.

There is no doubt but that the public finally pays. Since the railroads themselves are a necessity, and are supported by the revenue derived from the public, anything adding to their cost of operation must be finally absorbed by the public. But this means the public at large, since the business of few railroads is confined to any one community, or even one state. Therefore this cost must be absorbed by the population in the territory which the road serves. The first question then is whether the public at large should bear the entire expense of the cost of improvements in some particular community, or whether that community should bear directly its proportionate share in such improvement. And, secondly, if the community should bear its share directly, what should be its just proportion. It will probably be admitted by nearly everyone, except those with a partison bias, that the community should share the cost; but the answer as to what their proportion should be is not so readily arrived at.

The participation of the State in this expense - the city or county being considered the community - or even the county bearing a portion of the city's share, is also worthy of consideration. There might be some doubt as to the propriety of the State participating in the expense of separating the grade at some crossings, but as to those on the main state highways, whether in town or in the rural district, the State should bear a portion of the expense of this separation as the State shares in the benefits. The same thing might also be said as to the participation of the county in the grade crossings eliminated in the towns. In very few states, however, does the State participate, as will be seen in the summary of the various statutes which is given further on.

The chaos existing at present is mainly due to the lack of uniformity in the laws of the various states. In the past the railroads have generally borne the great part of the cost. This condition is now somewhat relieved by the statutes in some of the states which seek to apportion this more equitably. It will be seen by the summary on pages 11 to 15, however, that the apportionment of cost provided for in the various states which have laws on the subject, is not at all uniform. Also that a large percentage of the states either have no laws at all on the subject or else very indefinite ones.

The present condition could be helped if a majority of the states had statutes with proper provisions for the determination of the advisability of grade separation and distribution of the cost, and if there were a greater uniformity amongst these laws. It is of course realized that as long as this matter is properly under the control of the several states, that this uniformity of law is hard to be realized. However a thorough study of the question and an attempt for all parties concerned to really get together on a fair basis would accomplish wonders toward that end. There is no reason why a fair compromise could not be arrived at. For this, however, the dealings of all parties would have to be just and fair with the other parties concerned. If cooperation rather an controversy mark the solution the city and railroad should both gain. The following two extreme cases will well illustrate the sort of thing that should be avoided. In one case a city endeavored to compel the railroad to depress its tracks, allowing no change at all in the street grades, the entire cost to be borne by the railroad. In another case, where a railroad was going to elevate its tracks, it endeavored to carry the track across the public square and park by a bare steel viaduct with open floor. These two cases show an unreasonable disregard for the rights of the other party.

In an article by C.W. Stark in the Engineering Record of March 13, 1915, is a very good discussion of the apportionment of cost, One point brought out by him is that when the community shares the cost it will not be so apt to make unreasonable demands, and will be more likely to be satisfied with the more utilitarian structures proposed by the railroads, rather than with the extremely expensive structures favored by the community. The writer, while agreeing with Mr. Stark on the whole, does not believe that the aesthetic considerations should be lost sight of. He believes that a proper combination of the two can be made that will not add materially to the cost. This consideration is especially necessary in the residential districts. Mr. Stark's beliefs are given in his summary as given below.

1. That the absence of any grade crossing law means increasing chaos as grade crossings become more and more dangerous.

2. That the situation is only slightly mitigated by leaving it to the public service commission to decide in each case as to the distribution of the expense of elimination work.

3. That to compel the railroad to bear the entire expense is indefensible.

4. That a flexible percentage basis depending on which party raises the issue is fatal to the necessary co-operation.

5. That only a fixed percentage division of the entire expense will lead to the best solutions of all grade crossing problems.

6. That the New York percentages as applied to existing crossings - 50 for the railroad, 25 for the municipality and 25 for the State - are equitable and conducive to a vigorous program of grade separation.

7. That a number of points are involved in the question of participation in the expense by street railways affected by grade separations, and those should be given careful consideration.

8. That a plan should be devised for using the State's funds approximately as fast as they are available, so that legislators will not be misled by the balance, already assigned to definite improvements.

9. That railroads should not be required to pay more than 25% of the cost of opening new streets under or over the tracks.

10. That municipalities should pay a small percentage (not to exceed 20%) of the first and annual costs of protecting existing grade crossings.

The article by Mr. Stark excited a large amount of comment among railroad officials, some of which is here given. E.H. Lee, Vice President and Chief Engineer of the C.& W.I. said: "If the city, county and State assume a fair share of the cost of grade-crossing elimination, it will largely reduce the demands made and the expenditure for needless improvements of this character." He then cited the case of Chicago where the railroads had spent nearly $80,000,000.00 and the city, which agreed to assume abutting land damages, had spent less than 1% of that amount due to the fact that the railroads had been compelled to elevate their tracks. W.H. Courtenay, Chief Engineer of the L.& N. brought out the point that damage to abutting property is less if the city, county or State pays same. He also said: "There is much to be said in favor of an arrangement by which the railroad corporation shall pay the cost of that part of the construction for grade separation on its own right of way or property, and the general public pay the remainder." F.B. Freeman, Chief Engineer of the Boston and Albany, doubted the fairness of even 50% for the railroads.

The writer agrees on the whole with the beliefs as expressed by Mr. Stark. There are two opposing views on this matter of apportionment as given in the beliefs above. One is that each separation should be treated as a separate problem and the distribution be made by a commission; and the other, that there should be a percentage fixed by law to cover all cases. He believes that the latter will, in the long run, lead to the best solution. The writer is inclined to favor the division of cost in which the railroad pays for the portion on its own right of way and the public pays for the approaches, including damages, in the apportionment in ordinary cases; but in the case of complete depression or elevation this would throw the entire cost on the railroad, so that for a fair division to be applicable to all cases it is necessary to fall back upon the fixed percentage basis. For a fixed percentage the writer also favors the New York law as given in the table on page 14, except that on a new highway he does not believe that the railroad should pay more than 25% if any at all.

There are two considerations that the writer believes should always be borne in mind in making a fair apportionment of cost. The street railways or other public service corporations should certainly pay for the cost of moving their own facilities and any increased cost of the work due to the existence of their facilities. Also, in the apportionment, the railroad should bear that portion of the cost equivalent to providing utilitarian features, of proper appearance; but the additional cost of providing viaducts of unusual width for boulevard purposes, or of structures of unusual beauty or design for ornamental purposes, should undoubtedly be borne by the community demanding such increased expenditures.

The writer believes that the question of the apportionment of the cost of grade separation is the most important consideration in the general problem of elimination of existing grade crossings. Therefore he has given this question as much space as he thinks justifiable in an article of this character.

The following table gives a summary of existing State laws on cost apportionment and has been made up from data collected by the American Railway Engineering Association corrected to the year 1920. Under each State is given the existing laws on the apportionment of the cost and with it is given, where the information is available, the practice in some of the towns on existing work; in most cases it being by agreement. The table is of necessity brief in the information that it gives, as space is not available for detailed information. This should not detract from its value for the purpose intended. Anyone desiring more detailed information as to the law or practice in any state is referred to the proceedings of the A.R.E.A., volume 19, pages 633 to 653, and volume 22, pages 292 to 303.

Table I

APPORTIONMENT OF COST OF GRADE SEPARATION

STATE OR TOWN	PERCENTAGE OF EXPENSE Railroad	City or County	State	Street Railway	REMARKS
ALABAMA	100	-	-	-	Law never tried in courts.
Birmingham	70-80	20-30	-	-	By agreement.
ARIZONA	-	-	-	-	In hands of Corporation Commission. Present work by agreement.
ARKANSAS	100	-	-	-	No law - general practice.
Little Rock	61	10 10 County	-	19	Agreement on one viaduct.
CALIFORNIA	-	-	-	-	Railroad Commission has exclusive power to order elimination and to apportion the expense.
COLORADO	-	-	-	-	Law similar to that of California.
Denver	33 1/3	33 1/3	-	33 1/3	Agreement on one subway.
CONNECTICUT	100 75 50	0 25 50	- - -	- - -	Depends on who initiates project and priority of highway.
DELAWARE	-	-	-	-	No law.
FLORIDA	-	-	-	-	No law.
GEORGIA	-	-	-	-	No law.
Savannah	33-67	33-50	-	33	By agreement in three cases.
Atlanta	On R/W	Approaches and damages	-	-	Agreement.

STATE OR TOWN	PERCENTAGE OF EXPENSE Railroad	City or County	State	Street Railway	REMARKS
IDAHO	-	-	-	-	No law.
Pocatello	100	-	-	-	Property owners bear paving cost off R/W.
ILLINOIS	-	-	-	-	Law similar to California. City generally bears damages to abutting property and St. Ry. cost to move own facility.
INDIANA	75	25 County	-	-	Applies to cities over 20,000.
Indianapolis	75	25	-	*	City portion is divided with street railway.
IOWA	100	Property damage	-	-	General provisions of law.
KANSAS	-	-	-	-	To be eliminated by County Commissioners where practicable. Cost to be apportioned by State Highway Comm.
Wichita	33 1/3	33 1/3	-	33 1/3	Agreement for future work.
KENTUCKY	-	-	-	-	No law.
Louisville	On R/W	Approaches	-	-	Agreement for all except one special job. City bears about 65%.
LOUISIANA	-	-	-	-	No law.
New Orleans	-	-	-	-	Divided between railroads and street railway.
MAINE	65	10	25	-	
MARYLAND	-	-	-	-	No specific law.
Baltimore	100	-	-	-	Except City and street railway bear cost of changing own facilities.

STATE OR TOWN	PERCENTAGE OF EXPENSE Railroad	City or County	State	Street Railway	REMARKS
MASS.	65	10 max.	Rest	15 max.	State sometimes divides its share with railroad in addition to 65%.
MICHIGAN	-	-	-	-	In hands of towns subject to approval of R.R. Commission. State pays a maximum of 25% on highways.
Detroit	-	-	-	-	City generally bears damages to abutting property and street ry. cost of own work.
MINNESOTA	-	-	-	-	No specific law. Railroad bears most of cost.
MISSISSIPPI	-	-	-	-	No specific law.
MISSOURI	-	-	-	-	Practically the same as Illinois.
MONTANA	-	-	-	-	Under control of Board of R.R. Commissioners.
NEBRASKA	100 generally	-	-	-	Statutes contradictory.
NEVADA	-	-	-	-	Commission has power to order work done and to apportion cost.
NEW HAMPSHIRE	-	-	-	-	No provision for division of expense.
NEW JERSEY	All except	-	-	10 max.	
Newark	80	20	-	-	By agreement.
NEW MEXICO	-	-	-	-	No specific law.

STATE OR TOWN	PERCENTAGE OF EXPENSE Railroad	City or County	State	Street Railway	REMARKS
NEW YORK	100	-	-	-	New Railroads.
	50	50	-	-	New Highway.
	50	25	25	-	Existing facilities.
Buffalo	100	-	-	-	On R/W) Special
	65	35	-	-	Off R/W) provision.
Syracuse	50	25	25	-	
N. CAROLINA	-	-	-	-	Commission has power to order work done and to apportion cost.
N. DAKOTA	-	-	-	-	No law fixing cost on other than carrier.
OHIO	65	35	-	-	
OKLAHOMA	-	-	-	-	Under control of Corporation Commission with 50% maximum for towns.
OREGON	-	-	-	-	Commission has exclusive power to order work and to apportion cost.
PENNSELVANIA	-	-	-	-	Commission has exclusive power. State's limit is 1/3 on highways.
Philadelphia	50	50	-	-	Agreement under old law.
RHODE ISLAND	65	35	-	-	General practice. Law provides for decision by court.
S. CAROLINA	-	-	-	-	Under control of Railroad Commission with certain limitations.
S. DAKOTA	On R/W	-	Approaches (or county)	-	General provisions of existing law.
TENNESSEE	-	-	-	-	No law.
Memphis	69	24	-	7	Four crossings.
Knoxville	31	63	-	6	Two different
	18	82	-	-	crossings.

STATE OR TOWN	PERCENTAGE OF EXPENSE Railroad	City or County	State	Street Railway	REMARKS
TEXAS	-	-	-	-	No general law.
Dallas	100	except	-	-	City to pay abuttal damages.
UTAH	-	-	-	-	Commission has exclusive power to order work and to apportion cost.
VERMONT	65	10	25	-	Existing crossing.
	60	15	25	-	New crossing.
VIRGINIA	100	-	-	-	R.R. grade changed.
	50	50	-	-	Highway grade changed.
WASHINGTON	50-100	0-50	-	-	Under control of Commission or cities over 20,000. Cities pay abuttal damages.
W. VIRGINIA	-	-	-	-	No general law.
WISCONSIN	-	-	-	-	Cost apportioned by Commission. State does not participate.
Milwaukee	70	25	-	5	One project.
WYOMING	-	-	-	-	No law.
DIST. COL.	On R/W	Approaches	-	-	On opening new streets the city also bears 50% of cost on right of way.
CANADA	35-50	35-40	15-25	-	General practice. Government limited to 25%.

PART II

THE ENGINEERING PHASE

1. URBAN

The engineering problems encountered in any grade separation are not always simple. Although the solution arrived at, in some cases, may be rather complex, still some method of separation of the grades can be worked out for any situation. Given a competent engineer and sufficient funds to work with, any problem can be properly solved.

Methods of Grade Separation

Following are the six methods by which any grade crossing may be eliminated.

1. The street is carried over the railroad track.
2. The street is carried under the railroad track.
3. The grade of the railroad is raised so that it will cross above the street.
4. The grade of the railroad is lowered so that it will pass under the street crossing.
5. The street is lowered and the railroad raised.
6. The street is raised and the railroad lowered.

In attacking any single problem, the engineer must soon decide as to which one of the various methods he will use on this particular problem. On a large job where there are several crossings he might use a combination of two or more methods of elimination.

General Classification of Methods.

The writer believes that in considering a problem that will require the elimination of several crossings in the same locality, the above methods may be more advantageously grouped under the three following heads for a study of the problem and a selection of method. This classification was used by the Division of Grade Separation and Bridges of the City of Detroit in their report in 1919 on the problem of that city.

a. The railroad track is left as it is and the street is either depressed under the track or elevated full height over the track.

b. The street is left as it is and the railroad depressed or elevated to the extent required.

c. Both railroad and street are changed and such compromises in grade made as best suit the requirements of the particular case.

The selection may be either one of the three methods or perhaps a combination of two of them.

Changing Grades of Streets

The chief advantage of this method is that it will prove by far the least expensive when there are a relatively small number of grade crossings to be eliminated. It is, however, the least desirable from the standpoint of the city, as it will cause the maximum obstruction to street traffic during the period of construction, and will also cause a maximum change in the grades of the city streets. In case the city is not paying a fixed percentage of the total cost, but is paying the abutal damages and perhaps a small additional amount, this scheme will be the more expensive for the city. Drainage is also an item of great importance in the case where the street is to be depressed and carried under the railroad. Proper means will have to be found for draining the subway, and this might be a serious problem if the street should be depressed below the elevation of the closest storm sewer or natural drainage.

From the railroad's standpoint, it is to their advantage to use the scheme that will be the cheapest, that will cause the minimum interference with their traffic and leave them with the best grades and alignment. For infrequent crossings method (a) will be the cheapest. Also this method will interfere with the railroad traffic less than any other, except in the rare case where there is to be a complete change in the alignment of the railroad and the old line can be operated until the new one is ready for traffic.

Changing Grade of Railroad

Where the grade separation is to be accomplished by changing the grade of the railroad there are two ways in which this can be done, i.e. by track elevation or by track depression. The essential features entering into each will be discussed before a comparison is made of the relative merits of the two. The writer wishes to make special mention at this point of an excellent paper delivered before the Western Society of Engineers in 1915 by C.N. Brainbridge, in which the subject of elevation and depression was discussed in much greater detail than the nature of this work will allow. The classification of bridges and other parts of the discussion below are borrowed from Mr. Bainbridge's paper. For a comparison of costs and design the reader is referred to that paper.

Track Elevation

In track elevation the tracks are generally carried on an embankment through the city blocks and by a bridge over the streets. The embankment is held in place by retaining walls, the usual type being a gravity wall with the batter on the side next to the embankment. Since the railroad grade must, of a necessity, be somewhat uniform, it is necessary to elevate the track through the block a sufficient amount to give the proper clearance over the street. This will necessitate a change of grade, or separation, of from 16 to 18 feet, or sometimes more, depending on the over head clearance desired on the street. The figures above are based on a depth of floor of from 3 to 4 feet on the bridge and a headroom of 13 to 14 feet for the street.

For the bridges across the streets there are several considerations not to be lost sight of. It is desirable that they be sightly in appearance for aesthetic reasons as well as to prevent undue depreciation in the value of adjacent property. This would apply particularly in residential districts and over boulevards. They should also be water-proof and as noiseless as possible. The earlier types of bridges were through plate girders or I-beam spans, generally with solid floors. The tendency now is toward reinforced concrete structures or steel girders masked with concrete. There is not much difference between the initial cost of concrete and steel bridges and the maintenance on the concrete bridges should be less. Also the concrete bridges more readily adapt themselves to aesthetic treatment when desired.

The bridges for track elevation work can be divided into the following four types, depending on the number of spans used:

A. Structures spanning the full width of the street with single spans.

B. Structures spanning the full width of the street with two spans, supports being placed in the center of the street.

C. Structures spanning the full width of the street with three spans, supports being placed at the curb lines.

D. Structures spanning the full width of the street with four spans, supports being placed at the curb lines and in the center of the street.

It is also desirable to meet the following requirements in selecting the type to use:

1. Keep the floor of the bridge as thin as possible:

2. Avoid any projections above the top of rail which might be a menace to safety:

3. Select a type of bridge which can be readily altered to provide for additional tracks.

In the majority of cases these three requirements will be met best by type "D". The objection to this type, and the same will apply equally to type B, is the support in the center of the street. The writer will concede this point in the case of boulevards, but on the normal city street he feels that the center support is an advantage rather than a disadvantage, on account of the fact that it tends to divert the traffic to its proper side of the street. This objection is especially of no moment on streets having a double car line. The main advantages of type"D" are that on account of the shorter spans the floor can be kept thin; I-beam spans can easily be used, thus avoiding the projections above the top of rail which would be caused by a through girder, and which are particularly objectionable if there is any switching to be done over the bridge; also this type of deck structure can be more readily altered to provide for any additional tracks that might be required in the future. In meeting this last requirement, if there is a good surety that the additional tracks will be needed in the not distant future, it might be desirable to construct the extra width of abutment in the original construction. All that would be necessary later on would be to provide the extra steel and the deck, as the writer has done on layouts he has made.

Sometimes an arch is used when building a structure of one span, and this class of structure is recommended by some engineers, mainly on account of the appearance. The writer however does not approve of this class of structure in spanning city streets on account of the loss of headroom which will occur at the supports. Rather than use a single span, in the cases where it is not desired to have a support in the center of the street, it will probably be found advantageous to use type "C". Also type "B" will sometimes be found to fit some particular crossing rather than type "D". It is also desirable, where the railroad does not cross the street at a right angle, to line the supports up with the street and make a skew bridge out of the structure.

Plates 4, 5, and 6 in PART III show how the last three types can be well adapted to grade separation work. Figures 1, 2 and 3, on pages 20 and 21, show how types "A", "B" and "D" have been adapted to grade separation work on the Illinois Central in Champaign, Illinois.

Track Depression

In track depression the right of way is excavated to the depth required and the adjacent earth is held back by means of retaining walls. The railroad tracks are laid in the bottom of this excavation, and the streets are carried over the tracks by means of bridges. The separation of grade required in track depression will be from 22 to 26 feet, depending on the overhead clearance required by the railroad and the depth of floor of the bridge. The figures above are based on a depth of floor of 4 feet on the bridge and an overhead clearance of 18 to 22 feet.

The bridges used to carry the streets over the excavation are of course lighter than the type required to carry the railroad trains. They are longer in span than the bridges required in track elevation, on account of the fact that the railroad right of way is generally wider than the city streets, so that the floor depth will be as great or greater than the railroad bridges. The same considerations should be given to the appearance of the structure as in track elevation. Concrete will generally be found to be the best material to use in these

Figure 1 - Type "A" Subway at Champaign, Ill.

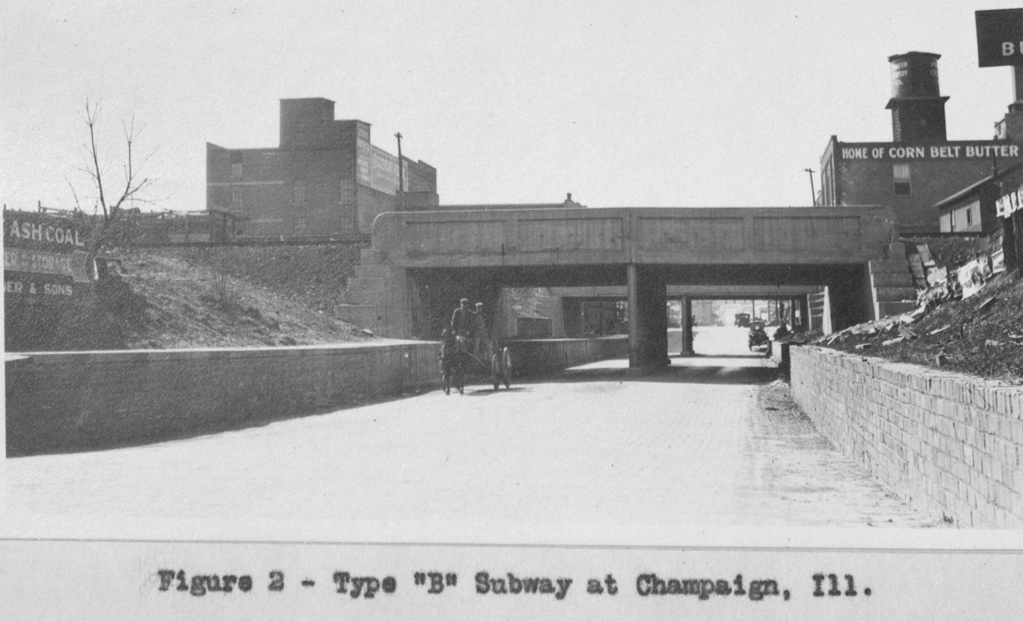


Figure 2 - Type "B" Subway at Champaign, Ill.

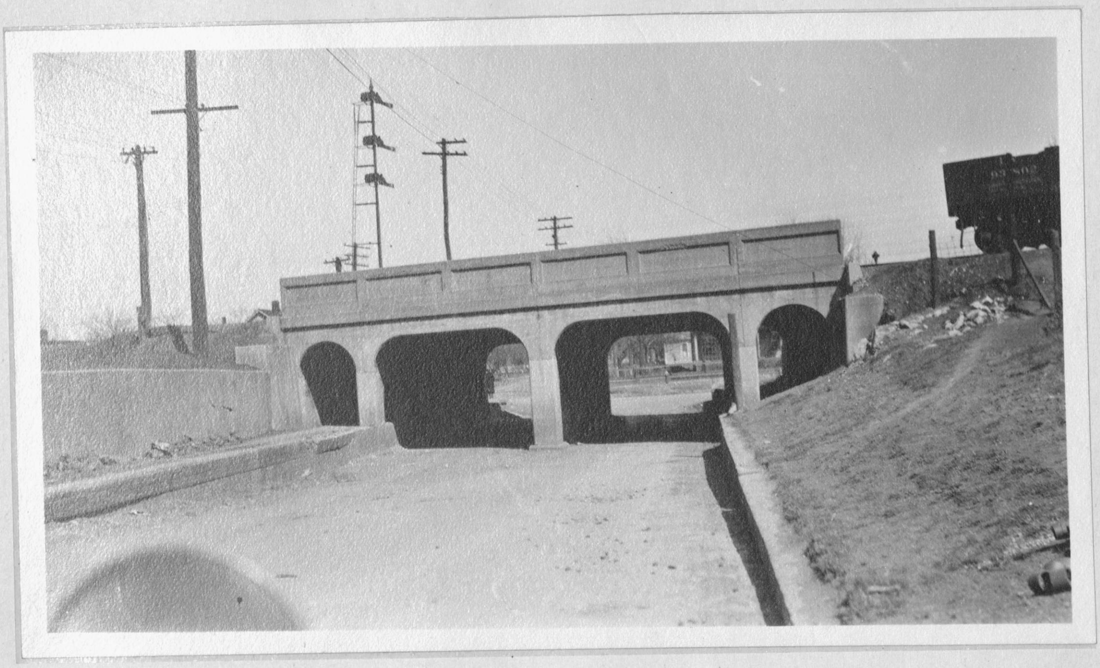


Figure 3 - Type "D" Subway at Champaign, Ill.

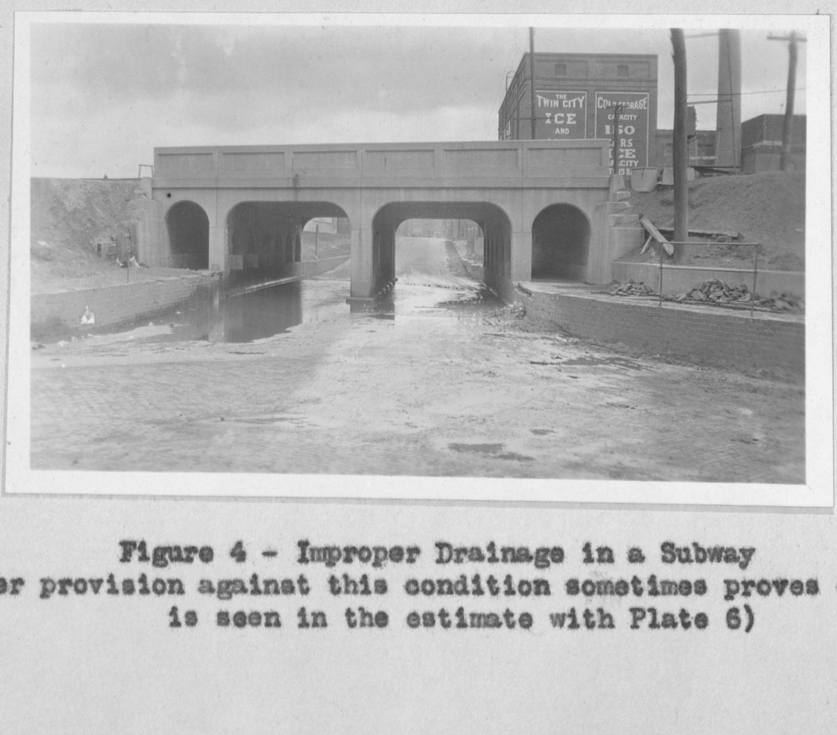


Figure 4 - Improper Drainage in a Subway
(Proper provision against this condition sometimes proves expensive as is seen in the estimate with Plate 6)

structures, although steel viaducts have been used to quite an extent on city streets, and timber bridges on rural highways and, in some cases, on city streets also.

The bridges used on track depression work can be divided into the following two types:

E. Bridges spanning the tracks with clear spans.

F. Bridges spanning the tracks with two or more spans with intermediate supports.

It is desirable to meet the same requirements, in selecting the type, as in track elevation, namely:

1. Keep the floor of the bridge as thin as possible;
2. Avoid any obstructions between the tracks;
3. Select a type of bridge which can be readily altered to provide for additional tracks.

Of these two types, "E" will be the cheapest. The first of the three requirements will be met very well by type "E" but will obviously be met best by type "F". The third requirement will be met best by type "F" as it will be much easier to modify to provide for additional tracks, although it will probably be better in the case of track depression to provide for all tracks thought necessary, at the time the work is done. The main objection to this type is the fact that it does not meet the second requirement, that of not having obstructions between the tracks. This can be overcome however by the placing of the tracks in pairs of 13 (or 14) and 18 feet centers respectively, having the bridge supports come between the tracks having centers of 18 feet. On bridges spanning a wide right of way it will not be advantageous to use a deck structure, if type "E" is used, but a through bridge. In that case type "F" will more readily lend itself to the use of concrete.

Track Elevation vs. Track Depression

Track elevation has the following advantages over track depression as a means of grade separation:

1. The construction will be cheaper and generally less difficult.
2. More tracks can be accomodated on a given width of right of way.
3. Connections to industries are more easily made.
4. Drainage is more easily accomplished.
5. Less trouble is experienced with heavy snowfalls.
6. The right of way is more easily kept clean.
7. The smoke nuisance is less.
8. Signals can be seen more distinctly.

Track depression has the following advantages over track elevation.

1. The streets can be kept clean more easily when they are above the railroad than when they are beneath.

2. The depression does not obstruct the view through the town as does an embankment.

3. The property damages will be less.

4. The noise will be less from depressed tracks.

5. The trains will be hidden from view - especially applies to residential districts.

From the above it appears that the advantages will generally be very much in favor of track elevation as opposed to track depression. This will especially be so from the standpoint of the railroads and industries, although from the standpoint of the city the advantage might lie the other way, particularly in the better residential districts.

Many elements enter into the question of cost and ease of construction. On account of the fact that the grades have to be separated so much less for elevation, the cost of grading is apparently very much in favor of elevation. This will have to be qualified in some instances however, as much will depend on the origin of the fill. The earth for the fill will have to be hauled in, and that from the excavation hauled out. In some cases the railroads will have use for the earth obtained from track depression, also the distance to haul in will usually be greater than the distance to remove the earth. Add to that the fact that for a large number of tracks the cost of the bridges on elevation will exceed those for depression, and it will sometimes be possible to find a case where the cost of depression will be much less than that of elevation. In many cases the costs will be nearly equal. One item to be considered is the cost of the retaining walls; on account of the extra height this will be greater in depression. For these reasons the majority of cases will find the cost of elevation much cheaper than that of depression.

There will be less interference with traffic in elevation, the construction problems will be less difficult and the time of construction will be less. This interference with traffic will apply to street traffic as well as to the railroad. It is almost impossible to depress the tracks the amount necessary without stopping the traffic on streets and building a parallel track to carry the traffic of the railroad. In elevation, where more than one track is to be raised, a trestle can be built to carry one or two tracks at the final grade and the fill dumped from this trestle. The street traffic at the same time can go on undisturbed.

In order that there shall be no encroachment by the railroad on private property, it will be necessary to build the retaining walls so that the inclined face will be toward the railroad side. For this reason a given right of way will not be able to carry the same number of tracks in depression as on elevation. On elevation the full width of the right of way can be utilized, while in depression allowance will have to be made for the thickness of the walls at the base with proper clearance. This will amount to at least one track, depending on centers and clearance, and in the case where the railroad has already utilized the full width of its right of way for tracks it will either have to take up one track or obtain additional right of way .

Industries can be taken care of with much greater ease with track elevation than with depression. Industries served by side tracks can adapt themselves to handle cars on the elevated level by slight changes to their buildings and doing their work on the second floor. In the case of depression this could not be so easily solved and the interference with shipping during construction would be much more serious. Although the industries could probably alter their buildings so as to do their shipping from basements or sub-basements the problem of so doing would be very much more difficult than in elevation. As to bringing the side tracks up to the ground level, it is very rarely that there would be sufficient distance between bridges to permit of this being done with proper grades. Even if the distance was sufficient it would necessitate encumbering the right of way with massive walls that would restrict the future development of both the right of way and the industries.

The question of who should bear the cost of the industry changes, while not quite on the subject at hand, might still be mentioned at this point. This cost is very great, both in elevation as well as depression, and the industries have claimed that the railroads are liable for any expense occasioned by the change of the railroad level. The railroads on the other hand insist that it is not by their initiative that the tracks are being changed and that therefore the industries should bear the complete cost themselves. Past practice has been for the industries to bear this cost.

The matter of drainage is even of more importance in track depression, than in the depression of the city streets which was discussed on page 17. The added importance is due to the fact that the tracks are being lowered a greater distance than the streets.

The main advantages that track depression possesses will apply more specifically to the better class residential districts, as mentioned before. However, sometimes on account of the topographical features, or in new work or development like the recent Kansas City Terminal work, the depression of the tracks may have marked advantages over elevation even in the down-town or industrial districts. It will be shown later that in some cities track depression has proved more advantageous (when the experience of various cities are summarized) but on the whole, when it becomes a question of complete elevation or depression of tracks, it will be found that track elevation will possess by far the greater number of advantages.

Recommendations of A.R.E.A.

It might be well at this point to give the following conclusions that were presented to the American Railway Engineering Association by the Committee on Roadway at the annual meeting in 1917.

1. Whenever grade separation through densely built up thoroughfares (short blocks, say from 12 to 15 crossings per mile) becomes imperative, elaborate studies of the kind and volume of traffic on each thoroughfare should be made and due records kept with a view to eliminating or vacating certain of the crossings as wholly unjustifiable from a cost standpoint, and opening lateral streets at a less cost in their stead.

2. If only a few crossings are to be eliminated in an industrial district, with reasonable assurance that no others will be required, the methods used, other things being equal, should not disturb the tracks.

3. If several crossings are to be eliminated in an industrial district, the most efficient method, other things being equal, is by track elevation.

4. In a residential district, if grades and other conditions on the railway will permit, complete depression, allowing the streets to remain at their original level or nearly so, is the preferable method.

Changing Grades of Both Streets and Railroad

All of the foregoing, including the recomendations of the committee of the A.R.E.A., has been based on the assumption that the separation will be accomplished by making the entire change in either the streets or the railroad. Generally, even in the cases of complete elevation or depression of the railroad, small changes are sometimes made in the grade of the street, 1 to 3 feet, where it is advantageous to do so, and where it will lessen the cost somewhat. Such changes will be considered as coming under the head of changing the grade of the railroad alone, as they do not have any material effect on the problem of separation from the standpoint of either track elevation or depression. In many cases however the question arises as to whether or not a partial elevation of the tracks with a partial depression of the streets, or a partial depression of the tracks with a partial elevation of the streets, would not be the plan to adopt.

The same problems mentioned under the discussion on changing the grade of the streets will also be met with here. However they are not as serious in this case, and the advantages of this method over changing the grades of the streets entirely, are much in its favor. The problems of drainage are not so acute when the street is to be only partially depressed, and also the matter of grades to be used on the approaches, especially on the viaducts where maximum grades are needed, can be handled much more easily.

In partial depression of the streets the matter of the economical amount of grade change will enter in. As far as the matter of actual cost is concerned it will usually be less when the tracks are elevated 8 to 12 feet and the street depressed the remainder of the distance necessary to obtain headroom. It will generally be found advantageous to leave the sidewalks at a higher level, from 4 to 5 feet, than that of the street. This will effect a saving in the cost of excavation and will also be advantageous to pedestrians, as they will not have to walk down and up as great a distance, for since a pedestrian does not require the headroom that street traffic does, there is no reason for requiring him to cover the same vertical rise and fall.

In elevation of the street over the railroad, the sidewalk must, of necessity, be carried at the same level as the roadway. In partial elevation of the street there is the same saving in vertical distance for both the pedestrian and vehicular traffic. As the streets are to be carried over the railroad by means of some type of viaduct, the greatest saving, as mentioned above, is that in the grades of the approaches. Partial elevation of the streets and partial depression of the railroad is generally done along with work of revising the grade of the railroad in connection with the grade separation, and not as a sole method of separating grade crossings.

It will often be found that the railroad concerned can make a good improvement in its existing grade line by cutting off the high spots and filling in the low ones. In that case their work will very well dovetail in with the separation of grades at crossings, by partial depression of the streets where the railroad is elevated, and by partial elevation of the streets where the railroad is depressed. This method of solution was used to some extent in the layouts for the proposed grade separation given as an example in PART III. In this problem the railroad was elevated or depressed where it would improve the railroad grade, at the other crossings the street was either elevated or depressed the full amount as best suited the topography of the crossing concerned. In general it will usually be found that this method of changing the grade of both the streets and the railroad will give the best solution of the particular problem. This is general, as there must of necessity be exceptions, of which Chicago is one example where only elevation can be used.

The matter of street grades, headroom, clear roadway and so forth are also worthy of consideration. The amount of roadway will depend somewhat on the character of the street. On first class residential streets and boulevards the roadway over or under the railroad should be of the same width as along the remainder of the street, and on other streets this is desirable if it can be accomplished, but there is no reason why the roadway of these other streets should not be narrowed across the tracks if there is no occasion for the parking of automobiles or the unloading of drays on this section of street. Grades should not be exsessive, but there is no reason why the grade for the approaches to a viaduct or a subway should be any less than the maximum grade on the street.

After the summation of the experiences of various cities, in which the grades and so forth will be mentioned along with the other experiences they have had, there will be found on page 31 a tabulation of the street grades and clearances used in various cities and states.

Experiences in Various Cities

The experience of various cities in grade separation is given below so as to present a fair idea of the different methods of solution that may be used under varying conditions. In each community the solution finally arrived at is the one that for that particular problem, seemed the best. It should be remembered that each community will require a separate solution that will only be comparable with other communities having essentially the same problem; also, that the interests of the city and the railroad are sometimes distinctly opposite and the solution must be either a compromise, or one party to the controversy must be compelled to assume its task unwillingly.

Detroit

Modern grade crossing elimination in Detroit dates from about 1900. In 1903 an agreement was made with the railroads by which they were to spend $200,000 each year. In 1917 the Division of Grade Separation and Bridges was organized to make a further study of the situation, and their report, made in 1919, is here briefly summarized.

At that time 43 grade crossings had been eliminated since 1900. There were 64 1/2 miles of line (parallel tracks being considered as one line) and 298 street crossimgs. At 58 crossings grades were separated, 43 having the track over the street and 15 the track under the street. 20 more were covered by existing contracts. Counts taken in 1917 on 147 crossings showed an average of 1011 street vehicles and 41 trains per day per crossing. All previous work had been to elevate the track 6 to 10 feet and lower the street 6 to 14 feet.

The recommendations of the committee were that of the three methods for grade separation, the first one (change the grade of the streets and leave the railroad undisturbed) be not considered. The most ideal for cost and convenience, for Detroit, was full track elevation and this was held true for any case where there were 8 or 9 street crossings per mile; but would not be true where there were few streets, large yards, nor where a large mileage of industry tracks was involved. On account of the consideration that would have to be given to manufacturing plants and yard and team tracks, the third plan of raising the tracks and lowering the streets was adopted but modified from previous practice to meet the following requirements:

On main arteries the maximum street depression should not exceed 2 to 3 feet and grades not over 2 1/2%.

On other important thoroughfares it should be 5 feet and grades 3% except that a greater depression might be allowed where there was little through traffic, but in no case should the grade be over 3 1/2 or 4%.

Subways should be concrete bridges with waterproof floors; no intermediate supports to be allowed in streets in widths up to 50 feet; over 50 feet, or at skew crossings, supports would be allowed at the curb lines but no supports to be allowed in the middle of the street if the distance from curb to curb should be less than 60 feet. (At present there are a number of such bridges in Detroit that have three or four supports).

One exception to be depression of 1.3 miles of the Grand Trunk as it already passed under 3 important streets and this was the most feasible solution for this line.

It is estimated that this program would cost from $30,000,000 to $50,000,000 and was to be completed by 1935 or 1940. In that case it was recognized that the present amount spent would have to be increased to from $2,000,000 to $4,000,000 per year. Heretofore the city has paid from 20 to 25% of the cost and the street railway from 2 to 3%. It was recognized that the 20 to 25% was a just portion for the city but attention was called to the proposed new charter which would limit the city's portion to property damages. It was recommended that the street railway pay their proper share which would be much more than 3%.

Chicago

There has been more grade separation work done in Chicago than in any other city in the country. The work began in 1892 and in 1916 there had been over 800 grade crossings eliminated at a cost of about $80,000,000. When Chicago first attacked the problem there was a large amount of money spent on costly viaducts over the railroad yards. It was soon seen that this was futile however and many of them have been torn down and track elevation has been adopted as the proper solution. The ground at Chicago is low and level and the streets in their natural condition are practically level, so track depression is out of the question. It was originally estimated that the completion of the work at Chicago would cost about $150,000,000 but this is too low now on account of the increased prices, so that $225,000,000 would probably be nearer correct.

As an example of the type of problems encountered there, the case of the Rock Island Separation at 79th Street might be given. The C.& W.I. also crossed here and it was decided to separate the railroad grades at the same time. The final solution depressed the street below and raised the Rock Island above the C.& W.I. The street headroom is 13 1/2 feet and that for the C.& W.I. is 17 feet. Steel coated with gunite was used in the construction.

Indianapolis

In Indianapolis also it was first attempted to separate the grades by the use of viaducts. They gave only partial relief, however, so the final solution was to elevate the tracks. At present none of the old viaducts are left. The history of the track elevation began in 1899 when the city tried to compel all of the railroads to elevate their tracks at their own expense in a given time. The railroads won the decision in the courts but in 1905 the State passed a law permitting cities of over 100,000 to require railroads to eliminate grade crossings. The apportionment of cost was; 75% to railroads, 17% to city, and 8% to county; if there was a street car line the city paid 14%, the county 6% and the street railway company 5%. Track elevation is now going on under this law, the tracks being elevated the full amount with little lowering of the streets. The elevation is about 18 feet, the headroom is 12 to 14 feet on streets without street cars and 15.75 feet on streets with interurban cars, and the maximum grade is 3% . The total estimated cost is $18,000,000.

Minneapolis

Although track elevation is more common than depression, Minneapolis is an exception in that depression was used. In that city 37 crossings were eliminated from 1912 to 1916 by this means. The tracks were depressed 18 to 20 feet and the streets raised 2 to 4 feet. There was a controversy between the railroads and the industries as to who should bear the cost of changing the facilities of the industries. The industries contended that the railroads should bear the cost and the railroads contended that the project was not at their initiative but was being forced by the city so that the industries should pay it. The matter was finally compromised by the railroads building a third track for serving the industry spurs and the railroads built this track at the depressed level and paid the industries the amount that it would have cost to have built a retaining wall and kept this track at the old level. Some buildings were torn down and rebuilt, some were underpinned and shipping and receiving rooms added beneath.

Subway at Alton, Illinois

A subway built at Alton, Illinois, where the C. & A. Ry. crosses College Avenue, is of interest as the street and the street railway were built at different grades. The State initiated the project as it wanted the electric line extended to the new insane asylum. The street railway headroom is 15 feet and the street headroom is 13 feet with 6% grades on the approaches. Part of the project was outside the city limits. The cost was divided as follows: State 31.67%; C. & A. 33.33%; street railway 25%; Alton 5%; township 5%.

Tower Grove Crossing at St. Louis

In St. Louis at the intersection of Tower Grove and Vandeventer Avenues, they were crossed by the Mo. Pac. main line and Oak Hill branch and the St. L. & S.F. Ry. In 1909 the traffic in 24 hours over this crossing was 400 street cars, 2,400 vehicles, 6,000 pedestrians, and 250 trains (100 of which were passenger). The question of elimination was taken up in 1905 and in 1907 the Board of Public Improvements and the railroads agreed to street depression at a cost of $500,000. This was rejected by the Assembly in 1908, considerable opposition having been voiced to what was termed the "tunnel plan", and in 1909 the Assembly passed an ordinance demanding track depression at a cost of $3,000,000. This was carried to court but was finally settled by partial street elevation and partial track depression. The street was raised 13 feet and the track depressed 13 feet, leaving a clearance of 22 feet from the top of the rail and making the street grade 3 1/2% on the approaches. The work was done from 1913 to 1915 at a total cost of $830,000. The city paid the property damages.

Recommendations at Dallas, Texas

In 1915 Mr. J.F. Wallace made an investigation of conditions at Dallas, Texas and recommended two plans. At that time the city had a population of about 130,000; there were 8 roads entering the city with a total of 77 miles of track and there were 160 grade crossings. His plan called for grade crossing elimination by means of track elevation at a cost of $5,000,000. He advocated as an alternative that a belt line be built around the city at a cost of $900,000 which would eliminate the necessity for most of the lines in town. The passenger trains could get into the Union Station along the river from the belt line and the other switching could be done at night. He favored this plan as he considered that gradually the necessity for switching in the city would decrease as the industries would eventually move out to sites along the belt line.

Grades and Clearances Used

The following tables have been taken from the paper given by Mr. Bainbridge before the Western Society of Engineers in 1915 on Grade Crossing Elimination.

Grades which have been used on work of this nature in various cities is given in the following table:

Table II

Location	Maximum Grade
Chicago, Ill.	3½%, usual 3%
Buffalo, N.Y.	4%
Joliet, Ill.	3½%
Evanston, Ill.	3½% or 3%
Milwaukee, Wis.	4%
Minneapolis, Minn.	5%, 4%, usual 3%
Cleveland, Ohio	6%, usual 4%
Detroit, Mich.	4%, usual 3%
Philadelphia, Pa.	5½%, usual 3%
Indianapolis, Ind.	4½%, usual 3%
Washington, D.C.	9%, 8%, 6%, usual 3%, 4%
Newton, Mass.	9%, 8½%, 7½%, 6%, usual 3% and 5%
Lynn, Mass.	3%, 4%, and 5%
Brockton, Mass.	9%, 5%

The following table gives the vertical clearances (side clearance also in a few cases) which have been used in the past for bridges over the tracks and for bridges over the streets in different localities:

Table III

CLEARANCES IN FEET OF BRIDGES OVER STREETS

Location	Sts. without St. Cars	Sts. with St. Cars
Chicago	12 to 13	13.5
Philadelphia	14	14
New York	14 usual, 11 and 12 special	14
Buffalo	13	14
Evanston	12 to 13	13.5
Kansas City	13	14.5
Cleveland	13	14.5
Detroit	13	14
Milwaukee	12	13.5

CLEARANCES IN FEET OF BRIDGES OVER TRACKS

Location	Clearances	Clearance at side
Chicago	16 to 18	...
Philadelphia	20	...
Rhode Island	18	...
Connecticut	18	...
New York City	16 to 18	...
New York State	21	...
Massachusetts	18	...
Buffalo	15 to 18	...
Minneapolis	18 to 18.5	...
Minnesota	21	8
North Dakota	21	8
Canada	22.5	...
Kentucky	22	...
Cleveland	16.25	...
New Hampshire	21	...
Michigan	18	...
Milwaukee	18	...
Vermont	22	7.5
Indiana	21	7

In choosing a street grade it can be borne in mind that 2 to 3% will not have a marked effect on traction, but any grade above that will. If possible, the grades should be limited to 4 or 5%, but this is not at all necessary if the ruling grade on the street is more than that. Vertical curves should be used, especially at the bottom of the grade when passing under the tracks, and should be so laid out that there will be no appreciable rise in grade within less than 15 feet from the face of the structure. In the proposed grade separation given as an example in PART III, a grade of 6% was used on both subways and viaducts. In this case there was no objection to this grade as the city was located on rather rolling ground and the maximum grades on the streets were that much.

The writer would recommend the following vertical clearances where the railroad crosses over the street;

13 feet for streets without street cars,
14 feet for streets with street cars,
15 feet for streets with interurban electric cars.

This would be sufficient for all normal cases, if greater headroom is desired the cost will vary about as the square of the depth. In the example in PART III a headroom of 14 feet was used in most cases. This was because there was no complete knowledge as to just what streets might be further developed by the street car company, so that provision was made for future eventualities in the original layout. 15 feet was adopted as the clearance to use for interurban crossings, but no crossings were involved in the design that were expected ever to be used by interurban lines in the near future.

The present tendency, in the laws of the various states, is toward an overhead clearance of from 21 to 23 feet for structures over a railroad track. In the example in PART III a clearance of 23 feet was used, as 23 feet from the top of the rail to the bottom of the overhead structure was the standard clearance of the railroad for which these estimates and layouts were made. A side clearance of 8.5 feet from the center of the track was used for the same reason. The writer considers that 23 feet is a proper clearance to use and be on the side of safety. For a side clearance he would recommend that in any case no clearance of less than 8 feet be used, as a matter of safety, although a side clearance of 7 feet will just clear a man on the side of a car, and is used by some roads. It will be noted that the clearance diagram of the A. R. E. A. Specifications for Steel Bridges allows for a vertical clearance of 22 feet measured from the top of rail and a side clearance of 8 feet measured from the center of the track, and coming down to at least 4 feet from the top of rail.

Effect of Interurban and Street Railway Cars

The net effect of street cars and interurban railways, as has been seen, is to add from 1 to 2 feet to the necessary street depression in subways, and to require somewhat stronger structures in the case of viaducts. It is for this reason that a part of the responsibility for the cost of the separation was apportioned to the street railways in PART I. When this extra headroom, or strength is added for the benefit of the contemplated extensions in the street car lines, as given above, it appears that the street railway company should not be relieved of its responsibility in this latter contingency.

Damages to Property

Only a rough estimate as to the amount of damages to property can be given here as this will entirely depend upon the nature of the work and the character of the district through which the railroad runs. On track elevation this property damage will generally be about 1% of the total cost of the work. On track depression it will be considerably less. On other kinds of elimination it will be more, running up to as much as 10% in cases where the total change of grade is in the streets.

2. RURAL

In grade separation on the highways, each crossing will present a separate problem and there will not be the necessity for a simultaneous solution of a number of crossings as is the case in a city. The crossing will be made by carrying the road over the railroad or under the railroad. The separation will be made by entirely changing the grade of the road leaving the railroad grade undisturbed, except in the rare cases where the grade separation is incident to a grade revision on the railroad, in which case there will be only a small change in the grade of the road, or none at all. Grade separation is seldom imperative on country highways unless the traffic is unusually heavy and the view, on approaching the railroad, is obstructed. The necessity for separation in the rural districts is not as great as in town, nor are the complications met with in solving the problem. As to the type of crossing to be used, under or over crossing, that will be determined by whether the railroad is on an embankment or in a cut at the place to be crossed.

Four solutions in eliminating highway grade crossings are as follows:

a. Crossings which can be eliminated by the construction of a subway under the railroad.

b. Crossings which can be eliminated by the construction of a highway viaduct over the railroad.

c. Crossings which can be eliminated by a relocation of the highway.

d. Crossings which can be eliminated from the main-traveled highways by diverting the travel to other roads.

Subways will be found to be advantageous when the railroad is on a high fill, or if the railroad has a bridge over a natural drainage in the near vicinity so that the road may be easily diverted under this bridge. Where the road must be depressed in order to construct the subway, drainage is again an important item the same as in the city work. Care must be taken that the road is not depressed below the adjacent natural drainage.

Where the crossing occurs in a cut or on the level, it will be found advantageous to use an overhead crossing, both from a construction standpoint and from the standpoint of economy. In case the crossing occurs on the level and there is a deep cut in the immediate vicinity, it will probably be advantageous to divert the road so that it may cross the railroad on a viaduct, at the cut. The overhead clearance for the viaduct will have to conform to the practice of the particular railroad involved. The grades of the approaches will of course depend somewhat on the ruling grades of the highway but it should not be necessary to use over 5 or 6%.

Items "c" and "d" are not commonly given as much attention as they should have. There are many highways that wander back and forth crossing the same railroad many times at grade. In the majority of cases proper relocation of the highway would eliminate all of these with the exception of probably one. These highways were originally laid out with the idea of maintaining light grades with as cheap construction as possible. With the increased motor traffic a new roadway surface is necessary and elimination of grade crossings desirable. With the new roadway, if a relocation is made, even though the construction will be more costly, there will generally be a saving over separation of the grade crossings.

Diverting traffic from one road to another so as to eliminate an existing grade crossing, is of course applicable only to a limited extent. It will depend on the distance between the roads, the normal direction of travel, the density of traffic and other such elements. The service of the highway system should not be curtailed to any great extent, but there will be many cases where this solution might be well considered in order to reduce the number of crossings requiring separation.

The following is the Kansas Highway Commission practice:

On Subways. Minimum roadway, 18 feet; minimum headroom, 14 feet. If practicable, a view of the center line of the highway is required for 300 feet from a point 150 feet either side of the subway.

On Viaducts. Minimum roadway on bridge, 18 feet; on approaches, 24 feet; maximum grade, 5%; clear headroom, 22 feet above top of rail.

On Relocation. The railroad pays 50 to 75% of the cost of the new right of way required.

Figure 5, shows a type of subway used on the Illinois highways which has a very good appearance. Plate 1, page 37, shows the details of a timber viaduct that the writer drew for a highway crossing in Louisiana. On this crossing the road was diverted a sufficient amount to cross the railroad where the track was in a cut; the State constructed the road to the edge of the cut, at the proper grade, and the railroad paid for the viaduct.

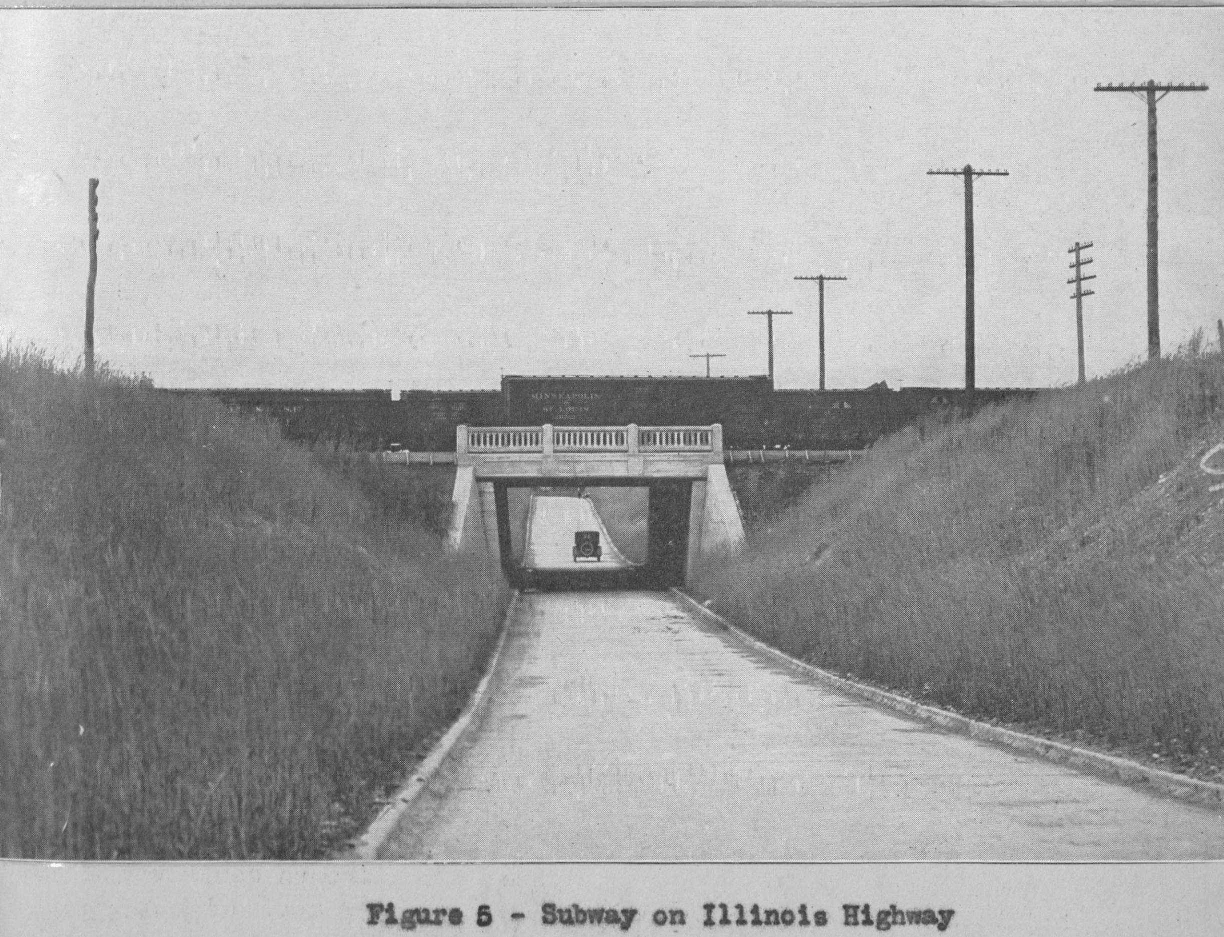
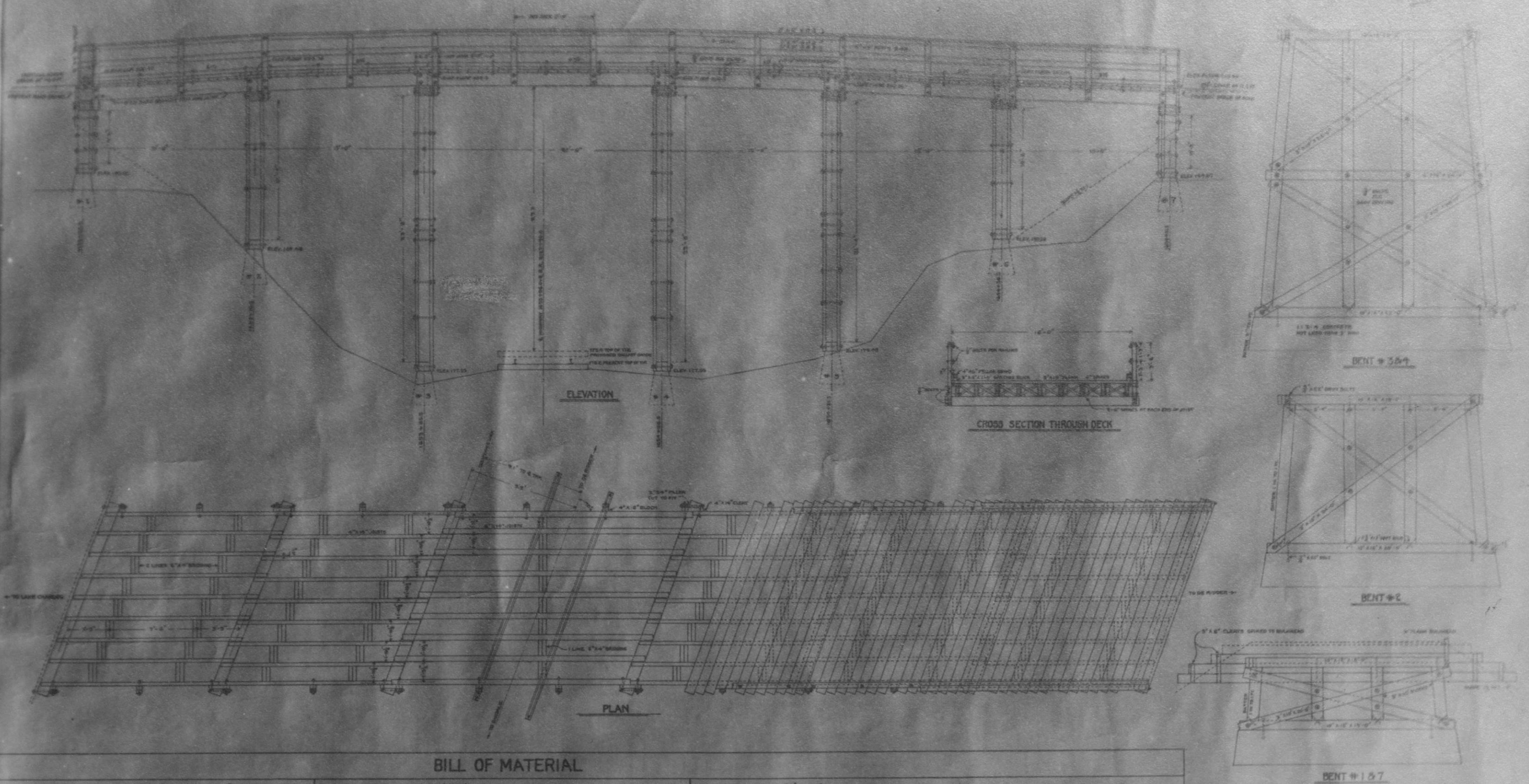


Figure 5 - Subway on Illinois Highway



BILL OF MATERIAL

4	POSTS	12" X 12" X 16'	BENTS # 6&7		CREO.
4	"	12" X 12" X 18'	" " 1&2		"
8	"	12" X 12" X 24'	" " 3&4		"
4	"	12" X 12" X 22'	" " 5		"
7	CAPS	10" X 12" X 18'			"
2	SILLS	10" X 12" X 19'			"
2	"	10" X 12" X 20'			"
3	"	10" X 12" X 22'			"
10	PCS.	3" X 10" X 20'	SWAY BRACING		"
6	"	3" X 10" X 22'	" "		"
10	"	3" X 10" X 26'	" "		"
45	"	4" X 14" X 16'	JOISTS		"
9	"	6" X 14" X 22'	"		"
10	"	4" X 6" X 16'	GUARD RAILS		"
2	"	4" X 6" X 22'	" "		"
50	LIN. FT.	3" X 6"	SPACING BLOCKS	GUARD RAILS	"
18	" "	3" X 10"	" "	SWAY BRACING	"
110	PCS.	3" X 10" X 18'	FLOOR		"
360	LIN. FT.	2" X 4"	BRIDGING		"

8	PCS	2" X 4" X 16'	S4S		RAILING	UNTREATED
2	"	2" X 4" X 18'	"		"	"
2	"	2" X 4" X 22'	"		"	"
16	"	2" X 6" X 16'	"		"	"
4	"	2" X 6" X 18'	"		"	"
4	"	2" X 6" X 22'	"		"	"
14	"	4" X 6" X 5'-7"	"		RAILING POSTS	"
14	"	4" X 6" X 4'-9"	"		" "	"
4	"	2" X 6" X 3'-4"	"		RAILING END POSTS	"
22	LIN. FT.	4" X 6"	BLOCKS	FOR	RAILING POSTS	CREOSOTED
10	" "	2" X 4"	FILLERS	"	" "	UNTREATED
20	" "	4" X 14"	CLEATS	"	JOISTS	CREOSOTED
2	PCS	3" X 10" X 22'			BULKHEAD	"
2	"	3" X 10" X 24'			"	"
2	"	3" X 10" X 28'			"	"
2	"	3" X 10" X 30'			"	"
4	"	3" X 6" X 1'-6"			BULKHEAD CLEATS	"
4	"	3" X 6" X 2'-6"			" "	"

14	BOLTS	¾" X 20"
70	"	¾" X 18"
20	"	¾" X 21"
2	"	¾" X 24"
16	"	⅝" X 10"
54	"	⅝" X 12"
44	"	⅝" X 14"
12	"	⅝" X 16"
20	"	⅝" X 22"
4	"	⅝" X 23"
4	"	⅝" X 25"
76	"	½" X 6"
212	C.I. BRIDGE WASHERS FOR	¾" BOLTS
308	C.I. O.G. "	" ⅝" "
152	CUT STEEL "	" ½" "
412	LBS. 60d SPIKES	
12	" 20d NAILS	
25	" 16d "	
28	DRIFT BOLTS	¾" X 22"
56	" "	¾" X 12"

NO ALLOWANCE MADE FOR EXTRA BOLTS

PAINT :–

RAILING 2 COATS WHITE LEAD AND LINSEED OIL. TOPS OF POSTS AND CAPS, THE CONTACT SURFACES OF JOISTS, AND THE REAR SURFACE OF BULKHEAD, 1 COAT OF SOFT COAL TAR PITCH OR ASPHALTIC PAINT.

PLATE 1

PART III

LAYOUTS AND DETAILED ESTIMATE FOR A PROPOSED GRADE SEPARATION

The proposed grade separation which is used as an example in this part, consisted of 16 grade crossings that were to be eliminated and 8 crossings that were already separated. These were over a distance of 5 miles, so that it was hardly economically justifiable to solve the problem by complete track elevation or track depression. The town in question is located in the South-west and has a population of about 110,000. There are a number of industries in the city and the traffic is rather heavy during some periods of the day. The railroad does not pass through the best residential section, but passes through the middle class and poorer sections and through a portion of the industrial section.

General Method of Solution

This problem was solved in the following manner. It was decided that it would not be advantageous to elevate or depress the tracks completely, but that a slight revision of some of the grades could be made which would give the railroad lighter grades and at the same time aid in the elimination of the grade crossings. This then made a partial change of the grades of both the streets and the railroad over a portion of the line and a complete change of the grade of the streets over the remainder. The layouts were then made, using subways where the railroad was raised, viaducts where the railroad was lowered, and where there was no change in the grade of the railroad the street was either raised or lowered as best suited that particular crossing. It was necessary to make a complete field survey so as to get the location of all streets and buildings and the profiles of the streets. The problem was somewhat further complicated where other railroads were concerned in the same crossing, which was true for Plate 5, and in some cases this was solved by arranging the grade of the crossing so as not to disturb the grade of the other railroad and in some cases by considering that the grade of the other railroad would be changed the same amount as the grade of the railroad directly interested.

Clearances and Width of Roadway Used.

The clearances and width of roadway adopted were as follows;
Bridges over railroad.

Overhead clearance - 23.5 feet measured from base of rail.
Side clearance - 8.5 feet measured from center of track.
Roadway - 24 feet usually, 30 feet if street car used viaduct.

Bridges over street.

Overhead clearance - 14 feet was used for all crossings with the exception of two for which a clearance of 13 feet was used.

Roadway - Where possible the clear roadway under the railroad was kept at the same width as the width of the street, curb to curb, prior to the separation.

The overhead clearance used for a bridge over the railroad is about a foot greater than the writer considers desirable, as he considers 22 feet from the top of rail (making $22\frac{1}{2}$ feet from the base of rail) a proper one to use. The clearance of 23 feet from top of rail had recently been adopted by the railroad in question, however, for structures of this type, so consequently it was used. The other clearances meet with the writer's approval. A maximum grade of 6% was adopted for the approaches, on both viaducts and subways, as this grade is not more than the maximum found on the streets elsewhere.

For bridges over the street, as stated before, 14 feet was adopted as the headroom on nearly all crossings so as to properly provide for any extension of the street car lines. 13 feet was adopted on the two crossings where it was certain there would be no street cars. A 10 foot clearance was used for sidewalks, making them 3 to 4 feet above the street grade. 15 feet was adopted as the headroom for interurban crossings, but as all interurban lines were at the time using an existing undercrossing, and there was no intention of changing the routing, this did not have to be considered at any particular crossing. The writer believes that it is generally advisable to keep the width of the roadway through the subway the same as on the street proper.

Explanation of Drawings

The writer has included in the following plates: layouts for five different crossings together with detailed estimates for same; a general layout of the entire project, with a complete estimate of the cost of the whole job; also, the necessary plans to show the type of structures used. A brief explanation will be given of the subject matter in each plate.

Plate 2

This is a layout of a typical viaduct. The approaches consist of an embankment held in place by retaining walls. The approach is about 100 feet on one end and about 200 feet on the other. The railroad will be lowered about 6 feet at this crossing. It will be noted that the cross street will be depressed so as to carry it under the viaduct. The roadway is 24 feet with a 7 foot walk on either side. For this crossing (and also for the one shown on Plate 3) the present main track and a future second main track are to be taken care of under one span that has skew piers. There is sufficient room for another track under the span on either side of the proposed double track if it ever becomes desirable.

Plate 3

This is a viaduct that will have a street car line. The roadway has been made 30 feet. The railroad will be lowered about 3 feet. It will be noted that the profile of the present street grade shows as steep a grade approaching the present crossing as will be used on the viaduct.

Plate 4

Plate 4 shows a subway using a bridge of type "B". The railroad will be raised about 3½ feet. On account of the existing street profile the grading here will be almost a minimum for this type of construction. The headroom is 13 feet as there is no likelihood of the street car line ever being extended on this street.

Plate 5

This subway uses a bridge of type "C". The problem is complicated by the fact that two other railroads have to be crossed. The road on the left is the one undertaking the work. The street grade is carried down further so as not to disturb the line in the center while the one on the extreme right is to be raised a sufficient amount to give proper clearance.

Plate 6

A bridge of type "D" is used for this subway. On account of the intersecting street which comes into the main street almost on the railroad, the solution was somewhat more complicated and the grading required is necessarily much more than on an ordinary subway. There is to be only one main track at present but the piers and abutments are to be made wide enough to provide for the future second main track indicated on the drawing.

Plate 7

This plate gives a profile of the line through the town and, at the bottom, a small scale map of the city streets crossed. On this the railroad is laid out as a straight line and where the streets are shown curved there is a curve in the railroad. It has been necessary to reduce this to a very small scale but it will give a good idea of the general layout. The proposed changes in the grade line, at mile post 343 and from 346 to 347, are indicated by showing the new grade in red. The crossings that are to be separated are shown in red while the present separated crossings are shown in green.

At present there are 6 under-crossings and 2 over-crossings. There are proposed 10 new under-crossings and 6 new over-crossings. The present separated crossings are, with but one exception, on unimportant streets. It can readily be seen from the profile that they have been constructed in every case, with the possible exception of one, because at the time of construction of the railroad a separated crossing was better suited to the topography at that point than a grade crossing. The proposed crossings are, with but one or two exceptions, on very important streets. It is very probable that one or two of the viaducts near mile post 347 will be omitted in the final construction and the traffic diverted to the other streets, but the subways between 343 and 344 are all on through streets in the residential district that cannot very well be vacated. On the present plan no streets have been vacated but a crossing has been provided for all existing street crossings and any possible vacation left for future action. One new crossing has been opened, the subway nearest to mile post 343, marked #2.

Plate 8

Plate 8 shows the cross section of the type of abutment, pier and retaining wall used for this estimate. The retaining wall was used for holding the natural earth where an excavation was made for the subways and also for holding the embankment on the viaduct approaches. The vertical side is placed next to the earth.

These structures are to be made of concrete lightly reinforced. The reinforcement will average about 15 pounds per cubic yard and this figure was used for the estimates, except in one or two unusual cases where more was allowed.

Plates 9 and 10

These show the detailed plans for the types of I-beam spans that are to be used in the construction. Plate 9 is for a 20 foot span and Plate 10 a 30 foot span. The loading used was E-65 although it will be noted that the span shown on Plate 10 is also strong enough for an E-70 loading, if necessary. This type of bridge is a very good one to use as it will provide a minimum depth of floor, although on the longer spans, as for instance the 30 foot, it will be noted that the weight of steel required will run somewhat higher per foot than for other types of structures. If desired, these bridges could be masked with concrete at a small additional cost.

The specifications used were the 1920 A.R.E.A. modified, with a maximum allowable extreme fiber stress of 15,000 pounds per square inch.

Plates 11 12 and 13

On these are given the detailed plans for the type of viaduct to be used in the construction. These plans are for a viaduct that was built at another crossing. The viaducts on the job under discussion are to be exactly as these plans with the following modifications. The sidewalk is to be on both sides of the roadway and on the shorter spans the inside girders are to be made the same depth as the outside ones. The prices used for the estimate for the viaducts were obtained from the cost of the one constructed, being on the basis of the cost per foot of deck and the cost per pier. Where piers were required on a large skew at the railroad crossings the price was increased proportionately as also was the price per foot of deck where a 30 foot roadway was used on bridges having street cars.

Basis of Estimates

The estimates accompanying the plates are based on the supposition that the railroad will pay for all construction work on its right of way and that the city will pay for all work on the city streets and private property and for all abuttal damages. Other railroads interested in any crossing will pay for the work on their own right of way. The estimates are therefore divided between the cost of the work on the railroad right of way and the cost of the other work. Only the cost of construction is included in the estimates; the property damage is not included as that was left for the city to handle.

In the distribution of the cost of separation given in the complete estimate on page 60, it will be noted that the amount to be paid by the city is a little less than 50% and that the amount to be paid by the various railroads is a little more than 50%. When the cost of the damages to the abutting property is added to the city portion the ratios will then be very much nearer the same. This will generally be the case on this basis of distribution when there are several various types of crossings, although, as will be seen in the estimate on page 60, for any single crossing the distribution of cost may be very much overbalanced one way or the other.

All of the layouts and estimates on this proposed separation were made by the writer and another engineer employed by the same railroad, working jointly. The prices used were those for the summer of 1920 and include all labor and freight charges.

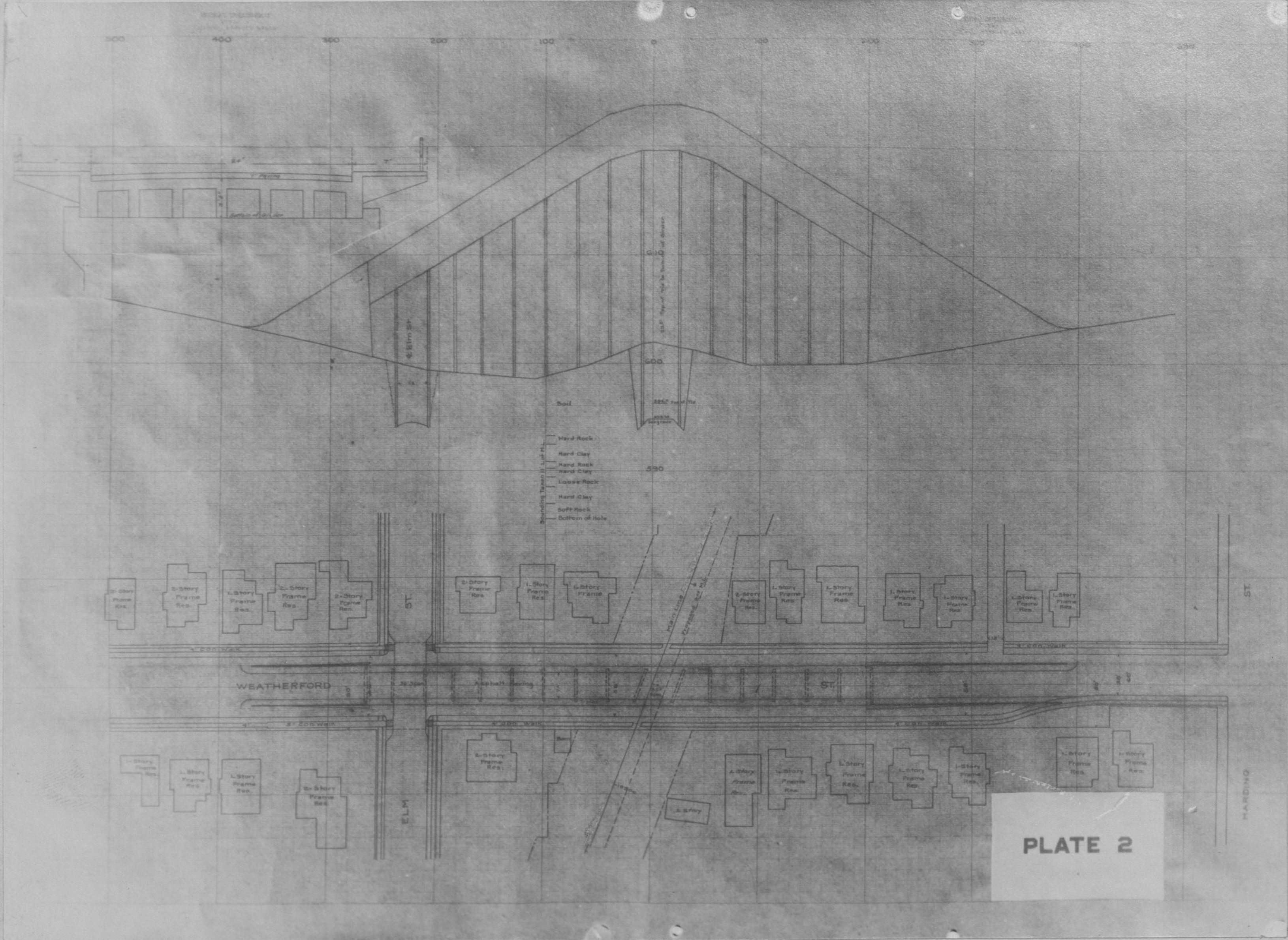

500
400
300
200
100
0
100
200
300
400
500
610
600
590
Soil
Hard Rock
Hard Clay
Hard Rock
Hard Clay
Loose Rock
Hard Clay
Soft Rock
Bottom of Hole
WEATHERFORD
Asphalt Paving
ST.
ELM
ST.
HARDING
ST.

PLATE 2

ESTIMATE OF COST OF VIADUCT SHOWN ON PLATE 2

PORTION ON RAILROAD RIGHT OF WAY

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
Engineering				$ 700.00
Foundation Excavation	Cu Yds	2.00	175	350.00
Deck	Lin Ft	90.00	105	9,450.00
Water Proofing	Sq Ft	.20	2,520	504.00
Piers: Square	Each	1,000.00	1½	1,500.00
Skew	"	1,100.00	2	2,200.00
Hand Railing	Lin Ft	1.25	210	262.50
Paving Viaduct	Sq Yds	2.00	280	560.00
Move Tel. Conduit	Lin Ft	1.00	105	105.00
Contingencies 5%				781.58
TOTAL				$ 16,413.08

ESTIMATE OF COST OF VIADUCT SHOWN ON PLATE 2

PORTION ON CITY STREETS AND PROPERTY

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
Engineering				$ 3,900.00
Embankment - Train haul.	Cu Yds	1.25	900	1,125.00
"	" "	.50	1,860	930.00
Foundation Excavation	" "	2.00	1,055	2,110.00
Concrete in Retain. Wall	" "	16.00	830	13,280.00
Reinforcing Steel	Lbs.	.06	12,450	747.00
Deck	Lin Ft	90.00	365	32,850.00
Water Proofing	Sq Ft	.20	8,760	1,752.00
Piers: Square	Each	1,000.00	11½	11,500.00
Hand Railing	Lin Ft	1.25	1,700	2,125.00
Paving Viaduct	Sq Yds	2.00	975	1,950.00
Paving on Fill	" "	4.00	1,700	6,800.00
Sidewalk	Sq Ft	.25	5,580	1,395.00
Concrete Curb	Lin Ft	.80	640	512.00
Street Excavation	Cu Yds	.50	1,250	625.00
Move: Tel Conduit	Lin Ft	1.00	325	325.00
4" Gas Main	" "	1.00	100	100.00
6" Water Main	" "	1.50	325	487.50
Sewer Main	" "	1.50	30	45.00
Contingencies 5%				4,127.92
TOTAL				$ 86,686.42

TOTAL COST OF CROSSING

Total of Estimates on Pages 44 & 45 — $ 103,099.50

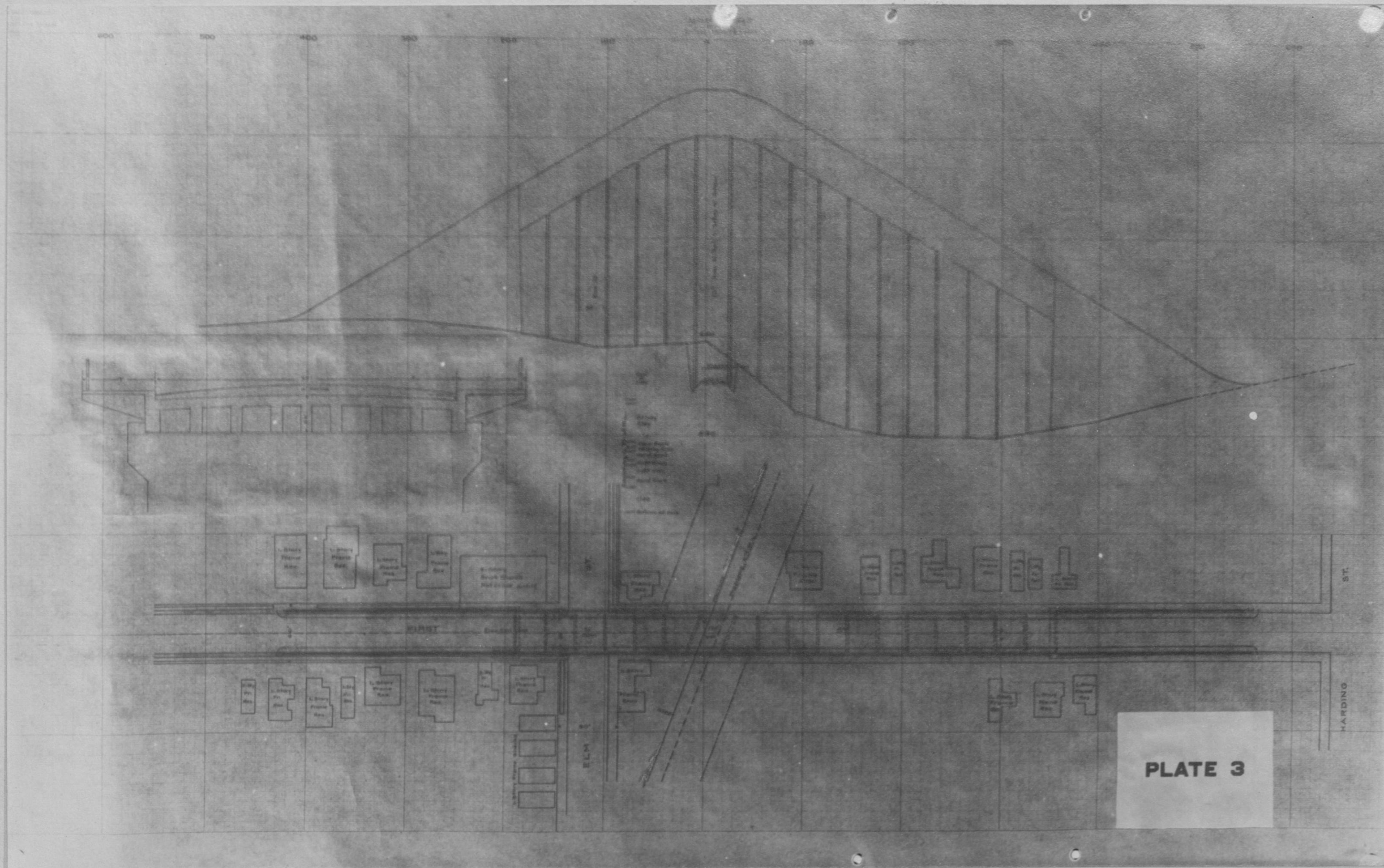


PLATE 3

ESTIMATE OF COST OF VIADUCT SHOWN ON PLATE 3

PORTION ON RAILROAD RIGHT OF WAY

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
Engineering				$ 1,000.00
Foundation Excavation	Cu Yds	2.00	200	400.00
Deck	Lin Ft	105.00	120	12,600.00
Water Proofing	Sq Ft	.20	3,600	720.00
Piers: Square	Each	1,250.00	2	2,500.00
Skew	"	1,300.00	2	2,600.00
Hand Railing	Lin Ft	1.25	240	300.00
Paving on Viaduct	Sq Yds	2.00	400	800.00
Move 10" Water Main	Lin Ft	1.50	120	180.00
Contingencies 5%				1,055.00
TOTAL				$ 22,155.00

ESTIMATE OF COST OF VIADUCT SHOWN ON PLATE 3

PORTION ON CITY STREETS AND PROPERTY

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
Engineering				$ 5,400.00
Embankment	Cu Yds	1.25	6,000	7,500.00
Foundation Excavation	" "	2.00	1,300	2,600.00
Concrete in Retain. Wall	" "	16.00	1,200	19,200.00
Reinforcing Steel	Lbs	.06	18,000	1,080.00
Deck	Lin Ft	105.00	425	44,625.00
Water Proofing	Sq Ft	.20	12,750	2,550.00
Piers: Square	Each	1,250.00	13	16,250.00
Hand Railing	Lin Ft	1.25	1,740	2,175.00
Paving on Viaduct	Sq Yds	2.00	1,420	2,840.00
Paving on Fill	" "	4.00	1,500	6,000.00
Sidewalk	Sq Ft	.25	5,400	1,350.00
Concrete Curb	Lin Ft	.80	930	744.00
Move 10" Water Main	" "	1.50	880	1,320.00
Contingencies 5%				5,681.70
TOTAL				$ 119,315.70

TOTAL COST OF CROSSING

Total of Estimates on Pages 47 & 48 $ 141,470.70

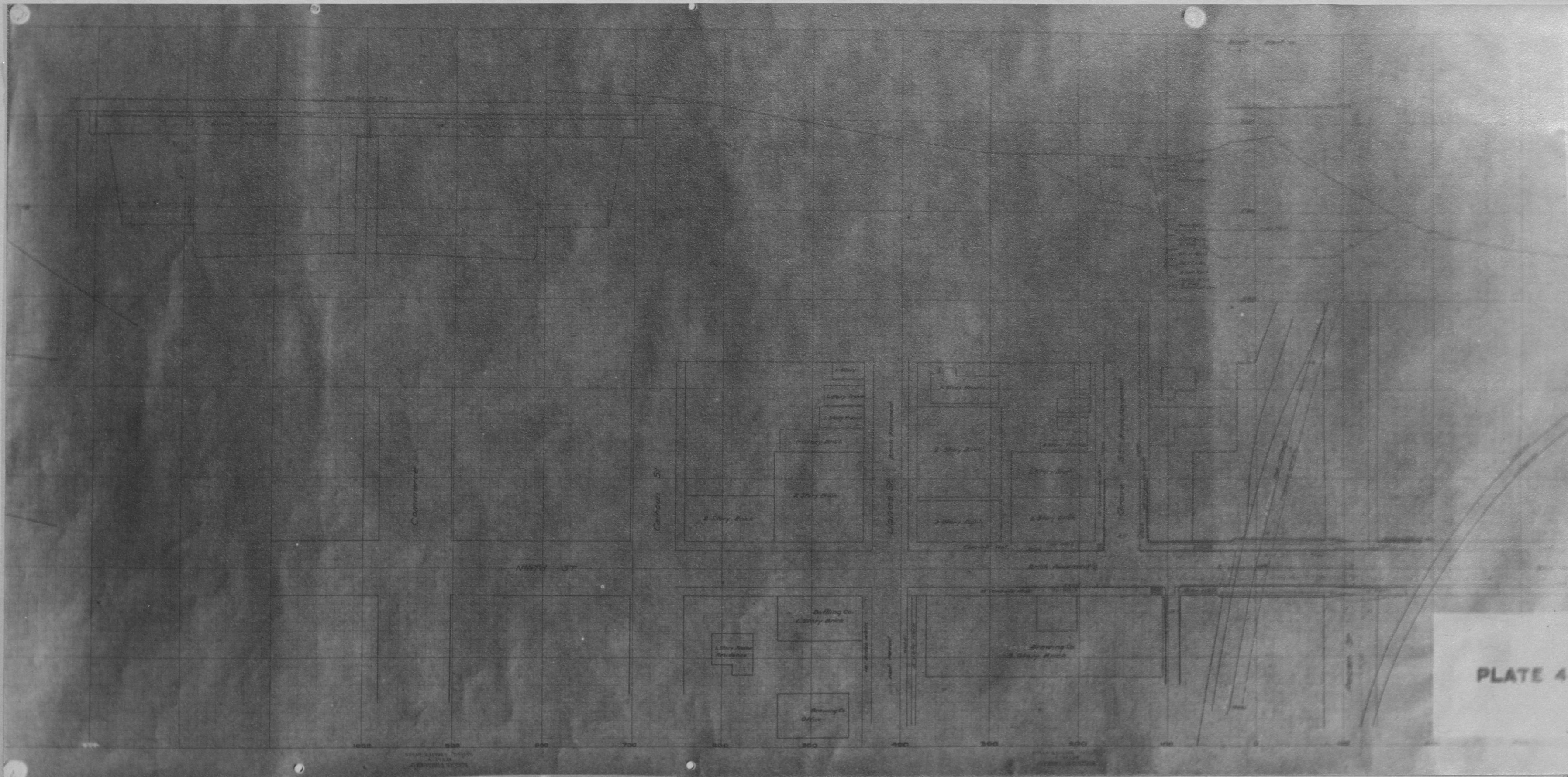

Commerce
Calhoun St
2 Story Brick
Ninth St
Brick Pavement
Brewing Co.

PLATE 4

ESTIMATE OF COST OF SUBWAY SHOWN ON PLATE 4

PORTION ON RAILROAD RIGHT OF WAY

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
Engineering				2,300.00
Subway Exc: Earth	Cu Yds	1.00	3,840	3,840.00
Loose Rock	" "	1.50	1,280	1,920.00
Solid Rock	" "	2.00	1,280	2,560.00
Foundation Exc: Earth	" "	1.50	70	105.00
Loose Rock	" "	2.25	120	270.00
Solid Rock	" "	3.00	130	390.00
Concrete	" "	16.00	1,130	18,080.00
Reinforcing Steel	Lbs	.06	16,950	1,017.00
Steel I-Beams & Girders	"	.07	155,000	10,850.00
Creo. Timber Flooring	M BM	80.00	13,000	1,040.00
Water Proofing	Sq Ft	.20	1,740	348.00
Ballast	Cu Yds	2.00	56	112.00
Hand Railing	Lin Ft	1.25	270	337.50
Concrete Sidewalk	Sq Ft	.25	2,200	550.00
Street Paving - Brick or Asphalt on Concrete Base	Sq Yds	4.00	600	2,400.00
Lower: 6" Gas Main	Lin Ft	1.00	135	135.00
6" Water Main	" "	1.50	150	225.00
Change Storm Sewer				5,000.00
Contingencies 5%				2,573.98
TOTAL - NEW WORK				$ 54,053.48
OPERATING EXPENSES				
Temporary Trestle	Lin Ft	13.00	168	2,184.00
TOTAL				$ 56,237.48

ESTIMATE OF COST OF SUBWAY SHOWN ON PLATE 4

PORTION ON CITY STREETS AND PROPERTY

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
Engineering				$ 1,300.00
Subway Exc: Earth	Cu Yds	1.00	3,390	3,390.00
Loose Rock	" "	1.50	270	405.00
Solid Rock	" "	2.00	470	940.00
Foundation Exc: Earth	" "	1.50	180	270.00
Loose Rock	" "	2.25	40	90.00
Solid Rock	" "	3.00	40	120.00
Concrete	" "	16.00	400	6,400.00
Reinforcing Steel	Lbs	.06	6,000	360.00
Hand Railing	Lin Ft	1.25	500	625.00
Concrete Sidewalk	Sq Ft	.25	4,700	1,175.00
Street Paving - Brick or Asphalt on Concrete Base	Sq Yds	4.00	1,700	6,800.00
Concrete Curb	Lin Ft	.80	310	248.00
Lower: 6" Gas Main	" "	1.00	210	210.00
6" Water Main	" "	1.50	350	525.00
Change Storm Sewer				5,000.00
Contingencies 5%				1,392.90
TOTAL				$ 29,250.90

TOTAL COST OF CROSSING

Total of Estimates on Pages 50 & 51	$ 85,488.38

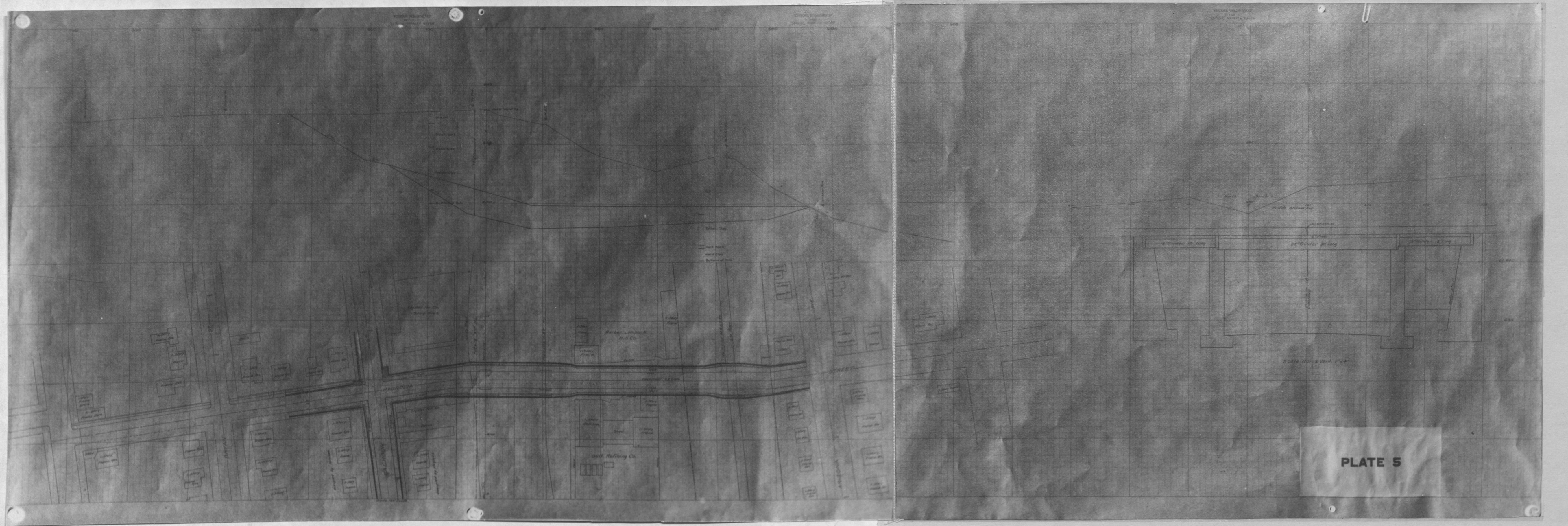


PLATE 5

ESTIMATE OF COST OF SUBWAY SHOWN ON PLATE 5

PORTION ON RAILROAD RIGHT OF WAY

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
Engineering				1,250.00
Subway Exc: Earth	Cu Yds	1.00	5,000	5,000.00
Foundation Exc: Earth	" "	1.50	280	420.00
Concrete	" "	16.00	850	13,600.00
Reinforcing Steel	Lbs	.06	12,750	765.00
Steel I-Beams	"	.07	49,000	3,430.00
Creo. Timber Flooring	M BM	80.00	6,000	480.00
Water Proofing	Sq Ft	.20	700	140.00
Ballast	Cu Yds	2.00	25	50.00
Hand Railing	Lin Ft	1.25	160	200.00
Concrete Sidewalk	Sq Ft	.25	2,000	500.00
Street Paving - Brick or Asphalt on Concrete Base	Sq Yds	4.00	320	1,280.00
Move 6" Gas Main	Lin Ft	1.00	100	100.00
Contingencies 5%				1,360.75
TOTAL - NEW CONSTRUCTION				$ 28,575.75
OPERATING EXPENSES				
Falsework	Lin Ft	13.00	80	1,040.00
Taking Up and Relaying Track	" "	.50	70	35.00
TOTAL				$ 29,650.75

ESTIMATE OF COST OF SUBWAY SHOWN ON PLATE 5

PORTION ON OTHER RAILROAD PROPERTY

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
Engineering				$ 4,000.00
Subway Exc: Earth	Cu Yds	1.00	14,850	14,850.00
Foundation Exc: Earth	" "	1.50	790	1,185.00
Concrete	" "	16.00	2,530	40,480.00
Reinforcing Steel	Lbs	.06	38,000	2,280.00
Steel I-Beams	"	.07	143,000	10,010.00
Creo. Timber Flooring	M BM	80.00	17,000	1,360.00
Water Proofing	Sq Ft	.20	2,200	440.00
Ballast	Cu Yds	2.00	75	150.00
Hand Railing	Lin Ft	1.25	780	975.00
Concrete Sidewalk	Sq Ft	.25	7,700	1,925.00
Street Paving - Brick or Asphalt on Concrete Base	Sq Yds	4.00	1,390	5,560.00
Drainage	Lin Ft	6.50	415	2,697.50
Move 6" Gas Main	" "	1.00	415	415.00
Contingencies 5%				4,316.37
TOTAL - NEW CONSTRUCTION				$ 90,643.87
OPERATING EXPENSES				
Falsework	Lin Ft	13.00	160	2,080.00
Taking Up and Relaying Track	" ".	.50	70	35.00
TOTAL				$ 92,758.87

ESTIMATE OF COST OF SUBWAY SHOWN ON PLATE 5

PORTION ON CITY STREETS AND PROPERTY

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
Engineering				$ 2,500.00
Subway Exc: Earth	Cu Yds	1.00	10,000	10,000.00
Foundation Exc: Earth	" "	1.50	850	1,275.00
Concrete	" "	16.00	1,200	19,200.00
Reinforcing Steel	Lbs	.06	18,000	1,080.00
Hand Railing	Lin Ft	1.25	120	150.00
Concrete Sidewalk	Sq Ft	.25	8,200	2,050.00
Street Paving - Brick or Asphalt on Concrete Base	Sq Yds	4.00	2,460	9,840.00
Concrete Curb	Lin Ft	.80	1,020	816.00
Drainage	" "	6.50	935	6,077.50
Move: 6" Gas Main	" "	1.00	360	360.00
6" Sewer	" "	1.50	350	525.00
8" Water Main	" "	1.50	400	600.00
Contingencies 5%				2,723.68
TOTAL				$ 57,197.18

TOTAL COST OF CROSSING

Total of Estimates on Pages 53, 54 & 55 $ 179,606.80

PLATE 6

ESTIMATE OF COST OF SUBWAY SHOWN ON PLATE 6

PORTION ON RAILROAD RIGHT OF WAY

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
Engineering				$ 3,500.00
Subway Exc: Earth	Cu Yds	1.00	5,000	5,000.00
Loose Rock	" "	1.50	3,000	4,500.00
Solid Rock	" "	2.00	500	1,000.00
Foundation Exc: Earth	" "	1.50	170	255.00
Loose Rock	" "	2.25	170	382.50
Concrete	" "	16.00	1,250	20,000.00
Reinforcing Steel	Lbs	.06	18,750	1,125.00
Steel I-Beams	"	.07	89,000	6,230.00
Creo. Timber Flooring	M BM	80.00	10,000	800.00
Water Proofing	Sq Ft	.20	1,400	280.00
Ballast	Cu Yds	2.00	45	90.00
Hand Railing	Lin Ft	1.25	240	300.00
Concrete Sidewalk	Sq Ft	.25	3,100	775.00
Street Paving - Brick or Asphalt on Concrete Base	Sq Yds	4.00	650	2,600.00
Drainage				28,850.00
Move Tel. Conduit	Lin Ft	1.50	180	270.00
Contingencies 5%				3,797.87
TOTAL - NEW CONSTRUCTION				$ 79,755.37
OPERATING EXPENSES				
Falsework	Lin Ft	13.00	126	1,538.00
TOTAL				$ 81,293.37

ESTIMATE OF COST OF SUBWAY SHOWN ON PLATE 6

PORTION ON CITY STREETS AND PROPERTY

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
Engineering				$ 3,600.00
Subway Exc: Earth	Cu Yds	1.00	17,000	17,000.00
Loose Rock	" "	1.50	4,000	6,000.00
Solid Rock	" "	2.00	1,000	2,000.00
Foundation Exc: Earth	" "	1.50	400	600.00
Loose Rock	" "	2.25	350	787.50
Concrete	" "	16.00	1,500	24,000.00
Reinforcing Steel	Lbs	.06	22,500	1,350.00
Hand Railing	Lin Ft	1.25	80	100.00
Concrete Sidewalk	Sq Ft	.25	13,000	3,250.00
Street Paving - Brick or Asphalt on Concrete Base	Sq Yds	4.00	3,900	15,600.00
Concrete Curb	Lin Ft	.80	2,500	2,000.00
Move Tel. Conduit	" "	1.50	500	750.00
Contingencies 5%				3,851.88
TOTAL				$ 80,889.38

TOTAL COST OF CROSSING

Total of Estimates on Pages 57 & 58 $ 162,182.75

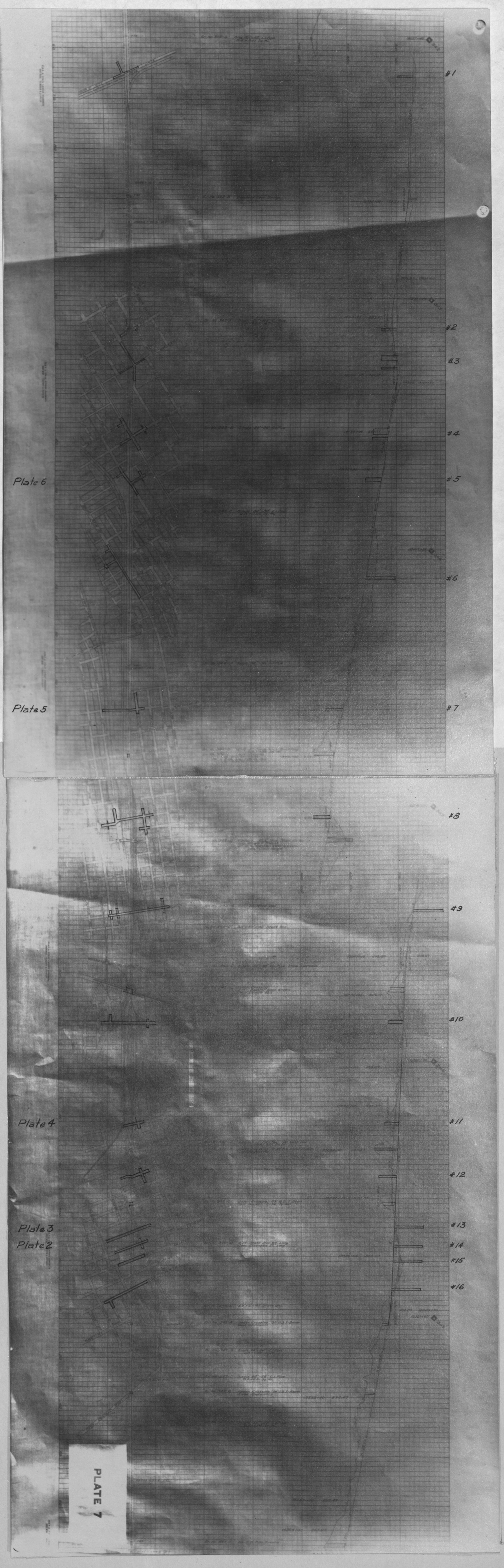

#1
#2
#3
#4
#5
#6
#7
#8
#9
#10
#11
#12
#13
#14
#15
#16
Plate 6
Plate 5
Plate 4
Plate 3
Plate 2

PLATE 7

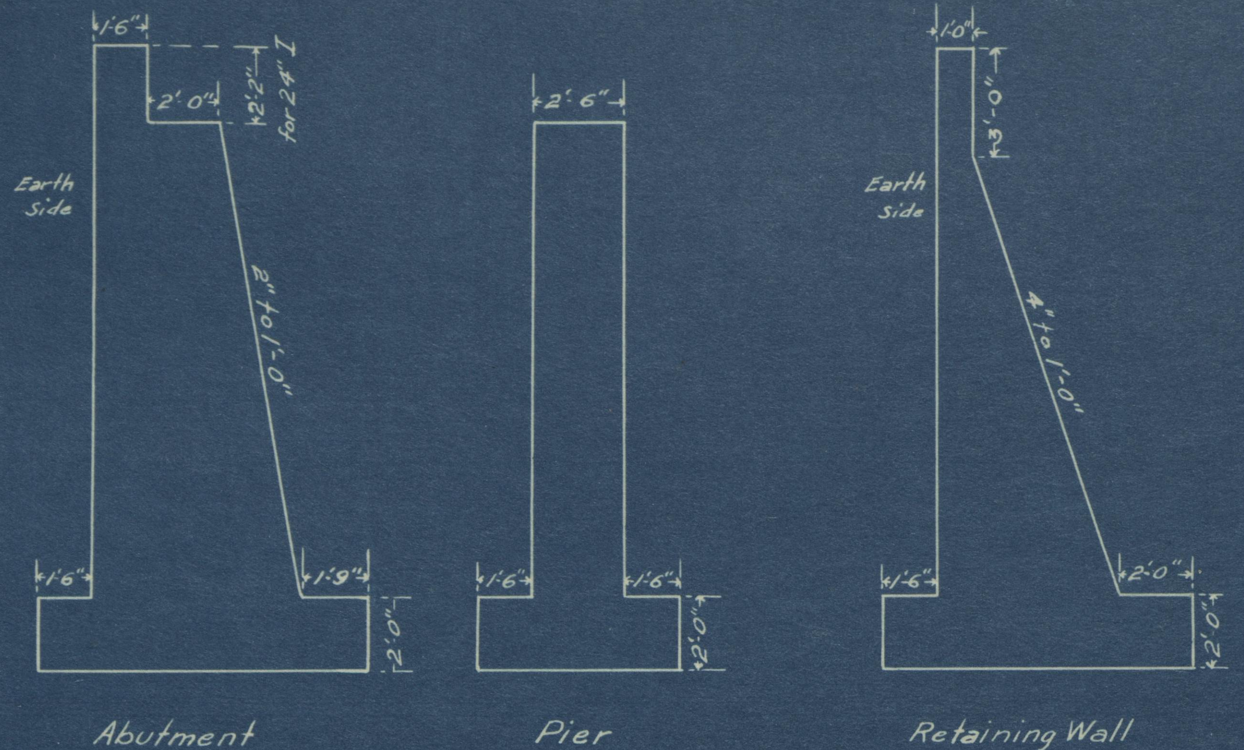
ESTIMATE OF COMPLETE SEPARATION AND GRADE REDUCTION

CROSSING NUMBER		TYPE OF CROSSING	DISTRIBUTION OF COST OF SEPARATION: PORTION ON RR PROPERTY	PORTION ON OTHER RR's	PORTION ON CITY STREETS	TOTAL COST OF CROSSINGS
1		Subway-A	25,498.20	-	-	$ 25,498.20
2		Subway-C	53,598.10	-	19,951.50	73,549.60
3		Double				
		Subway-D	89,338.38	-	62,825.70)	
		Subway-B	38,350.81	-	24,443.73)	214,958.62
4		Double				
		Subway-C	61,637.63	-	59,739.75)	
		Subway-C	33,719.00	-	48,937.87)	204,034.25
5	*	Subway-D	81,293.37	-	80,889.38	162,182.75
6		Viaduct	33,626.25	24,549.00	138,287.10	196,462.35
7	*	Subway-C	29,650.75	92,758.87	57,197.18	179,606.80
8		Subway-C	51,010.13	142,085.33	131,670.53	324,765.99
9		Viaduct	10,563.00	69,107.85	119,490.00	199,160.85
10		Subway-D	201,184.06	152,780.89	47,071.50	401,036.45
11	*	Subway-B	56,237.48	-	29,250.90	85,488.38
12		Subway-B	46,204.35	-	56,686.88	102,891.23
13	*	Viaduct	22,155.00	-	119,315.70	141,470.70
14	*	Viaduct	16,413.08	-	86,686.42	103,099.50
15		Viaduct	16,500.75	-	60,502.05	77,002.80
16		Viaduct	23,908.50	-	97,849.50	121,758.00
		TOTALS	890,888.84	481,281.94	1,240,795.69	2,612,966.47

* Detailed estimates for these crossings are given in the text.

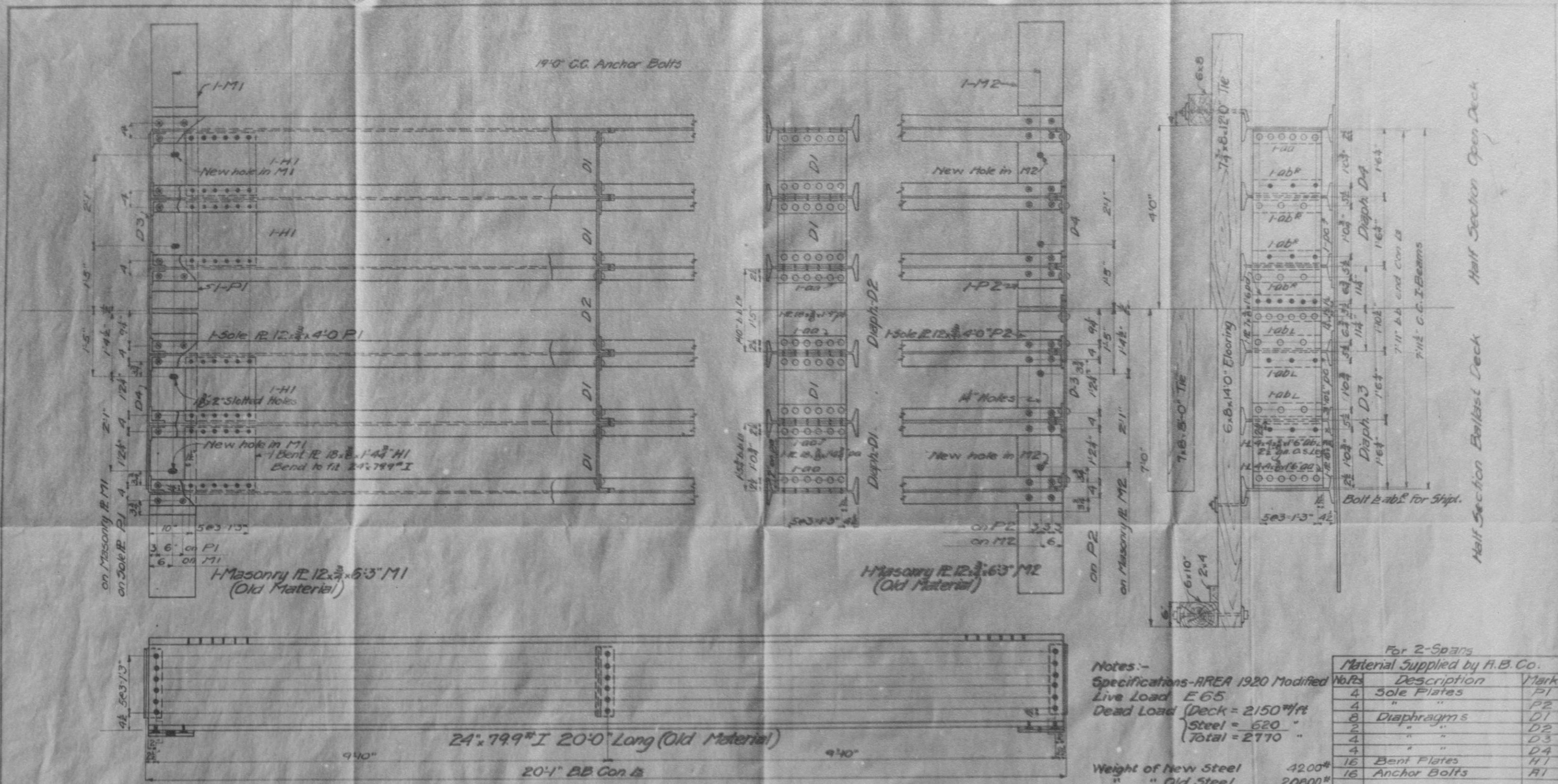
COST OF GRADE REVISION

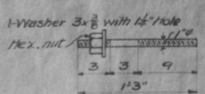
ITEM	UNIT	PRICE	QUANTITY	AMOUNT
		COST OF NEW CONSTRUCTION		
Engineering				$ 1,500.00
Embankment : Earth	Cu Yds	.50	46,300	23,150.00
Excavation : "	" "	.50	9,000	4,500.00
New Bridge Steel	Lbs	.07	3,000	210.00
Cast Iron Pipe : Culvert	Tons	60.00	3.4	204.00
Concrete : Plain	Cu Yds	16.00	75	1,200.00
Reinforced	" "	27.00	100	2,700.00
Contingencies 5%				1,673.20
TOTAL - NEW CONSTRUCTION				$ 35,137.20
		OPERATING EXPENSES		
Engineering				1,800.00
Embankment in Cuts	Cu Yds	.50	2,800	1,400.00
Excavation on Fills	" "	.50	1,200	600.00
Ballast	" "	2.00	10,000	20,000.00
Bridges Raised 1 Ft.	Lin Ft	.75	520	390.00
Track : Raised 1 Ft.	Trk Ft	.20	43,800	8,760.00
Lowered 1 Ft.	" "	.40	7,000	2,800.00
Surfaced	" "	.15	17,200	2,580.00
TOTAL - OPERATING EXPENSES				$ 38,330.00
Total Cost of Grade Revision				$ 73,467.20
Total Cost of Grade Separation				2,612,966.47
TOTAL COST OF ALL WORK				$ 2,686,433.67



Note:-
The reinforcing in the above structures is light and will average about 15 lbs. per cu.yd.

PLATE 8





Detail of Anchor Bolts A1

Base of Rail to Masonry

Tie & Tie Pl.	7 1/2
Ballast	6
Timber	6
I-Beam	2'-0
Sole Plate	3/4
Masonry Pl.	3/4
Total	3'-9"

Base of Rail to Clearance

Tie & Tie Pl.	7 1/2
Ballast	6
Timber	6
I-Beam	2'-0
Total	3'-7 1/2"

3-Old 20'-0" Spans, each composed of 4-24"x79.9# I-Beams now in Stock "C" at Winslow, are to be dismantled and the I-Beams and Masonry plates to be revamped as per these plans to make 2-20'-0" I-Beam Spans for E 65 Loading.
New material required for revamping ordered on Stock "C" Req. #198702.

Field Rivet List

No.	Diam	Grip	Location
72	7/8	3/4	D3 & D4 to D
96	7/8	1 1/8	" " " Is
48	"	7/8	" " " "
48	"	1 1/4	D1 & D2 to Is
24	"	7/8	" " " "
192	"	1 1/4	H1 to Is
96	7/8 ⊳	1 7/8	Sole Pls to Is

Summary For 2-Spans

No.	Diam	Length	Remarks
93	7/8 ⊳	2 1/4"	Excess = 15% + 10
93	"	2 3/8	" "
396	"	2 3/4	" "
120	7/8 ⊳	3 1/2	" "

Notes:-
Specifications - AREA 1920 Modified
Live Load E 65
Dead Load {Deck = 2150#/ft, Steel = 620 ", Total = 2770 "}

Weight of New Steel 4200#
" " Old Steel 20800#
Total Steel 25000#
No. Field holes to be drilled 416
No. Rivets to knock out 168
Rivets 7/8" Diam.
Open Holes 15/16 Diam.
Reaming: None
Paint: One coat Linseed Oil

For 2-Spans

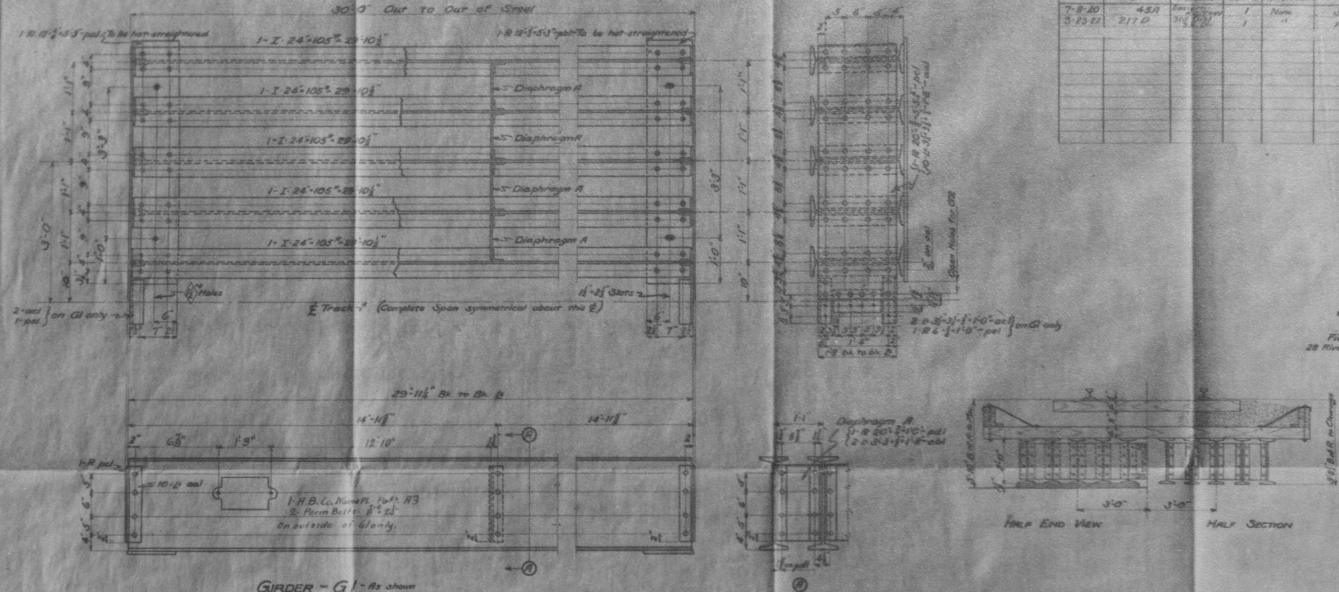
Material Supplied by A.B. Co.

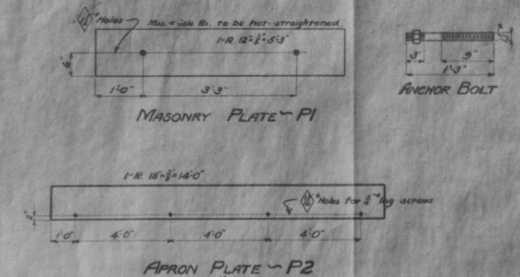
No. Pcs	Description	Mark
4	Sole Plates	P1
4	" "	P2
8	Diaphragms	D1
2	" "	D2
4	" "	D3
4	" "	D4
16	Bent Plates	H1
16	Anchor Bolts	A1

Moment	Shear	Section Per Rail
D = 62500	13500	
L = 303300	78600	
I = 300000	77900	3-24" I @ 79.9#
Total 666000	170000	S = 15300

Ballast Deck Plan
BES-4509

PLATE 9





List of Spans

Date	Bridge No.	Division & District	No. of Spans	No. of Apron Pls.	Requisition No.	Contract No.	Manufactured by
7-8-20	45A	[illegible]	1	None	306587	09473	Gary Plant
5-25-22	217 D	3rd Dist. [illegible]	1	"	159367	E680A	" "

Required for One Span		Mark
1	Girder	G1
1	Girder	G2
4	Masonry Plates	P1
8	Anchor Bolts - 1¼"φ×1'-3"	
*	Apron Plates	P2

* See "List of Spans" for no. req'd.

Field Rivets Required (= Actual No. + 15% + 10)
28 Rivets: Full Head; Dia. = ⅞"φ; Grip = ¾"; Length = 2¼"

Base of Rail to Masonry

Tie Pl. = 0'-0½"
Tie = 0'-6"
Ballast = 0'-8"
Floor = 0'-6"
I-Beams = 2'-0"
Sole Pl. = 0'-0½"
Mas. Pl. = 0'-0½"
Total = 3'-10"

General Notes:

Rivets: ⅞"φ
Open Holes: 15/16"φ unless noted.
Reaming: None.
Specifications: A.R.E.A.-1920
Shop Paint: 1 Coat Raw Linseed Oil.

Loading and Stresses

Dead Load { 1700# per ft. of span - Deck; 1142# " " " " - Actual wt. of steel }
Live Load - Cooper's E65
Impact - 97% - A.R.E.A. Specifications, 1920.

	Load # per ft. of rail	Max. Moment "# per rail	End Shear # per rail
Dead Load	1420	1797970	20 610
Live Load	Cooper's E65	7566000	100 600
Impact	97% of Live Load	7339000	97 580
Total		16 702970	218 790

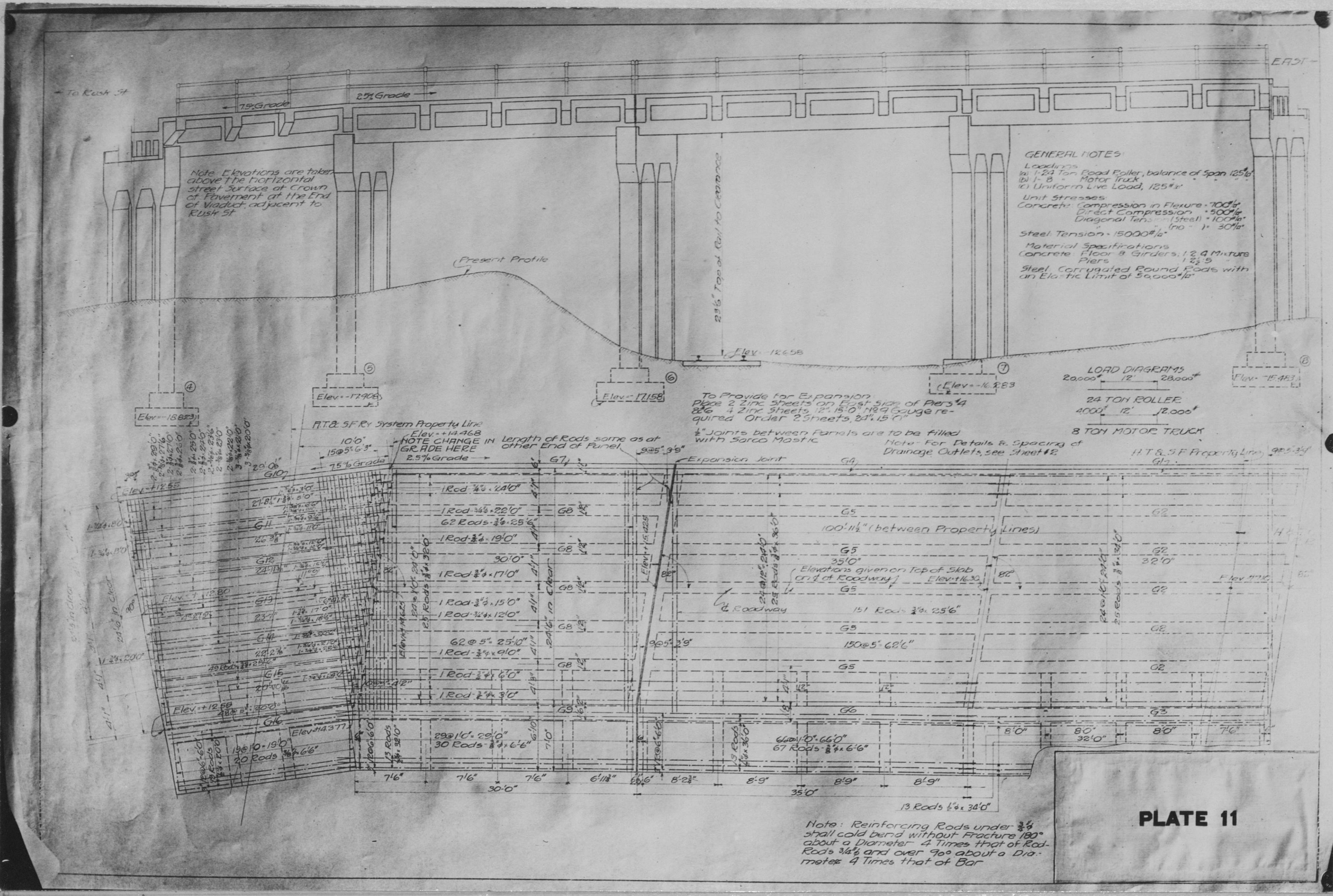
Extreme Fibre Stress = 16702970 ÷ (5×234.3) = 14,300 #/□"
Unit End Shear = 218790 ÷ (5×30.98) = 1410 #/□"
Bearing on Masonry = 218800 ÷ (12"×63") = 290 #/□"

For E-70 { L.L. Moment = 8,140,000"#, Imp. = 7,890000. Tot.(D.L.+L.L.+Imp.) = 17,822,000"#
Extreme Fibre Stress = 17,828,000 ÷ (5×234.3) = 15,200 #/□" }

Gary Plant Contract E680A

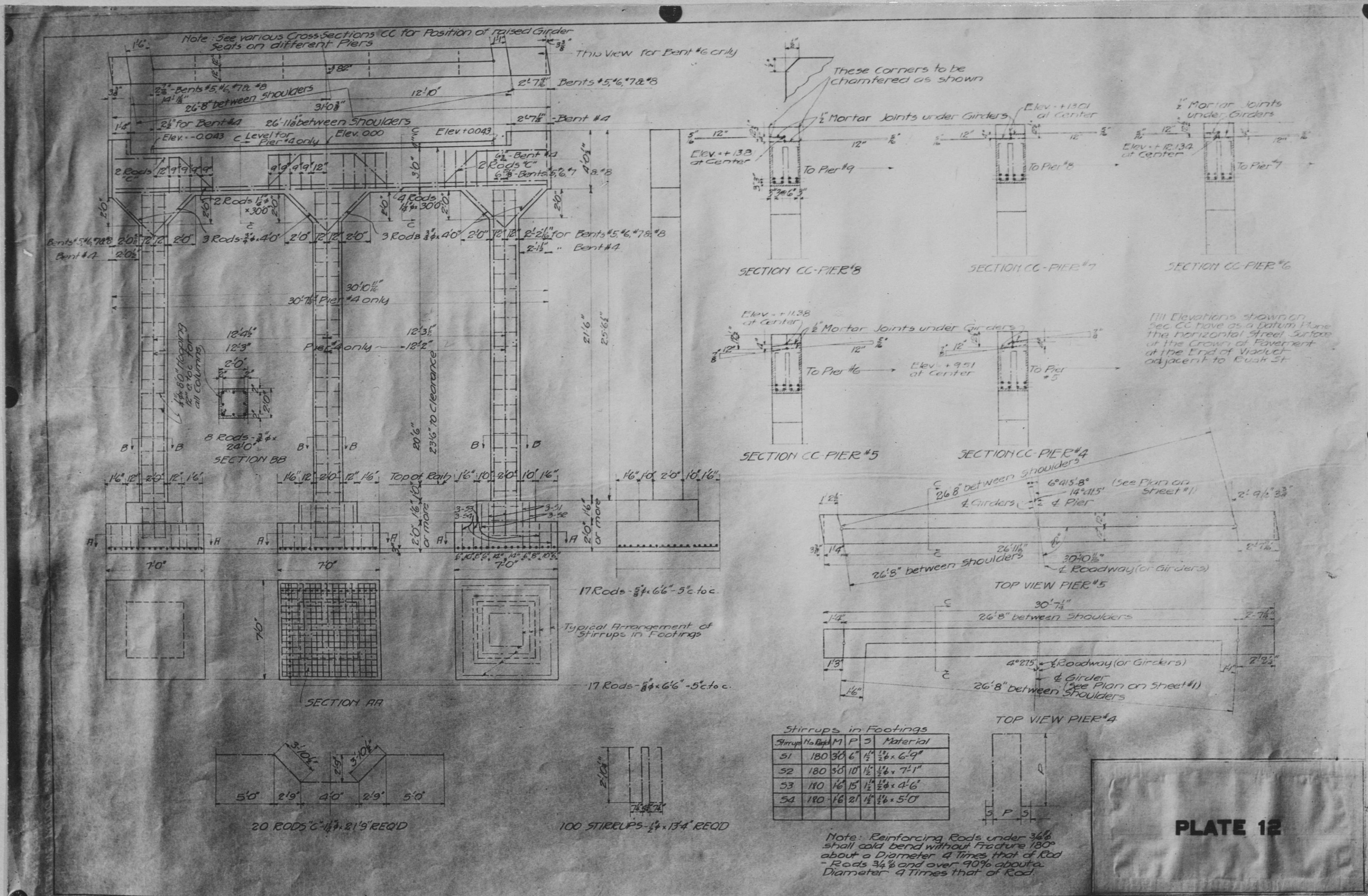
①

PLATE 10



To Rusk St
EAST
7.5% Grade
2.5% Grade
Note: Elevations are taken above the horizontal street surface at Crown of Pavement at the End of Viaduct adjacent to Rusk St
Present Profile
GENERAL NOTES:
Loadings
(a) 1-24 Ton Road Roller, balance of Span 125#/□'
(b) 1-8 " Motor Truck
(c) Uniform Live Load, 125#/□'
Unit Stresses
Concrete: Compression in Flexure = 700#/□"
Direct Compression = 500#/□"
Steel Tension = 15000#/□"
Material Specifications
Concrete: Floor & Girders: 1:2:4 Mixture
Piers 1:2½:5
Steel: Corrugated Round Rods with an Elastic Limit of 50,000#/□"
LOAD DIAGRAMS
24 TON ROLLER
8 TON MOTOR TRUCK
To Provide for Expansion Place 2 Zinc Sheets on East Side of Piers #4 & 6. 4 Zinc Sheets 12"x15'0" No. 9 Gauge required. Order 2 Sheets 24"x15'0"
½" Joints between Panels are to be filled with Sarco Mastic
Note: For Details & Spacing of Drainage Outlets, see Sheet #12
A.T.& S.F. Ry. System Property Line
NOTE CHANGE IN GRADE HERE
Length of Rods same as at other End of Panel
Expansion Joint
100'-11½" (between Property Lines)
Elevations given on Top of Slab on ℄ of Roadway
℄ Roadway
Note: Reinforcing Rods under ¾" shall cold bend without Fracture 180° about a Diameter 4 Times that of Rod. Rods ¾" and over 90° about a Diameter 4 Times that of Bar

PLATE 11

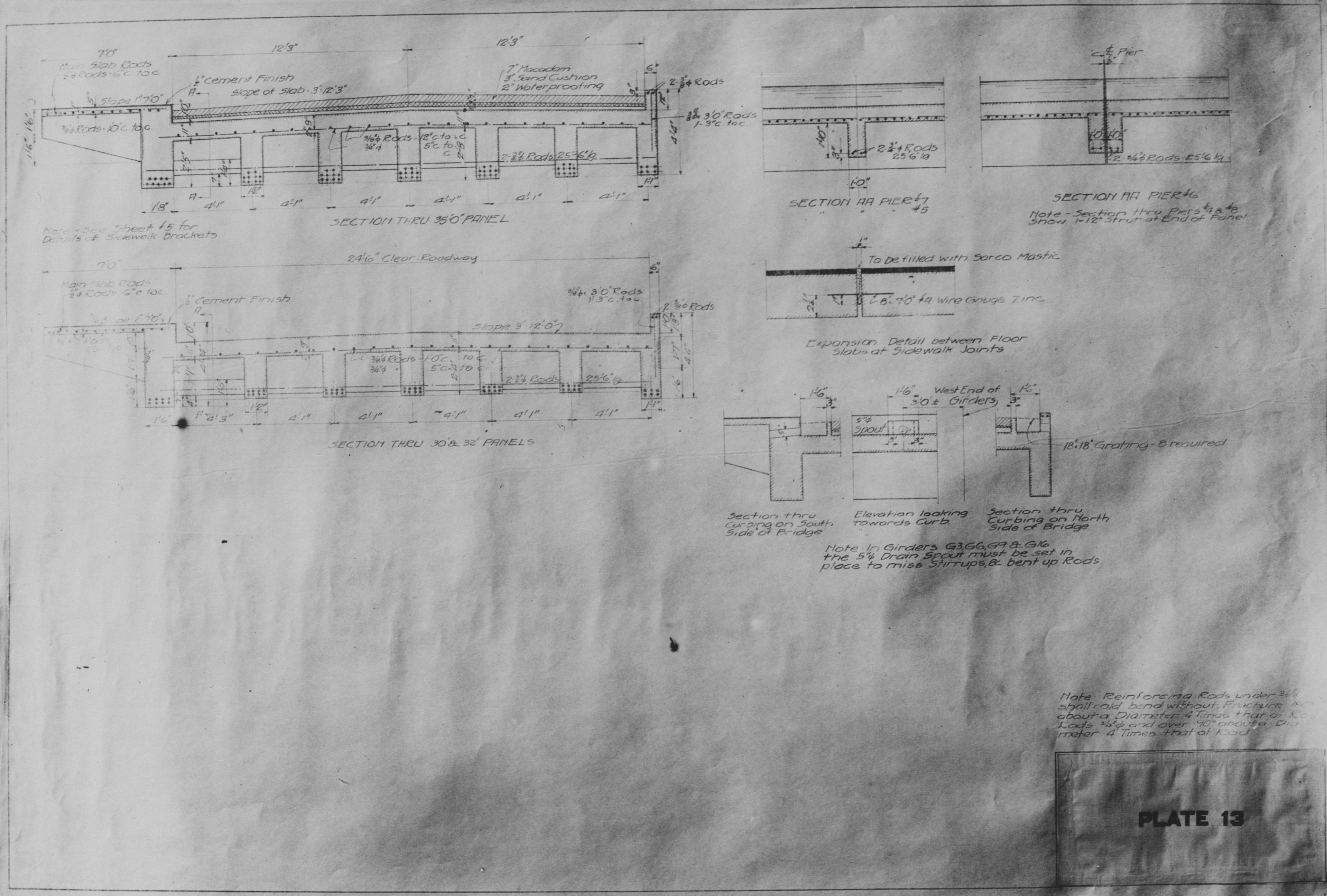


Stirrups in Footings

Stirrups	No. Req'd	M	P	S	Material
S1	180	3'0"	6"	1½"	½"φ x 6'-9"
S2	180	3'0"	10"	1½"	½"φ x 7'-1"
S3	180	1'6"	15"	1½"	½"φ x 4'-6"
S4	180	1'6	21"	1½"	½"φ x 5'-0"

Note: Reinforcing Rods under ¾"φ shall cold bend without Fracture 180° about a Diameter 4 Times that of Rod - Rods ¾"φ and over 90% about a Diameter 4 Times that of Rod.

PLATE 12


SECTION THRU 35'0" PANEL
Note - See Sheet #5 for Details of Sidewalk Brackets
7" Macadam
3" Sand Cushion
2" Waterproofing
Slope of Slab 3"-12'3"
1" Cement Finish
SECTION THRU 30' & 32' PANELS
24'6" Clear Roadway
SECTION AA PIER #7 #5
SECTION AA PIER #6
Note - Section thru Piers #4 & #8 Show 1-12" Strut at End of Panel
To be filled with Sarco Mastic
Expansion Detail between Floor Slabs at Sidewalk Joints
West End of Girders
18"x18" Grating - 8 required
Section thru Curbing on South Side of Bridge
Elevation looking towards Curb.
Section thru Curbing on North Side of Bridge
Note In Girders G3, G6, G9 & G16 the 5" Drain Spout must be set in place to miss Stirrups & bent up Rods
PLATE 13

BIBLIOGRAPHY

Williams, C. C.
1917, The Design of Railway Location, John Wiley and Sons, pp. 330-47.

Bainbridge, C. N.
1915, Study of Grade Crossing Elimination in Cities, Journal Western Society of Engineers, v. 20, pp. 628-70.
1915, Track Depression Project at Minneapolis, Railway Age Gazette, v. 59, pp. 1059-63.

Smith, C.E.
1915, Needless Grade Separation Required of Railroads, Engineering Record, v. 71, p. 674.

Stark, C. W.
1915, Grade Crossing Law and Its Effect on Grade Crossing Elimination, Engineering Record, v. 71, pp. 327-29.

Wagner, S. T.
1917, Elimination of Grade Crossings in Cities, Journal of the Franklin Institute, v. 184, pp. 715-16.

Watson, M. W.
1918, Eliminating Railway Grade Crossings, Railway Review, v. 63, pp. 880-81.

Golinkin, A. L.
1919, Civic and Engineering Features of Grade Crossing Elimination, Municipal Engineering, v. 57, pp. 61-63.

Wonson, E. L.
1915, Elimination of the Tower Grove Crossings, St. Louis, Mo., Railway Age Gazette, v. 59, pp. 799-802.

Proceedings American Railway Engineering Association.
1918, v. 19, pp. 633-53.
1917, v. 18, pp. 668-69.
1921, v. 22, pp. 291-304.

Engineering Record.
1915, Chaos in Apportioning the Cost of Grade Crossing Elimination, (editorial), v. 71, p. 319.
1915, Chief Engineers Discuss Grade Crossing Law and Cost Distribution, v. 71, pp. 455-56.
1915, Elimination of Tower Grove Grade Crossings at St. Louis Completed, v. 72, pp. 627-29.
1916, Trite but Still True (editorial), v. 74, p. 697.

Engineering News.
1915, Factors in Grade Separation, v. 73, pp. 422-23.
1915, Assessing Costs of Railway Grade Crossing Removal (editorial), v. 74, p. 370.

Engineering News-Record.
1917, Elevation vs. Depression and Track Change vs. Street Change, v. 78, pp. 129-30.
1918, Divide Cost Five Ways on Alton Grade Separation, v. 80, pp. 651-52.
1919, Grade Crossing Problems Demand Cooperation (editorial), v. 82, pp. 501-502.
1919, Detroit Plans Comprehensive Scheme for Grade Crossing Removal, v. 82, pp. 511-13.
1919, Grade Crossing Elimination at Indianapolis, v. 83, pp. 266-67.

Railway Age Gazette.
1915, Rock Island Track Elevation Work at Chicago, v. 58, pp. 690-94.
1915, Public and Grade Separation (editorial), v. 59, pp. 41-42.
1915, Grade Crossing Elimination (editorial), v. 59, pp. 634-35.
1915, Elimination of Grade Crossings in Dallas, Texas (report), v. 59, pp. 1087-88.
1915, To Promote Safety at Highway Crossings (editorial), v. 59, pp. 1119-20.

Engineering and Contracting.
1919, Summary of State Laws for Elimination of Railroad Grade Crossings, v. 51, pp. 17-19.
1919, General Problems and Aspects of Grade Separation, v. 51, pp. 381-84.