1906 REVISION

MANUAL

FOR

IOWA HIGHWAY OFFICERS

BY THE

IOWA HIGHWAY COMMISSION

DIRECTORS

A. MARSTON,
Dean of Division of Engineering

C. F. CURTISS,
Dean of Division of Agriculture.

T. H. MACDONALD,
Secretary.

AMES, IOWA

JULY, 1906

A General Survey of Our Public Highways

The highways of a country are one of the surest guides to the degree of the advancement and the development of the economic and social life of a people. They have been called the veins of a nation through which surge the rich corpuscles of agricultural and commercial productions into all of its parts, nourishing and quickening them into life and activity. Early in our history the United States built the famous Cumberland Road and planned a great network of such highways that would extend into and through all the states.

Then the railroads became of more importance and attracted the attention which had been centered upon the public roads. Mile after mile the steel tracks were pushed westward, close after the prairie schooners of the tireless emigrants. So rapid was their advance and so quickly did they reach the furthermost parts of the nation that the people were misled into the belief that transportation problems had been solved for all time. Large grants of public lands and many concessions were made to different corporations until the railroads acquired proportions and interests far greater than those of any other industry.

The period of pioneer railroad building is now well advanced. The energy formerly devoted to this cause is being turned to what may be called road perfecting, and large sums of money are being spent yearly in this work. Grades are being reduced, curves eased or taken out altogether, and many miles of excellent double track are being laid. The interurban and suburban lines of electric and steam railways also are forming a vast network connecting the business centers with the surrounding towns. This bewildering activity in the interests of improved transportation has attracted the attention of the people from the importance of the public highways in problems of transportation and their vital influence on such.

The old spirit that characterized the building of the first great national road has only recently been awakened by those who realize that in the full development of a country the public roads are primary. Railroads at best are unwieldly and costly and the degree to which they are able to serve the best interests of a country through which they run is determined directly by the public highways. At the inception of road building in the United States the leading men of the day championed the move-

ment, and now the foremost men in every state have not only given its revival their approval, but have aided its advancement in every possible manner. President Roosevelt has pronounced road improvement as a mark of those "solid, stable qualities which tell for permanent greatness" in a nation. The movement for improved highways has passed far beyond the stage when it was seized upon by reformers and those whose own interests demanded them and now claims as its friends the best and most conservative business men of every community.

Railroad officials instead of opposing its advance on the theory that it will result in less traffic by rail, realize that improved public roads mean an increaseed amount of shipping both to and from the farms, so distributed that a continuity of operation hitherto unknown will be possible. In fact much of the increased popularity of the idea with all classes is due to personal faith in the judgment and business discretion of leaders in it.

Any marked improvement in the road situation in Iowa will only come after a period during which men must be trained to take up the work of road making and maintenance in a systematic way. It will be the aim of the Commission to keep constantly in touch with the new methods and progressive ideas which are introduced; to experiment and test materials of construction; to conduct each year a school of instruction and to print and distribute from time to time such material as is thought will prove helpful to the road officers of the state.

IOWA HIGHWAY COMMISSION PLANS AND PUBLICATIONS

The following list contains the bulletins and such material which is sent out free of cost to road officers.

1. Bulletin No. 6, "THE GOOD ROADS PROBLEM IN IOWA."
2. MANUAL FOR IOWA ROAD OFFICERS.
   1906 REVISION.
   1905 Edition now exhausted.
3. "ROAD MAINTENANCE BY THE DRAG METHOD."—This bulletin contains cuts of the work done in the state, diagrams of drags, etc., etc.
4. Plans for reinforced culverts and bridges of any style or size wished are prepared and blueprints sent out by the Commission.
5. The "1906 PROCEEDINGS OF THE GOOD ROADS ASSOCIATION" can be obtained by writing to the Commission.

In addition to these publications, Bulletin No. 1, Vol. III, "TESTS OF CEMENT" can be obtained from the Engineering Experiment Station.

SECTION ONE.

GENERAL DATA RELATING TO PUBLIC ROADS

1. **MILEAGE AND CLASSIFICATION.** In the state there are approxminately 100,000 miles of public roads, averaging something over 1000 miles per county. Of this number perhaps twenty-five per cent. should be classed as main traveled roads. This would place no man over two miles from a main road running in each direction, and the great majority of the population, would be within a mile or less of a main traveled road. In starting a system of improved roads for a county it is very important that a map should be made, classifying roads into MAIN TRAVELED ROADS, AND SECOND CLASS ROADS. This classification is, at this stage of development, sufficient. In some other states and in France and such nations as have perfected their systems of highway construction and maintenance, the classifications of the roads is very distinct and much more complete but in this state such detailed classification is not necessary at this time.

"ROADS OF THE FIRST CLASS will reach out in every direction from the centers of population, and will enable everyone to enjoy their use. They would become a common blessing benefiting alike the farmer during any season of the year to reach his town market with his productions. They would diffuse the business of the community through all days of the year. Mud would no longer

lodge the farmer at home for weeks at a time. The farmer could, by their use, take advantage of the very best markets in the year."

"The town dweller, be he a business man or not, would then be relieved from paying the greatest tax that we as a people pay, namely, mud tax. This tax we pay year after year simply because we are not conscious of paying it. If the mud tax, that is paid in the state of Iowa annually, was actually put upon our highways, this whole system would be solved."

In most parts of the state this system is well developed and definite. Along these roads, or within easy access to them, lives by far the larger part of the population in the district. The explanation for this is difficult. In many cases the roads were laid out first and the incoming settlers built their homes near them. The old state and territorial roads are, for this reason, still the principal highways wherever they have been laid out. Economy of administration does not enter into the question of choosing a site for the house on the farm as does the desirability of placing it near the road which is most traveled. The reasons for this are apparent and need not be considered, but the situation produced is important since by improving a small percentage of the entire mileage of the county a large percentage of the entire population will be located directly along one of these improved roads.

THE SECOND CLASS ROADS will be the cross roads and those in the thinly populated sections which serve only a small number of people. These should be kept passable but the bulk of the road funds should be concentrated upon the other class until the system is perfected. Under Section Five standard cross sections are shown for these two classes of roads which are recommended to road officers for use in road construction.

2. **ANNUAL EXPENDITURE.** The importance of the proper expenditure of the road funds (including bridge funds) is apparent when the taxes for one year are considered. For 1904 the taxes levied were as follows (in addition to poll taxes):

County bridge tax	$1,628,719.89
County road tax	544,184.45
Township road tax	2,283,129.64
Total	$4,456,033.98

The actual amounts for one year are very large and the loss to the state by poor administration of these funds is a heavy drain. Cumulative effects are a serious economic problem. In a county with a taxable valuation of $6,000,000, with maximum levies in each of its road taxes, the total amount would be approximately $50,000. In addition to this sum, some counties spend

the mulct tax on the roads and this may amount to some $15,000 in an average county. From a business standpoint no community township, or county, can slight the proper administration of these taxes and not misuse a considerable sum of money.

3. **THE ROAD CENSUS.** With the possible exception of Illinois, we have the most products to haul over the roads and the worst roads over which to haul them. Not that they are in a bad condition all the time or even most of the time, neither is the most of the hauling done over them when they are in their worst condition, but they are unreliable always.

The justification for the expenditure of public money in the improvement of the highways must be found in the traffic itself. Not only the present amount of travel on the road but also the amount it would be increased, by improved conditions, should be taken into account. The importance of accurate and reliable information in this connection can be readily understood and the almost entire lack of such is a severe detriment to the cause. The especial need of such data in Iowa and the necessity of placing road improvement here on a broad firm basis, controlled by business discretion and managed by business methods are readily apparent when the extent of the interests affected are considered.

According to the 1900 census, fifty six and one-half per cent. of the total population of Iowa was engaged in agricultural pursuits. Her farms were valued at over $1,834,000,000 and in the value of all farm products, she ranked first. Practically all of these products which went to the market had to be either hauled or driven there over roads. Then, too, it may be said that very many of the other important industries of the state are dependent upon agriculture in a large measure to supply the means for their maintenance, and, because of this, their activity is considerably governed by the state of the roads.

The volume of traffic over the public roads on which is based their value to the community through which they pass can only be estimated by totaling the amount that each individual uses the road. This immense task has been undertaken by the Commission for the entire state and the results will be published in a Bulletin dealing with this subject fully. The results will be compiled from the Agricultural Road Schedules which was a supplementary card in the 1905 census. The following table has been compiled from the Adair County cards and show the actual amount of traffic of all kinds over the roads of that county.

ADAIR COUNTY—TOWNSHIPS	Total acres reported	Average size of full loads hauled	Average distance to market	Total ton miles hauling	Average time per round trip hauling
	Acres	Pounds	Miles	Ton-miles	Hours
Bridgewater Cor.	1,330.00	1,760.00	.92	239.25	1.90
Fontanelle Cor.	1,034.00	2,875.00	1.10	2,331.10	2.70
Union	19,173.00	2,000.00	6.17	18,236.70	6.00
Grand River	21,150.20	1,992.00	9.20	28,162.30	5.90
Harrison	23,027.00	1,980.00	10.00	25,564.26	8.90
Lincoln	21,337.00	1,824.00	4.40	17,421.90	4.10
Orient	19,578.00	2,032.00	3.00	12,933.30	2.60
Lee	16,389.00	1,887.00	4.20	14,635.15	3.90
Jefferson	22,577.94	1,966.00	5.44	25,213.55	4.86
Greenfield	2,778.00	2,141.85	1.40	1,200.45	1.90
Richland	20,875.00	2,010.00	7.00	19,511.00	5.70
Summerset	19,233.00	2,007.00	3.11	11,137.00	2.89
Prussia	21,270.50	1,985.00	6.53	31,374.75	5.78
Walnut	18,991.00	1,838.00	4.31	39,784.29	4.30
Washington	23,251.00	1,670.00	4.91	19,658.00	4.73
Jackson	19,586.50	1,884.00	4.00	13,861.00	4.16
Eureka	21,595.00	1,650.00	8.33	22,152.00	5.58
Summit	17,256.50	1,900.00	4.00	15,175.00	4.00
Grove	21,481.00	1,875.00	6.11	20,652.00	7.56
Total	332,013. *	37,246. *	94.13*	339,387.00*	87.46*
Average	17,474.	1,960.	4.95	17,862.00	4.60

ADAIR COUNTY—TOWNSHIPS	Average time per ton mile.	Average time required per acre hauling	Total miles traveled without considerable load to market	Total miles traveled other than to market	Total of all miles of light travel
	Minutes	Minutes	Miles	Miles	Miles
Bridgewater Cor.	140.80	254.00	1,040.00	10,556.00	11,596.00
Fontanelle Cor.	102.00	254.00	2,548.00	29,900.00	32,448.00
Union	58.00	55.00	48,516.00	54,860.00	103,376.00
Grand River	39.00	52.00	78,040.56	92,612.00	170,652.56
Harrison	54.00	60.00	153,940.80	123,344.00	277,284.00
Lincoln	61.00	49.00	106,080.00	131,352.00	237,432.00
Orient	51.00	34.00	57,096.00	105,872.00	162,968.00
Lee	59.00	53.00	44,252.00	70,902.00	115,154.00
Jefferson	55.00	61.00	131,456.00	96,564.00	228,020.00
Greenfield	76.00	32.80	11,830.00	20,332.00	32,162.00
Richland	49.00	46.00	107,432.00	117,312.00	224,744.00
Summerset	55.00	32.00	57,356.00	45,500.00	102,856.00
Prussia	53.50	79.00	94,536.00	132,694.00	227,230.00
Walnut	65.00	139.00	99,476.00	149,760.00	249,236.00
Washington	69.00	57.00	52,572.00	243,412.00	295,984.00
Jackson	66.00	47.00	73,502.00	58,760.00	132,262.00
Eureka	49.00	50.00	106,860.00	232,804.00	339,664.00
Summit	63.00	55.00	71,136.00	104,260.00	175,396.00
Grove	78.60	75.60	91,598.00	124,592.00	216,190.00
Total	1,243.90*	1,460.40*	1,389,267. *	1,945,388. *	3,334,654. *
Average	65.70	76.90	73,119.	102,388.	175,508.

The summary of this table shows that in a county which is essentially agricultural in character the amount of travel over the roads is divided as follows:

Total miles traveled without considerable load to market	1,945,388
Total miles traveled other than to market	1,389,267
Total miles traveled without loads	3,334,654
Total ton miles of hauling	339,387

The total farm acreage of this county is 360,224 and the actual number of acres reported on the census cards is 332,013 showing that over 93 per cent. of the total farm acreage has been reported on the cards from which this data has been compiled and that the results obtained from them must be considered fairly accurate. The actual number of farms in this county is 2,387 and these results show that for the average farm there is from 140 to 150 ton miles of heavy hauling and about 1400 miles of light travel per year. It will be seen that the important traffic from the standpoint of road improvement is not the heavy hauling but rather the light travel. Taking the average time required per ton mile, it means that the averge farmer only does heavy hauling about fifteen days per year, while marketing his crops, hauling an average load of 1960 pounds. If through road improvement he is enabled to haul a larger load the actual money saved would not be an enormous sum as has been claimed by many enthusiasts writing on this subject and who have deduced their estimates from data manifestly inadequate. The travel to market and the other light travel are without doubt the most important classes of traffic which the public roads carry and the value of improvement must be based largely on the stimulus and beneficial results it gives to these two classes.

The whole subject of the value of road improvement and the amount and kind of traffic over our public highways will be taken up in a bulletin which will be issued as soon as the road census cards have been tabulated for all the counties, or at least for as many counties as will be necessary to give a fairly accurate estimate.

FIG 1. RELATION BETWEEN PRICES AND CONDITION OF ROADS
WOODBURY COUNTY 1902-3

4. **THE RELATION OF PRICES FOR AGRICULTURAL PRODUCTS TO THE CONDITION OF THE HIGHWAYS.** In the marketing of a considerable amount of the farm produce, it is almost invariably the rule that full loads are hauled, although the number of pounds which constitute such a load is entirely dependent upon the conditions of the roads. Although this hauling is fairly well distributed throughout the year, the largest proportion is done during the months that the roads are the most unreliable. It is also during this time that the maximum prices are usually reached. Market quotations are frequently so favorable when the roads are impassable that it is a positive financial loss to farmers who are not able to deliver their crops to market. If there is any relation between these prices for these products and the condition of the road it is very desirable that this fact be thoroughly understood. The accompanying diagram (Fig. 1)

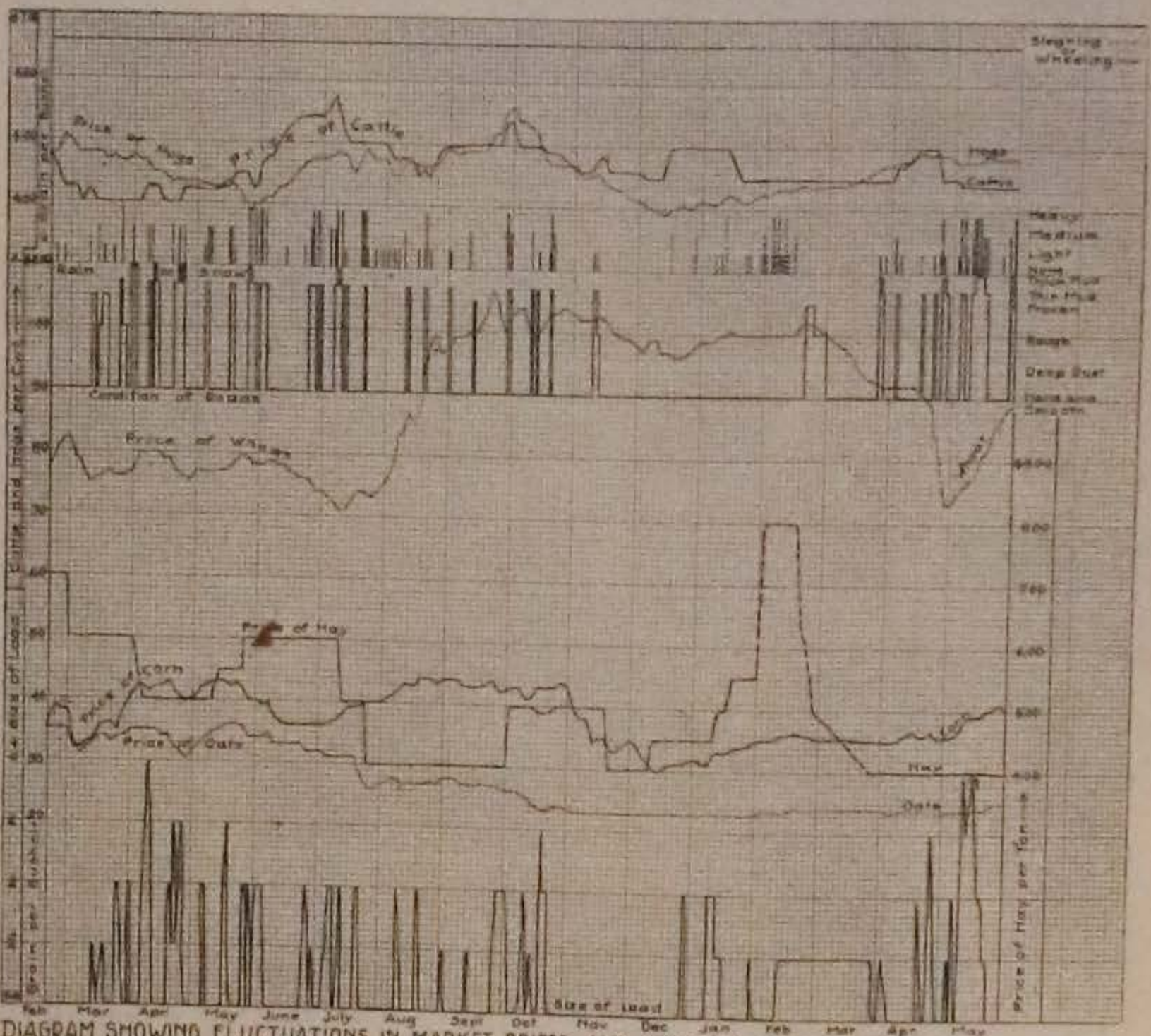


DIAGRAM SHOWING FLUCTUATIONS IN MARKET PRICES AND CONDITION OF ROADS IN HARRISON COUNTY
from Feb 1904 to May 1905

has been prepared from records kept for the Civil Engineering Department at a point in Woodbury County during the winter of 1902-3.*

In this diagram the tractive resistance was estimated from the reported condition of the roads and based on traction tests which were being conducted at the same time. The highest price for oats, corn and hogs occurred at the time that the roads were in a practically impassable condition. This brings out very graphically that a certain relation does exist between prices of such products and the condition of the roads. More complete records are now being kept in six representative counties of the state, which will give a much better insight into this relation.

Figure No. 2 shows the same general relation existing in Harrison County, 1903-4. A series of diagrams plotted from record books kept at a number of different points in the state will be printed in a later publication of the Commission.

SECTION TWO.

TOPOGRAPHY OF IOWA

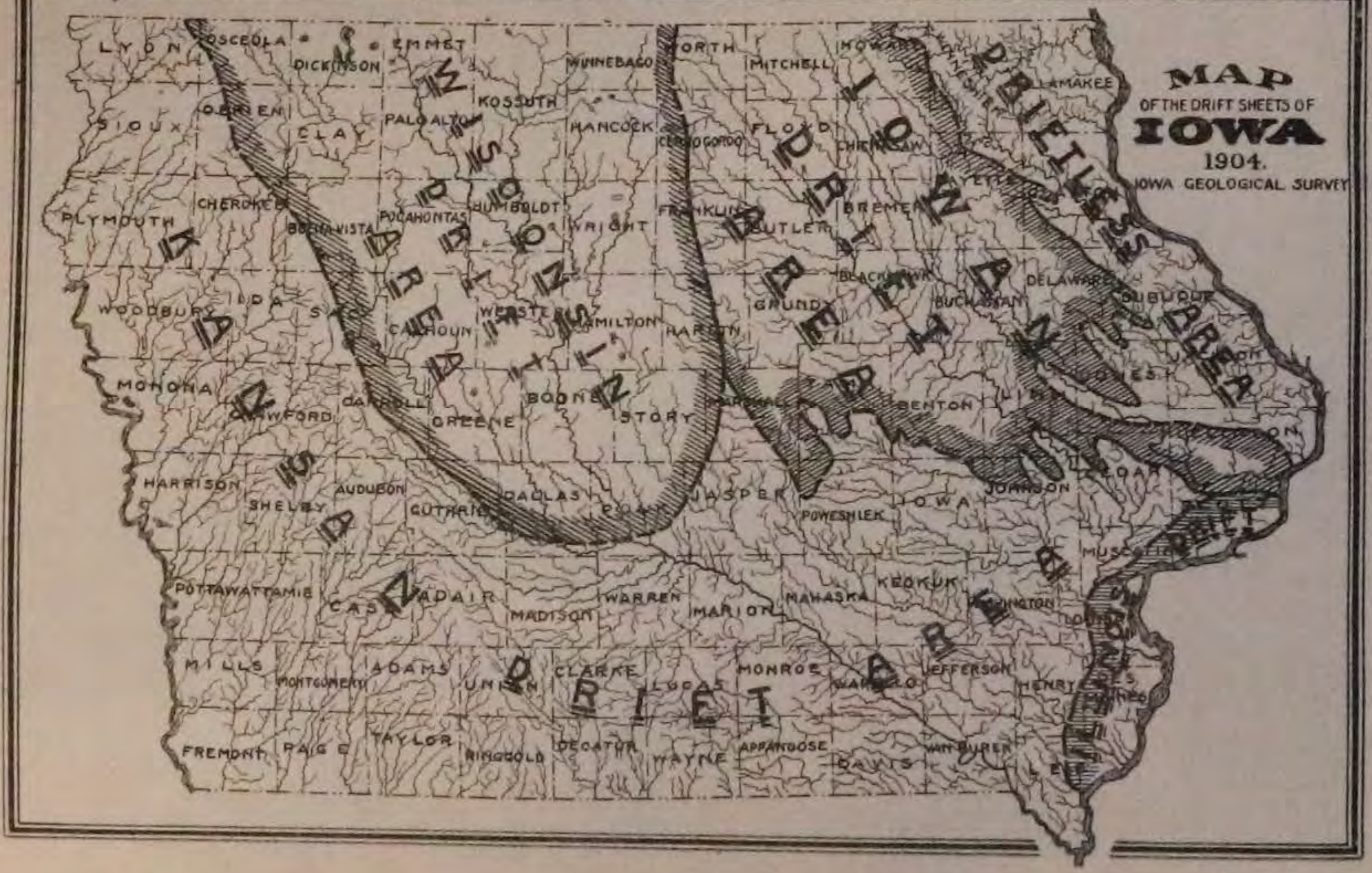
1. GENERAL TOPOGRAPHY. Iowa is one of the prairie states of the middle west. On the west its boundary is the Missouri river and on the east the great Mississippi. With the exception of the comparatively rough country along both these streams, the whole surface is a gentle undulating plain, rising toward the north and west. The total difference in elevation across the state is small. Between the river level at Keokuk and Sidney, the highest town in the state, there is a difference of about 1200 feet, and of this amount 100 feet is used in gaining the top of the cliffs along the river.

Notwithstanding the seeming similarity of the geological features of the state, from a roadmaker's viewpoint there are several distinct districts, each presenting conditions considerably different from the others.

Nearly the whole surface of the state is a glaciated area and the superficial features owe their formation to the great ice sheets which swept over the state, now advancing and again retreating, but always depositing a great mass of glacial debris and thus giving the state a soil world famous for its fertility.

Of these ice invasions there have been at least five distinct periods, known as the pre-Kansas, the Kansan, the Illinoian, the Iowan and the Wisconsin. Of these only three, the Kansan, the Iowan and the Wisconsin, are of particular importance to the road builder. The northeastern corner of the state is the

*Thesis work of Messrs. A. B. Chattin and E. McClure.


MAP
OF THE DRIFT SHEETS OF
IOWA
1904.
IOWA GEOLOGICAL SURVEY
KOSSUTH
HANCOCK
WRIGHT
FRANKLIN
BUTLER
BREMER
FLOYD
CHICKASAW
MITCHELL
WINNEBAGO
WORTH
EMMET
DICKINSON
OSCEOLA
LYON
O'BRIEN
CLAY
PALO ALTO
SIOUX
CHEROKEE
BUENA VISTA
POCAHONTAS
HUMBOLDT
PLYMOUTH
WOODBURY
IDA
SAC
CALHOUN
WEBSTER
HAMILTON
HARDIN
GRUNDY
BLACKHAWK
BUCHANAN
DELAWARE
DUBUQUE
MONONA
CRAWFORD
CARROLL
GREENE
BOONE
STORY
MARSHALL
BENTON
LINN
JONES
HARRISON
SHELBY
AUDUBON
GUTHRIE
DALLAS
POLK
JASPER
POWESHIEK
IOWA
JOHNSON
LINN
POTTAWATTAMIE
CASS
ADAIR
MADISON
WARREN
MARION
MAHASKA
KEOKUK
WASHINGTON
MILLS
MONTGOMERY
ADAMS
UNION
CLARKE
LUCAS
MONROE
WAPELLO
JEFFERSON
HENRY
MUSCATINE
LOUISA
DES MOINES
FREMONT
PAGE
TAYLOR
RINGGOLD
DECATUR
WAYNE
APPANOOSE
DAVIS
VAN BUREN
LEE
DRIFTLESS AREA
IOWAN DRIFT AREA
KANSAN DRIFT AREA
NEBRASKAN DRIFT AREA
DRIFTLESS AREA

only unglaciated district. There a district, including Allamakee county and parts of Clayton, Fayette, Dubuque and Jackson counties, stands out in all the ruggedness of the original topography covered only with the wind-blown soil, or "loess" as it is called.

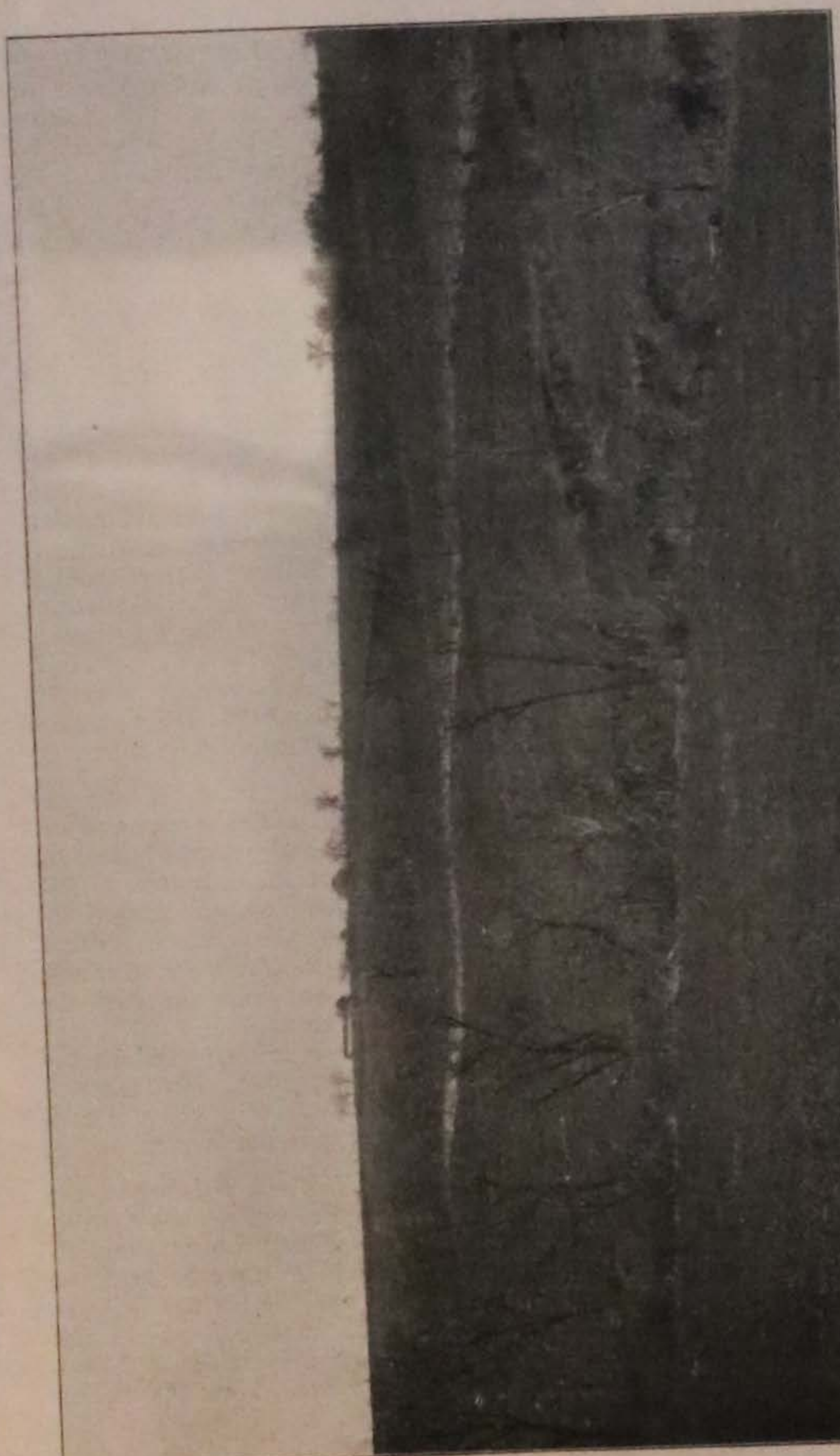
In the accompanying cut the principal drift areas are shown in outline. Even a superficial examination of the map discloses a marked variation in the number and extent of the drainage lines of the different areas, which is a sure index to their respective ages.

The drainage systems of the state belong to the Missouri and the Mississippi rivers, each taking the water from its side of the great water shed which runs in a more or less well defined course from Dickinson county southward to Wayne county so that more than two-thirds of the total area of the state belongs to the Mississippi system.

Many of the hills are covered by a thick layer of loess believed to have been deposited there by the winds. (See Figure No. 3). The soil is the so-called "typical boulder clay" and is a mixture of all kinds of material, including sand, clay, pebbles, and boulders, all worked together in a single mass. The weathering of this material has produced the yellowish color merging to shades of red and brown. The wind-blown portion is a lighter colored clay and in many places is only of slight thickness.

With such conditions the road problems of this area are obvious. The roads have, almost without exception, been opened along the section lines which run regardless of hills and valleys. There are many roads in this part of the state that are rarely used on account of steep grades and yet the land lies useless. This means an acre wasted every forty rods, besides the cost of maintaining two lines of fence in place of one. The direct loss, however, in these localities is due to two causes, the increased cost of transportation and of road construction and maintenance. Without taking up in detail the effect of heavy grades, it is apparent that the maximum grade of a road will determine the size of the load that can be hauled into town and wherever the road crosses a series of hills, the cost of reducing the maximum grade to a reasonable one will in most cases be much greater than an entire relocation as has already been demonstrated in various counties. Also the loess and the Kansan drift or till wash badly and as soon as the sod is broken with the road tools, the surface water begins its destroying action and dangerous gutters or trenches may be washed in a road by a single heavy downpour of rain. There are no satisfactory methods for taking care of the water that are not too expensive for practical use on the roads with heavy grades in this district.

Area of the Missouri Loess—Typical Loess Bluffs along the Missouri River



The Mature Character of the Topography of Southern Iowa

There is practically no road material in this area except along the streams and in comparatively few places where the Afton gravels outcrop. The road material carried by the Kansan ice sheet has become thoroughly oxidized and weathered, but the streams have carried a considerable amount of sand and gravel into this region from the Wisconsin drift area. Stone is found along the eastern border of this area and in a few isolated quarries.

2. **DRIFT AREAS.** The problems presented by these different drainage and drift areas to road officers are so different that a short review is given of the existing conditions in each area.

THE LOESS.—(Soil deposited by the wind). Along each river is a district covered by soil which has evidently settled from the atmosphere and varies in thickness from the high bluffs along the Missouri river to a thin sheet that conforms with, rather than changes, the existing topography of the southern counties. There are, from the viewpoint of the soil chemist, three distinct types of this soil, that of the Missouri river, the second of the Mississippi, and the third that lying between these two covering the Kansan drift of southern Iowa.

This soil is composed of finely divided particles yet very porous and contains no road building material. The counties covered by it correspond closely to the Kansan drift area.

THE KANSAN DRIFT. As shown on the drift map the Kansan drift is predominant in Iowa. The counties covered by it in the south, southwestern and western parts of the state have the mature topography of extreme age. The water and atmospheric agencies have moulded and shaped the whole country into series of parallel ridges with narrow uplands between them. Above the bottom lands the drainage is almost perfect. Few if any natural lakes or ponds exist and even the small streams have almost numberless tributaries.

The soil or glacial debris, where it is left exposed by the loess, is much more dense than the overlying layer. The extreme age of this soil is shown by the decayed boulders which it contains, many of which crumble readily between the fingers.

THE IOWAN DRIFT. The Iowan drift sheet followed the Kansan and now covers a strip about three counties wide, extending from the north state line to Johnson and Cedar counties. This section of the state represents the middle stage between the new topography of the Wisconsin drift and the mature features of the Kansan. The drainage lines, while well defined, are not deep cut channels but shallow basins; and the divides, although not well defined, contain few undrained spots. Here the section

Wisconsin Drift Area—"A monotonous stretch of prairie, liberally dotted with undrained ponds, sloughs and lakes."

line roads encounter few hills or steep grades. Gravel is quite abundant and many of the streams have rock-cut channels. Some of this stone is very good grade, although there is much that is very soft, especially when first quarried. This is notably true of the stone taken from the state quarries at Anamosa.

The bridge problem here is a difficult one since the stream courses are so poorly defined that they change their channels frequently. The broad channels of the water courses open difficult problems in bridging and grading. During seasons of the year the streams spread over wide bottoms, often cutting new channels or changing the direction of the old. There are counties which are keeping up from year to year hundreds of feet of pile bridging which could be saved by a competent road builder. Many of these long bridges have grown from short spans of perhaps sixteen feet by putting in new spans after the unprotected embankment has been carried away by high water. In some of the counties of this area careful attention has not been paid to the foundations for the larger steel bridges and these, too, have washed out, entailing serious loss.

THE WISCONSIN DRIFT. The youngest drift in the state is that brought down by the Wisconsin ice sheet which pushed one lobe, like a giant finger, from the north state line to Dallas and Polk counties. Capital Hill in Des Moines is one of the morainal hills marking the southern edge of this ice invasion. The whole topography in its immaturity is sharply contrasted to the mature features of the Kansan drift area. The only naturally well drained areas are along the streams. A glance at the drift may indicate clearly the lack of drainage lines in north central Iowa. It has been well described by one writer as "a monotonous stretch of prairie, liberally dotted with undrained ponds, sloughs and lakes." Again, in this district the section line location plays havoc with the highways, but for quite a different reason, for here it is the flat grades that make road building difficult and costly.

Drainage is first of all the important principle underlying the agriculture of this region. Not drainage as applied locally but of whole districts, involving large county ditches and miles of smaller tile drains. And so it is with road building, but as yet the road officers have not in general applied their knowledge gained, perhaps on their own farms, to the roads.

The divides between the streams are broad, roughly defined areas almost entirely without drainage.

All along the borders of this area are the low hills marking the terminal moraine of the Wisconsin ice sheet. Gravel is abundant in many places along these hills, the gravel knobs being quite characteristic of this moraine. The rivers also of this

region have deposited many banks of good gravel, and sand along their courses. This supply of available road material has only been developed and used in a desultory manner by most of the counties, and there are only a few, notably among which are Carroll and Greene counties, that have a fixed policy in road improvement and which have permanent results to show for the money expended.

SECTION THREE.

IOWA'S ROAD LAWS

HISTORY AND DEVELOPMENT OF ROAD LEGISLATION IN THE STATE

The development of the system of laws for any people is indicative. In it may be read the unfolding of the ideals of government as the country grows older and living becomes more complex. In the same way the laws relative to any particular governmental activity will reflect the attitude taken towards it in each succeeding generation. The ideals, however, inherited and acquired, which are the forces persuading and compelling men to seek higher planes of action, must always be tempered and, in a measure, defeated by certain personal limitations and interests. The resulting measures are often a curious compromise shown sometimes in the form but more often in the application of these measures which is strikingly apparent in the history of Iowa's road laws. These deviations are not the true expression of the purposes of the laws and for this reason can only delay the forward movement.

Before attempting to analyze the development of the system of road laws in Iowa, it is desirable that the political history and status of the state should be clearly understood.

In April, 1682, La Salle took possession of the Mississippi and all the country watered by its tributaries in the name of Louis XIV of France. After the fall of Quebec in 1759, by the treaty of Paris all the country between the Mississippi river and the Rocky Mountains was transferred to Spain but by secret treaty in 1800, France again regained control of the country which was purchased by the United States in 1803; one year later this land was divided into the Territory of Orleans and the District of Louisiana. The former of these was organized under a complete territorial government while the District was placed somewhat indefinitely under the control of the Governor and judges of the Territory of Indiana. The people of Louisiana were so disatisfied with the form of government that in 1805 they were organized into an independent territory and were re-

organized in 1812 as the Territory of Missouri. When Missouri was admitted to the Union in 1812, no provisions seem to have been made for the remainder of Louisiana north and west of that state. The region was left in this indefinite condition until Congress in 1834 made it a part of the Territory of Michigan for the purposes of temporary government. Two years later the Territory of Wisconsin was established and the inhabitants of Iowa came under a regularly organized government. At this time the growth of the population in this region was so rapid that in 1838 the Territory of Iowa was created.

The territories were given broad powers of legislation, the only limitation being that they should "extend to all rightful subjects of legislation." The subject of road laws was one of the first to be considered as a proper one for legislation and in the first session of the Legislative Assembly, held at Burlington in 1838-39, were enacted the first road laws of Iowa.

1. **ROAD LEGISLATION. (1838 to 1857.)** The first of these acts is given in full because those following were very similar:

"An Act, to locate and establish a Territorial Road from Keokuk, on the Mississippi River, to Iowa City, on the Des Moines River.

"Sec. 1. Be it enacted by the Council and the House of Representa tives of the Territory of Iowa; that James Lutton, Joseph Robb, and James McMurry be and they are hereby appointed commissioners to locate and mark a Territorial Road, commencing at Keokuk, in Lee County, on the Mississippi River, thence to the horse tail reach, on the Des Moines River, thence up said river as near as practicable to Iowa City, on said river, passing through Farmington, New Lexington, Bentonsport, Columbus and Philadelphia, in the county of Van Buren.

"Sec. 2. And be it further enacted that the commissioners aforesaid, or any two of them, shall meet at Keokuk on the first day of June next, for the purpose of proceeding to the discharge of their duties, as commissioners aforesaid, and that they be and hereby are authorized to adjourn from time to time and from place to place, as they may agree and determine; and that in case said commissioners may have adjourned, then let the sheriff of Lee County be authorized and he is hereby required on the application of any of said commissioners, either written or verbal, to notify in writing said commissioners of some other day, to be by him appointed, and request their attendance on such day at the place aforesaid.

Approved, December 14, 1838."

TERRITORIAL ROAD LAWS. This act evidently pointed out to the legislators the need of a general law covering such grounds and so later in the session the following act was passed:

"An Act to provide for laying and opening Territorial Roads.

"Sec. 1. Be it enacted by the Council and House of Representatives of the Territory of Iowa, that all Territorial Roads to be hereafter located and established within this Territory shall be viewed, sur-

veyed and established and returns made thereof agreeably to the provisions of this act within one year from the passage of the act, by which said road or roads may be granted or authorized to be laid out respectively.

"Sec. 2. The commissioners appointed to locate and establish any Territorial Road shall cause the same to be correctly surveyed and marked from the beginning throughout the whole distance by setting stakes in the prairie at three hundred yards distance and blazing trees in the timber; they shall establish mile posts, which will be marked with a marking iron in regular progression from the beginning to the termination of said road and shall also establish a post at every angle in the said road, marking as aforesaid upon the same and upon a tree in its vicinity, if any there be, the bearing from the true meridian of the course beginning at said angle post set as herein directed and note the bearing and distance of two trees in opposite directions, if there be any in the vicinity, from each angle and mile post.

"Sec. 3. The commissioners and surveyor of each road shall make a certified return of the survey and plat of the whole length of said road, specifying in said return the width, the depth and course of all streams, the position of all swamps and marshes and the face of the country generally, noting when timber and when prairie and the distance said road shall have been located in each county.

"Sec. 4. Said return and plat shall be signed by a majority of the commissioners, and the surveyor of said road forwarded to the Secretary of the Territory within sixty days after the view and survey of the same, to be by him recorded and preserved; and they shall also within sixty days as aforesaid, deposit in the office of the Clerk of the Board of Commissioners of each county through which said road shall be laid, a return and plat as aforesaid of so much of said road as shall be laid out and established in said county to be recorded as aforesaid.

"Sec. 5. The said commissioners shall after the completion of the survey of said road as aforesaid, make out a certified account of all services rendered as well by the surveyor and other hands as by themselves, charging to each county, through which said road may have been laid, a proportion of the expense agreeably to the number of days employed thereon and the board of commissioners of said county shall audit and settle the same.

"Sec. 6. All Territorial Roads authorized to be laid out by any laws of this Territory and not yet commenced shall be laid out in the manner prescribed in this act and the commissioners shall comply with all the regulations herein contained; and further, the established width of all Territorial Roads shall be seventy feet.

"Sec. 7. When any road shall have been located and established agreeably to the provisions of this act, the same shall be forever a public highway and shall be opened and worked by the counties through which it shall be laid as county roads are; and no part of the expense of laying out and establishing any Territorial Road or of the damages sustained by any person or persons in consequence of laying out any Territorial Road shall be paid out of the Territorial Treasury."

"Approved: December 29, 1838."

COUNTY COMMISSIONERS. During this same year an act was passed which provided that three county commissioners should be elected to transact all the county business and levy such taxes as were necessary. These provisions may be regarded as the beginning of road legislation in Iowa under the

territorial form of government. Every session of legislature many miles of road were authorized by acts with very little if any regard in choosing of locations; the importance of a good highway system had not yet made itself manifest.

Almost as soon as Iowa was organized into a Territory, agitation was begun within her borders for a State Constitution. This did not arise from any particular dissatisfaction with the existing form of government but rather from the progressive spirit of those who desired that Iowa should have the full rights and dignity of the other states. Finally in 1846 a Constitution was devised which was approved both by Congress and by the people of the state and Iowa was formally admitted into the Union.

A supplemental act to the one which granted admission to the states of Iowa and Florida provided among other things that five per cent. of the net proceeds from the sale of all public lands in the state should be appropriated for making roads and canals. When the General Assembly ratified the proposition of Congress they made an exception of this one section and asked that they be allowed to use the funds so derived for the purpose of the public schools. Permission to do this was later given them by a special act of Congress, so this fund was diverted from the roads and canals for which it had been originally intended.

There is nothing in the Constitution of 1846 curtailing the powers of the General Assembly to make provisions concerning public roads and the inference is that up to this time there had been no considerable abuse of this freedom.

2. **EARLY STATE ROAD LAWS.** The form of these early laws does not excite suspicion. They undoubtedly represented more nearly the most progressive ideas of that period than do our present road laws reflect the most advanced thought concerning highway legislation. The manner of application of this law, however, is worthy of particular attention and the situation up to 1857 is well expressed by Mr. Charles Aldrich in "The Annals of Iowa." He says:

"Some curious results would be reached in studying the manner in which public roads were projected and located by acts of the Legislature, Territorial and State, up to the adoption of our present Constitution. These inchoate highways would seem legitimately to have had but one purpose—that of facilitating travel and intercourse between different portions of the Territory or State. But in time their establishment became an abuse which the makers of our Constitution did well to suppress. Candidates for the legislature were ready and even eager to promise to secure the establishment of these roads in order to obtain support in securing nominations as well as votes at the elections. The carrying out of pledges was generally easy, for as a rule these projects met with very little opposition in the Legislature.

"Then these laws provided not a little patronage in the appointment of commissioners to locate the roads, who were also generally

authorized to appoint one or more practical engineers and surveyors, a team, a tent and other camp equipage, and one or more common laborers, the subsistence for the party were also required. The location of some roads required several weeks, and, as the work was undertaken as early in the season as animals could subsist on prairie grass, they were real junketing, picnicing excursions. Nothing could be more pleasant than going out to perform such official duties. The pay was sufficient in those days of small things to make the position of commission a very welcome appointment. The appointments seldom went a-begging. The prairies were most beautiful with their carpets of green grass interspersed with myriads of flowers and fairly alive with feathered game. Deer and elk were occasionally killed and as soon as the spring floods subsided fish were plenty and of the choicest quality. Enterprising frontiersmen who had gone out beyond the settlements to make themselves homes always gave them the heartiest welcome. Such settlers were hospitable to all comers but especially so to those parties whose work promised to open up roads and place them in communion with the populous places.

"But it not only became apparent that this work had too often degenerated into schemes of politicians either to acquire influence and votes, or to pay off debts already incurred, but that railroads then rapidly extending westward, would largely obviate the necessity for even genuine State roads. So the convention of 1857, in Article III, Section 30, of the present constitution prohibited the General Assembly from 'laying out, opening and working roads and highways.'

"The summer of that year saw the last parties engaged in laying out State roads. The Legislature of 1856, however, had been so industrious in the establishment of State roads that it takes almost three pages in the index merely to name the various laws or sections in which they were decreed. The commissioners in the summer of that year were very active and 'made hay while the sun shone,' well knowing that the laws would provide for no more such roads. And so the usage—so pleasant to its beneficiaries—came to an end."

Hardly had the Constitution of 1846 been adopted before it became apparent that it needed strengthening. It had only been accepted by less than five hundred votes out of a total of over eighteen thousand five hundred, and it was not difficult to get a new constitutional convention called to meet in 1857.

Constitutional Limitations. In this convention a constitution modeled upon the old one, but in every way fuller and more perfect, was drawn up. By this time, the Legislatures had so abused the freedom granted them in certain particluars that the makers of the new constitution sought to end this practice and Section 30, Article 4 was inserted for this purpose:

"The General Assembly shall not pass local or special laws in the following cases:

"For the assessment and collection of taxes for state, county and road purposes;

"For laying out, opening and working roads or highways."

Laws of Seventh General Assembly. In 1858, the Seventh General Assembly, the first one to meet under the new Constitution, passed a new set of road laws into which were introduced many of the features which are still retained. A board of

three men in each township was provided to transact the township business, and were called township trustees. Without attempting to quote these in full, they are as follows: (Chapter 154).

"Sec. 1. The township trustees shall meet and divide their respective townships into as many road districts as they may deem necessary.

"Sec. 2. A supervisor shall be elected from each road district to hold office for one year.

"Sec. 3. The township clerk shall notify the supervisor of his election and shall administer the oath of office to him.

"Sec. 6. The supervisor shall require all able bodied male residents of his district to perform two days' labor on the public highways.

"Sec. 9. The supervisor shall perform the same amount of labor as is required of the able bodied man, for which he shall be allowed one dallor and fifty cents per day.

"Sec. 12. The township trustees shall determine the amount of property tax to be levied for roads, bridges, plows and scrapers which shall not be less than one nor more than three mills on the dollar of the township assessment for that year.

"Sec. 14. The township clerk shall make an entry of the tax list showing what it is and for what road district, and require the supervisor to collect the same.

"Sec. 17. The supervisor shall superintend all road work in his district and (Section 18) shall report the same."

The Board of Supervisors. The revised Code provided that the duties and power of the county commissioners under the territorial form of government should be vested in a county court which also had jurisdiction in probate. The Eighth General Assembly, which met in 1860 created the county board of supervisors. The duties of the territorial commissioners were taken from the county court and given to this new board, among which specific duties were the following:

To lay out, establish, alter or discontinue any county roads heretofore or now laid out or hereafter to be laid out, through or within their respective counties as may be provided for by law.

To provide for the erection of all bridges which may be necessary and which the public convenience may require within their respective counties, and to keep the same in repair.

It will be seen by reference to these laws that they gave the supervisors general supervision over the highways, including the bridges, and the trustees the power to levy the taxes necessary for keeping the roads, including smaller culverts, in repair, while the Board of Supervisors was entrusted with levying the taxes for the more important bridges.

3. **NEW ROAD LAWS, including those passed and revised by the 31st General Assembly, 1906.** The laws given in the preceding pages show the introduction into the system of road laws

of all the officers who are charged with the administration of the road and bridge funds at the present time except the road superintendent. Few changes were made from this time until the 29th General Assembly passed an act making each township one road district and requiring the property road tax to be paid in money and to be expended under the direction of the road superintendent. The wording of this measure was somewhat indefinite and the 31st General Assembly revised it (S. F. 138, H. F. 379) so that it now reads as follows:

TOWNSHIP ROAD LAW. "Sec. 1532-a. *Repeal—Consolidation of Township into one road district.* That section one thousand five hundred and thirty-two (1532) of the code be, and the same is, hereby repealed, and the following enacted as a substitute therefor:

"The board of township trustees of each civil township in this state, at its regular meeting in April, 1903, shall consolidate said township into one road district, and all road funds belonging to the road districts of said township shall at once become a general township road fund, out of which all claims for work done or material furnished for road purposes prior to the change, and unsettled, shall be paid.

"Sec. 1533. *Duty of Trustees.* Where the one road district plan is adopted, the board of township trustees shall order and direct the expenditure of the road funds and labor belonging or owing to the township; may let, by contract, to the lowest responsible, competent bidder, any part or all of the work on the roads for the current year, or may appoint not to exceed four superintendents of roads, to oversee, subject to the direction of the board, all or any part of the work, but it shall not incur an indebtedness for such purposes unless the same has been or shall at the time be provided for by an authorized levy; and shall order the township road tax for the succeeding year paid in money and collected by the county treasurer. It shall cause both the property and poll road tax to be equitably and judiciously expended for road purposes in the entire road district; shall cause at least seventy-five per cent. of the township toad tax locally assessed to be thus expended by the fifteenth day of July in each year; shall cause the noxious weeds growing in the roads to be cut twice a year, when necessary, and at such times as to prevent their seeding, and it may allow any land owner a reasonable compensation for the destruction thereof, when growing in the roads abutting upon his land. If a superintendent of roads is employed, it shall fix the term of office, which shall not exceed one year, and compensation which shall not exceed three dollars a day; and no contract shall be made without reserving the right of the board to dispense with his services at its pleasure."

This act is deemed of sufficient importance to repeat it here in full as there seems to be considerable lack of information concerning a number of its requirements. In some parts of the state the provisions have not been complied with and a general dissatisfied condition has resulted. In such cases the townships have really been proceeding under the old road district plan.

ADDITIONAL ONE MILL LEVY IN COUNTY ROAD FUND ON PETITION. To give the county supervisors power to levy an additional mill for road work on petition, Section 1530 was changed by the 31st G. A. to read as follows:

Sec. 1530. *County Road Fund—how levied and paid out.* The board of supervisors of each county may, at the time of levying taxes for other purposes, levy a tax of not more than one mill on the dollar of the assessed value of the taxable property in its county, including all taxable property in cities and incorporated towns, which shall be collected at the same time and in the same manner as other taxes, and be known as the county road fund, and paid out only on the order of the board for work done on the roads of the county in such places as it shall determine, provided that on written petition of a majority of the electors who are free holders of any township in any county, the board of supervisors may levy an additional mill in said township, to be expended by said board of supervisors on roads in township where same is levied; but so much of the county road fund as arises from property within any city or incorporated town shall be expended on the roads or streets within such city or town, or on the roads adjacent thereto, under the direction of the city or town council; and the county treasurer shall receive the same compensation for collecting this tax as he does for collecting corporation taxes. In case the board of supervisors do not make a levy for county road fund, or levy less than one mill for said county road fund, the board of supervisors shall levy such an additional sum for the benefit of such townships as shall have certified a desire for such additional levy, as provided for in section fifteen hundred and twenty-eight of this chapter; but the amount for the general township fund and the county road fund shall not exceed in any year five mills on the dollar.

THE NEW DRAG ACT. During the past winter a number of bills were brought before the Thirty-first General Assembly recognizing the drag as a suitable implement for earth road maintenance, and providing for its use by road officers. The one which was finally selected and passed reads as follows:

H. F. 15

An act to provide for improving the public highways by the use of the road drag.

Be it enacted by the General Assembly of the State of Iowa.

Section 1. On and after the passage of this act, the township trustees are hereby authorized to have work done upon the public highways by use of a road drag to be approved by said trustees.

Section 2. The trustees shall have the road drag used upon the public highway under the direction of the road superintendent when in their judgment the road would be improved thereby. In choice of persons to do the work, preference shall be given other things being equal to the occupants of the land abutting upon the road at the point where the work is to be done. Provided that when there is more than one occupant the superintendent may decide to which the preference shall be given. Reasonable compensation shall be allowed for such work, but in case shall it succeed fifty cents per mile for each time same is dragged; and there shall not be expended therefor more than five dollars ($5) per mile for any mile on which said work is done during any one year.

Section 3. This act, being deemed of immediate importance, shall be in force from and after its publication in the Register and Leader and the Des Moines Daily Capital, newspapers published in Des Moines, Iowa.

Approved February 14, A. D. 1906.

While this law definitely provides that payments shall be made at a rate not to exceed fifty cents per mile per time dragged, it is being interpreted by many of the trustees to mean that anyone who takes care of his road with a King drag shall be paid five dollars per mile per year. As the law stands it provides a very reasonable compensation for doing this work, and although in many cases the flat rate of five dollars per mile might result in much more than this amount of work being given to the road, in general it would result in the dissipation of the road funds without adequate returns.

This law was passed to do away with the objection to the use of the drag made by some that the farmers should not pay their taxes and also help keep the road in repair without proper compensation. While the old law gave the trustees sufficient authority to pay for having the work done, there were those who were opposed to this idea of road maintenance and sought to evade their responsibility in the matter by raising legal objections. The law, as it stands, does away with such objections and makes the duty of the trustees clear, and the road officers should be careful to interpret its provisions in such a manner as to render them economical and effectual.

The following form is suggested for use as a contract between the trustees and the men who are to do the work:

CONTRACT FOR CARE OF PUBLIC ROADS
BETWEEN
BOARD OF TRUSTEES OF
.....Township
AND
.....

Under H. F. 15, Laws of the 31st General Assembly.

We (or I).....agree to make and use a drag during the year.....1906 to ..... 1907 at the rate of .....cents per mile per time dragged, subject to the following conditions:

1. The drag shall be approved by the road superintendent.

2. The road will be dragged as soon after a rain as the earth will work away from the front of the drag, without balling, but while it is still moist.

Signed.....

Date.....1906.

Approved:—Board of Trustees,

By .....
Chairman.

THE NEW WIDE TIRE ACT. The action of the drag in throwing a little earth toward the center of the road each time it is used is supplemented by the rolling and compacting action of the traffic and the horses' hoofs, and the two together are necessary to build up a hard, impervious crown on the traveled way. The last legislature recognized this fact when it passed the law providing for the refunding of road taxes to anyone who should use nothing but wide tired wagons on the road. The bill reads as follows:

S. F. No. 6. *An act to encourage the use of wagons with wide tires on public highways and providing for a rebate of a portion of their road tax to persons using wagons with wide tires not less than three inches in width when hauling heavy loads on the public highways of this state. Be it enacted by the General Assembly of the state of Iowa:*

Section 1. That all persons who shall in good faith use wagons on the public highways of this state with tires not less than three inches in width, for hauling loads exceeding eight hundred pounds in weight, for the year ending the first day of July, nineteen hundred and seven (1907) and each succeeding year thereafter, shall receive a rebate of one-fourth (1-4) of their assessed highway tax for that year, and in like manner

each succeeding year thereafter; provided that such rebate shall not exceed the sum of five dollars ($5) in any one year to any person.

Section 2. Any person complying with the provision of Section One (1) of this act, who shall make and subscribe to an affidavit that he has for the last preceding year of July first, nineteen hundred and seven or any succeeding year thereafter, used only such wagons with tires not less than three inches in width, for hauling loads exceeding eight hundred pounds in weight, on the public highways of this state, shall receive payment by the Township Trustees of the Township in which such person resides, of one-fourth (1-4) of the road tax assessed and levied on the property of said person. Such payment shall not exceed in any one year the sum of five dollars ($5.00) and all Township Trustees and Township Clerks are hereby authorized to administer such oath.

Approved March 10, A. D. 1906.

There was some opposition to this bill when it was passed as it was believed it would be ineffectual in accomplishing results, but such has not proved to be the case as it has been taken up quite generally by the farmers and particularly by those who are buying new wagons. The generous rebate is an encouragement and a compensation for the increased first cost of the wider tires, and after the law is in effect for a reasonable number of years its provision should be made mandatory.

4. ORGANIZATION UNDER THE PRESENT ROAD LAWS:

County Supervisors. This board is given general jurisdiction over the highways of the county. It has the power to establish, vacate or change them as provided for in the laws. It is their duty to levy the one-mill county road tax and to expend the same. They have to erect and repair all the bridges above a certain span, which varies from 12 to 16 feet, and to pay for the same by taxes, the maximum of which is now limited to four mills, except by a special vote of the people.

County Auditor. The county auditor acts as the secretary of the board of trustees and is required to keep on file in his office the complete records of all their transactions, and reports which come to them. He is also required to make each year, a financial report of the county which in brief should show the entire business transacted during the preceding year, by the county officers, so arranged that it will be a source of information, and readily understood by the taxpayer.

Board of Trustees. The board of trustees is a local board entrusted with the care of the roads in the individual townships. This board has the power to levy road taxes up to a minimum of

four mills and to expend the same on the public highways. For the money so raised they are required to account to the board of supervisors, the same to be approved by them and published in their proceedings.

Township Clerk. This officer acts in the capacity of secretary to the board of trustees, and the law now requires the county treasurer to pay over to him the road taxes for the township. He is required to make a report of all delinquent road taxes to the county auditor; to certify to the auditor the property road tax levied by the board of trustees; to make out and deliver to the superintendent of roads, a list of all persons required to pay road and poll taxes; to make to the board of supervisors, on the first Monday in each year, a "full and itemized account" for the board of trustees of all their receipts and expenditures during the preceding year, and to have custody of all the general township fund and of all the road machinery.

The Road Superintendent. The road superintendent is required to expend the road money of the township under the direction of the trustees and to report the same in itemized statement to the township clerk on the first Monday of April and of November of each year.

5. ADMINISTRATION OF ROAD FUNDS. In a general way the method provided by law and the officers necessary for carrying out its provisions are given in the preceding articles. It is a well established fact, however, that lax business methods prevail in expending and accounting for a large proportion of the taxes raised for road and bridge purposes. It is quite impossible to go into the average county and find adequate records of money paid out by the road officers.

The bridge work in different counties is let by contract or put in by day labor under the supervision of the board of supervisors. The practice is not uniform in the state but there are a number of the important points to be observed in bridge work which quite generally receive very little attention.

When the work is let by contract an inspector should be provided by the board of supervisors to act as their representative on the work and to keep a full and accurate account of each day's progress. The points which he should have carefully in mind are the foundations, the material furnished, the workmanship, the painting, and the recording. The data to be recorded is given in a following paragraph.

If the work is put in by day-labor the same points should be just as carefully observed and a competent foreman should first be secured to take charge of the work. The Commission offers its services to any counties to help in securing men to

inspect on work they are putting in or to act as foreman to take charge of county or township bridge work.

County Bridge Fund. It is suggested that the following items be taken into consideration in recording the receipt and expenditure of bridge funds each year:

Receipts.

Amount of bridge funds on hand at beginning of fiscal year.
Received from county treasurer.
Amounts received from sale of old material.

Expenditures. These should be classed under two heads and itemized as follows:

New Bridges.
Span.
Name of builder.
Superstructure.
Material.
Unit cost.
Total cost.
Foundations.
Piers.
Material.
Unit cost.
Total cost.
Abutments.
Material.
Unit cost.
Total cost.

Repairs.
Material.
Labor.

In order to promote economical and efficient handling of county funds it is highly important to keep records similar to these from year to year which will show the cost of the bridge work to the county and thus bring into comparison the administration of road supervisors as they succeed each other. If there is a considerable change from year to year the records would show the reason for this. Such records would also be valuable in showing the number of structures, their size, first cost, and cost of maintenance. Whenever large contracts are let or the board is in doubt as to the best methods or materials to use in bridge work some competent engineer should be employed. The loss each year due to incompetent handling of these funds is a serious drain.

County Road Fund. The county road fund, although one mill only, has been in some counties used to such good advantage that seemingly more permanent results have been accomplished

with it than with the four mill township levy. In some counties this fund is used for improving important roads by grading, graveling or macadamizing. In other counties it has been used to help out the bridge fund in constructing permanent culverts. These are exceptions, however, as in most of the counties this fund has been dissipated in much the same manner as have the township funds.

Where contracts are let for road work they should show the cost, unit and total, of the labor, material such as tile, gravel, etc., the amount of road improved, and its location. Other expenditures, such as machinery, repairs and such items should be carefully reported together with the date, and the supervisor in charge of the work. The fund should be distributed as fairly as possible by each supervisor in his district but in conjunction with the other supervisors toward a system of roads already planned for the county.

Township Road Fund. The new road law gives promise of some excellent results, but the practical working of the same has been such as to merit a thorough discussion of some of the principles involved. In the first place the order of new provisions of the law will be taken up as fully as possible as there seems to be a very serious lack of information on this subject.

THE TOWNSHIP, THE UNIT ROAD DISTRICT. The act makes it mandatory upon the board of trustees to constitute each civil township into one road district. In a number of places this plan has not been followed and thus the first requirement of the law has been violated. The old law gave the power of discretion to the trustees as to whether the township should be made into one road district but the new law takes away this right and makes the township the only legal road district.

THE GENERAL TOWNSHIP ROAD FUND. The maximum levy property for this fund is four mills and was formerly optional as to whether it should be paid in cash or labor but the new law takes away this right of choice and requires the taxes to be paid in cash and to be collected as are the other taxes. It now constitutes the general township road fund out of which all claims for labor or material for the township shall be paid. "Under the old law all road taxes in the townships where there was no consolidation of the road taxes were payable with the first installment of the county and state taxes, while the road taxes in townships where there had been this consolidation were payable in two installments, as were the other taxes."

As the law now stands it is the duty of the township clerk within four weeks after the township trustees have levied the

property road tax to certify the same to the county auditor who shall enter it upon the tax lists for collection by the county treasurer in one installment.*

PAYMENT TO TOWNSHIP CLERK. The county treasurer is required to pay over to the township clerk on the last Monday in April and October of each year all the road taxes belonging to that township and to receive a duplicate receipt for the same, one of which he shall retain and one of which he shall deliver to the trustees before the first Monday in May or November of that year.

EXPENDITURE OF TOWNSHIP FUNDS. The township trustees are required to spend this money by one of two methods: (1) They may let the work by contract to the lowest responsible bidder, or, (2) They may appoint road superintendents who shall be subject to their directions but who shall oversee the work. This section of the law has been very seriously misconstrued.

(1) When all or any part of the work is let by contract the trustees have supervision of the work to the extent of requiring the contract to be fully and carefully executed, *but they are not eligible to take the contract either collectively or individually.* This system for letting all or any part of the work as may be done under the law is a good one when properly executed. In many townships, however, contracts have been let in such a manner that they have defeated their own purpose. Road contracts should never be let through competitive bids in which the units upon which the bids are made are the day labor of a man and of a man and team. The only object for letting a contract is to accomplish a certain piece of work economically and well and at a certain total cost which is known before the work is begun. The day labor contract is diametrically opposed to each of these. When this method is followed the lowest bids will always be lower than the real market value of efficient labor, whether of man or team. This being true a man who bids lower than these values must furnish second rate labor even to pay expenses. Also this method of letting contracts puts a premium upon slow work and there is no way to determine beforehand what the final cost of any piece of work will be. In letting work by contract the trustees should have an estimate prepared by a competent engineer of the number of yards of earth to be moved, culverts to be constructed, tiling to be done, and all the work necessary to make a finished job. An advertisement for bids should be inserted in the papers for a certain period of time. On the date set all the bids should be opened and the contrart let to the lowest responsible bidder. The contractor whose bid is accepted should be required to furnish bond of sufficient amount to guarantee the faithful performance of the work.

(2) If the trustees decide to have the work done under the supervision of road superintendents, men should be selected for their qualifications along that line. The law as revised by the 31st General Assembly provides that not more than four men may be employed for this work. The best results have been secured so far in townships where one man had direction of the whole work. *Township trustees or other township or county officers are not eligible for this office. "These men and all public officers should at all times stand in an adversary position to the persons to whom the work of construction work is let and under no circumstances should they be in any manner interested therein." Neither should they be hired by the township superintendent to work on the roads, as that puts them in the position of employee, while they are required by this act to supervise the work of the Superintendent and to demand that the money be spent in a competent manner on the roads.* It would be better to have but one superintendent for the township and let him have if necessary a number of assistants in other parts to take care of minor repairs. The more the work is concentrated under one man, the more economical will be the administration of the road funds, provided a competent man is selected. The funds of the average township amounts to about $1,200 per year and if this amount is divided among three or four superintendents, the permanent results accomplished by each will be a minimum. This method is little better than the old labor system. In some cases, as where a river divides a township or some similar local condition is imposed, it is necessary to have two superintendents but not more. As has been said, the trustee is not eligible to become the Superintendent of Roads, although this is being done in a number of cases. In one case where the township records were examined by the Commission it was found that the three trustees had divided the money equally among themselves but the road work showed very poor management of road funds and practically no good was accomplished with about $1,500 which was spent on the roads during the year. The excuse is given that it is clearly opposed to the law and contrary to public policy for the trustees to elect themselves to office, keep their own time and audit their own bills. If a trustee wishes to become superintendent of roads, he should first resign as trustee.

County Financial Report. Chapter III of the laws of the 29th General Assembly require the auditor to publish each year, during the month of January, the financial report of the county, which the supervisors shall order printed in pamphlet form, and distributed among the tax payers of the county. The law states definitely a large number of itemized accounts which are to be included in this report which do not need to be mention-

ed in detail. The law clearly intends this report to include a record of all the transactions of the county and township officials for the information of the tax payers of the county. Some counties have not begun to issue these reports. In other counties these have been compiled in such a way that they give very little if any information to the tax payer as to the expenditure of the funds raised, and it is questionable if some of them are worthy of distribution as a source of information along this line. Such a report is clearly intended to convey information concerning the kind of work done and the amount accomplished with the different funds, and if it does not do this it fails in its purpose completely. This report should be so given that anyone looking over it will know for what purposes the money was spent. This applies equally well to the bridge fund or to any of the other county funds. A large proportion of these reports do not contain even a mention of the expenditures of the township road fund and the law clearly contemplates that the report of the township trustees should be embodied in such a pamphlet. Neither are the reports of the township trustees always printed in the newspapers under the proceedings of the board of supervisors as the law requires. Often times no report of this fund is made that the public may know in what way the money is being spent. This lack has probably helped to make the trustees more careless in the reports which they hand in, and it is probably true that many of the county auditors do not print some of these reports. They are clearly of no value. In a large number of cases the trustees have not even made a report and it has been found by the Commission to be quite the common thing for a county auditor to have only fifty per cent of the reports from the townships on file in his office. This carelessness is clearly the fault of the auditor as he is responsible for getting these reports from the townships in and requiring them to be correct before he submits them to the board of supervisors for their approval.

SECTION FOUR.

THE STATE HIGHWAY COMMISSION

1. Law Establishing the State Highway Commission. The law establishing the State Highway Commission is known as House File 371. It was passed by the 30th General Assembly and approved April 13, 1904.

An Act to create a highway commission for the State of Iowa, and defiining the duties of same (Additional to chapter four (4) of title thirteen (XIII) of the Code, relating to the state college of agriculture and mechanic arts).
Be it enacted by the General Assembly of the State of Iowa:

SECTION I. *Highway Commission—Duties.* That the Iowa State College of Agriculture and Mechanic Arts, at Ames, shall act as a highway commission for Iowa, whose duties shall be:

1. To devise and adopt plans and systems of highway construction and maintenance, suited to the needs of the different counties of the state, and conduct demonstrations in such highway construction of county supervisors, township trustees, superintendents, students of the college and others.

2. To disseminate information and instruction to county supervisars, and other highway officers who make request, to answer inquiries and advise such supervisors and officers on questions pertaining to highway improvements, construction and maintenance, and when the board of supervisors of a county adjudge that the public necessity requires a public demonstration of improved highways construction or maintenance in said county, and so request and agree to furnish necessary tools, help and motor power for same, the commission shall furnish as soon as practicable thereafter, a trained and competent highway builder for such demonstration free to the county.

3. To formulate reasonable conditions and regulations for public demonstration, and to promulgaate advisory rules and regulations for the repair and maintenance of highways.

4. To keep a record of all the important operations of the highway commission, and report same to the governor at the close of each fiscal year.

SECTION II. *In Effect.* This act, being deemed of immediate importance, shall take effect and be in force on and after its publication in the Register and Leader and Des Moines Capital, newspaperspublished at Des Moines, Iowa.

Approved April 13, A. D. 1904.

Funds for carrying out this bill become available July 1st, 1904, and the provisions of the law followed in the work of the commission.

The appropriation for the first two years was $7,000.00 but the last General Assembly increased this to an annual appropriation of $5,000.00. This is the smallest amount appropriated by any state that has established a highway commission.

2. Organization of the Commission In compliance with the above act the Highway Commission was organized by the assignment of the work to the Divisions of Engineering and of Agriculture and the Deans of these two divisions became the Directors of the Commission.

The immediate carrying out of the work has been under the direction of Thos. H. MacDonald. Mr. J. B. Davidson has charge of the road machines. Much of the work of surveying drafting, care of machines, etc., is done by students of the College. The Commission is fortunate in this respect as there are a large number of men who are skilled along these lines who are available during the summer months when most of the road work is done.

3. Work of the Commission. In following the details of the law the work of the Commission has been divided into four main classes.

The Road School.
Plans and Publications.
Demonstration Work.
Experimental Work.

THE ROAD SCHOOL was held in 1905, June 12th to 18th, and will be held this year August 13th to 19th. The date was placed later in the summer to give people a better chance to attend. The results were very encouraging last year and plans have been made for a much better and broader scope of lectures and demonstration work this year. The aim of this school an dof the work that is given is to train men to be practicable and up to date road builders. There is no necessity to take up a discussion in detail as the whole question of road improvement in the state is one of men rather than money.

PLANS AND PUBLICATIONS. This revision of the manual is the fourth bulletin of the Commission as follows: "Good Roads Problem in Iowa," "1905 Edition of the Manual," "First Annual Report," and "1906 Revision of the Manual." A reprint will also be taken from this manual of Section Six on "The Drag Method of Road Maintenance." The editions of the first two bulletins are now exhausted but copies of the three later will be sent free on request.

The specifications and standard plans shown herein are types of the kind sent out upon application by road officers.

DEMONSTRATION WORK. The Commission has sent as much as possible experienced men to help the different counties and townships start with the work of permanent bridge and culvert work. This work has been done without charge, except for the actual living expenses in the county. Counties or townships desiring such work done should write to the Commission as soon as possible as the requests for such work are continually increasing.

EXPERIMENTAL WORK. The experimental and investigating work of the Commission has been along several lines, one of the chief being the road census preliminary results of which are given in Section One.

ROAD LABORATORY. The Commission has access to the materials and testing machines of the Engineering Division of the College and is planning tests of road materials and concrete plain and reinforced in conjunction with this Division.

The machines owned by the Commission consist of the following: a 4 cylinder Deval Abrasion and Impact Machine, a I. I. C. briquette machine and a Page-Johnson Cementation machine. In addition to these a 100,000 pound beam testing machine will be added immediately for the culvert experiments.

ROAD MATERIAL TESTS. The following tables show tests of road materials made upon samples of crushed stone and gravel sent in by various counties in the state.

RESULTS OF ABRASIONS AND CEMENTATION TESTS.

GRAVEL.

		Coefficient of wear	Per cent of wear	Cementation value
Greene Co.	No. 2	6.85	5.905	4.00
	" 3	15.62	2.50	6.00
	" 4	11.00	3.64	13.00
	" 5	6.25	6.45	4.50
Story Co.	" 1	10.02	4.55	17.00
	" 2	3.42	10.30	9.20
	" 3	10.10	3.96	4.25
Emmet Co.	" 4	5.77	6.98	21.00
	" 5	10.60	3.77	8.75
	" 6	4.96	8.09	16.75
Carroll Co.	" 2	8.80	4.45	7.80
	" 4	12.25	3.41	6.20
Buchanan Co.	" 1	6.60	6.57	14.00
	" 2	6.25	6.41	9.00
	" 3	26.90	1.60	0.00

STONE.

Name	Kind	Coefficient of wear	Per cent. of wear	Cementation value
Ellsworth	Limestone	9.55	4.18	105.5
Peru	"	2.95	13.54	13.0
Centerville	"	5.85	6.81	7.0
Le Claire	"	6.55	6.09	13.4
Waverly	"	8.80	4.54	10.0
Marshalltown	"	7.78	5.72	23.0

TESTS OF IOWA GRAVEL

MECHANICAL ANALYSIS.

Gravel	No.	Pebbles per cent	Sand per cent
Greene Co.	1	80.8	19.2
	2	46.3	53.7
	3	34.3	65.7
	4	43.0	57.0
	5	57.1	42.9
Carroll Co.	1	33.8	66.2
Story Co.	1	58.7	41.3
	2	47.3	52.7
	3	42.4	57.6
Emmet Co.	1	65.2	34.8
	2	30.4	69.6
	3	51.7	48.3

COMPRESSIVE STRENGTH OF GRAVEL CONCRETE

Gravel		7 Days		28 Days		3 Months	
		1-6	1-3-6	1-6	1-3-6	1-6	1-3-6
		lbs. sq in	lbs. sq in	lbs. sq in	lbs. sq in	lbs. sq in	lbs. sq in
Greene Co.	No. 1	625	540	1030	825	834	725
	" 2	774	531	1490	1008	1505	1158
	" 3	636	529	1170	773	1043	....
	" 4	475	486	865	817	752	943
	" 5	557	765	1195	1310	1280	1328
Carroll Co.	" 1	504	520	1137	974	1090	1082
Story Co.	" 1	720	694	1485	1585	1383	1639
	" 2	735	551	1370	1450	1339	1422
	" 3	531	637	1275	1130	....	....
Emmet Co.	" 1	940	735	1950	1436	....	....
	" 2	389	485	744	1018	....	....
	" 3	465	476	873	779	....	....
Average.		612.6	578.25	1215.3	1092.1	1153.25	1185.42

Average percent of water to the 1-6 is 14.13.
Average percent of water to the 1-3-6 is 11.71.

SECTION FIVE.

ROAD CONSTRUCTION IN IOWA.

As has been stated there are approximately 100,000 miles of public roads in the state and of this number not more than 1,000 miles at the outside have received a surfacing of gravel or broken stone. These figures show the necessity of adopting the best and most economical methods of earth road construction and maintenance. Even for counties which are using considerable gravel or other surfacing material the earth road is first in importance for it is money wasted to improve a poorly built earth road with any surfacing material.

There are a certain number of general considerations which apply to all roads and which should receive particular attention in this connection.

1. ROAD LOCATION.

Practically all of our public roads are laid out on the section lines and the new roads that are opened from time to time are being located in the same way. As the state becomes more thickly settled the call is constantly for new roads but there is very seldom any thought of departing from the section lines. As a result of this custom, the road system of the state has been developed without any regard to the engineering principles of economy and efficiency. In the parts of the state covered by the Iowan and Wisconsin drift sheets this condition is not so important. The drainage lines are not as yet so well defined and the grades for the most part are not heavy.

In the large area, however, covered by the Kansan drift this phase of the question is an important one. The drainage system as shown on the map is well developed. The whole section has been cut by the water and other agencies into such a series of ridges and valleys that an exclusive system of section line location for the roads causes impracticable grades and enormous expense for moving earth. The topography here is such that a road must be curved either in plan or profile. The section line location prohibits the first and thus necessitates the second, which is much the worse.

The heaviest grade on any road will limit the size of loads that can be hauled over it and for economy of transportation the maximum grade should be kept as low as possible.

In addition to economy of transportation, the first cost of construction can often be materially lowered and the annual cost of maintenance be decreased by building around a hill rather than

over it, or by buying a new right of way around a series of hills. Often times the total cost of entirely relocating a road will be less than trying to make even a faint start at a good road on the section line.

The accompanying cut, Figure (7) was taken to illustrate this condition. The section line road which climbs one steep hill after another, parallels a valley which may be seen only a short

Fig. 7—Section Line Location
This road parallels a valley which is proper location for the road.

distance to the left, in which the road could have avoided all the hills shown. In one place on this road a new right of way was purchased around a hill and an almost level road made at a cost of only $70.00. On one alone of the near-by hills the grading done cost about $1,000.00.

A railroad running out from the same town followed the valley almost parallel to the wagon road, showing what a competent engineer would do with the highway location.

2. ROAD DRAINAGE.

The most important of all considerations in the construction of earth roads in this state is efficient drainage. There are two phases of the general subject to consider, which may be classed as district drainage and local drainage.

District Drainage—Where Needed. In the north central part of the state, in the area covered by the Wisconsin drift sheet, the drainage is new and undeveloped. Here the outlets in many places cannot be found for the side ditches or tile drains. Figure No. (8) illustrates one of the typical ponds of this section through

which several costly but unsuccessful attempts have been made to construct a road. In these localities, district drainage must first be provided. For this work the law requires that a competent engineer be employed to make the estimates and plans for the proposed improvements.

Proceedings by the Road Officers to Establish District Drainage. Where the abutting property owners will not institute the necessary proceedings to establish the drainage district to drain a highway, the township trustees shall file a petition with the county auditor describing the highway to be drained and the

Fig. 8—Typical Pond of Northern Iowa

lands to be crossed in the construction of such a drain. The payment of the cost of the drain if constructed after the engineer's report is filed, is made out of the township road fund.

If, however, a drainage district has been established by the petition of land owners, the trustees are required to pay the actual cost of constructing the drain across the road out of the township road fund and the board of supervisors is required to pay for any bridges across the same out of the county bridge fund.

The highways lying within a drainage district will always be benefited to an extent by the establishment of such a drain and should be assessed by the commissioners.

Assessment of Public Highways. Public highways within a drainage district are benefited by the construction of ditches and hence may be assessed for a portion of their cost and maintenance. The assessment, however, must be made upon a different

basis from that of farm lands. The title to land occupied by highways is in the abutting owners, who are assessed for the improvements as "farm land." The public highways do not derive their benefit from added productiveness of the soil as do farm lands, but from their improvements as roads for travel. The public using such roads receives a benefit by reason of their improvement. An assessment for road benefits when made, must be paid by all property owners in township and county upon the basis of assessed valuation of property and is not restricted to property within the drainage district. The Iowa law charges the cost of constructing a ditch across a right of way and of building necessary bridges to the township road fund and the county bridge fund respectively.

The assessment against highways within the district should be a percentage of the entire cost of the ditch improvement on the theory that there is a ratio of value existing between highways and the property they serve. The greater value of the property served by the road, the greater the value of a good road to it. The drainage ditches of a district may in some cases make possible improvements of very great value to the highways: in others they may affect them but little.

The percentage of cost of district drainage which should be assessed against the highways should not often be less than two per cent nor more than eight per cent. From this amount should be deducted the cost of construction across rights of way in the several cases, since in Iowa the law charges this expense to the road fund.*

Co-operation of Road Officers and Land Owners. Without recourse to the law the road officers, both township and county, can make the best investment of the road funds which are spent for drainage by co-operating with the land owners. In nearly all cases where road drainage is needed, the land on one or both sides would be materially benefited and most property owners should be willing to meet their share of the expense necessary to secure such drainage, and these property owners should have the co-operation of the road officers.

Open Ditches. In drainage ditches, careful attention should be given to the grade. They should be deep enough to afford outlets for the tile drains necessary. The bottoms should be wide enough to avoid stoppage, and the sides should be sloped at least 1 to 1.

Where a considerable amount of drainage is undertaken by the township or county, careful plans and specifications should be prepared by a competent drainage engineer.

---

*Extract from talk by Mr. C. G. Elliott, given before the Iowa State Drainage Convention at Ames, January 13 and 14, 1905.

SIZES AND COST OF OPEN DITCHES. The cost of open drainage ditches is estimated by the cubic yard.

To calculate the number of cubic yards per foot of length of ditch multiply the average width by the average depth and divide by 27. Thus a 7 ft. x 12 ft. ditch contains $\frac{7 \times 12}{27} =$ 3 1-9 cubic yds. per foot length.

The cost per cubic yard in Iowa varies from 7c to 18c, depending on the size of the job, the character of the soil, and other local conditions, including the certainty of the contractor getting his money promptly. The larger the work the less is the cost per cubic yard.

The tables for open ditches are calculated by the well known Kutter's formula, using a "coefficient of roughness" equal to 4.030. The coefficient of roughness is the value recommended by Kutter for channels in moderately good condition having stones and weeds occasionally, and agrees with actual guagings of drainage channels made at the Iowa State College. For ditches in first-class condition, the number of acres may be increased about 25 per cent. The tables have been calculated for ditches having sides with slopes of one foot horizontal to one foot vertical but are approximately correct for other slopes.

The capacity of the ditches has been made as recommended by C. G. Elliott, U. S. Agricultural Department drainage expert, as follows, the ditches to run not more than 8-10 full for the capacities mentioned:

Above the heavy upper line, (table 2) 3-4 in. depth of water per 24 hours.

Between the heavy lines 1-2 in. depth of water per 24 hours.

Below the lower heavy line 1-4 in. depth of water per 24 hours.

Local conditions may vary the size needed, and it is necessary to consult a drainage engineer in each case.

TABLE 2. NUMBER OF ACRES DRAINED BY OPEN DITCHES

Depth of Water 3 feet. Depth of Ditch at least 4 feet.

GRADES		AVERAGE WIDTH OF WATER							
Per Cent	Feet per Mile	4 Feet	6 Feet	8 Feet	10 Feet	15 Feet	20 Feet	30 Feet	50 Feet
0.02	1.0			725	970	1570	2240	5300	18400
0.04	2.1	400	690	1000	1360	2250	4700	7470	26100
0.06	3.2	492	850	1260	1690	2770	5770	18400	31500
0.08	4.2	572	980	1460	1950	4820	6670	21460	37400
0.10	5.3	636	1100	1630	2180	5360	7440	23700	41400
0.15	7.8	791	1330	2010	2670	6600	19000	30200	52100
0.20	10.6	905	1560	2310	4720	7870	21800	35000	60300
0.25	13.2	1020	1740	2660	5300	17500	24600	39000	67700
0.30	15.8	1100	1970	2900	5850	19400	26800	42700	74000
0.40	21.1	1300	2.90	5050	6740	22200	30800	49400	85700
0.50	26.4	1475	2550	5620	7500	24800	34800	55300	95200
0.60	31.7	1600	2790	6230	16500	27200	37700	60400	
0.70	37.0	1720	3010	6650	17800	29400	41200		
0.80	42.2	1850	4850	7170	19100				
0.90	47.5	1955	5140	7550	20100				
1.00	52.8	2050	5400	7980					

Depth of Water 7 feet. Depth of Ditch at least 9 feet

GRADES		AVERAGE WIDTH OF WATER					
Per Cent	Feet per Mile	8 Feet	10 Feet	15 Feet	20 Feet	30 Feet	50 Feet
0.02	1.0	2300	4700	16600	28000	48000	88500
0.04	2.1	4850	6740	23400	35400	58000	106000
0.06	3.2	5920	17000	29600	43400	72000	129000
0.08	4.2	6940	19100	34200	50000	83000	150000
0.10	5.3	7720	21800	38400	56000	92600	167000
0.15	7.8	19400	27000	47200	68500	112000	202000
0.20	10.6	22400	31300	54200	78700	130000	235000
0.25	13.2	25000	34800	60500	88000	146000	
0.30	15.8	27400	38200	66200	96500		
0.40	21.1	31700	44100				
0.50	26.4	35400					

Local Drainage. The discussion on district drainage touched upon the general points in securing outlets in an undrained area, but there are no sections of the state where what may be termed local drainage is not necessary in the construction of earth, gravel or macadam roads. Sand roads are the only ones benefited by an excess of moisture.

In local drainage there are first, the ground water, and second, the surface water to remove.

To provide for these two kinds of water a well built road must have *First, subdrainage; second, a crown, and third, side-ditches.*

SUBDRAINAGE. In all places where the ground water level or point of saturation rises within eighteen inches to two feet of the surface for a considerable part of the year, the foundation will be greatly improved by tile drainage. Wherever bog springs, seeps or springs occur along the right of way, tile drainage is *essential* to road improvement.

In places where a grade is to be constructed over a low stretch that becomes marshy at certain times of the year, tile should first be laid to protect the foundation; also a line of tile along the road will greatly lessen the injury to the road foundation "when the frost is going out." This is a self-evident fact as it removes the ground water rising from capillary action or flowing from the hills to the lower places and provides an outlet for the same. The action of the frost would be without effect if the moisture could be kept away and this is secured by careful subdrainage.

There is some discussion as to the proper position for locating the tile, but it has been well established that the proper place for a line of tile is under one of the side ditches. The minimum depth should be three feet but four feet is much to be preferred if a sufficient outlet can be secured. In some places where the water seeps to the surface or there are springs it may be necessary to lay a line of tile on each side of the road. In general, however, one line will be sufficient.

Tile Drains. To aid in proportioning the sizes of tile, table No. 3 has been included; also a table of prices based on the local prices at Ames is given, but before using this for any particular places, the local markets should be consulted. To get the full benefit of tile drainage the tile should be carefully proportioned to the amount of water to be removed. The tables are by the Civil Engineering Department of the Iowa State College.

Ordinary 4 inch tile should be used, with 5 inch or 6 inch sizes for very long lines.

In laying the tile it is absolutely necessary that certain points be emphasized and carefully observed. The tile should be deep

enough to be below the frost line if possible. It should be of ample size and the grade should be continuous to the outlet. The outlet should be carefully protected by a bulkhead of concrete or brick, and covered with a grating to prevent the entrance of small animals.

Table No. 3 is computed from the form of Poncelet's formula recommended for the use with tile drains by C. G. Elliott, drainage expert to the U. S. Agricultural Department, Washington, D. C., who recommends the above sizes to drain ground only. If surface water is also to be removed as in the case of ponds without other outlets, the tiles will drain safely only one-half to one-third the number of acres given in the table.

When part of the land in the water shed is rolling, not requiring tiling, count only one-fifth to one-third of such rolling land, in addition to all of the low, flat land, in getting the size of tiles to remove ground water only.

Cost of Tile Drains. The following data show the average cost of tile drains during 1904 in the vicinity of the college. Local markets should be consulted before applying them elsewhere:

The cost of hauling given above is on the basis of $1.25 per ton, or $2.50 per day for a man and team, making two trips.

The prices for digging and laying given above include board furnished by the ditcher. If the farmer furnishes board deduct about 20 per cent. The prices for digging and laying are for average ground, except those in the last column, and should be increased for quicksand or very wet soils.

TABLE 3. NUMBER OF ACRES DRAINED BY TILES REMOVING ¼-INCH DEPTH OF WATER IN 24 HRS.

GRADES		DIAMETERS OF TILE DRAINS											GRADES	
Per Cent	Inches Per Rod	3 Inch	4 Inch	6 Inch	8 Inch	10 Inch	12 Inch	15 Inch	18 Inch	20 Inch	22 Inch	24 Inch	Inches Per Rod	Per Cent
0.03	1-16					37	59	109	159	205	254	319	1-16	0.03
0.05	3-32		5	13	28	49	75	131	219	264	332	411	3-32	0.05
0.10	3-16	4	7	19	40	69	109	186	289	373	471	5-2	3-16	0.10
0.15	9-32	4	9	24	49	85	132	232	355	458	577	713	9-32	0.15
0.25	3-8	4	10	28	56	97	153	264	410	529	667	823	3-8	0.20
0.30	9-16	6	12	33	69	119	188	322	502	648	808	1008	9-16	0.30
0.40	13-16	7	14	39	79	138	216	371	580	748	942	1165	13-16	0.40
0.50	1	8	16	44	89	154	246	416	648	838	1050	1300	1	0.50
0.60	1 3-16	9	17	48	97	169	266	457	710	911	1154	1422	1 3-16	0.60
0.70	1 3-8	10	19	50	105	182	287	488	768	988	1242	1549	1 3-8	0.70
0.80	1 9-16	10	20	55	114	195	307	526	822	1059	1332	1645	1 9-16	0.80
0.90	1 3-4	10	21	59	119	207	326	558	872	1123	1414	1747	1 3-4	0.90
1.00	2	11	22	62	126	218	343	589	917	1176	1495	1838	2	1.00
1.50	3	13	28	75	153	267	419	722	1123	1450	1824	2256	3	1.50
2.00	4	15	31	88	178	309	485	832	1297	1676	2110	2594	4	2.00
3.00	5 15-16	19	39	107	216	377	593	1020	1589	1957	2592		5 15-16	3.00
4.00	7 15-16	22	45	123	253	437	683	1176					7 15-16	4.00
5.00	9 7-8	25	50	138	280	486	765						9 7-8	5.00
7.50	14 7-8	30	61	169	344								14 7-8	7.50
10.00	19 13-16	35	71	195									19 13-16	10.00

To all estimates it is wise to add 5 per cent to 10 per cent for contingencies and engineering.

TABLE 4. COST OF TILE DRAINS

Size of Tile	Price Per 1000 Feet	Weight Per Foot	Cost of Hauling 1000 Feet 5 Miles	Cost of Digging and Laying Per Rod			Refilling Per Rod	Digging, Laying and Refilling (County Work, Wet Soil) Per Rod Per Foot Deep
				3 Feet Deep or Less	Add per Foot for Additional Depth Over 3 Feet			
					3-6 Ft.	Over 6 Ft.		
3 in.	$ 16.00	5	$ 3.12	$0.35	$0.15	$0.30	2c-5c	
4 in.	22.00	8	5.00	0.35	0.15	0.30	2c-5c	
5 in.	30.00	10	6.25	0.35	0.15	0.30	2c-5c	
6 in.	40.00	12	7.50	0.35	0.15	0.30	2c-5c	
7 in.	50.00	15	9.37	0.35	0.20	0.35	2c-5c	
8 in.	60.00	20	12.50	0.40	0.20	0.35	2c-5c	25c
10 in.	95.00	30	18.75	0.45	0.20	0.35	2c-5c	25c
12 in.	120.00	40	25.00	0.50	0.20	0.35	2c-5c	30c
15 in.	250.00	50	31.25					35c
18 in.	400.00	80	50.00					
20 in.	600.00	100	62.50					
24 in.	800.00	125	78.12					

Contract and Specifications for Tile Drains. Many disputes between property owners or road officers and tile contractors would be prevented, and better work could be required and secured, if a definite written contract were made out and signed in the beginning, containing as a part thereof a complete set of printed specifications. On this account it is strongly recommended that in each case the following form of contract and specifications, modified from those recommended by Mr. C. G. Elliott, should be filled out and signed by both parties.

The engineer should be called in during construction, and on completion of the work, to see that the contract and specifications, together with the map and profiles, are strictly complied with.

Specimen contracts and a complete set of specifications are included in Section Nine on "Specifications and Contracts."

Side Ditches. The second system of drainage necessary for a well constructed road is side ditches. In road construction as it is quite generally practiced at this time in the state, the side ditches are carried at the same depth over the hills and through the lower places as are the road grades. In many places the dirt is much easier to move on the tops of the hills than in the lower places, with the result that the best grades are built on top of the hills. This is all wrong. The side ditches should be cut out and the dirt carried to the lower places, and unless the

hill is to be materially lowered, the top surface, which has become compacted by the travel, should be left as it is.

The first requirement of properly constructed side ditches is a continuous grade to an outlet, and for this a *road contractor or superintendent should understand the use of a level and be able to lay out and plan the grade.*

The second requirement is that the ditches should be wide and comparatively shallow except where it is absolutely necessary to make a cut through the rise. This is necessary from the point of economy of first cost and of maintenance; also to lessen the danger to travelers, of a deep, narrow ditch. The water should not be carried further than is necessary in the side ditches as it increases the washing and also makes deep cuts necessary near the outlet to furnish the continuous grade. Where the road has considerable grade, careful attention should be given to prevent washing or undermining of the roadway, the gutter should be paved with stone or brick. It is frequently best in constructing side ditches, to provide for freshets by making the banks low on the outside at certain points which will allow an excess of water to escape without damage to the roadbed, as would be the case if a large quantity of water was carried a considerable distance in the side ditches.

The Crown. For the main traveled portion of the road, a crown of one inch to the foot is recommended with considerably steeper slopes outside of this to the side ditches. (See Fig 9). The crown should be about three feet above the side ditches, that can be changed to meet the requirements and can be readily adjusted to different road grades. For a steep road grade the crown should be increased to throw the water to the side rather than allow it to run for a considerable distance on the road. On ordinary grades if a crown of one inch to the foot is maintained it will prove sufficient for proper drainage to the side ditches. On an 18 foot traveled way the rise at the center would be nine inches.

3. CONSTRUCTION OF AN EARTH ROAD.

In the construction of an earth road the first important consideration, as has been stated, is securing adequate drainage. This has been considered fully in the preceding article.

Cross Section. The accompanying figure, No. 9 , is given as the preliminary cross section of an earth road which is recommended by the Commission for use on the main traveled or first class roads. This has been designed after a careful study of the best types of earth roads that are found in the state at this time. The traveled way is eighteen feet wide. This is ample room to accommodate all the ordinary traffic found on even the most traveled country roads, but is not too wide to be easily

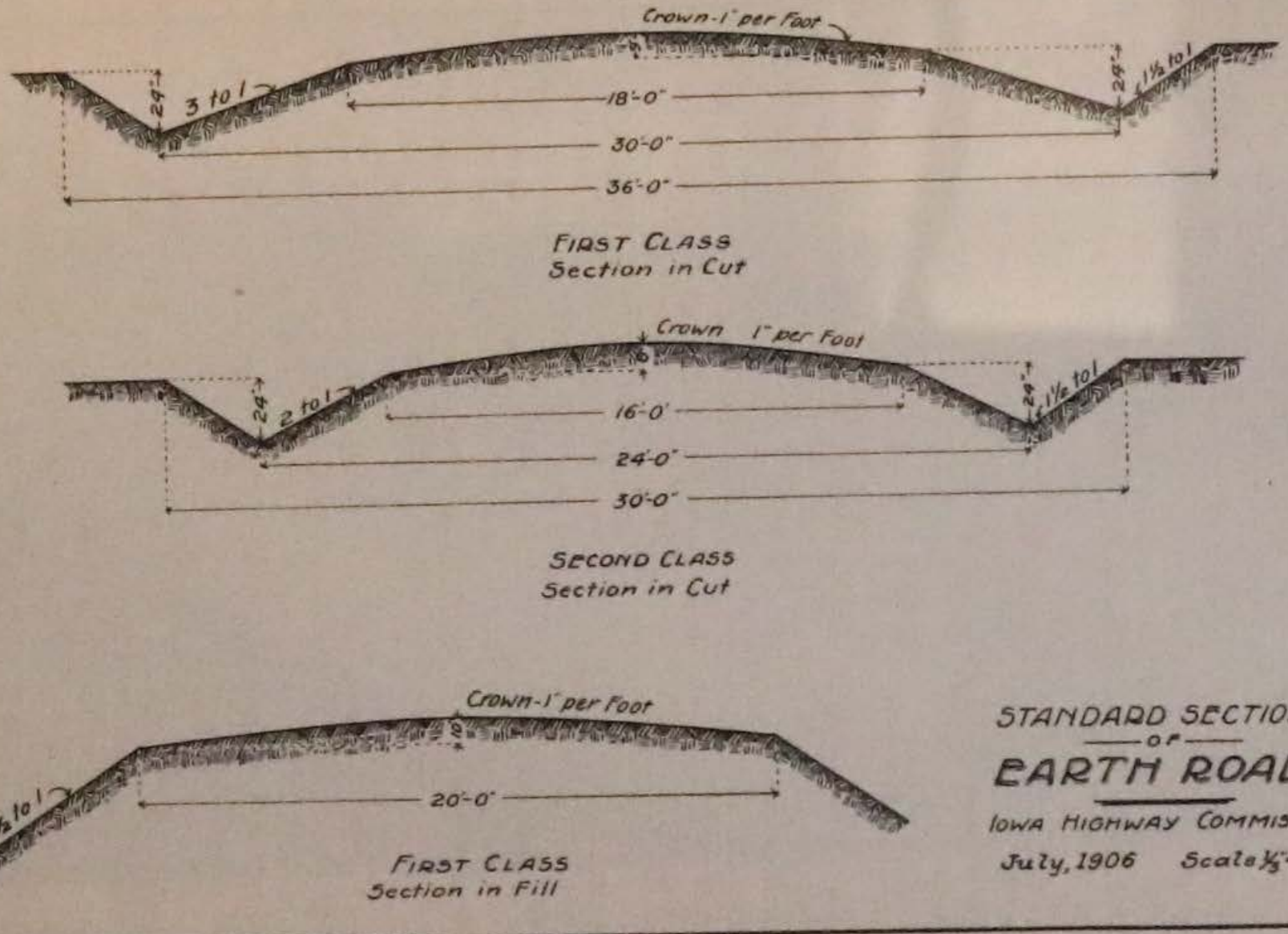

Crown-1" per Foot
24'-
3 to 1
18'-0"
30'-0"
36'-0"
1½ to 1
24'-
FIRST CLASS
Section in Cut
Crown 1" per Foot
24'-
2 to 1
16'-0"
24'-0"
30'-0"
1½ to 1
24'-
SECOND CLASS
Section in Cut
Crown-1" per Foot
1½ to 1
20'-0"
FIRST CLASS
Section in Fill
STANDARD SECTIONS
—OF—
EARTH ROADS
IOWA HIGHWAY COMMISSION
July, 1906 Scale ½"-1'-0"

Fig. No. 9

maintained in proper condition. The side ditches are wide and sufficiently deep, but the slope to the bottom is so gradual that the entire width of the graded portion could be used if necessary in turning out to pass another team, and a wagon could be driven to the bottom of the ditch with no danger of overturning. The advantages of such construction are very apparent. The outside of the banks are sloped away at a 1 1-2 horizontal to 1 vertical slope. This is the angle of repose or angle at which earth will stand without caving, and the bank is more easily maintained in this shape. A rounding or parabolic contour with the shoulders kept full is to be strongly recommended. This shape allows the travel to be distributed over a considerable portion of the road, keeping down the wear. The tendency of earth roads is to wear quite rapidly, but the parabolic form is less easily hollowed out than if the road is first constructed with two plane surfaces meeting at a point in the center. This last construction is the one quite frequently met with in the state. The road superintendent begins at the side ditch and makes a continuous slope from the bottom of each side ditch to the center of the road, leaving there, in most cases, a pile of sod and clods that is never touched by the travel if possible. This shape very soon wears hollow on each side and the water cannot escape to the side ditches but runs or stands in the traveled way.

The cross section for the embankment has the same width of traveled way as the section in the cut with the side slopes carried down to a slope of 1 1-2 to 1. This slope is recommended for use as it is the angle of repose for ordinary earth work.

For roads of the second class the cross section as shown is recommended. This gives a traveled way of sixteen feet which will carry the traffic of the ordinary roads which lead away from the main traveled ways.

These sections are for use on the roads which are not constructed with the elevating grader. When this machine is used it is necessary to make the side ditches wider and farther apart. These are ordinarily used in flat districts where the grades are necessarily three to five feet high.

Figure No. 10 shows a well built earth road constructed during the Road School at Ames in June, 1905, with a reversible grader.

Clearing. In some localities there is a considerable growth of timber or brush along the right of way; in other localities "niggerheads" or boulders are scattered quite thickly over the surface. In such places it will be necessary, before commencing the construction, to clear the location. An earth road through a wooded district may be cleared of stumps and quite large trees at a minimum cost, by the use of dynamite.

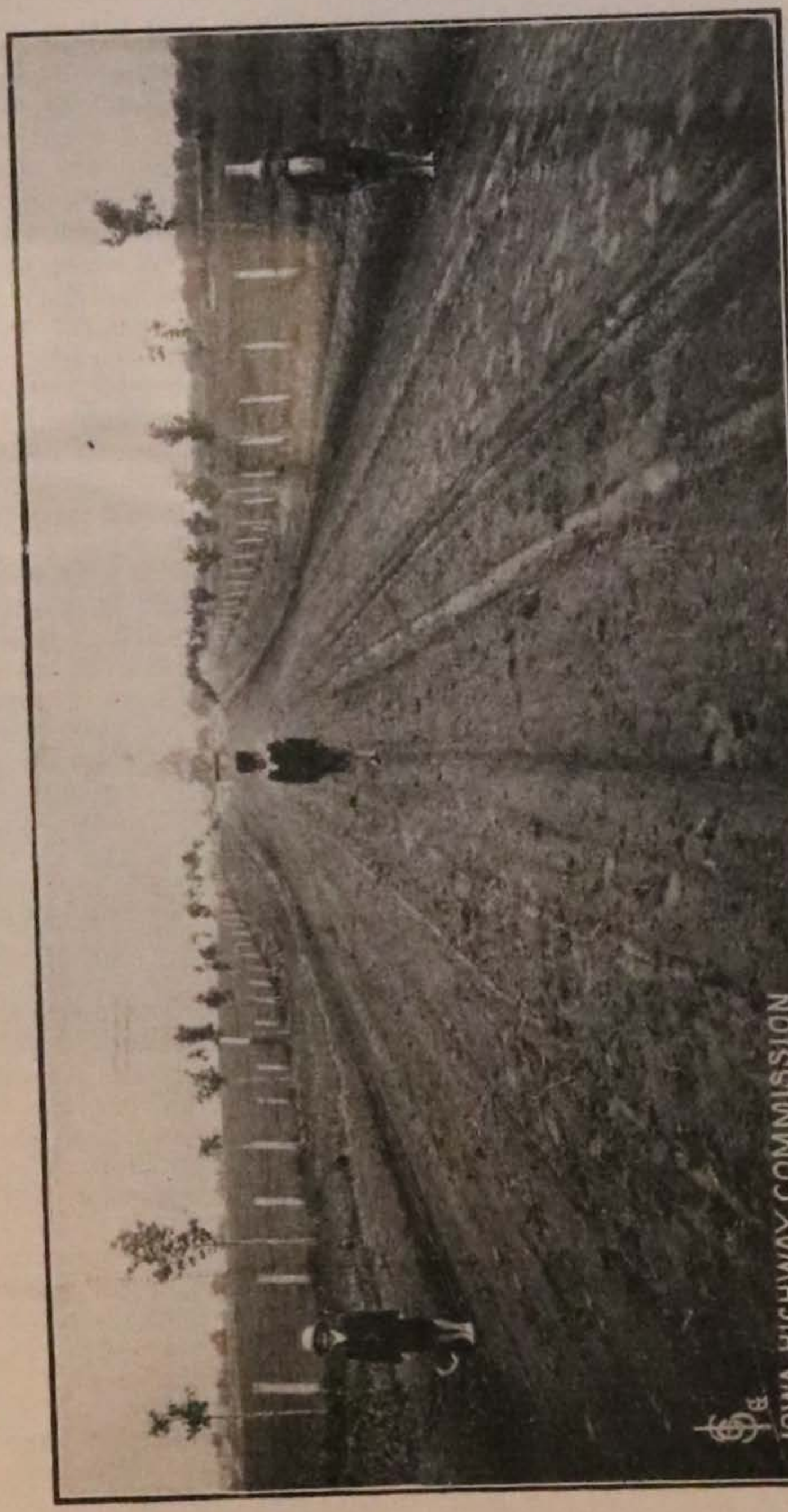


Fig. 10—A Well Built Earth Road.

While it is necessary to place this explosive in the hands of a competent person and to maintain every precaution to guard against accidents, it can be very highly recommended for this purpose.

Selection of Materials. Where grades have been put up by using the so-called "gumbo" of the flat portions of the state, they have quite generally proved unsatisfactory. When saturated with water this material seems to "melt" away and a grade soon disappears unless the location is first well drained. In a plastic state, it rolls so badly that the wheels frequently cannot be turned and when dried it bakes so hard it cannot be worked. These last conditions can be considerably helped by building the top of the "hill dirt." One serious objection to the use of the side dirt in these low stretches is the lowering of the side ditches below the outlet. Vegetable and loamy soil should also be avoided as much as possible.

In many cuts pockets of quick-sand occur and material from these should be carefully avoided. All sod should be plowed or cut by the road machine in as thin layers as possible to facilitate handling and it should always be placed in the bottom of the grades. There is no excuse for leaving a line of heavy chunks of sod in a road. If plowed or cut thin, sod can be considerably broken up by the handling and it will also be compacted by the horses' hoofs and the passage of the wheels over it in building the embankment.

Cost of Earthwork. Without going into details as to the amount that earthwork ought to cost, the following figures are given as the prices at which earthwork has been let by contract in a few counties in Iowa.

Carroll County. The work of grading the roads complete has been let in one supervisor's district in this county at 70c per rod. This includes all work that can be done with a road machine but does not include any wheel or slip scraper work.

Calhoun County. One contractor in this county gives the following prices at which he has been taking contracts:

Elevating Grader Work—Delivery direct to embankment—4 1-2c to 6c per cubic yard.

Wheel Scraper Work—7c to 12c for hauls up to 200-300 feet, and 1c per yard of overhaul, that is, 1c for a cubic yard hauled 100 feet over the free haul limit.

Where the haul is long the elevating grader is used to load dump wagons and the price depends on the length of the haul.

Kossuth County. Slip and wheel scraper work 7c to 15c per cubic yard.

O'Brien County. By using the elevating grader drawn by traction engine to load the wagons, earth was hauled about one-half mile at a cost approximating 10 cts. per cubic yard.

Dallas County. This county owns a regular grading outfit under direction of a county superintendent of roads. An elevating grader is used on the level streets and the cuts made with the wheelers. The cost averages about three hundred dollars per mile.

These are only a few examples of prices but they serve to show the economy of letting the work by contract, provided the drawing up of the contract and the measurement of the earthwork is handled by a competent man or of putting all the work under direction of a competent superintendent.

Fig. 11—An Efficient Well Trained Team for Road Building

Whether the work is let by contract or not, the number of cubic yards should be measured in every case, and the cost to the public per cubic yard ascertained. It is best to have this done by a surveyor. For the lack of this one thing a large part of our road money is being wasted every year, for neither the public nor road officers would tolerate, for a moment, the inefficient methods in use, if they knew the actual cost and waste of money.

4. CONSTRUCTION OF GRAVEL ROADS. For a certain per cent. of our public highways, which will include the main traveled roads, it is the conclusion of the Commission that some

surfacing material such as gravel or broken stone will have to be used and there is no reason why counties should not begin this construction now to the full extent possible by setting aside for it a material percentage of the present road funds.

Material. Gravel is quite liberally distributed in many parts of the Iowan drift sheet and along the terminal borders of the Wisconsin drift area. It is also well distributed along the streams of these areas and also along some of the streams that flow through the Kansan drift area.

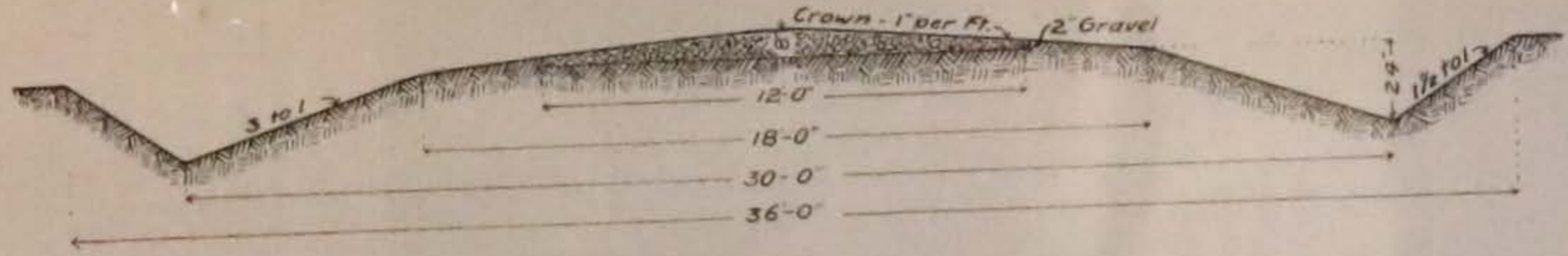
Bank gravel usually contains a certain amount of clay which makes a good binding material, if it is not present in large quantities, and is well distributed through the material. The river or wash gravels do not always contain a sufficient quantity of the binder to pack when placed on the roads and they must either have a certain amount artificially mixed with them, or they will not be thoroughly compacted until a certain amount of soil is

Fig. 12—Gravel Pit near Coon Rapids, Iowa
Note pile of large stones discarded from gravel.

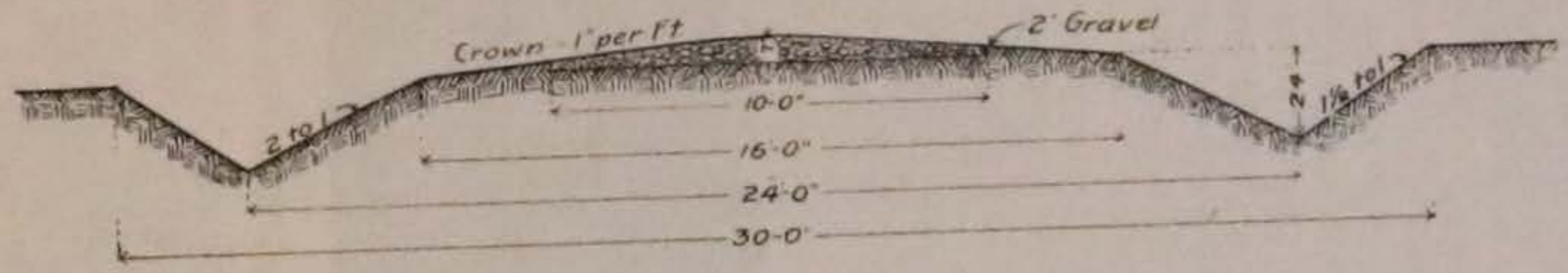
carried on to them by the traffic. The material should be as carefully selected as possible and in hauling a man should be kept constantly at the pit to see that a uniform material is secured and that large stones are pitched out and that sand pockets, or other unsuitable material are carefully avoided.

Figure No. 12 shows a gravel pit near Coon Rapids. The gravel here contains a considerable percentage of stones too large to be used on the road. These may be seen in the foreground.

The cost of the material is in the neighborhood of $.30 to



FIRST CLASS
Section in Cut



SECOND CLASS
Section in Cut

STANDARD SECTIONS
— or —
GRAVEL ROADS
IOWA HIGHWAY COMMISSION
July 1906 Scale ⅜"=1'-0"

Fig. 13

$.35 per cubic yard delivered on the road, if the haul is not too great and at this rate, after roads have been graded to the proper cross section, graveling can be done for about $300 a mile. In other sections where material is not available it can be shipped by rail for considerable distances and used on the road without making the cost run too high, providing favorable freight rates can be secured.

Cross Section. There is some difference of opinion and practice as to the proper way of placing the material on the road. A cross section of a gravel road is given in the accompanying Figure 13, which is recommended by the Commission. This cross section can be secured, after the earth is graded as shown, by placing one load of the material to each nine feet, or spreading with a grader to a width of about 10 feet,

Fig. 14—A Well Built Gravel Road in Greene County

making the outside edge about 2 inches in thickness. After this layer is packed by the traffic a second layer should be added in the same manner as the first. It has been shown by results that this method will give excellent results, although some counties practice putting on two loads to each nine feet at the same time, dumping one on top of the other, while other localities dump two loads side by side. The gravel that has considerable binding material in it, so that it packs easily, can be spread more than one that contains little of this binder. With the first of these the traffic compacts it before there is any considerable waste, while if a gravel with little binding material in it is dumped on

the road and spread, it wastes to the sides under the action of the traffic. About 15 per cent. of binding material seems to be the proper amount to use.

Gravels can be sent to the road materials' laboratory of the Iowa Highway Commission, Ames, Iowa, where they will be tested free—the binding materials determined and advice given

Before attempting the construction of a gravel road careful attention must be given to the proper grade and drainage as these are essential. The more money invested in the surface material the better should be the sub-grade. A country road in Carroll county has been graveled several times but each time the gravel has disappeared owing to imperfect drainage. The gravel roads are very efficient during all the year if kept in shape by continuous maintenance such as the smoothing of the roads with the King drag or similar implement and by the addition of new material when the road "wears out" in places.

Figure 14 is of a well constructed gravel road in Green county and Figure 30 shows effect of maintenance with King drag.

5. MACADAM ROADS. There is no reason why the construction of macadam or broken stone roads should not begin at once in many counties. This does not mean the indiscriminate or haphazard way of building a stretch here and there that has characterized so much of this work. Rather, it means a careful, systematic selection of the roads to be improved, which will be those radiating out from the business centers and which have the most traffic over them. By building short stretches each year only a short time would elapse before a county could have a system of main travelled roads that could be used at all times of the year. Expert advice can be obtained free from the Iowa Highway Commission, in planning and constructing such roads.

The Material. A considerable part of the eastern part of the state is underlain by limestone which outcrops at the surface in many places. Many stone crushing plants are already operating, a partial list of which is included in this manual. Much of the limestone is somewhat too soft to be used as road material and most of it, also, should never be used until it has been thoroughly dried or hardened. This is true of the stone which comes from the state quarries at Anamosa.

Materials sent to the road material laboratory of the Iowa Highway Commission, Ames, Iowa, will be tested free and advice regarding their use given.

The cost of this stone from stone crusher plants in considerable quantities should not be over $.50 to $.60 per yard of 2,250 lbs. f. o. b. the quarry. The price of crushed stone is showing a marked decrease in some of the contracts recently let.

There is no reason, as has been stated before, why a county should not operate a stone crusher economically and well. When the attempt is made, however, much care should be taken in selecting a competent man as foreman in charge.

Figures No. 15 and 16 are of macadam roads near Clinton, Ia.

6. ROAD MACHINE. The road officers of Iowa in their efforts to improve the road situation have been too easily influenced to buy various machines which have proven of little value to them, either because the machines were not designed to meet the requirements or because they were not properly handled. In many places the road situation has become almost desperate and almost new road implements and machines have been discarded to give way to something just enough different to give promise of better results. As a result of this practice the counties and townships now have a considerable investment tied up in various kinds of machinery and by far the largest percentages of this in the so-called road machine or scraping grader.

Some of the townships, under the old system, were divided into a number of smaller districts, each of which owned one of these graders. The manufacturers have pushed the sale of these machines representing them as the ultimate solution for all the road problems which exist. A short review of the various machines now in use is given to aid in selecting machinery.

Drag or Scoop Scrapers. The drag or scoop scrapers, also commonly known as "slips" or "slushers." For two horses these are made in two sizes, which hold about 5 and 7 cu. ft. respectively. The larger size will put in the embankment in ordinary use not to exceed 6 cu. ft. This limits the proper use of this scraper entirely to side work and it should never be used when the earth is to be hauled even short distances along the road.

Wheel Scrapers. There are three sizes of wheel scrapers, holding approximately 9, 12 and 17 cu. ft. each. The smallest size, the No. 1, is most used in Iowa and unfortunately this is a size that the counties or townships positively should not buy. It is not uncommon to see a snap team used in loading these. Neither is it uncommon to see long hauls being made with the team arriving at the dump with an almost empty scraper. In practically all places where wheel scrapers should be used there will be a light down hill pull after filling. There is a No. 2 1-2 scraper that can be handled without difficulty by an experienced holder, and which carries twice as much per load as the No. 1. It is true that the No. 1 wheeler costs something less than the larger sizes, but between the larger drag scraper and the No. 2 wheeler, there is no place for the No. 1 size. One of the great-

est causes of waste of our road money is the use of small scrapers to haul long distances. No contractor would tolerate, for a moment, the methods very frequently used in our road work, nor would the public, if they knew how the road money is being wasted.

The wheel scraper can be used economically in short hauls up to about 300 feet and is of particular value in cutting out the side of ditches where the road drainage is to be carried through a knoll or rise in the ground.

The Road Machine. The road machine, also commonly called the road grader or reversible grader, is a suitable machine for finishing a road. After the cuts and fills necessary have been made along a stretch of road the grade can be finished effectively and economically with this machine. It is, however, an exceptional stretch of ground that could be effectively built into a finished road by the use of this machine alone. It often seems, however, that the prevalent idea of road construction is to drive one of these machines over a piece of road cutting the side ditches the same depth over hills and hollows alike, and making the same cross section for the whole length of road. This method of road making is as incorrect as the old slip scraper methods under the old labor tax system.

The common way, during the past few years, of working the roads with one of these machines has been for the township superintendent to hire men and teams near the strip of road on which he is to work. Each man is allowed to drive his own team and there is one man on the grader to operate, which makes three to five men and four teams necessary for the operation of the machine. This is not economical or efficient. The best driving can be done by one man skilled in the work and the machine should always be operated by a man who is a skilled road builder.

The training of the teams is a considerable task in itself and when once teams are secured which will work well together they should be used continually. If the grader is not to be operated in a country where a considerable amount of mud will have to be encountered, mule teams make the best animals for this work. In wet or muddy places, however, they are not so dependable as are horses.

The field of utility for this machine is a large one where there are grades to be finished or where the country is rolling enough so that high grades are not needed, but it is not an economical machine to use for simple road maintenance, nor can it be used economically where dirt has to be moved lengthwise of the road.

The few practical suggestions for the use of this machine on stony hills are taken from a paper by J. H. McMillen, read before the Good Roads Association:

"In working away from a high bank use three teams strung out rather than four horses abreast. Use a good equalizer where the teams are working four abreast. Large rocks should be blasted with dynamite. On steep hills load the grader as heavy as possible going down hill and do not attempt to work up grade. On hills where ditches are washed out on either side, work the earth away from the center of the road into the ditches, thus filling them and leaving the road hard and smooth and at the same time lowering the grade. If the ditches are washed on one side only, work the dirt across from the opposite side to fill the ditch. Slope the banks of all side-ditches on the outside."

The Elevating Grader The elevating grader is being used with considerable success in many parts of the state. There are parts of the state that are so flat it is necessary to build road grades that water will not cover in wet times, and the elevating grader can be used with considerable success if care is taken, to *construct the side ditches to a continuous grade*, and *not to deepen them below an outlet.*

In a more rolling district these machines can be used to good advantage to load dump wagons, but experience so far seems to indicate that it is usually not a good investment for a township to spend the large sum necessary to purchase, or to try to operate one of them, with an unskilled set of men. There is a large sum of money tied up in such a machine, which is used only during a small part of each year. Also it requires a trained crew of men and horses, and a complete outfit for "camping on the job" to prevent loss of time. If the machine is owned by the county, however, it can be operated very successfully in this way provided a competent man is secured as foreman. It would perhaps in most instances be preferable to let the work to a contractor owning such an outfit, after receiving competitive bids per cu. yd., as his profits then depend directly on the results he obtains. It is absolutely necessary in the use of both the ordinary reversible machine and the elevating grader that experienced and competent men be placed in charge of them and that the horses or mules used be trained for the work.

Stone Crushers. There are only a very limited number of stone crushers owned by counties in the state. There is no reason why such a plant could not be run successfully by the counties, but so far their operation seems to be unnecessarily costly. A rotary screen should be fitted up in connection with the crusher and when the material is to be used for road construc-

tion it should be separated into three sizes. Three sizes commonly are 2 1-2", 1 3-4", 3-4", the last is also known as the screenings.

Stone crushing plants are going to be a necessity in the future, in many cases where the local material is available for stone roads and for use in concrete.

Probably the most successful county crusher plant in the

Fig. 15—Macadam Road in Clinton County

state is the one in Lee county. The following is the report of first cost and cost of operation:

Report of Stone Quarry for the Year 1905:

Cost of crusher	$1350.00
Labor moving and setting machine	34.75
Tools and supplies	19.06
Material for platform and bins	32.00
Freight on crusher and tools	12.97
Labor and supplies crushing and quarrying	421.74
	$1870.52

The estimated amount of stone crushed is 400 yards at a total cost of $421.74 or $1.05 per cu. yd. for the crushed product.

Fig. 16—A Macadam Road near Clinton, Iowa.

SECTION SIX.

ROAD MAINTENANCE.

The work of road maintenance in Iowa is largely confined to the care of earth roads. Within the past two years the methods have undergone a complete change and the use of the split log drag and other simple contrivances for this purpose has extended into every township and county of the state.

1. DRAG METHOD OF ROAD MAINTENANCE.

The History and Development of the Method. In the Genesee Farmer of August, 1838, there appeared an article which

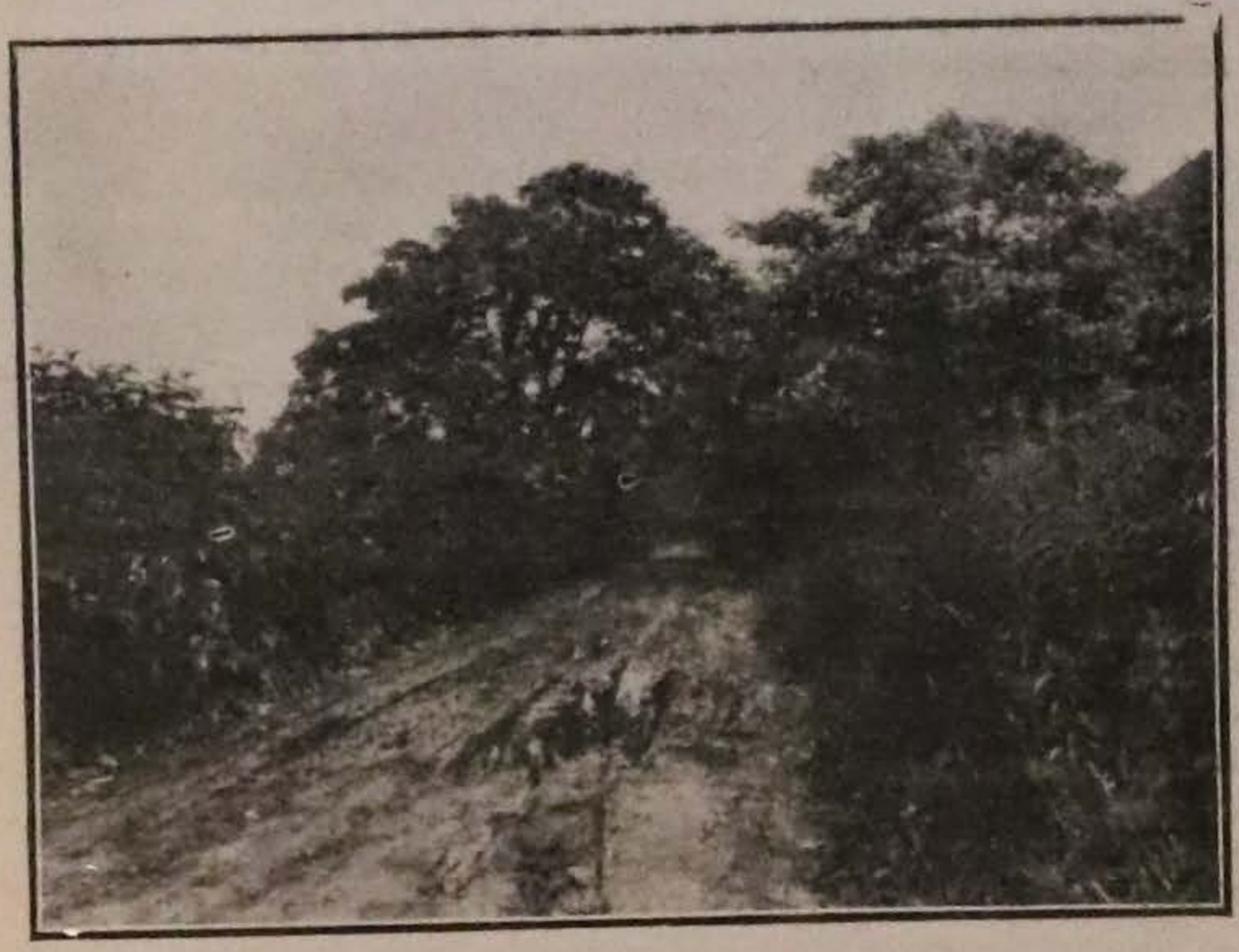


Fig. 17—A Poorly Drained Road with Rank Growth of Weeds Bordering

recommended for use on the public roads a contrivance similar to the "split log" drag. Without giving the article in full the following extracts will show the idea as then advanced:

"A stick of timber six feet in length, twelve inches in width and five or six in thickness is to be provided; hard, heavy wood should be

selected as the bolts or screws in such wood are more secure. . . . This stick forms the scraper, and is drawn by a suitable neap or tongue. . . . One part of the neap where split, is cut shorter than the other so that when used the scraper does not run square on the road but diagonally or quartering. The slant in the six feet is about one foot, which is sufficient to throw all the stones out of the line of travel, level the ruts and smooth the whole surface. The cutting part of the scraper is composed of a thin wide bar of iron screwed or bolted upon the front of the scraper, the lower edge coming half an inch below the wood, which by bevelling backwards is made thin at the place on which the iron is put. It may be remarked, however, that such a scraper can do no good where the roads are muddy, and that to keep roads dry is essential to their formation, preservation or repairs. Where the road can be kept dry, there is no difficulty in keeping the carriage-way in good order, as an occasional use of this scraper, and the work is quickly performed with a good span of horses, will remove all the small stones, level ridges by cutting them off, and by quartering movement deposit them in the ruts that have created the elevations."

The principle involved has been put into common practice in many of the eastern states for a long time and many communities in Iowa have been keeping up their roads by dragging them with such things as harrows, railroad iron or planks, but the movement had not become general over the state.

During the past twelve years while Iowa's business was each year almost completely stopped by the mud blockade, Mr. D. Ward King, a farmer living near Maitland, Missouri, has proved the possibility of having passable roads during the entire twelve months.

A frost-bitten pump stock and an old fence post nailed together thirty inches apart, probably made and used by some former tenant of the farm for leveling his wheat field, was the first drag used by Mr. King, and who after smoothing his roads for the first time was so well satisfied and pleased with the results that he has continued for twelve years to drag a half mile of road from his "own front gate to his neighbor's front gate toward town."

After several years the condition of this road warranted the Missouri State Board of Agriculture in sending Mr. King into different parts of the state to give the results of his work before farmers institutes and such gatherings as were interested in the subject.

During the early spring of 1905 Mr. Henry Wallace of Des Moines suggested to the Chicago & Northwestern railroad the possibility of spreading the road dragging idea from a special train similar to the Seed Corn Specials. After some investigation the Northwestern started a car at Onawa on the Missouri River bottom as an experiment to prove what might be done with encouraging this idea.

Accompanying this car, besides Mr. King, were representatives of the Iowa Highway Commission, Wallace's Farmer, the Iowa State Register and Farmer, and the Northwestern Railroad. Fifteen counties were visited through the flat district of northern Iowa and into the eastern part of the state, the final meeting being held at De Witt. Two meetings were held at each point and at the close of the afternoon meeting a demonstration with the drag was given on a nearby street. No trouble was experienced in finding a place suitable for using it or one that was not left much improved over its former condition.

The business men of the towns where these talks and demonstrations were given, responded generously by offering prizes

Fig. 18 The C. & N-W. GoodRoads Car at Eagle Grove, Iowa

for the stretches of road kept in the best condition for a year by this method. At Denison $350.00 were subscribed for this purpose, fifty-two men promised to make and use the drag and ten towns were represented; at Bancroft the records show $300.00 subscribed, forty-seven names and thirteen towns, and at Nevada $200.00 subscribed, sixty names and fifteen towns represented. With only one exception the towns responded with subscriptions for prizes. This fact is indicative of the response which meets practical and efficient ideas in road improvement and the high regard in which it is held by the business men of the average town in the state.

Later in the year, during June, the Commission engaged Mr. King as an instructor at the Road School held at Ames. In addition to the "split log" drag, a number of other simple implements were used in the demonstrations, including the McMillen "V" drag.

October 19th the Chicago, Burlington & Quincy Railroad started a "hard dirt roads" special car at Council Bluffs, continuing across the state and stopping in all at about seventeen towns where meetings were held and where the reception of the idea was encouraging and enthusiastic. The commercial clubs were the chief promoters of the meetings in this part of the state and many clubs offered premiums for the best stretches of road kept for a year by this method.

In February, 1906, the Chicago & Alton road sent a similar car over its lines from Chicago through Illinois and into Missouri. At all the towns the meetings were well attended and the whole trip was a successful one. The Sante Fe Road adopted the same method of arousing interest in their territory and in March sent Mr. King and others over a portion of their lines in Kansas.

These special cars have been watched with much interest by other states and other railroads and it is not improbable that the same plan of awakening public sentiment for better roads will be pursued by them during the next few years.

Besides these different series of drag meetings a large number of talks have been given before farmers institutes, commercial clubs, and similar organizations and gatherings interested in the improvement of the public roads, until the whole state has become enthusiastic with this method of road maintenance.

New Laws Enacted Relating to the Use of the Drag. The 31st General Assembly recognizing the importance of providing for the general introduction of the drag method of caring for the roads passed a law providing for the payment out of the township road funds for work done with this implement. This Act is given in full under Section Three. To encourage a more general use of wide tired wagons on the roads an act was passed providing for a rebate of a certain proportion of the road taxes to any one who would use nothing but wide tired wagons for heavy hauling. This Act is also given in full under Section Three. The use of wide tired wagons in connection with the use of the drag gives an ideal combination for the betterment of the roads as the action of the one is supplemented by that of the other.

General Topography and Soil Areas of the State. Section Two takes up in detail the different glacial areas of the state but in a general way it may be said that the ice sheets which

swept southward over Iowa at an early date plowed down and leveled the hills and filled the valleys until the whole state was reduced to a fairly level plain. These glaciers touched all the counties of Iowa except a few in the extreme northeast corner where from Dubuque, extending north past McGregor and through Allamakee and parts of Winneshiek counties the topography is rough and broken, standing out in all the original ruggedness, and covered only by the loess or wind-blow soil from the Mississippi Valley.

Roughly speaking, north of the Northwestern Railroad, and extending from the Missouri bottoms to a line running south through Worth and Franklin counties is the Wisconsin drift area. The area included is covered by the black, rich soil which has been given the somewhat indefinite term of gumbo; and which is liberally dotted by ponds and sluggish streams. The drainage problem is a serious one. Along the Missouri River bottoms we find largely the same kind of soil in a very flat, undrained district.

East of the line through Worth and Franklin counties and north of the Northwestern railroad we get into the Iowan Drift area which is not so flat and which has reached such a stage that the drainage lines are well defined and where the soil is somewhat lighter and in some districts contains so much sand that the methods of dealing with sand roads has become quite a serious matter.

South of the line of the Northwestern is the Kansan Drift area which has also been covered to a considerable depth by what is termed Missouri and Mississippi loess which is supposed to be the soil carried and deposited by the wind. This area is much more broken by the drainage lines and even a glance at the maps shows the numberless streams and their more numerous tributaries extending into nearly every quarter section of land. The drainage of this district is almost perfect except along some of the bottom lands.

The differences in the soil and in the topography of these different areas bring up special problems which are common to these sections only, but the big question of earth road maintenance is the same all over the state.

Theory of Road Dragging. The recent study that has been given the earth road has brought out some characteristics that were not generally known to exist and the common idea that our soil had none of the qualities that could make it a road material suited to certain classes of roads and certain kinds of traffic has given away to the knowledge that with proper care an earth road can be made passable at all times of the year and excellent during

most of the year. The experience of the past two years has proven this general fact beyond doubt or question.

The roads designated as first class roads in Section One carry so much heavy traffic that as soon as possible they should be surfaced with a road metal of some kind such as gravel or broken stone. The reference here is rather to the larger percentage which have been called second class roads and which have average rural traffic over them. That all kinds of roads are greatly benefitted by care with the drag is shown in the report from mail carriers from Tipton, Iowa.

There are perhaps no better judges than the rural mail carriers of the condition from day to day of the country roads and the effect upon them of the use of any particular methods of construction or maintenance. These men see the effects of all kinds of weather upon the road surfaces and their opinion of the value of the method of caring for them is well shown in the following table taken from a report sent in by carriers whose routes lead out of Tipton, Iowa.

REPORT OF RURAL MAIL CARRIERS FROM CEDAR COUNTY, MAY, 1906.

No. Miles in route	Av. time to make the trip in dry weather	Av. time during February to May	No. miles dragged roads in route	Average condition of dragged compared to undragged roads
27	6 Hrs.	8 Hrs.	6 Hrs.	Good.
28	7 Hrs.	9 Hrs.	4 Hrs.	Good.
26	6 Hrs.	7 Hrs.	3 Hrs.	Good.
27⅛	6 Hrs.	8 Hrs.	3 Hrs.	Dragged roads are much better.
28⅛	6 Hrs.	8 Hrs.	12 Hrs.	Dragged roads in fine condition.
27½	6¼ Hrs.	8½ Hrs.	3 Hrs.	Dragged roads are much the best at all seasons.

The difference in time required during the period from February to May over the average time in dry weather is very marked as shown by this report, being in all cases about two hours longer during the season when we have the worst roads. The saving of time and the ease of rural free delivery which is made possible by the continuous use of the drag is a very strong argument for the adoption of this method of road maintenance over the entire state and the rural routes should be the ones particularly selected by the township trustees and the road superintendents in contracting for such work.

The results as shown in this report could not be obtained if the soil in the roads remained the same as it does in the fields on

either side. The explanation of the change lies in the changed condition of the soil itself.

PUDDLED EARTH. In its new condition, the soil has been called "puddled earth," and the characteristics taken on lift the whole idea of road dragging to the plane of a more or less permanent improvement. That is, were there no inherent qualities in this puddled earth similar to the characteristics of a good road metal, road dragging would mean simply a temporary expedient affording only temporary relief and no lasting benefits. This soil however after having been subjected to the traffic for a period of years could not be used for agricultural purposes. The combined action of the traffic, the water and the disintegrating effect of the frost materially change its physical and chemical composition. The vegetable matter or humus, as it is called, almost completely disappears as does the surface soil and a large percent of clay is gradually worked up from below. In many cases the road grader or other tools of the road builder have entirely removed the top soil so that the clay stratum forms the road surface.

In the process of manufacturing bricks the clay is run through what is termed a pug mill and there mixed with water to a plastic mortar. The action of the traffic is not unsimilar to the action of the pug mill and the result produced is in a measure the same. Following this comparison a step farther it becomes apparent that the drying and baking action of the sun and wind is not unsimilar except in intensity to the burning of the bricks in kilns.

The condition of the soil in any well traveled road is such that when moist with water it can be moulded into a cup shaped form which will hold water until it evaporates. Each time the wheels form a rut or a horse's hoof makes a print a cup is formed that in many places will retain the water for an indefinite period unless it disappears by evaporation. This fact also accounts for the mud holes which are frequently found on the tops of hills and in spots where the drainage would be excellent if this puddled earth were porous enough to afford the same drainage as does the soil in the fields on either side. Besides these facts which support the theory, there are other common instances such as the standing of water in a hog wallow for long periods of dry weather and the forming of a hard crust over a road surface when water stands at almost the same level on either side. This is noticeable in numerous places in the swamps and sloughs of northern Iowa. In this latter instance the covering of the road is usually the gumbo typical of this section of the country and with which the drag produces perhaps the most astonishing effects. It is frequently erroneously stated that the drag puddles

the earth, but this is a clear misstatement of facts. The term *puddled earth* applies to any kind of soil that has been so changed by the agencies mentioned before, that when dampened it can be moulded into water proof forms. It follows from this that the use of the drag will only produce the best results on soils that have been in the process of change for years from the light, porous agricultural soil to the puddled earth condition, or on soils which are naturally dense and heavy as clay or gumbo.

As we diverge from the heavy compact soils and approach the loose porous types, the lasting benefits of the drag become less and less apparent, till a stage is reached where its action may even become a detriment such as would be true on a sand road. This fact will also serve to answer many of the questions which have been raised in regard to the effect of the drag on roads covered with sod or on stone roads or in other special cases which need not be taken up in detail.

Spouty Places. On many roads there are the so called seepy or spouty places which give way first and become the worst under traffic. Such places as these are caused by the water which soaks into the ground working downward from the surface until it strikes a hard stratum, usually clay, which it cannot penetrate and along which it follows until it breaks out at the surface of the ground. In the southern part of the state, the points at which the drainage ditches between the hills become definitely defined are at almost the same level for a large area. These points mark the division plane between the porous top soil or loess and the clay sub-stratum of the Kansan drift. Wherever a road is cut through these hills, at some place this clay sub-stratum will carry the water to the surface and if there is a considerable amount of such water, a weak spot in the road will be formed. Such places by persistent dragging can be kept covered with a hard crust that will turn the water, but the best remedy is a tile drain from the upper side of the road to cut off this water and carry it to an outlet. In other parts of the state weak spots in the road are caused by a high level of the ground water. One correspondent writes as follows: "A low flat undrained stretch, having water standing on both sides of the road, gave me some trouble. A four inch crust was underlaid with mud and would give away under horses feet and the wheels. I gave this stretch extra dragging each time to keep it in shape and I succeeded." Tile sub-drainage would lower the level of the ground water and no extra dragging would be needed to keep the road in shape.

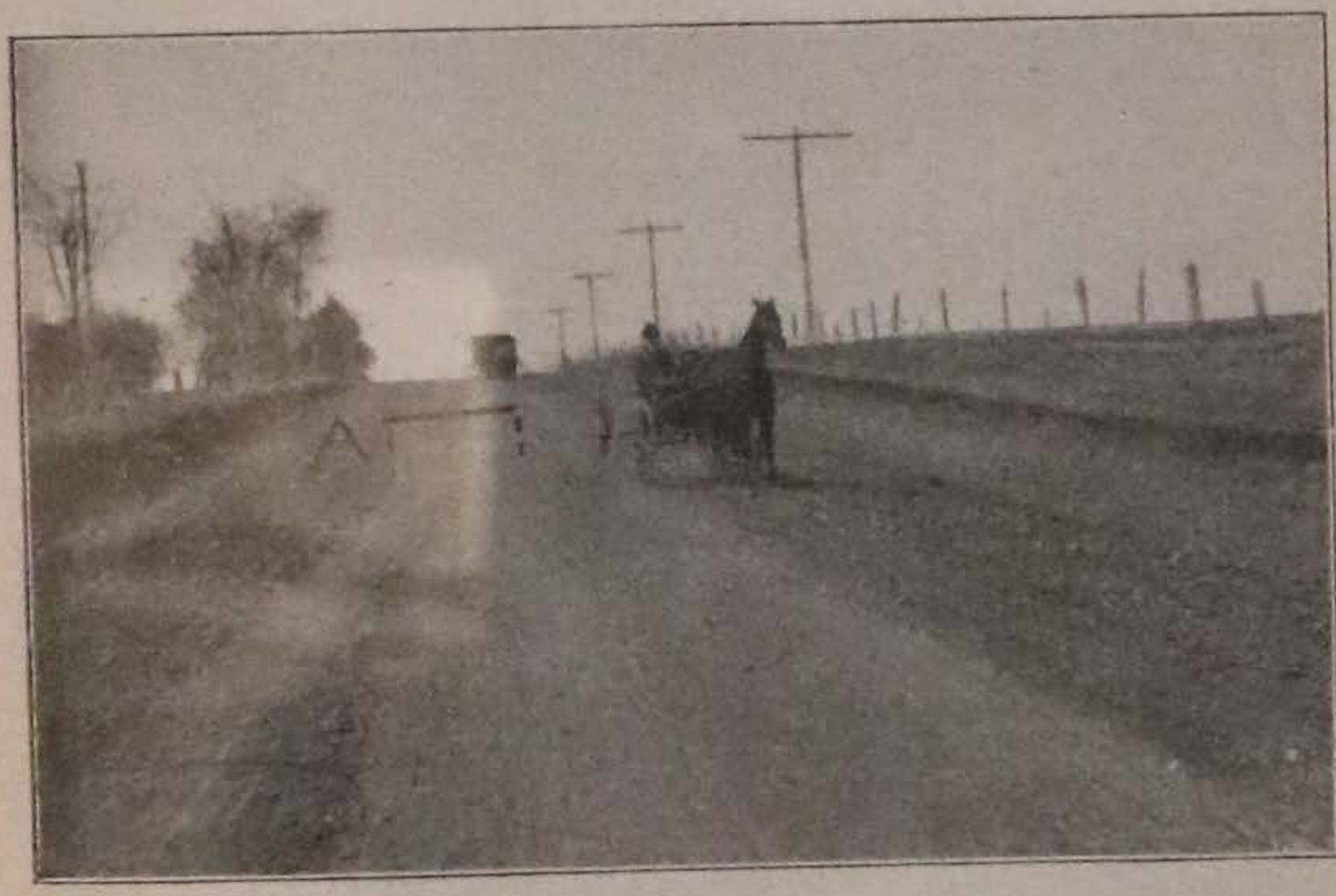


Fig. 19—Dragged Road in Red Oak Township, Cedar County
The line (A) shows point where trench was dug, shown in the following view (20)

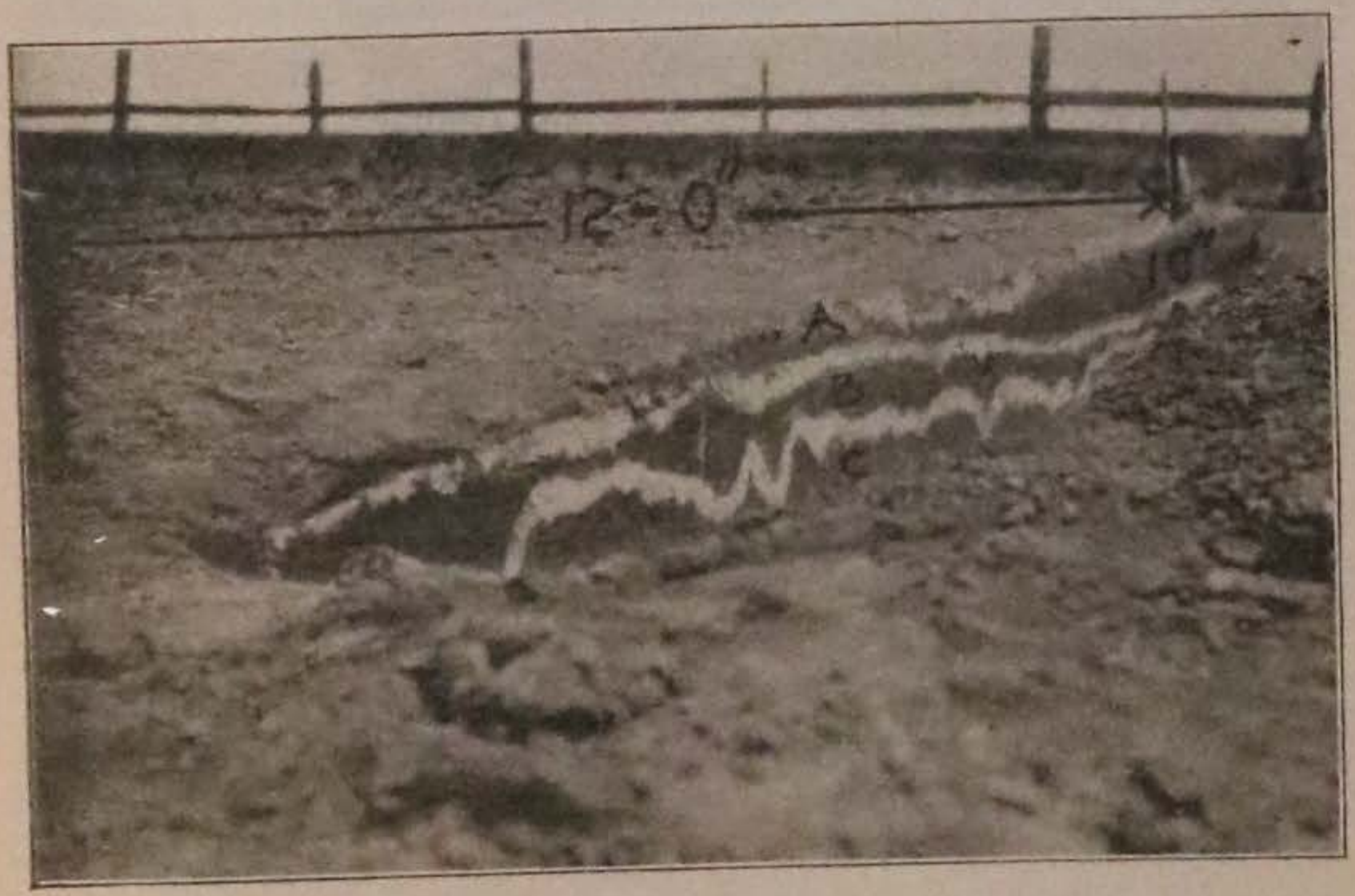


Fig. 20—Cross Section of Dragged Road
This road shows a crown of about ten inches added in one year

THE CROSS-SECTION OF A DRAGGED ROAD. The usefulness of the drag is not then, in preparing the road material or in packing the earth, but rather in placing the material already prepared in position to be compacted by the wheels of the traffic and the horses hoofs. How well the drag does this part is shown in the accompanying views taken in Cedar County about four miles northwest of Tipton.

Figure 19 shows a view of a road on May 9th which had at that time just been dragged for one year. The black line marked "A" marks the place where the trench was dug, half way across the road, to give the section shown in Figure 20.

The two stakes are just twelve feet apart and the trench is dug just to the middle of the traveled way. To define the different layers clearly in a photograph the dividing lines were traced with white paint. These lines, however, were so distinct that a view taken before the paint was used, shows the same divisions quite plainly.

On an undragged road there will be a certain thickness of soil near the surface which is more compact. This is shown plainly in the section marked "B." The thickness of this layer ranges from two to six inches except in the rut which extends up to eight inches into the soil below marked "C." Evidently these ruts were in the road at some time when the grader smoothed up the surface, as they were filled with the black top soil.

The top of section "B" was evidently the surface of the road at the time the use of the drag was commenced. The center is much lower than the shoulders and the thickness of the compacted layer much less where the traffic was concentrated than at the sides where the traffic was light, being only about two to three inches thick at the center.

Section "A" is the layer of earth added in one year by the use of the drag. An exact account was not kept of the number of times during the year the road was dragged. The number of times was probably greater than was altogether necessary, as the drag was run at least twice and sometimes more over the road every time it was thought any improvement could be made. The thickness of section "A" ranges from three inches at the sides to ten inches at the center. This illustrates how the drag builds up the crown of the road by placing a thin layer of the moist "puddled earth" over the road surface which is rolled smooth and hard by the traffic. If the use of the drag is persistent and careful the crown is built thicker and thicker of this dense hard "puddled earth."

The ten inch crown as shown in this section is the result of the actual operation of a drag for only a year and while

the crown would very likely build very much slower during succeeding years, it would seem that a few years' use of the drag would build a very thick surface over the road which would not be very easily affected by water or frost action.

Figure 21. April 7, 1900. This view was taken the same date as Figures 22 and 23, which are nearby roads. The value of dragging is clearly apparent. This is a portion of road shown in Figure 23.

While it would be possible to bring evidence from a large number of correspondents over the state as to the utility of the drag and the results produced, the following may be considered a fair representative: "In reference to the condition of a road taken care of by me with the King drag, I would say that this is an excellent four mile strip, but much more than one man should try to keep up. The entire distance is a smooth oval surface, but the half mile which was worked in the early spring of 1905, of what was formerly known as sink holes in clay hills, is in such a condition that heavy loads of logs were hauled over it in February, March and April. Formerly many people stuck on these hills during these months. The hard surface is quite narrow and a few days ago a light spring wagon pulled to the gutter on one of these hills in order to pass a load of logs. The center held the load, but the spring wagon had to be dug loose. This half mile is intensely hard and while the rest of the four mile strip was not dragged until May, there are only two places

that were even spongy. A four horse load of corn that passed easily over this road stuck several times before driving half a mile after leaving it."

Figure 22. April 7, 1906. Looking west on the upper Iowa City road to corner where the Poor Farm road meets at northwest corner of Tipton. Men who have lived in this territory for a long period of years and who have traveled the road continuously claim that the road was in worse condition this spring than ever before. This road has been well graded every year. It was put in extra good condition in 1905. Figure 24 is a continuation of this road and shows it in its dry condition.

The Effect of the Shade on Dragged Roads. If the road is well shaded the effect of the drag is much more noticeable as the moisture is retained longer and it gives the traffic a better chance to pound the road into a hard surface covering. The dust is also much less on such a road. The following is taken from a letter concerning the road above referred to: "The branches over the road are so dense that the sun has very little chance to penetrate them, consequently the road retains its moisture for a considerable period and it is always very hard. It is seldom at all dusty." The photographs accompanying this sketch were taken in Cedar County, near Tipton, to show the contrast between the dragged and undragged roads.

*This series of photographs was sent the Commission by F. T. Reeder, Tipton, Ia.

Figure 23. April 7, 1906. Looking north from the intersection of the upper Iowa City road and Poor Farm road. The "Advertiser" of April 7th, says: "The only main traveled road leading out of town that is in good condition is the Poor Farm road which is as good as the city streets. Travel between here and Stanwood is now done nearly altogether on that road people prefering to go a mile or so out of their way to find a good road."

Methods of Making Drags. There are two forms of drags commonly used; the split log drag and the "V" shaped drag. The principle is the same in both and which is the better to use will depend on the individual preference of the user. The accompanying cuts show the methods of making these drags. The material best suited to the King drag is the large end of a telephone pole or a red elm log. Drags should be made as light as possible as it is very easy to make them heavy. The weight and length of the drag can be adjusted to the weight of the team that is to be used on it, but it should always be made light enough so that the driver can ride.

Figure 24. April 27, 1906. "On the upper Iowa City road from Tipton near the Fair grounds. The road is dry, rutty and rough. In the foreground the travel is close to the fence on the north side of the road, but soon crosses to the south side going on the bank close to the sheds."

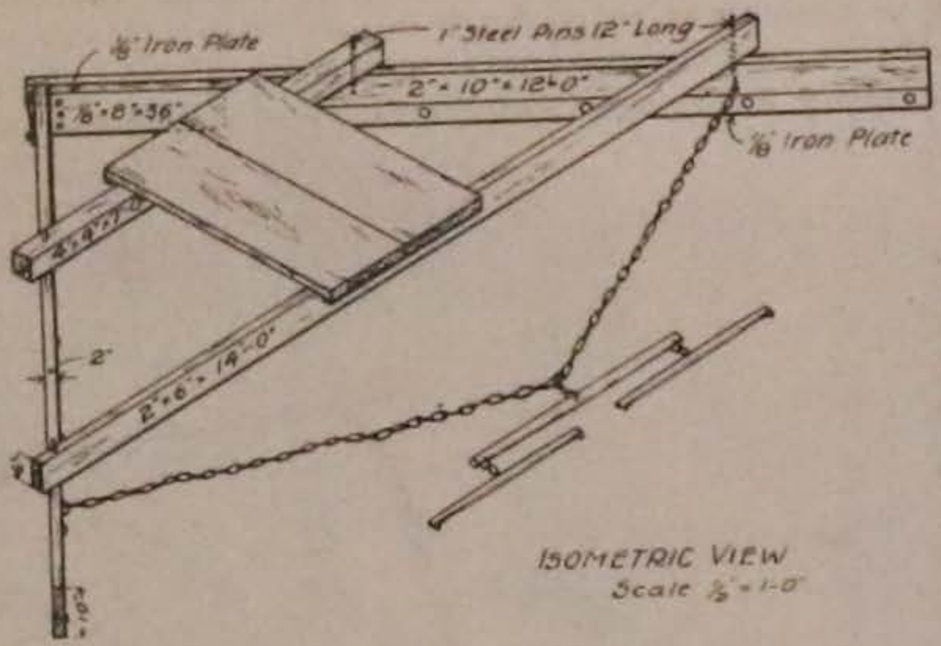
Figure 26. April 27, 1906. Contrast the roads shown here with Figures 19 and 23 taken the same date.

When to Use the Drag. If the drag has never been used and the road is full of ruts and holes, the best time to drag is as soon after a rain as it is possible to get on the road and while the earth is still in a wet condition. Four horses will be necessary to pull the drag and they will move a considerable amount of material which will fill up the holes and level the ridges. After the first time, the road will have to be dragged while some of it is too wet and some too dry, but it will gradually approach the condition when the whole road will be ready at about the same time. When the material is dry enough to work away from the front of the drag and yet wet enough to pack into a solid layer is the ideal time to use it. It is not necessary to go into detail on this point as each road must be dragged at the time best suited to that one particular road, and this can only be found out by experiment. If the King drag is used it ought to be pulled at about a 45° angle with the center of the road, and if the "V" shaped form is used, it should be pulled parallel to the center of the road. Road maintenance with the drag method is both economical and efficient and there is no reason why every mile of main road in the state should not be kept up with this method. The law as given provides for payment for the work and forms are included for letting this work to individual farm-

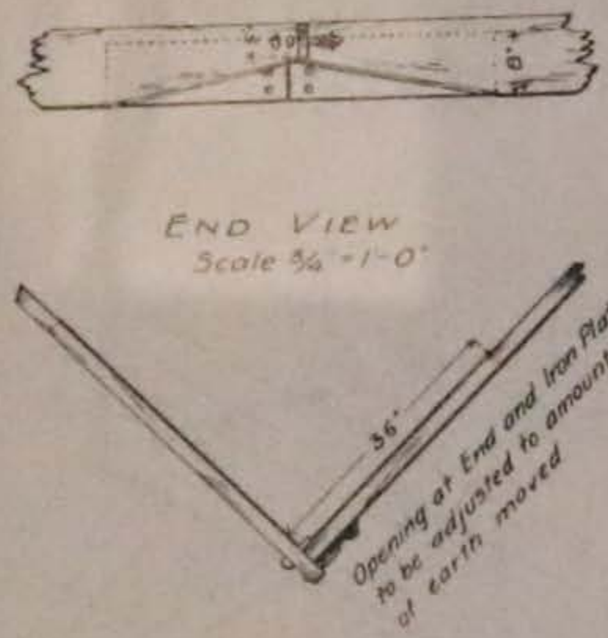
ers. Not more than two miles should be given to one man to care for and one drag to each half mile would be much better.

Is it Necessary to Grade a Road Before Using the Drag? This is one of the most troublesome questions that comes up in connection with the use of the drag. There is no doubt, however, that the best results have been produced on roads having good side ditches and a substantial grade. In some places, particularly in the northern part of the state, it is very necessary to have a grade before using the drag. The individual cases must be each decided on its own merits.

In many places the drag with a careful use of the plow would help the road considerably, even where no grade has been thrown up, and the best way to answer this question is to try the drag.



ISOMETRIC VIEW
Scale ½" = 1'-0"



BILL OF MATERIAL

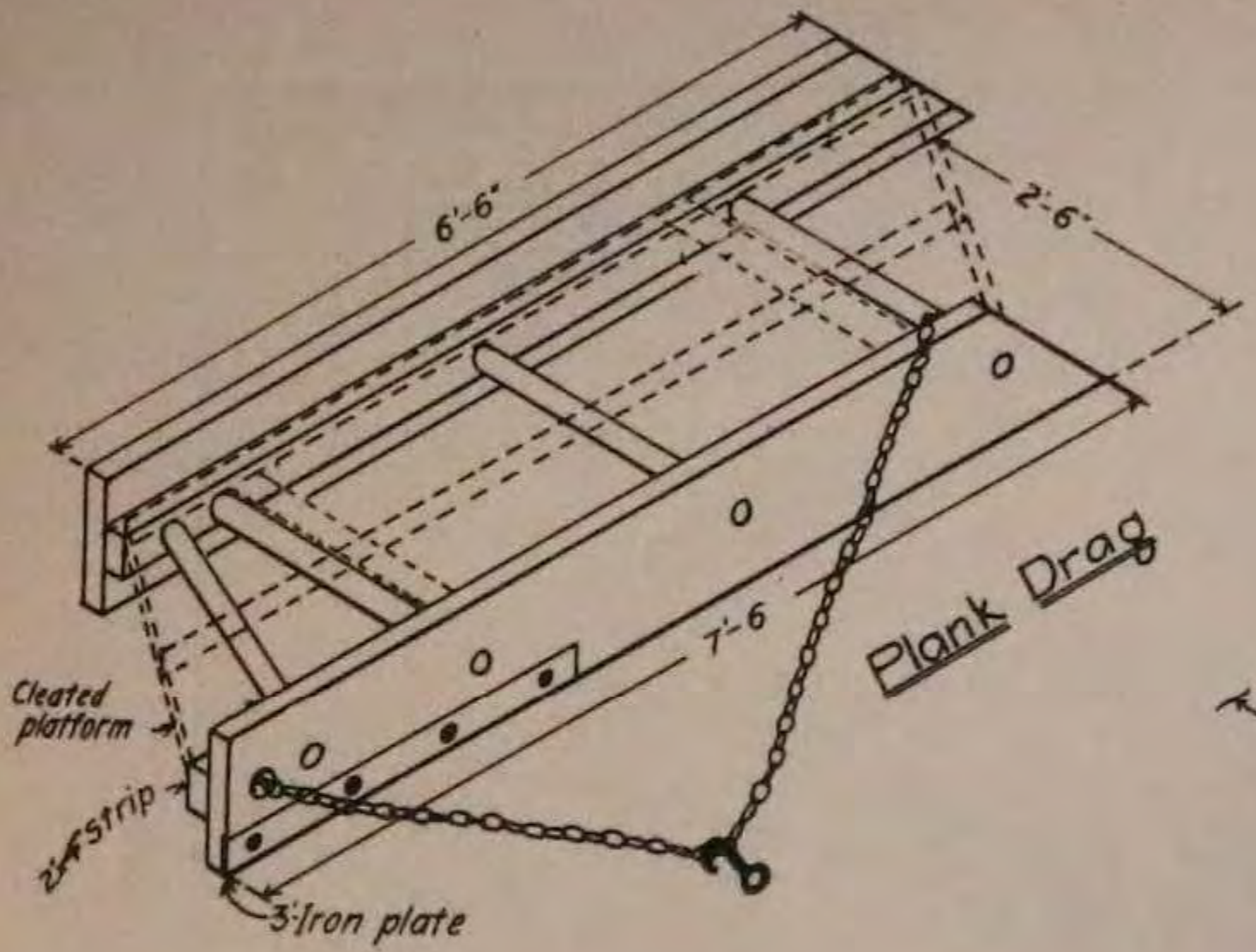
Item	Dimensions	No.
Planks	2" × 10" × 12'-0"	2
"	2" × 6" × 14'-0"	1
"	4" × 4" × 6'-0"	1
"	1½" × 18" × 4'-3"	2
Iron Bands	⅛" × 4" × 9'-0"	2
"	⅛" × 10" × 3'-0"	2
Steel Pins	1" × 12"	4

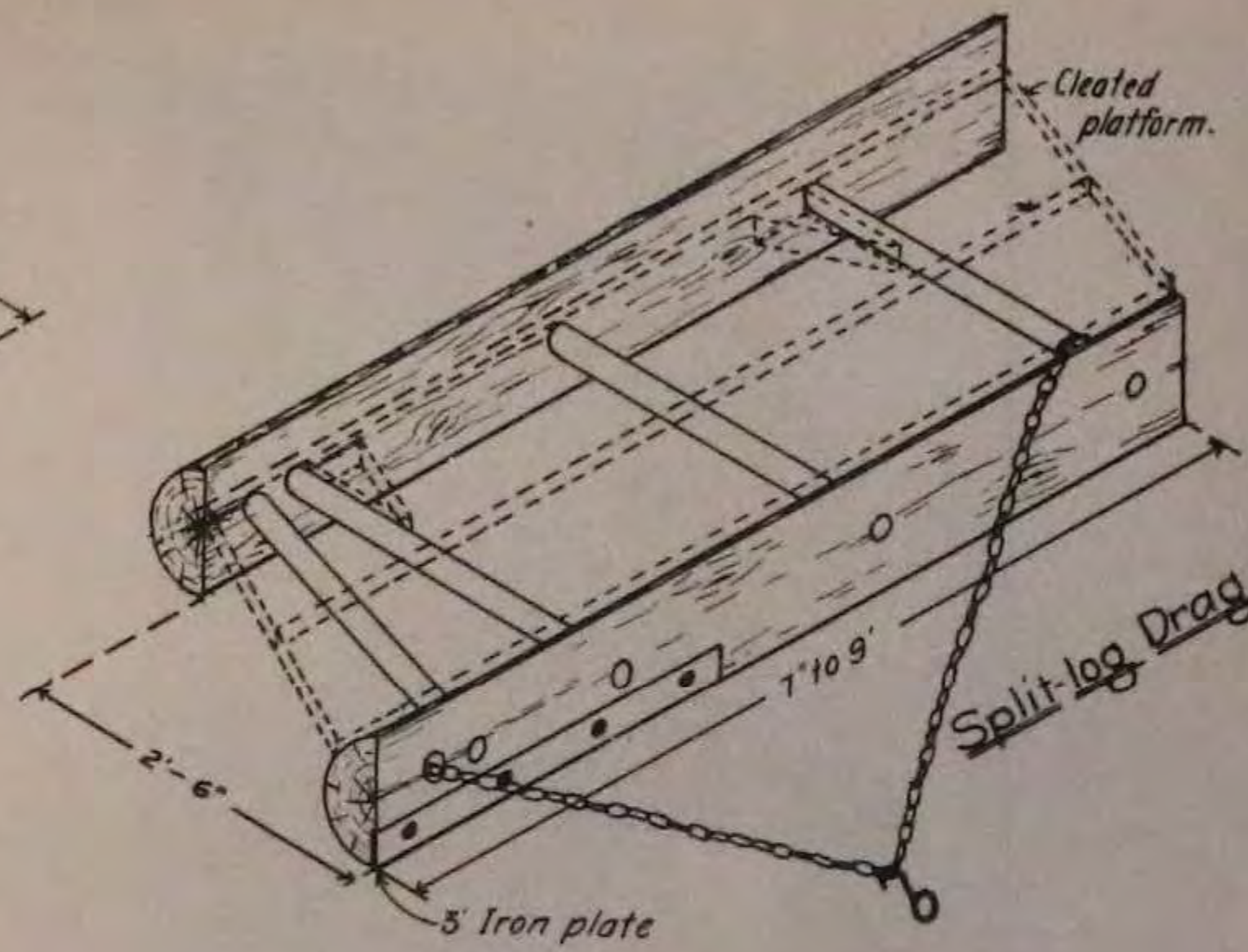
DIAGRAM
— OF —
V ROAD DRAG

Made from Directions
By J. H. McMillen, Hesper, Ia.

IOWA HIGHWAY COMMISSION
July 1906

Figure 28. The V Drag.





INSTRUCTIONS: After each rain drive up one side of the wheel track and back on the other side at least once with drag in position to throw the earth to the center. Ride on the drag. Haul at an angle of 45°

Gradually widen the strip dragged as the road improves.

To round up the road better plow a shallow furrow occasionally each side of the dragged strip, and work the loose dirt to the center.

TWO PLANS
-FOR-
THE KING ROAD DRAG

IOWA HIGHWAY COMMISSION

March 1906

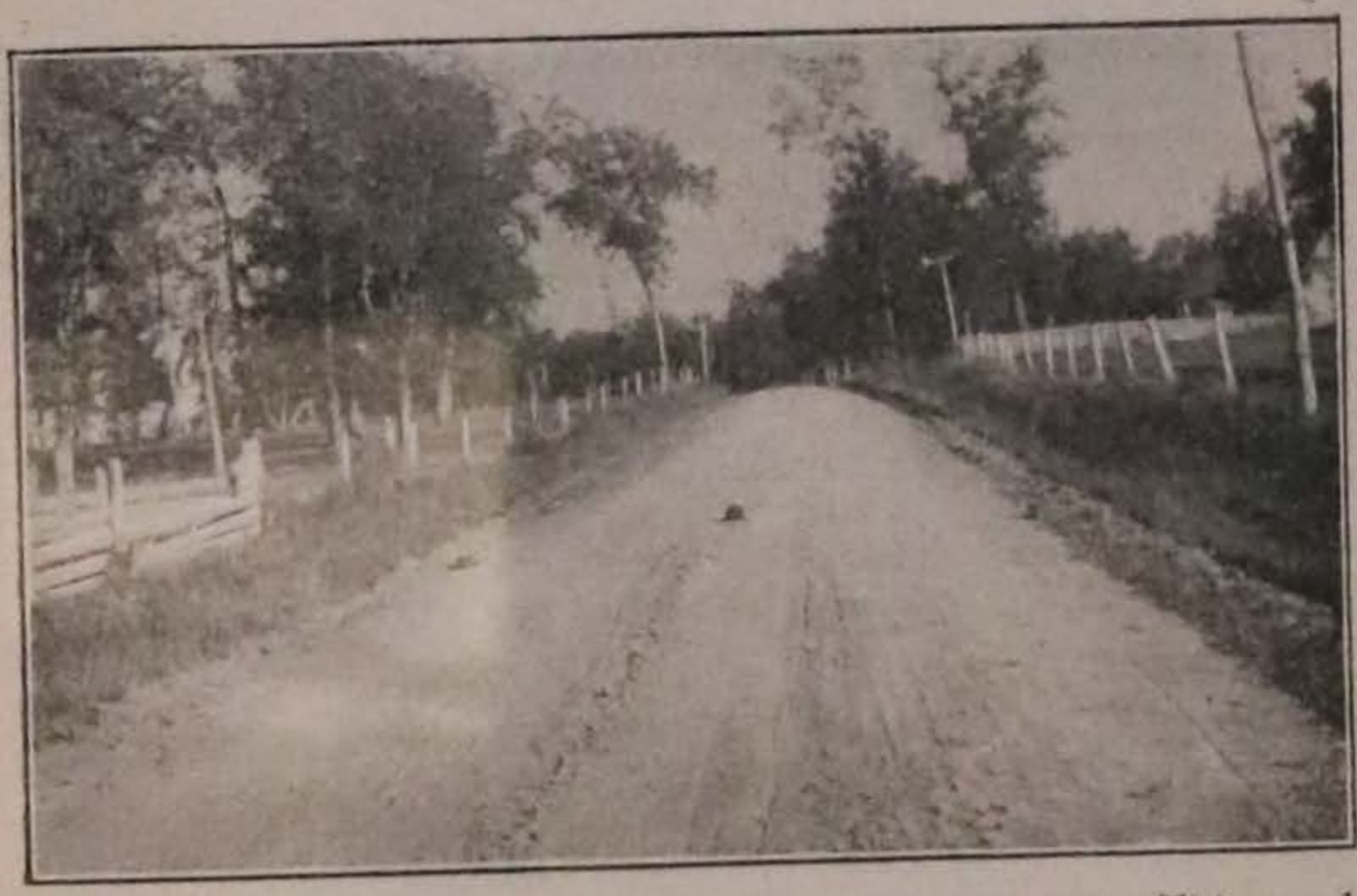


Figure 29. A Dragged Road Near Tipton. This road has only been dragged a year, but during the spring of 1906 heavy loads of saw logs were hauled over it without difficulty.

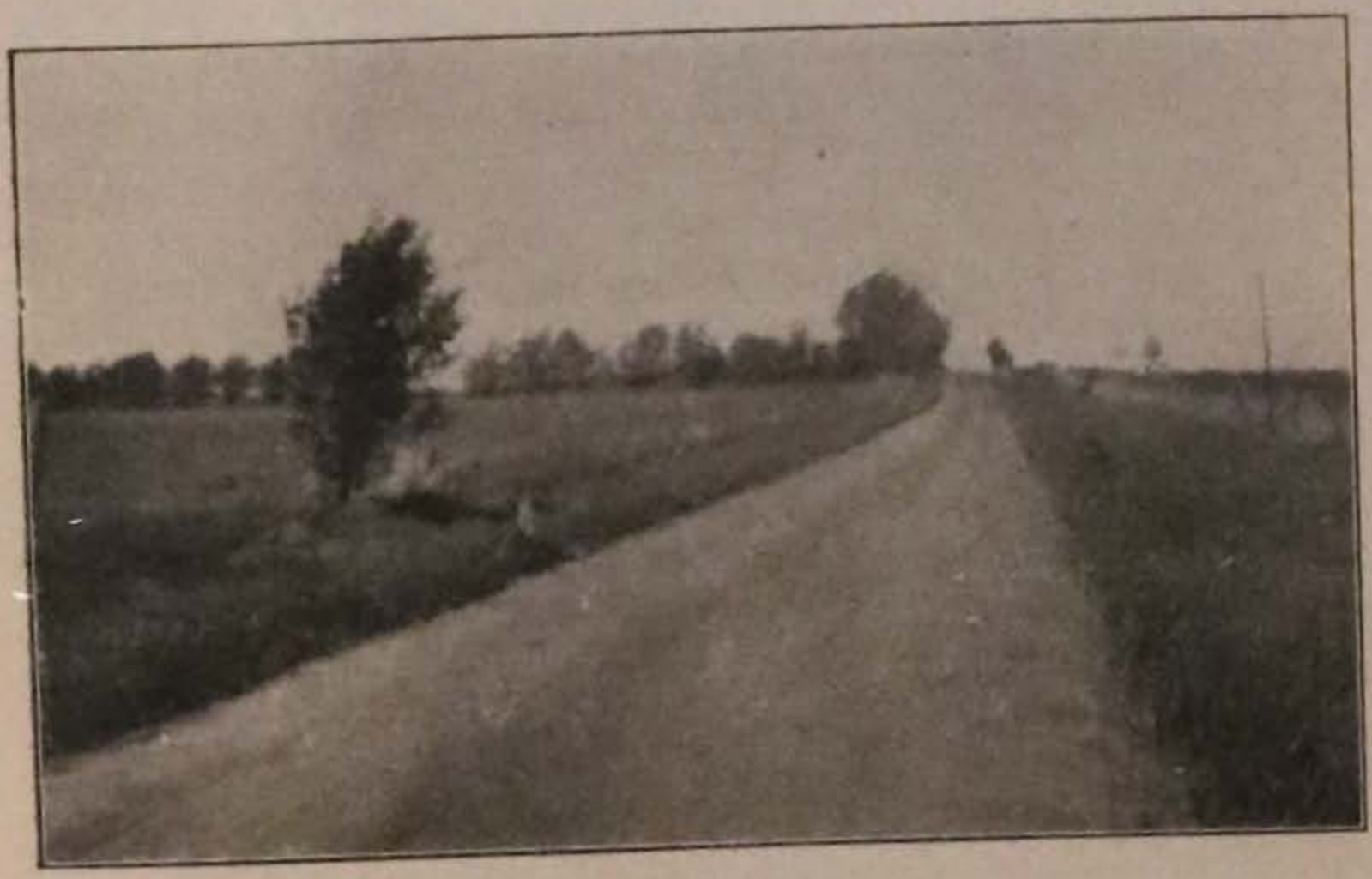


Figure 30. Gravel Road in Carrol County. This road has been maintained by the drag method.

2. MAINTENANCE OF SIDE DITCHES AND SUB-DRAINS.

Sub-Drains. Where tile have been laid to take the ground water, the outlets should be carefully examined from time to time and any necessary repairs made at once. This will consist in removing brush and drift which frequently collects around the tile outlet and in keeping the screen or grating, which should be placed at the end of the tile, free from obstruction. Where the tile outlets into a stream or slough it may frequently be necessary to dig away a considerable amount of sediment deposited by the spring floods to provide a free egress for the water, and in some cases a few lengths of tile near the opening may have to be taken up and replaced with new ones or cleaned.

Side Ditches. If side ditches are constructed, as advocated in the article on road construction, with sloping sides, there will be less danger of stoppage by loose material which is drifted by the wind into the road and held by vertical banks. Weeds and grass should be cut at the proper season by the road superintendent and if it is any considerable amount it should be raked in piles and burned. Where side ditches are beginning to wash badly they should be paved with some kind of stone or brick or the water carried through tile for the necessary distance.

A very handy implement for cleaning the side ditches is made by fitting together two 2 x 4's six or eight feet long in an "A" shaped form. The back ends should be about three feet apart and the whole covered with a platform. One side and the front edge should be shod, dropping the iron slightly below the wood. It is pulled with a chain long enough to keep the front end down. This ditcher is recommended by J. B. Stevenson, New Hampton, Mo.

3. WEEDS OF THE HIGHWAY.

The weeds of farms are caused in part by the roadside weeds being allowed to go to seed. Many of our troublesome varieties are started in the city streets where they are often allowed to grow unchecked. In this way they move along the highways to the farms. We have three classes of weeds common along roadsides: First, the annual; second, the biennial; third, the perennial.

Annual Weeds. The seeds of annual weeds germinate in the spring, produce flowers and seeds the same season and this ends their existence. The annuals differ in regard to their pertinacity. Shepherd's purse is easily subdued; crab grass is not so easily destroyed, since it strikes root so easily at the nodes; foxtails are easily subdued as individuals, but the chief difficulty is that

these plants seed so abundantly that the soil contains myriads of seeds, a large number of which are ready to take the place of those that have been destroyed.

Biennial Weeds. Biennail plants produce only vegetative organs the first season; in many of these a rosette of leaves spreads over the ground; the second season a flower stem is thrown up which bears flowers and seeds. Bull thistle, mullein, burdock, and parsnip are conspicuous examples. Biennial weeds will not appear where the ground is properly plowed or where weeds are cut off below the surface of the ground.

Perennial Weeds. These plants produce underground stems which send up stalks and in turn produce flowers and seed. When cut, new flowering stems are produced. The weeds of this class cannot be removed by simply cutting off the stems below the ground. As illustration of this class, morning glory, milkweed and horse nettle may be cited. The weeds of this class do not depend for their existence on seed production, as is evidenced by the horseradish, which has continued to propogate in this country without seeds. Other weeds of this class are largely extended by their root propagation.

Extermination. Each weed needs specific treatment, but a few illustrations may be of service. The Squirrel-tail grass may be taken as a type. This weed is an annual or winter annual, but some have thought it to be a perennial and that it comes up from a well knit sod. In well cultivated fields there is very little trouble, as the cultivation of garden and field crop prevents growth. To prevent its seeding in the meadow, grass should be cut early, but the seed, as stated before matures earlier than blue grass and much earlier than timothy. In this way blue grass will have a chance to grow and it will not be necessary to plow up the roadside if the grass is cut in this way for a few years. Farmers and road overseers should not neglect the roadsides and out of the way places where this weed grows so luxuriantly, and where it may produce seed enough to sow neighboring farms.

The mustards may be exterminated by treatment with copper sulphate solution. This is made by the use of one pound of copper sulphate to four gallons of water at the rate of fifty gallons to the acre.

The method of treatment for the Canadian Thistle is to cut down and remove all of the roots as far as is possible. If done frequently and thoroughly the weed can be removed. In large patches plow the ground, harrow and remove the thistle, either burn the material or put into compost heaps. This should be

done five or six times during the season as occasion may require.

Planting to corn or roots is a method much in vogue for the destruction of the Horse Nettle. As in the previous method the plant should be kept down before seeding time. When the crop appears above ground the use of the horse and hand hoe should not be sparing. There is no question about this mode of treatment being effective if properly carried out, but failure often lies in negligence during the latter by lying dormant in the soil and making their appearance the next season.

The removal of the nettle when in a well advanced stage, but before the production of seed (as when cut with clover or early cereals) is often restorted to, the idea being to kill the plant by shock. It must be confessed, however, that this method is not sufficiently effective to be endorsed as a means of complete eradication.

Dock is a common weed everywhere along the roadsides. The most efficient means of destroying this weed is to root it out by hand in the spring when the soil is wet.

Laws of Iowa with Reference to the Extermination of Weeds.

There are several Iowa laws that deal with the subject of the extermination of weeds along the roadsides. The laws are adequate for many of the most pernicious weeds. The laws are as follows:

The law in regard to the Canada Thistle was amended and in the Supplement to the Code of Iowa, 1902, this statute appears as follows:

SECTION 1562. "The road supervisor, when notified in writing that any Canada thistles or any other variety of thistles are growing upon any lands or lots within his district, shall cause a written notice to be served on the owner, agent, or lessee of such lands or lots, if found within the county, notifying him to destroy said thistles within ten days from the service of said notice, and in case the same are not destroyed within such time, or if such owner, agent, or lessee is not found within the county, then the road supervisor shall cause the same to be destroyed, and make return in writing to the board of supervisors of his county, with a bill for his expenses or charges therefor, which in no case shall exceed two dollars per day for such services, which shall be audited and allowed by said board and paid from the county fund, and the amount so paid shall be entered up and levied against the lands or lots on which said thistles have been destroyed, and collected by the county treasurer the same as other taxes and returned to the county fund."

SECTION 1562a. "It shall be the duty of road supervisors to cause to be cut near the surface all weeds on the public roads in their respective districts between the fifteenth day of July and the fifteenth day of August each year. But nothing herein shall prevent the land owner from harvesting the grass grown upon the roads along his land in proper season." Supplement to Code of Iowa, 1902.

(Extracts from the paper by Prof. L. H. Pammel).

Effect of Dragging on the Weeds. The drag is a valuable agent of weed destruction as it keeps them broken off at the ground level. A dragged road can be discerned at a glance, as the portion dragged is always free from weeds.

SECTION SEVEN.

BRIDGE AND CULVERT CONSTRUCTION AND MAINTENANCE.

1. General Status. The forms of construction now used in the state may be classed as wooden, steel or masonry or a combination of wood and steel, masonry and steel or of wood, masonry and steel. The various combinations made possible by these materials have caused every county to have now across its waterways a heterogeneous number of bridges and culverts without similarity of design or construction. It is only within the past year or two that a very few counties have adopted in a measure standard plans for such structures and have begun to work toward standardizing the county work along these lines.

The experimentation with various forms of materials and various forms of construction has been long and disastrous and as yet has resulted in no general fixed policy. The 30th General Assembly, to relieve the indebted condition of many of the counties, raised the maximum levy in the bridge fund from three to four mills, but still the condition is intolerable.

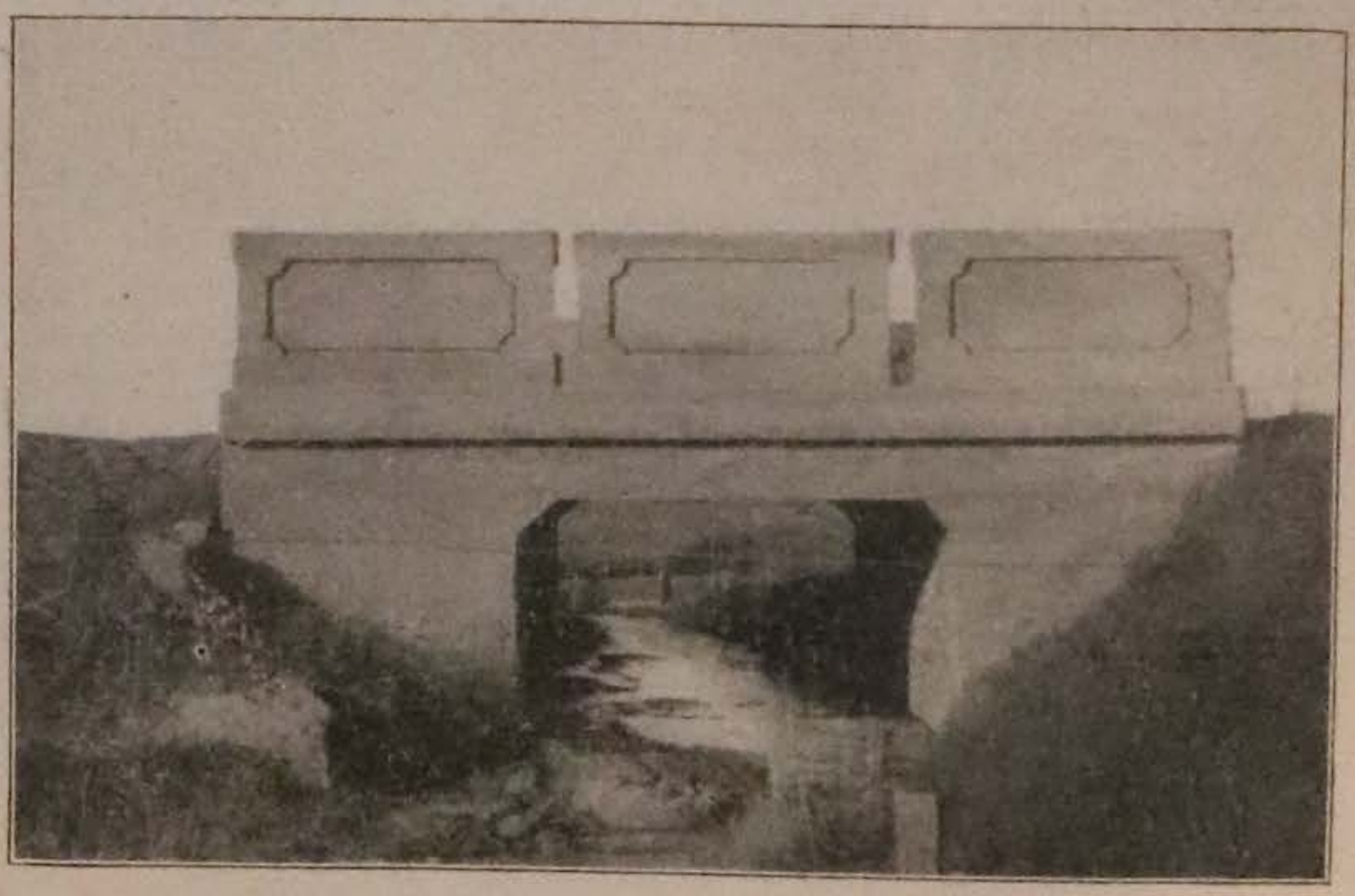


Fig. 81—Reinforced Flat Top Culvert in Greene County

Our roads and road superintendents have long been the objects of our wrath while the waterways were the real scapegoats of the situation. In addition to the four mill bridge fund proper, a considerable part of the one mill county road fund and of the four mill township road fund have been deflected for bridge and culvert construction and maintenance, leaving only a small percentage of the total funds collected for the improvement of the roads themselves.

Part of this loss is now due to a deterioration in the quality of the bridge lumber and the constantly increasing price. For instance, white oak which was formerly used is now diverted to supply other commercial demands and oak of a poorer quality used, or in most cases some other wood entirely is substituted.

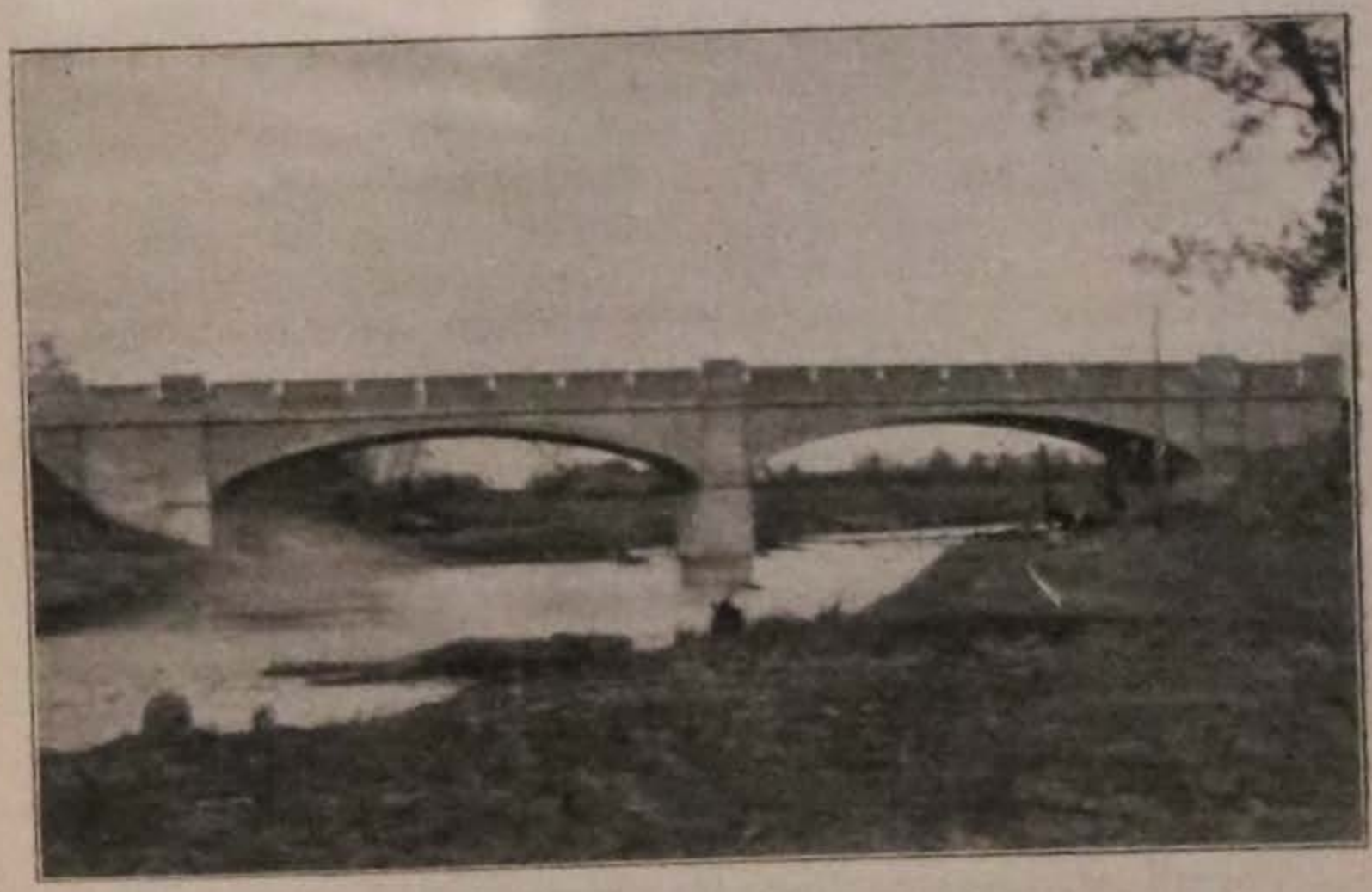


Fig. 32—Reinforced Concrete Arch near Jefferson, Iowa

A 300 foot bridge in Iowa county was refloored in just twenty-four months after a pine floor had been laid. Three to four years is about the limit of usefulness for lumber bridge and culvert floors on main traveled highways.

Administration of Bridge Funds. A greater loss than this, however, is due to the practical workings of the system followed in planning and constructing both county and township work of this nature. To illustrate this the following list of bridges is taken from a local paper in Butler county:

"Over the South Fork—6 bridges with a total length of 640 feet, no permanent abutments.

"Over Mains' Creek—7 bridges with a total length of 280 feet."

These instances are frequent, particularly in this section of the state where the stream valleys are broad and shallow. In nearly every instance the water flows over the grades when the streams rise and obviously the remedy is fewer and better bridges, with the channels straightened where possible and the low grades rip-rapped to let the floods flow quickly and naturally away.

In the construction of steel bridges, while the sizes have been cut down as much as possible, verbal contracts without adequate plans, specifications, or inspection of materials or workmanship have caused, particularly at flood times, monetary losses that it would be impossible even to estimate. "During 1905 Lee county spent $61,499.77 in building new bridges and the repair of old bridges damaged by floods."*

It would be both impossible and uneconomical to attempt to provide entirely for unusual floods but the loss can be minimized by structures designed and erected under skilled supervision. In this particular instance Lee county appointed a county engineer to have charge of all their work in conjunction with the board of supervisors.

In the use of concrete, which is about to be largely developed, many of the practices are already creeping in that have given so much trouble with the wooden and steel bridges. One of the chief of these is the attempt some of the supervisors and trustees are making to design and construct their own bridges and culverts. The very fact that it is contrary to public policy which requires that public officers shall at all times stand in an adversary position to those who do the public work and whose bills they audit should prohibit this practice.

Forms of Construction Recommended for Permanent Construction. It is strongly recommended that counties and townships adopt, as far as practicable, standard designs and specifications for steel and masonry bridges, masonry to be used for the shorter spans and steel with masonry abutments for the longer spans. The Highway Commission will prepare these plans free of cost on application.

Area of Water Way Required. The method that is used considerably by railroad engineers for determining the sizes of openings for water ways is to take the ravine cross-section and figure the discharge by Kutter's formula at high water as marked by the debris or other evidences which show this line and then figuring the size of the culvert or bridge

*County Financial Report for 1905.

required by the same formula, using in both the proper coefficients of roughness of channel, grade and other variabilities which enter into this formula. This method is too involved for the ordinary use by road officers, but any competent drainage engineer understands the practical use of this formula and it would be a wise economy to call in such a person in determining such water ways required. Prof. A. N. Talbot has evolved the following formula which he proposes as "a guide to judgment" for determining the size of openings required:

*Area of water way in square feet $= C \sqrt[4]{(\text{Drainage area in acres})^3}$

The C is the coefficient depending upon the kind of land to be drained. In the northeast portion of the state along the Mississippi river where the slopes are very steep and the ground broken, C will vary from 2-3 to 1. In the southern part of the state where the agricultural land is rolling but subject to floods at times when the snow is melting or during freshets, C is approximately 1-3. In the north central section of the state where the slopes are flat and the proportion of run off is small, C may be used at 1-3 to 1-6. As an example of this,—if the drainage area in the north central section should be 200 acres, by this formula, using a coefficient of 1-6, we would have area of water way required $= 1\text{-}6\ \sqrt[4]{(200)^3} = 1\text{-}6 \times 54 = 9$ sq. ft., which would be equal to a 3′ x 3′ culvert. Such a formula must be used with a great deal of judgment and the records and experience of people living near the streams should be given considerable weight in fixing the high water mark and the amount of water carried during flood times.

2. PILE BRIDGES. Much improvement can be made in the quality of the ordinary pile bridge, whether erected under contract or not, by obeying the following suggestions:

Materials. Pile bridges should never be more than thirty feet high as the length of piling becomes too great. All piling should be inspected on delivery for *size, quality, straightness and general conformation to specifications.* Red cedar and oak are the best kinds of piling and for floors and other dimension, taking into consideration cost and supply, fir is probably the best available lumber. Timber should be uniform in quality. *Large heart-checks, coarse growth, open grains are objectionable* and all timber showing such should be rejected.

Design. A pile trestle should contain at least four piles and if over ten feet high the outside piles should have a batter of two or three inches per foot. For heights of trestle greater than ten feet, the piles should be sway braced by 2x3″x12″ diagonals bolted to the piles which they cross.

*From Masonry Construction, Prof. I. O. Baker.

Construction. The piles should be driven true to line and the tops banded wherever necessary to prevent splitting. The piles should be cut off at exact elevations and no shimming up of caps allowed.

Bearing Power of Piles. For determining the bearing power of piles a formula which is held in considerable favor by engineers is the Engineering News formula:

$$\text{Safe load in pounds} = \frac{2\ W\ H}{S+1}$$

In which W=weight of hammer in pounds, H=fall of hammer in feet, S=penetration of pile in inches under last blow. As an example: If pile was lowered 1-2" by fall of a 1500 pound hammer 20 feet, a safe load in pounds would be as follows:

$$\frac{2 \times 1500 \times 20}{1\text{-}2 + 1} = 4{,}000 \text{ pounds} = 20 \text{ tons.}$$

3. Steel Bridges. STANDARD PLANS FOR ORDINARY SPANS. Counties and townships should adopt a standard set of plans for all ordinary spans of steel bridges varying perhaps by five feet for shorter spans and by ten feet for the longer spans. This plan is put into very successful operation by all railroad companies and the two cases are parellel.

The accompanying cut shows all the plans and specifications that were sent out to cover a $2000.00 highway bridge. While the main members are probably designed as heavy as ordinary for the light class of such bridges, no adequate details are shown and no specifications are given. No supervisor should think of letting contracts on so meager plans and specifications. The best prepared plans always leave some weak points and such a plan as the above does not even approach completeness. While it is not as yet possible to prepare plans for all the counties, it is suggested that each county adopt standard specifications for their highway bridges, and for such use the standards of the American Bridge Company are recommended. These plans and specifications could then be submitted to the bridge companies who would furnish bids and show drawings. These bids and drawings will be checked by the Commission and a report given as to the relative economy of the different designs.

Standing Specifications. Complete and carefully written specifications must necessarily be prepared by engineers, experienced in designing, shop practice and erection. They should specify in clear concise terms the loadings to be used, the material, the principles of detailing and such other matter as is pertinent to the subject. The suggestions given in Section Eight

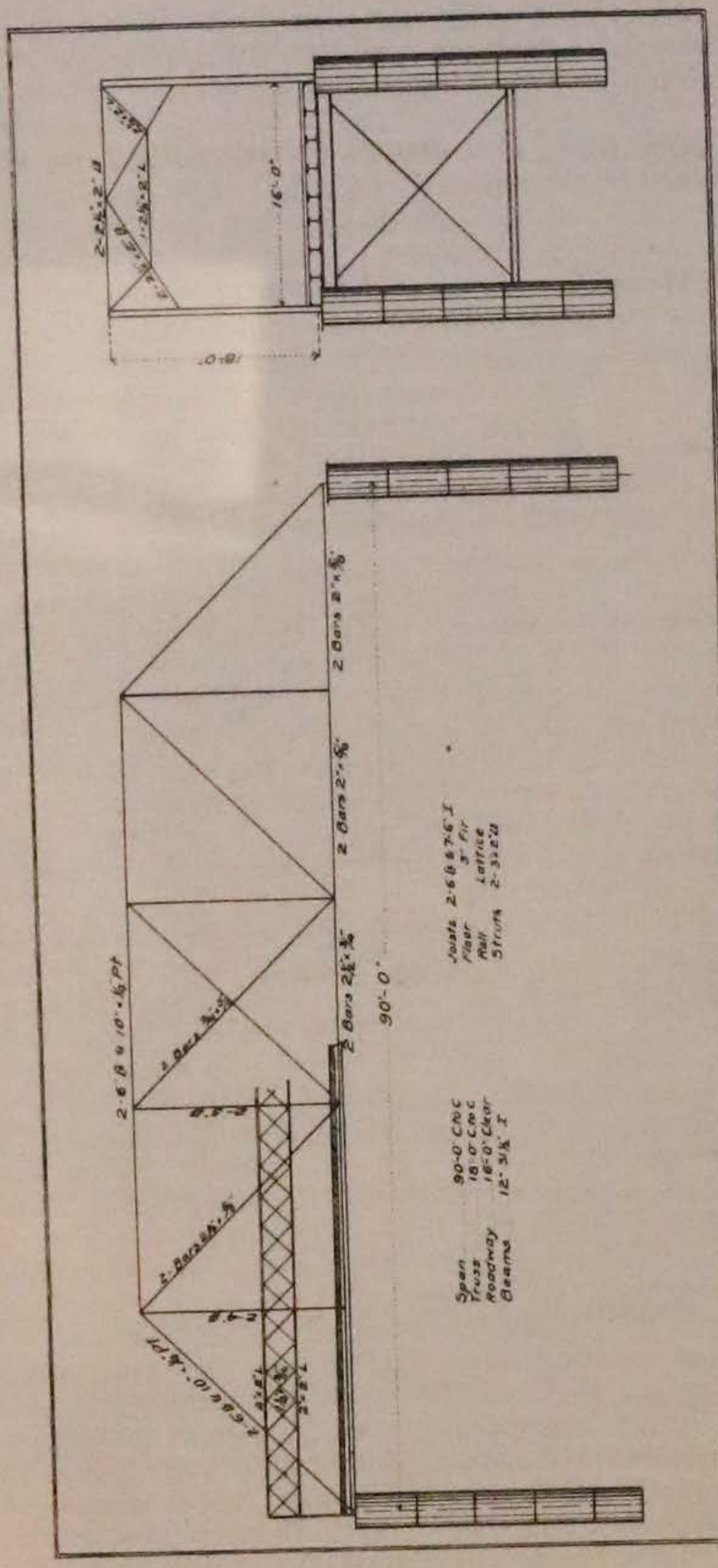


Fig. 33—Plan of 90 Foot Steel Bridge. Submitted as complete plans and specifications. Cost, $200.00

may be used in purchasing steel structures. These specifications are much abridged from the American Bridge Company's General Specifications for Steel Highway Bridges.

4. CONCRETE CULVERTS AND BRIDGES. Development of this Work in the State. This field now just developing in Iowa. In two or three eastern states where the "state aid" plan has been adopted, and where all permanent improvement of the highways is under state supervision, reinforced concrete is fast superseding all other material for culverts and bridges.

It is perhaps unnecessary to mention that the conditions which have to be met in introducing this form generally over the state, due to our present political organization, present a more or less difficult problem. In most of the counties townships are required to build and maintain all small bridges and culverts up to 16 feet span. For each township there are usually three trustees, and in 99 counties, averaging 16 townships each, there are over 4,000 men whom it is necessary to convince that a type of construction radically different from the one which they are commonly using is better and more economical. Most of these men are practical men, who are making a success of their business, and are more or less prominent in their locality. Most of them, too, it is only fair to state, are anxious to spend the money entrusted to them in the best way possible. With these conditions in mind it becomes necessary to advance such forms of construction as will appeal to these men from a business standpoint.

In order to gain a general idea of the amount of work which had been done in the state during 1905 by the counties, a blank form was sent out to each county board asking for the number of arch or flat-top reinforced concrete bridges and culverts built during the year. As usual with such inquiries, the results were not altogether satisfactory. Forty-five of the ninety-nine counties sent in reports which gave the following results:

Twenty-seven counties used no concrete during the year 1905, but of this number eleven had used concrete in either culverts or piers prior to that time, or else contracts were let for work to be erected during the coming year. This leaves fourteen, or about thirty-two per cent of the total number of replies received, reporting no concrete used. It is possible that in some of these instances the report covered only one supervisor's district, and yet so many of the counties reporting "no concrete used" is indicative of the need of the agitation of this subject and of the distribution of all possible information along this line.

Two counties, Decatur and Calhoun, report the use of concrete for piers and abutments only. Those reporting contracts let for work to be constructed during the coming year are Audu-

bon, Carroll and Clinton. In a few cases the township road officers are taking up the work, as is reported from Wapello and Grundy counties. Among those reporting "no concrete used" are a number of counties in which there is every reason to believe the work has already begun, and the report must be incorrect or at least incomplete. The counties which have begun the use of this material are holding steadily to their course and building each year a number of permanent structures. The following schedule shows the work done in a number of these counties during the past year. The first schedule (One) is for the flat top culverts and the second schedule (Two) is for the arch top culverts and bridges.

SCHEDULE ONE.

County	Flat Top Culverts or Bridges	Cost
Blackhawk,	four 26 ft. clear span, Thatcher bars	$3,150.00
	two 23 ft. clear span, 1 per cent x sec. area	2,480.00
	one 20 ft. clear span, 1 per cent sec. area	460.00
Boone,	14 ft. clear span, 2,000 lb. I beams, 7 I.s	271.00
Bremer,	four 12 ft. to 16 ft. spans, R. R. rails and ¾ in. to 1¾ in. steel rods ave. 5 ft. span, Kahn bars	125.00
Greene,	16 ft. span, Kahn bars	400.00
	5 ft. span 60 lb. R. R. rails	195.00
Dickinson,	5x5 ft, top ⅝ in. round rods, 2 in. c to c, cu. yd.	6.00
Humboldt,	4 ft. 30 ft. long	165.00
Hamilton,	2x2—38 ft. long, barbed wire	76.40
	2x2—40 ft. long, barbed wire	79.00
Poweshiek,	4—60 ft. long, Kahn 1 in. cc. Concrete $7.50 per yd.	750.00
Story,	4x6—16 ft. roadway	300.00
Washington,	3 ft. span, 3 in. gas pipe, 18 in. cc.	190.00
Woodbury,	6 ft. span, 60 ft. long, Johnson bars and wire meshing	600.00

SCHEDULE TWO.

County	Arched Top Culverts or Bridges	Cost
Blackhawk,	17½ ft. span, 1 per cent sectional area, Thatcher bars	$1,200.00
Bremer,	6 ft—6 ft. to 8 ft. span, barbed wire, ave.	75.00
Hamilton,	6x5 ft. 3 in., 40 ft long 200 lb. barbed wire	287.00
	5x6 ft. 4 in., 40 ft. long barbed wire	300.00
	3x4 ft. 6 in., 40 ft. long, 120 lb. barbed wire	300.00
Story,	5 ft span	370.00

Tama, 3-6 ft. span, $9.45 per cu. yd.
Woodbury, 12 ft. span, 8¾ in. x 22 ft. 6 in. Johnson;
20¾ in. x 14 ft Johnson..... 800.00
Worth, 16 ft. span, none..... 210.00
8 ft. span, none..... 75.00

Schedule Three includes cost of brick and stone arches.

SCHEDULE THREE.

County	Brick and Stone Arches	Cost
Boone,	brick arch, 5 ft. span, 50 ft. long.....	$ 350.00
	stone arch, 5 ft span, 30 ft long.....	164.00
Union,	brick arch, 6x6—20 ft. long, $13 per ft.....	260.00
	brich arch, 6x6—26 ft. long, $13 per ft.....	338.00

Cost of Concrete Work. Particular attention is called to the range in prices as given for the different counties. This may be accounted for in a measure by the variation in the price of the materials delivered, and also the relative difficulty of pursuing the work under conditions imposed by the location of the structures. However, these reasons are not altogether satisfactory when the range of prices is so wide. For instance, one county reports the work to cost 35c per cubic foot which means $9.45 per cubic yard, while another county reports the concrete to cost $6.50 per cubic yard. A good example of the reasonable cost of concrete work under favorable circumstances is the reinforced concrete bridge reported from Boone county. The abutments and wing walls are about seven feet high and eighteen inches wide on top, with a batter of about ½" to the foot on the outside. The top is a 14" slab of concrete with a clear span of 14 feet reinforced with seven lines of 6" I beams having their ends embedded in either abutment. There is a 16 foot roadway with a 10" felloe-rail on either side and a two-rail gas pipe railing. Sand and gravel cost $1.00 per cubic yard and cement $2.00 per barrel plus haulage. The structure completed cost $271.00.

The following itemized statements of concrete work are taken from a paper read before the I. G. R. A. by Henry Haag, supervisor of Green county:

ITEMIZED COSTS.

5 FT. x 8 FT. REINFORCED CONCRETE CULVERT.

Foundations required piling and three feet of excavation below bed of stream.

40 yards river gravel hauled 3½ miles @ 75c	$ 30.00
40 bbl. Portland cement @ $2	80.00
7 pcs. 7″ I-beams, 1070 lbs. @ $1	10.70
800 lbs. old junk rods and bars at 60c per hundred	4.80
28 Stub piling 10′ @ 50c each	14.00
3 men and team two days driving piling @ $6	12.00
4 men excavating 2 days @ $1.50	4.50
Use of lumber and wastage in forms	15.00
Hauling piles, pile driver, lumber and cement and tools	8.00
Filling in bridge after completion, 2 men and team 1 day	4.50
2 men 1 day taking off forms and false work @ $1.50	3.00
	$ 225.50
Deducting for extra work in driving piling which cost	28.00
Cost of bridge in ordinary ground	$ 197.50

Fig. 34—Flat Top Culvert near Jefferson, Iowa.

The cost of the concrete in this bridge was $6.00 per yard, there being 33 yards of concrete in the bridge, as follows:

Foundations contained	232 cu. ft.
Walls and wings	392 cu. ft.
Slab floor	220 cu. ft.
Wheel guard	43 cu. ft.
	887 cu. ft. or 33 yards

The following is the cost of the different items per yard:

Cement	$ 2.40
Labor	1.75
Steel	.45
Gravel	.90
Lumber	.50
	$ 6.00

ITEMIZED COST.

7 FT. x 8 FT. REINFORCED CONCRETE CULVERT.

Foundation on blue clay three feet below bed of stream.

8 yards pit gravel donated and used in foundations.	
50 yards river gravel @ $1	$ 50.00
65 bbl. Portland cement @ $2	130.00
Kahn trussed bars for reinforcing slab floor	50.00
2400 lbs. old junk rods, bars and angles @ 60c	14.40
Excavation, 2 teams, 3 men 3 days @ $8	24.00
Lumber, use of and wastage for forms	20.00
Considerable bridge lumber that we had on hand was used.	
Joists, etc., not damaged and no charge made against the work.	
Building forms	10.00
4 men 6 days @ $2, mixing concrete	48.00
Man and team @ $3 hauling water, gravel and cement to mixing boards 6 days	18.00
2 men 1 day @ $2 taking off forms	4.00
Team hauling lumber and tools back	3.00
Filling in dirt on and around bridge after completion, 2 teams one day @ $3	6.00
Total cost	$ 385.40

The cost of the concrete in this bridge was $7.30 per yard, there being 53 yards of concrete in the bridge as follows:

Foundations contained	220 cu. ft.
Walls and wings	612 cu. ft.
Wheel guard	85 cu. ft.
Hand rail	100 cu. ft.
Slab floor	396 cu. ft.
	1413 cu. ft. or 53 cu. yds.

The following is the cost of the different items per yard:

Cement	$ 2.35 per yard
Gravel	1.00 per yard
Labor	2.30 per yard
Steel	1.15 per yard
Lumber	.50 per yard

As to the relative merits of the contract system and the day labor system on such work, an examination of the reports from the various counties showed that of those reporting which system was used, just half used the contract system and the other half the day labor system. For the ordinary small structures where the counties can find a thoroughly reliable foreman to take charge of the work, they will in most cases undoubtedly get the work done more economically by day labor, but for the larger structures and those entailing a considerable amount of machinery, equipment and engineering skill the contract system should be used. When this system is followed the county should not fail to have a man employed who thoroughly understands the work to inspect during the progress of construction and require the conditions of the contract to be fulfilled. The time to inspect concrete is while it is being mixed and placed in position—not after the structure is completed.

Concrete Materials. To so many county and township men there seems to be a certain misunderstanding of the properties of concrete, and why certain conditions must be imposed upon its use to produce reliable results. While it is true that a certain amount of technical skill and knowledge must be employed in proportioning the materials and in designing the structures, the whole subject can be well understood by any county or township road official who will give to it intelligent thought. In the first place it is necessary to know the influence that each of the materials used in its composition has on the final product, and when these are understood such conditions as might be called theoretical or impractical will be found not only reasonable but essential.

Fig. 35—Test Culverts of Iowa Highway Commission, showing wing walls and short section of Culvert.

PORTLAND CEMENT. The superiority of Portland cement over either natural or slag cements would recommend its use even to the exclusion of the others. The manufacture of this cement was first begun in 1827 and it takes its name from its resemblance in color when set or hardened to the stone found on the Isle of Portland. It is the product of the burning together of about 75 percent of limestone and about 25 percent of clay, finely ground and intimately mixed together and burned to the point of incipient vitrification, or the point at which the materials fuse, forming a clinker. This clinker is then ground to a very fine powder which is placed in bags or barrels ready for the market.

There are a number of very important considerations which effect the quality of the finished product, the first being the *composition and proportioning of the raw materials.* If the proportion of lime is too high the result will be a cement which sets slowly and will likely contain "free" lime. If the proportion of clay is too high the clinker is likely to be overburned and the setting or hardening quality of the cement will be damaged, if not destroyed.

There are also a number of substances, such as magnesia and sulphate of lime, which are regarded as impurities detrimental to the quality of the cement if found in any considerable amount, and the raw materials must be so chosen as to give low proportions of such impurities.

The second consideration is the *burning or clinkering of the materials.* Revolving, cylindrical kilns are used, the raw materials passing in at one end and issuing from the other in small black lumps or clinkers. Under-burning does not often occur except with a mixture having too high a proportion of clay or in consequence of some defect in the kiln itself. An example of this occurred where the product of a certain kiln was changed from a poor to a standard grade of cement by increasing the

length of the kiln about 20 feet. Under-burning produces a quick setting, weak cement and one which would usually fail to pass the fineness test.

Over-burning is also apt to occur with a mixture having too high a proportion of clay, and the product will be a slow setting cement, deficient in hardening qualities.

TESTS OF CEMENT. To prove the quality of cement a number of standard tests have been devised as follows:

(1). Tensile Strength,
(2). Time of Setting,
(3). Soundness, (4). Specific Gravity.

These tests are reliable when conducted in a first class laboratory and there are sufficient "tricks of the trade" to make it desirable for prospective purchasers to order cement subject to the standard tests.

Two sets of standard cement tests are in common use, namely, the U. S. Army Specifications and the American Society for Testing Materials Specifications. The latter is perhaps the most generally used now. The respective requirements of these specifications are given in the following table taken from Engineering Experiment Station bulletin, "TESTS OF CEMENT."

Specification Requirements for Portland Cement.

Kind of Test	American Society for Testing Materials		U. S. Army Engineers	
	Min.	Max lbs. per sq. in.	Slow Setting	Quick Setting
Tensile Strength				
Neat 1 day old	150	200		
Neat 7 days old	450	550	450 lbs. per	400
Neat 28 days old	550	650	540 sq. in.	480
1 cement to 3 sand, 7 days old	150	200	140	120
1 cement to 3 sand, 28 days old	200	300	220	180
Soundness Pats	Cold Test and Steaming 3 hours		Cold Test and Boiling 6 hours after Set	
	After Set 24 hours			
Fineness	Not Less Than		Not Less Than	
Passing No. 100 sieve	92 per cent		92 per cent	92 per cent
Passing No. 200 sieve	75 per cent		....	....
Time of Setting			Slow Setting	Quick Setting
Initial Set	Not Less Than 30 min.		Not Less Than 45 m.	20-30 m.
Hard Set	Not less than 1 hour Not more than 10 hours		Not More Than 10 hrs	45 m. — 2½ hrs.
Specific Gravity	Not less than 3.10		Between 3.10 and 3.25	
Sulphuric Acid (SO3)	Not more than 1.75 per cent		....	....
Magnesia (MgO)	Not more than 4 per cent		....	....

The bulletin named gives the results of tests made in the laboratory on many of the brands of cement offered for sale throughout the state. It is sent free on request.

THE PURCHASE OF CEMENT. Many of the counties are beginning to buy cement in car load lots and the following specifications for buying is recommended to trustees and supervisors:

SPECIFICATIONS TO ACCOMPANY ORDERS FOR PORTLAND CEMENT.

Condition on Delivery. The cement shall be packed in strong and undamaged paper or cloth sacks, each stamped with the name of the cement and company manufacturing same. The average net weight of the cement shall be 94 lbs. in each sack. It shall be dry and free from lumps.

Tests. The quality of the cement shall conform fully to the requirements of the 1904 Specifications of the American Society for Testing Materials. Tests to be made in any laboratory selected by the purchaser.

Failure to Pass Specifications. If the cement fails to pass the requirements of these specifications named, the cement shall be rejected, and removed, all to be without expense to the county or township.

Agreement.

We (name of company) accept the attached order on the conditions named above.

Signed.....(Company)
By....., Agent
Date.....

PRODUCTION OF CEMENT. The production of Portland cement in the United States for 1904 was 26,505,881 barrels, an increase of more than four million barrels over the 1903 output. Up to the present time there have been no cement factories in the state, but recently definite steps have been taken to establish a Portland cement factory at Mason City.

The prices paid for cement have varied considerably in the different counties, varying from $1.50 to $2.50 per barrel. With the establishment of new factories, and an increased output from those already in operation, it is not likely that the price will remain long above the quotations for the past year.

DIRECTORY OF CEMENT MANUFACTURERS.

AA Chicago Brand Portland Cement—
Chicago Portland Cement Co., 211 Stock Exchange Bldg., Chicago, Ill.

Alpha Brand Portland Cement—
Alpha Portland Cement Co., 740 Marquette Building, Chicago, Ill.

Alsen Brand American Portland Cement—
Alsen's American Portland Cement Works, Alsen, N. Y.
Atlas Brand Portland Cement—
Atlas Portland Cement Co., 30 Broad St., New York City.
Bronson Brand Portland Cement—
The Bronson Portland Cement Co., Bronson, Michigan.
Buckeye Brand Portland Cement—
Buckeye Portland Cement Co., Bellefontaine, Ohio.
Dragon Brand Portland Cement—
The Lawrence Cement Co., Siegfried, Pa.
Giant Brand Portland Cement—
American Cement Co., 22 S. 15th St., Philadelphia, Pa.
Iola Brand Portland Cement—
Iola Portland Cement Co., Iola, Kan.
Lehigh Brand Portland Cement—
Lehigh Portland Cement Co., Allentown, Pa.
Marquette Brand Portland Cement—
Marquette Cement Mfg. Co., LaSalle, Ill.
Owl Brand Portland Cement—
German-American Portland Cement Works, 1511 Marquette Bldg., Chicago, Ill., and LaSalle, Ill.
Peerless Brand Portland Cement—
Peerless Portland Cement Co., Union City, Mich.
Red Ring Brand Portland Cement—
St. Louis Portland Cement Co., St. Louis, Mo.
Saylor's Brand Portland Cement—
Coplay Cement Mfg. Co., 1123 Broadway, New York City.
Sunflower Brand Portland Cement—
Kansas Portland Cement Co., Iola, Kan.
Universal Brand Portland Cement—
Cement Department Illinois Steel Co., The Rookery, Chicago.
Vulcanite Brand Portland Cement—
Vulcanite Portland Cement Co., Land Title Bldg., Philadelphia.
Yankton Brand Portland Cement—
Western Portland Cement Co., Yankton, S. D.

Sand.

For the purposes of this article, to distinguish sand from gravel, such material as passes a No. 10 screen, i. e. a wire screen having 10 meshes per lineal inch or 100 meshes per sq. inch, will be called sand. The possible supplies are along the stream beds and gravel banks, either near streams, in which case the material has probably been deposited by water, or removed from them, which signifies its glacial deposition. Water tends to separate the sand into uniform sizes and the per cent.

of voids may run high in river sand beds or banks, but it is usually freer from loam and vegetable matter than the other class of gravel banks. Any of these sources will usually supply a good grade of sand if proper precautions are taken. The material must be free from vegetable matter of all kinds and although some laboratory tests show that the presence of even a considerable per cent. of loam does not have any injurious effect upon a medium mortar, e. g. 1 part cement to 3 parts of sand, only reasonably clean material should be used. Loam or earthy matter does not have the same specific gravity as sand and in ordinary mixing would not be uniformly distributed through the mortar, but more important than this is the detrimental feature of introducing too much fine material. That the sand shall be clean is far more important than whether it is round or sharp and a sand that is made up of different sizes of particles is much better than one having uniform grains.

The cost of sand delivered at the work during the past year was from 25 cents to $1.00.

Tests of Sand for Concrete. Tables of tests of Iowa sand and gravel for concrete are given in Section Four.

Screened Gravel and Broken Stone. Screened gravel ranging from particles just retained on a No. 10 screen up to pebbles 2 1-2 inches in diameter makes an excellent aggregate for concrete. Such a material will contain a smaller per cent. voids than broken stone with angular fragments.

Stones broken to pass a 2 1-2 inch screen for slabs not less than 6 inches in thickness, and broken to pass a 2 inch screen for slabs under 6 inches will prove equally satisfactory. The question of relative strength need not enter this discussion as with first class materials of each kind the choice should be based entirely on the cost per cubic yard delivered. If there is considerable percentage of stone dust, the amount of sand should be decreased.

The cost of crushed stone will vary with the distance from a crusher. A good grade of stone can be purchased at 60 cents to 65 cents per ton (2227 lbs.) f. o. b. the quarry. The freight rate when consigned to road officers for a 50 mile haul is about 52 cents per ton.

Directory of Crusher Companies

About the only deposits in Iowa suitable for crushing are the limestone. There are a few counties in the eastern part of the state where granite boulders are scattered over the ground in sufficient quantities to warrant their being used for this purpose, but at present the only crushed rock available is that from the

limestone quarries. There are a large number of crusher plants in the state and a list is included here for convenience in ordering.

Arquitt, B. N. & Sons, Farley, Ia., C. G. W. Ry.
Bealer, E. J. C., Cedar Valley, Ia., C., R. I. & P.
Cedar River Stone Co., Waverly, Ia., C. G. W. Ry.
Chilton, Charles, Ottumwa, Ia., C., R. I. & P. Ry.
Dearborn, H. Bros., Stone City, Ia., C., M. & St. P. Ry.
Des Moines Bld. & Crushed Stone Co., Peru, Ia., C. G. W.
Erickson, F. Co., Stone City, Ia., C., M. & St. P. Ry.
Ellsworth Stone Co., Iowa Falls, Ia., D. M., I. F. & N. Ry.
Kemper, E. G., Burlington, Ia., Burl. Rt.
Linswood Quarry Co., Linwood, Ia., C., R. I. & P. and C., M. & St. P. Rys.
Le Grand Quarry Co., Marshalltown, Ia., C. & N.-W. Ry.
Laines, Andrew, Dudley, Ia., C., B. & Q. Ry.
McManus & Tucker, Keokuk, Ia., C., B. & Q. and C., R. I. & P. Rys.
Shields, T. H. & Sons, Dudley, Ia., C. B. & Q. Ry.

Owing to the wide variation in the quality of the limestone which we have in the state, a careful investigation of the products should be made before a supply is ordered. Probably the best rock that is now available is the blue limestone.

Unscreened Gravel. By far the largest proportion of gravel which has been used by the county or township road men has been unscreened gravel or sand in some proportion such as 1 cement to 5 or 6 parts gravel and sand. Such a material costs from 50 cents to $1.25 per cu. yd. delivered. The use of the unscreened material will be discussed under the paragraph on proportioning.

"In using gravel for concrete, care must be taken that it is free from dirt or soil. Some engineers claim gravel with 12 per cent. soil distributed through it does not injure it for concrete purposes. We have obtained good results with a pit or bank gravel that was washed clean and with clean river gravel. We would not use or advise the use of dirty gravel."*

It is very likely that some concrete that has been made with a poor quality of gravel will deteriorate very rapidly under frost action and it is poor economy to use such gravel or sand for concrete work.

Concrete. Concrete has been defined as "an artificial stone" and the nearer it approaches the nature of a good natural stone, the better results it will give. It may be regarded as having a matrix or mortar of sand and cement in which are imbedded

*Paper by Henry Haag, Greene County.

and entirely surrounded by this mortar, larger particles of inert matter such as gravel or broken stone.

There are four conditions which govern or limit the strength and durability of concrete:*

1. **The quality of the cement.**
2. **The texture of the aggregate.**
3. **The quantity of cement in a unit volume of concrete.**
4. **The density of the concrete.**

The quality of the cement and the texture of the sand, gravel or broken stone have been discussed. The amount of cement per unit volume and the density of the concrete is dependent upon the proper proportion of the material.

Proportions for Use. Much work has already been done with a proper understanding of the necessity of carefully proportioning the materials. For the mortar a 1:3 mixture at least should be used and for a stronger concrete 1 part of cement to 2 parts of sand. This point of having a good mortar cannot be emphasized too strongly as there is no doubt that some of the counties are using mortars entirely too "lean" or deficient in cement. A mortar containing too much sand is not only weak but at the same time uneconomical.

The following schedule shows the decrase in strength of mortars as the proportion of sand is increased.

Schedule Four

Strength of Portland Cement Mortars in Compression. Age 4 Months--Watertown Arsenal.

Proportions by Cement	Volume Sand	Compressive Strength per sq. in.
1	1	4370
1	2	2506
1	3	1812
1	4	830
1	5	532
1	6	169

The strength per sq. in. in compression of the 1:4 mortar is less than one-half the strength of the 1:3 mortar, and only one-third of the 1:2 mortar.

*Taylor and Thompson--Concrete Plain and Reinforced.

The theory of the proportioning of the materials for concrete is to select such an amount of each that it will exactly fill the voids in the material of the next larger size—that is, the cement should thoroughly coat the grains of sand, and the mortar should be sufficient to completely fill the voids in the broken stone or gravel. To gain the greatest strength with the least cement, it is necessary that the materials be correctly proportioned, and this should be done before any piece of work is undertaken that will involve the use of a large quantity of a certain kind of material. The following proportions are given as a guide to the general practice at this time.

For arches and flat tops for culverts:

1 part cement, 2 parts sand, 4 parts broken stone, or

1 part cement, 1 1-2 parts sand, 4 parts screened gravel.

For wing walls, or piers, or abutments:

1 part cement, 3 parts sand, 6 parts broken stone, or

1 part cement, 2 parts sand, 5 parts screened gravel.

Where a gravel concrete is used engineers ordinarily require about ten per cent. additional cement to be used over broken stone concrete.

Broken Stone vs. Gravel. There is considerable discussion as to which is the better for the aggregate in concrete. In reference to this it may be said that the gravel is ordinarily a harder and tougher material than the broken stone. It is rounded so that less bridging occurs to form voids in the concrete. Less ramming is required, and with the well selected gravel there is less danger of an improper proportioning of the materials. On the other hand broken stone, being sharp and angular, gives a better surface for adhesion of mortar and is ordinarily cleaner. For ordinary work the advantage will lie with the material which is available at the lowest cost, as good work can be produced with either provided careful attention is given to the selection and proportioning of the materials.

The cost of screening gravel may be estimated at 35 cents per yard, and it is recommended that only screened gravel be used except on very small jobs. For culverts under a five foot span the unscreened gravel can be satisfactorily used if when tested with a No. 10 screen, the proportions give a mortar not weaker than 1 part cement to 3 parts sand.

In figuring the cost of concrete it is desirable to know how much material is required to make a cubic yard of concrete of different proportions, and for this purpose the following table has been prepared.

SCHEDULE FIVE.

Quantities of Materials for 1 cubic yard of Rammed Concrete. Cement 3.8 cu. ft. per bbl.*

PROPORTION BY PARTS			PROPORTION BY VOLUME		
Cement	Sand	Stone	Cement bbl.	Sand cu. yd.	Screened gravel or broken stone cu. yd.
1	2	4	1.57	0.44	0·88
1	2½	5	1.3	0.46	0.92
1	2	5	1.10	0.47	0.94

If unscreened gravel is used the amount of material required will be about as given in the following schedule. It must be accented that these tables are given for estimating quantities but are sufficiently close to approximate the final cost.

SCHEDULE SIX.

Quantities of Materials for 1 cubic yard of Concrete. Using Unscreed Gravel.

PROPORTION BY PARTS		PROPORTION BY VOLUME	
Cement	Unscreened Gravel	Cement	Unscreened Gravel
1	4	1.78	1.00
1	5	1.40	1.05
1	6	1.28	1.08
1	7	0.9	0.97

Mixing. There are two methods of mixing concrete on the work, (1) *by hand*, (2) *by machinery*.

When hand mixing is employed a tight platform should be built near the work. The material, except the cement, may be measured in wheel barrows or bottomless boxes, but such an amount should be mixed at one time as will require an even number of sacks or barrels of the cement.

The sand should first be placed on the platform, then the cement spread evenly over it. The shovelers, working in pairs, turn these ingredients until they are thoroughly mixed dry. Water is added and the operation continued as long as necessary. The broken stone or gravel is then added to the mortar and the concrete thorougly mixed. Three to five turnings are ordinarily necessary to accomplish the best results.

* Taylor and Thompson—Concrete P. and R.

For ordinary use a wet mixture is recommended, especially in thin slab construction reinforced with steel. It is important however to have the forms almost water-tight or a considerable amount of cement may be carried away by the excess water. A wet mixture requires all the water that can be incorporated with the mixture.

For small jobs four men can work to advantage in mixing the concrete and should mix and place about seven to eight cubic yards in 10 hours if there is no delay in building forms and if the raw material is close at hand and the concrete can be shoveled to place from the mixing platform.

This platform should be about 15 feet square with a narrow edge around two or three sides. It should be water-tight and finished with no projecting nails or edges on top. There is a tendency to adopt the mixing box and hoes used commonly by plasterers but this is a slow uneconomical method compared to the mixing platform and square pointed shovels.

Machine mixing can be used to great advantage on work requiring considerable concrete. Greene county which is doing a large amount of this work has purchased a steam mixer and keeps the concrete gang constantly employed. If a machine mixer is used the cost of labor will be less and the product will be more uniform.

Placing the Concrete. The forms for the concrete should be constructed of lumber so stiff that there will be no bulging when the concrete is rammed into place. The simplest manner of holding the forms true is by bracing the outside and also wiring across between the forms. When the concrete is set the wires can be clipped close to the surface.

The concrete should be deposited in layers not over 6 inches in thickness and thoroughly rammed into place. With a wet mixture only a slight "settling" or "joggling" should be given the material. Forms of one inch lumber should have studs not over two feet apart and of two inch stuff not over four feet apart with such external bracing as is necessary. For the comparatively thin slabs a small rammer should be used and care taken to compact the concrete around the steel reinforcement without displacing it. Considerable care should also be taken not to drop or throw the concrete any distance as this separates the different materials and destroys the homogenity of the product.

When joints have to be made between two days work, the surface of the concrete should be left as rough as possible. Before a fresh layer is added, the old surface should be thoroughly cleaned and wet, then to insure a good joint, neat cement should be sprinkled over it.

Specifications. A set of specifications is included in this chapter for the use of concrete and steel in culverts and bridges.

Reinforced Concrete. Concrete beams or slabs when reinforced with iron or steel rods will safely carry much heavier loads than plain concrete. It can also be used for structures that would be neither safe nor economical if built of the concrete alone. This is especially true of flat topped bridges and culverts which the Highway Commission is recommending for general use. The design is a simple box-shaped structure with wing walls extending at each end at an angle of about 30 degrees to the axis of the culvert. This shape was adopted for several reasons, chief among them being the simplicity of design and consequent ease of construction, forms that can be built at reasonable cost, and economical combination of steel and concrete. Each side and also top and bottom act as beams and the stresses imposed may be easily and quite accurately figured. In favor of this form of construction there is no thrust tending to force the walls outward as is true with arch culverts. In many places the limited head room in which these culverts are to be constructed makes it impossible to put in the arch top. Figure No. Thirty-five shows the test culverts of the Highway Commission. The dimensions of the culvert should be proportioned to the loads they are to carry and in order to do this a uniform practice should be followed. A number of formulas for use in reinforced concrete construction have been advocated by different men but a number of these involve certain properties which are common only to the reinforcement for which they are formulated. A simple straight-line formula has been proposed by Mr. Theo. L. Condron of Chicago, based on the tests which have been made with reinforced concrete. This formula has been modified by the Commission and used in designing the standard concrete culverts. A diagram has been plotted from the formula, and furnishes a very simple method of finding the required dimensions. However, rather than insert the theory of the formula or the diagram here, which would be of doubtful value in this connection a table has been made up, from which may readily be taken the sizes and reinforcements necessary for constructing culverts up to a 12 foot clear span. These culverts are designed to carry a 16 to 20 ton road roller and a dead load of 600 pounds per lineal foot, with a safety factor 4. These loads are greater than will come up in general practice but a large factor of safety must necessarily be used to guard against possible failure due to incompetent handling of material and such exigencies as commonly come in county and township work.

The following schedule gives the dimensions of some of the standard designs.

Dimensions of Standard Culverts.

Thickness of Concrete				Steel Reinforcement—No. of Corr. Bars		
Size	Top	Sides	Bott'm	Top	Sides	Bottom
2x2	6 in.	6 in.	4 in.	½ in. — 8 in. C to C	½ in. — 24 in. C to C	½ in. — 24 in. C to C
2x3	7 in.	6 in.	5 in.	⅝ in. — 7 in. C to C	⅝ in. — 24 in. C to C	⅝ in. — 18 in. C to C
3x4	8 in.	6 in.	5 in.	⅝ in. — 6 in. C to C	⅝ in. — 20 in. C to C	⅝ in. — 24 in. C to C
4x6	10 in.	7 in.	8 in.	¾ in. — 8 in. C to C	¾ in. — 20 in. C to C	¾ in. — 24 in. C to C
6x6	10 in.	8 in.	8 in.	¾ in. — 8 in. C to C	¾ in. — 16 in. C to C	¾ in — 16 in. C to C

To substitute any other form of bar in the standard plans choose an equivalent area from Schedule No. 7 and select the size of bar corresponding to this area from Schedule 8.

SCHEDULE SEVEN

Table of Equivalent Steel Areas for Use in Standard Plans

SIZE OF BAR	Sectional Area of High Elastic Limit Steel with Mechanical Bond	Sectional Area of Low Elastic Limit Steel without Mechanical Bond
½ inch	0.25	0.31
⅝ "	0.39	0.49
¾ "	0.56	0.70
⅞ "	0.76	0.95
1 "	1.00	1.25

SCHEDULE EIGHT

Areas and Sizes of Various Reinforcing Bars.

NAME OF BAR	Size	Area per Sq. In.	Weight per Lin. Ft.	DESCRIPTION
Corrugated Bars Sold by the Expanded Metal and Bar Company, St. Louis, Mo.	½"	0.25	0.85 lb.	High Elastic Limit Steel. Square, Corrugated.
	⅝"	0.39	1.33	
	¾"	0.56	1.91	
	⅞"	0.766	2.60	
	1"	1.00	3.40	
Ransome Bars Sold by the Ransome and Smith Co. New York.	½"	0.25	0.85	High Elastic Limit Steel. Round Twisted.
	⅝"	0.39	1.33	
	¾"	0.56	1.91	
	⅞"	0.766	2.60	
	1"	1.00	3.40	
Thatcher Bars Sold by the Concrete Steel Engineering Co., New York.	½"	0.18	0.61	Low Elastic Limit Steel. Round Corrugated.
	⅝"	0.28	0.95	
	¾"	0.41	1.39	
	⅞"	0.55	1.87	
	1"	0.71	2.42	
Plain Bars	½"	0.25	0.85	Low Elastic Limit Steel. Square Smooth.
	¾"	0.56	1.91	
	1"	1.00	3.40	
	½"	0.196	0.67	Low Elastic Limit Steel. Round Smooth.
	¾"	0.44	1.50	
	1"	0.78	2.67	

"Ordinarily independent foundations are built for the side wall in the case of larger culverts and are connected by a 5 inch slab of concrete to protect from undermining. The reinforcing used amounts to 1 per cent. for the culvert tops and one-half per cent. for the sides. While corrugated bars are mentioned in the above tables the specifications provide for using plain bars if more economical."

There is considerable discussion among engineers as to the relative merits of a high or low elastic limit steel. The tests made so far show a higher strength developed by the use of the high elastic steel with a mechanical bond.

Cost of Steel. Patented forms of steel in small quantities cost delivered $2.75 to $3.25 per cwt. cut to lengths. Plain mild steel bars cost $2.20 to $2.60 per cwt. delivered.

Standard Plans. A number of cuts of the standard plans of the Commission are included. The original design is 12 in. x 18 in. in size and blue prints together with specifications are prepared and sent free of cost to road officers. How important it is to adopt standard plans and to require strict adherence to the terms of the specifications by contractors and foremen is shown in the accompanying figure.

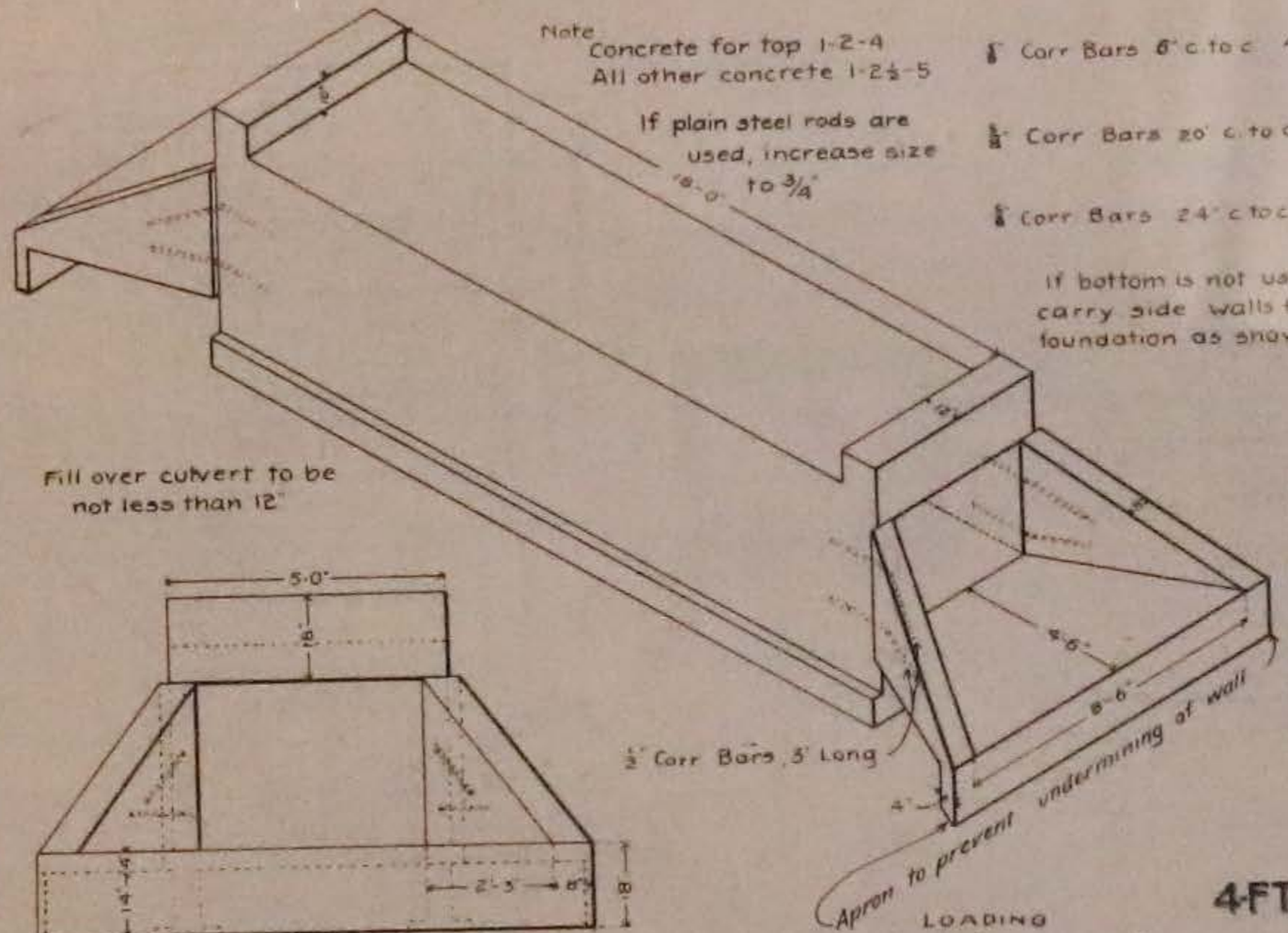
Fig. 36—Failure of Spandrel and Wing Walls on 12 foot Sub Culvert

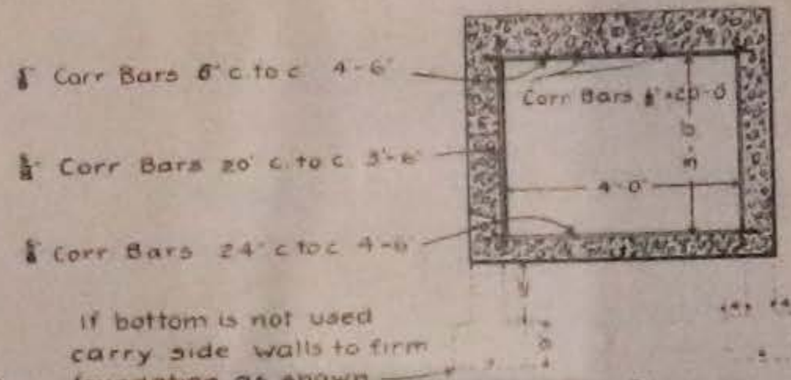
Plans were submitted and approved for a 14 foot slab top culvert reinforced with steel. The contract was let on these plans and the above is a photograph as it now stands. In place of following the plans submitted the contractor substituted a 12 foot arch culvert as shown in Figure Thirty-seven. The wing walls are not worthy the name of being walls as they more nearly resemble batches of concrete shoveled down at the end of the culvert, without any particular design or form. The poor little spandrel wall is 6 inches thick and 18 inches high to hold a fill about 8 feet high. On the opposite end it has shoved out about three inches and is now tottering ready to fall. Such work as this will check the development of the use of concrete and cause counties and townships to lose faith in the material that is by all odds the best for use in bridge and culvert construction.

Foremen and Inspectors. The Commission is constantly in touch with concrete foremen and inspectors and will help any county to secure competent men for this work.

Fig. 37—A Typical Timber Culvert in Typical Condition

Fig. 38—A Reinforced Concrete Culvert now in common use in the Eastern States





CROSS SECTION
Scale ½" = 1'-0"

END VIEW
Scale ½" = 1'-0"

TABLE OF QUANTITIES

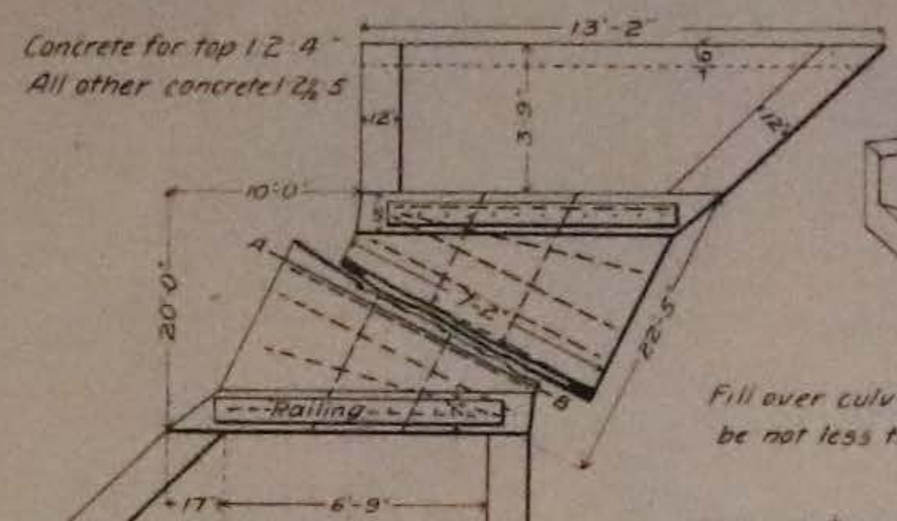
Item		For Culvert As Shown	For Each Additional Ft in Length
Concrete	1-2-4	67 cu ft	3.35 cu ft
	1-2½-5	15.15	4.67
Cement		11 bbls	41 bbls
Sand		37 Cu yds	13 cu yds
Broken Stone or Pebbles		7	2.8
Corr Bars	⅝"-4'-6"	40 Bars	2 Bars
	⅝"-5'-6"	24	1.2
	⅝"-4'-6"	10	0.5
	½"-3'-0"	8	
	½"-20'-0"	2	
Total of Bars		373 ft = 453 lbs	

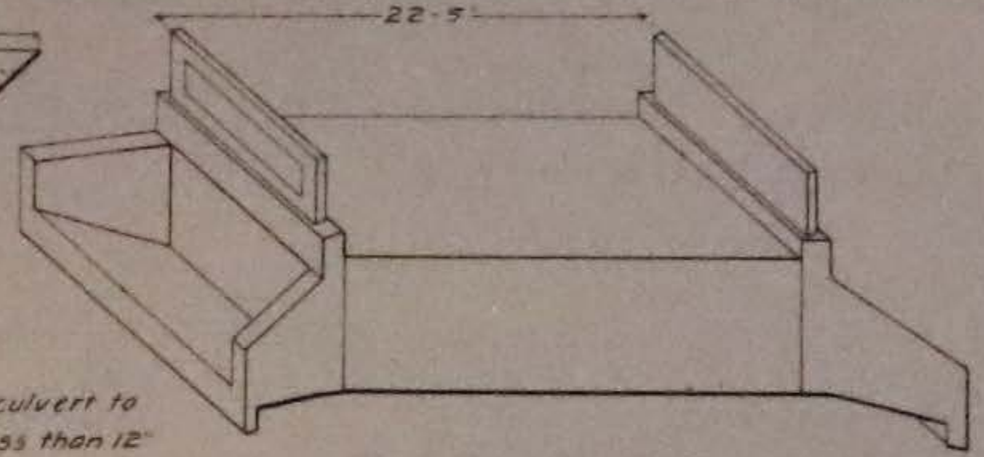
LOADING
U.L.L. 100 lbs per sq. ft
C.L.L. 20 ton roller
D.L 500 lbs. per sq. ft

DESIGN
—FOR—
4-FT. × 3-FT. BOX CULVERT
—OF—
REINFORCED CONCRETE

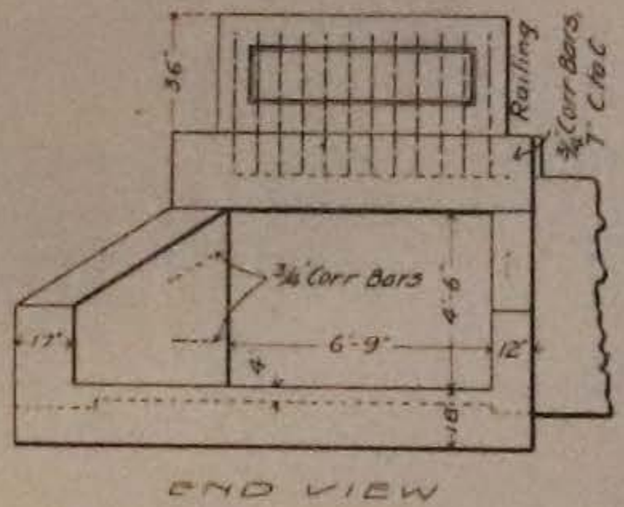
IOWA HIGHWAY COMMISSION
June, 1908

Fig. 39

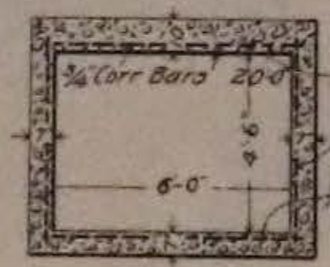




Fill over culvert to be not less than 12"



END VIEW



SECTION A-B

LOADING

ULL 100 Lbs per Sq Ft
CLL 20-Ton Roller
DL 500 Lbs per Sq Ft

TABLE OF QUANTITIES

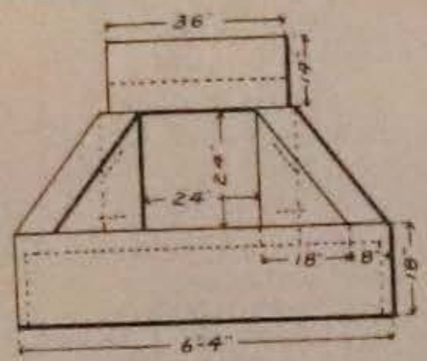
Item	For Culvert As Shown	For Each Additional Foot in Length
Concrete 1:2:4	176 Cu Ft	6.1 Cu Ft
" 1:2½:5	319 " "	9.6 " "
Cement	24.9 Bbls	0.80 Bbls
Sand	8.0 Cu Yds	0.26 Cu Yds
Broken Stone or Pebbles	17.0 " "	0.54 " "
Corr Bars ⅜"×6'-6"	45 Bars	2 Bars
" ¾"×4'-6"	26 "	1.2
" ¾"×3'-6"	8 "	
" ¾"×22'-5"	2 "	
" ¾"×3'-6"	24 "	
Total Corr Bars	562.5 Ft	107.44 Lbs

DESIGN
FOR
4½-FT. × 6-FT. BOX CULVERT
OF
REINFORCED CONCRETE

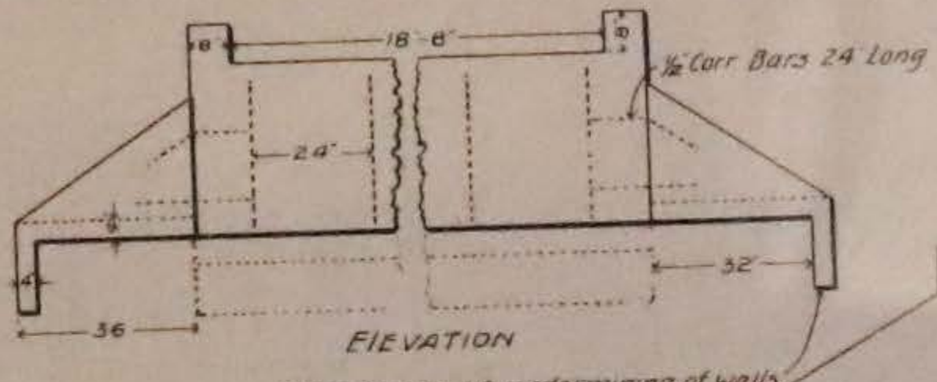
IOWA HIGHWAY COMMISSION

July 1906 Scale ½"=1'-0"

Fig. 40

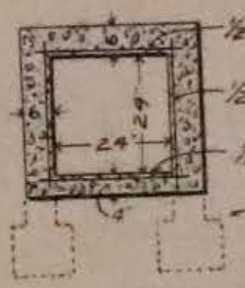


END VIEW



ELEVATION

Apron to prevent undermining of walls



If bottom is not used, carry side walls to firm foundation as shown

CROSS SECTION

LOADING

ULL - 100 Lbs per Sq Ft
CLL - 20-ton Roller
DL - 500 Lbs per Sq Ft

Concrete for Top 1-2-4
All Other Concrete 1-2½-5

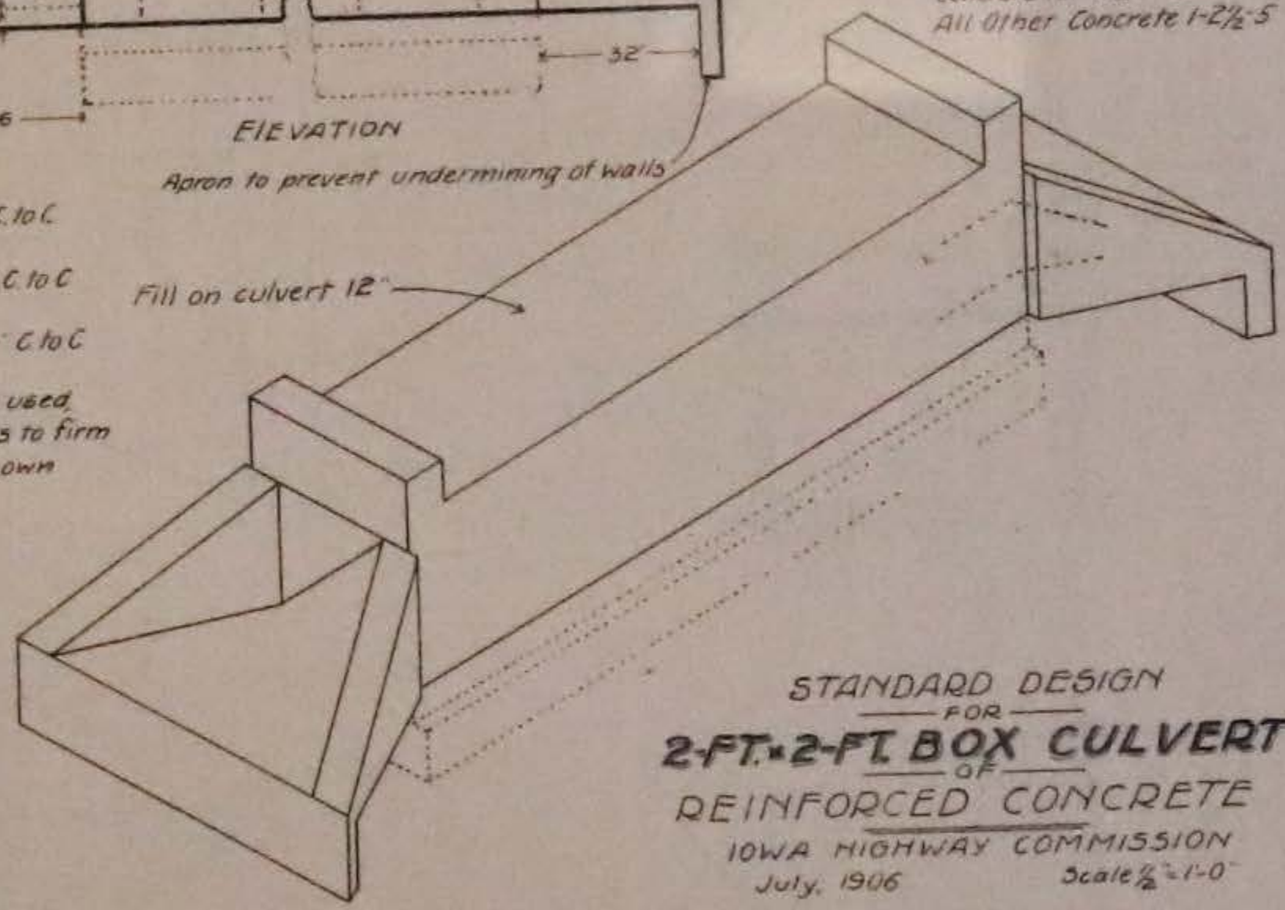


TABLE OF QUANTITIES

Item	For Culvert As Shown	For Each Add'l Foot in Length
Concrete 1-2-4	32.7 Cu Ft	1.6 Cu Ft
1-2½-5	83.6	3.0
Cement	5.7 Bbls	0.23 Bbls
Sand	1.9 Cu Yds	0.08 Cu Yds
Broken Stone or Pebbles	4.0	0.16
Corr Bars ½-30	60 Bars	3 Bars
½-24"	8	
Total Corr Bars	166 Ft = 141 Lbs	

STANDARD DESIGN
FOR
2-FT.-2-FT. BOX CULVERT
OF
REINFORCED CONCRETE
IOWA HIGHWAY COMMISSION
July, 1906 Scale ½"=1'-0"

Fig. 41

Fig. 42

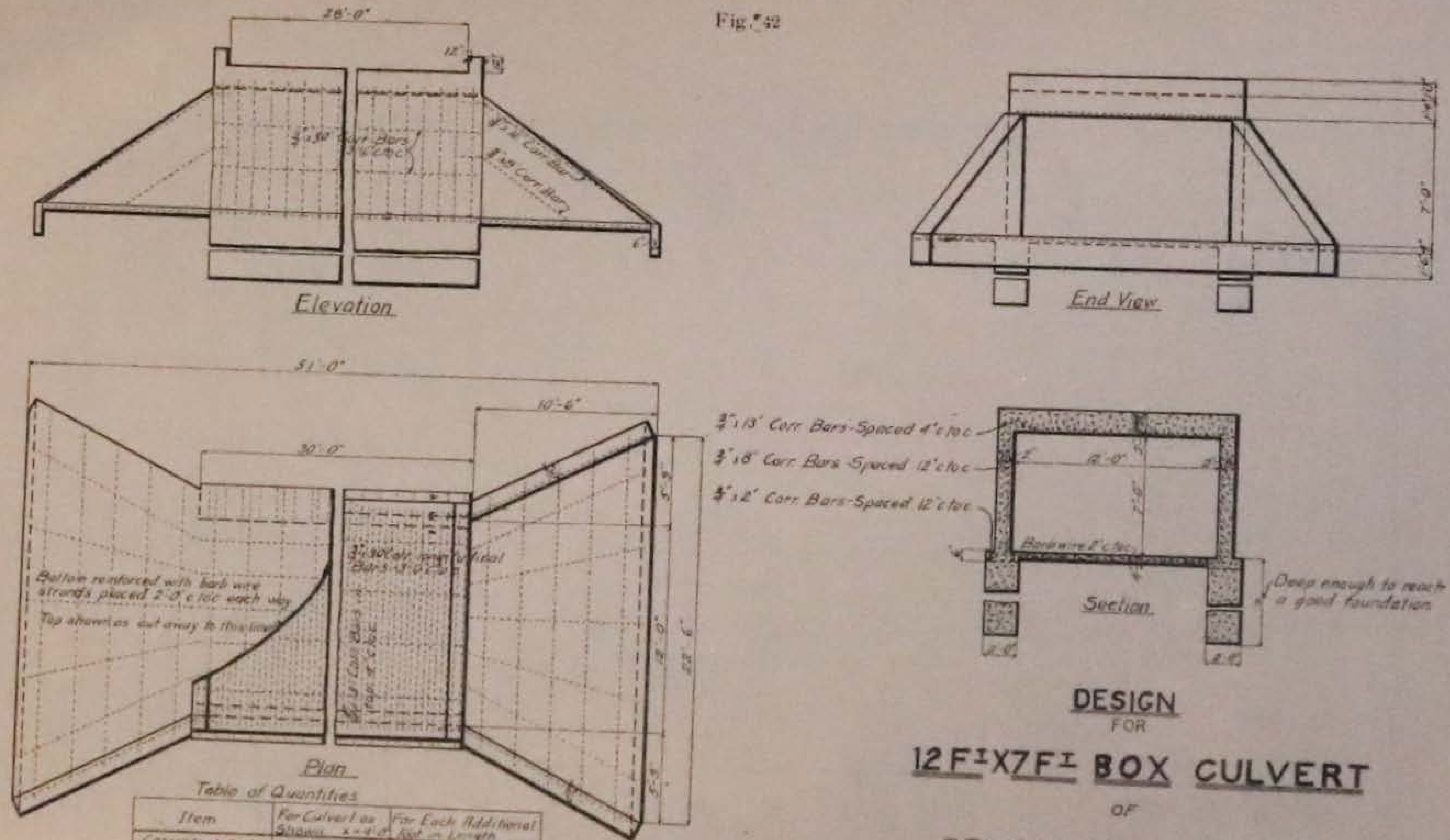


Table of Quantities

Item	For Culvert as Shown x=4'-0"	For Each Additional Foot in Length
Concrete 1-2-4	570.8 Cu ft	19.2 Cu ft
" 1-3-5	1262.0 " "	31.3 " "
Cement	82 Bbls	2.7 Bbls
Sand	33 Cu yds	0.92 Cu yds
Broken Stone or Pebbles	57.6 "	1.60 "
Corr Bars 3/4"x30'	8 Bars	Increase length 1'-0" each
" 3/4"x13'	40 "	3 Bars
" 3/4"x8'	64 "	2 "
" 3/4"x2'	60 "	2 "
" 3/4"x16'	4 "	0
Total Corr Bars	2064 ft - 4088 lbs	67 ft - 128 lbs
Barb wire	6330 ft - 40 lbs	149 ft - 8 lbs

Note
Concrete for top 1-2-4
All other concrete 1-3-5
Table of quantities figured for a 4 ft foundation

SECTION EIGHT.

SPECIFICATION.

The specifications included in the chapter are those commonly used. While the ones given here are much abridged, they are yet much more definite and comprehensive than those usually in effect through the counties and townships.

The list given is as follows:

1. Tile Drains. (Recommended by Civil Engineering Dept.).

2. Macadam Roads. Clinton Co.

3. Steel Bridges. Abridged from the American Building Co. Standard Ppecifications.

4. Concrete for Culverts and Bridges.

5. Purchase of Cement in Section Seven.

1. STANDARD SPECIFICATIONS—TILE DRAINS

CONTRACT

It is hereby agreed between..... , contractor, employer, and..... that the contractor shall, except for the furnishing of the tile along the ditch and the refilling of the ditch, entirely construct for the employer the following described drains:

....
....
....
....
....
....

It is further agreed that for the above work the employer lshal pay the following prices:

....
....
....

It is further agreed that the employer..... .....furnish board free to the contractor and his helpers during active prosecution of the work.

It is further agreed that the contractor shall begin thework by.....and complete the same by.....

It is further agreed that all the above work and the payments therefore shall be in strict accordance with the specifications given below and with the engineers' maps, profiels, and plans, all of which are hereby made a part of this contract.

Witness the hands of the respective parties, this..... day of .....A. D.....

.....Employer.

.....Contractor.

SPECIFICATIONS

1. Staking Out the Work. The work will be staked out by the engineer, and his stakes must be carefully preserved and followed.

2. Digging the Ditches. The digging of each ditch must begin at its outlet, or at its junction with another tile drain, and proceed toward its upper end. The ditch must be dug along one side of the line of survey stakes, and about ten inches distant from it, in a straight and neat manner, and the top soil thrown on one side of the ditch and the clay on the other. When a change in the direction of ditch is made, it must be kept near enough to the stakes so that they can be used in the grading bottom. In taking out the last draft, the bade of the spade must go not deeper than the proposed grade line or bed upon which the tile rests.

3. Grading the Bottom. The ditch must be dug accurately and truly to grade at the depths indicated by the figures given by the engineer, measured from the grade stakes. At each grade stake a firm support shall be erected, and on these supports a fine stout cord shall be tightly stretched over the center line of the ditch and made parallel with the grade by careful measurements at each stake, using a carpenter's level. Supports shall be kept erected at three grade stakes, and the work checked each time by sighting over them. Intermediate supports shall be set and lined in by careful sighting wherever necessary to support the cord every 50 feet. A suitable measuring stick shall be passed along the entire ditch and the bottom in all parts made true to grade by measuring from the cord. The bottom must be dressed with the tile hoe, or in the case of large tiles with the shovel, so that a groove will be made to receive the tile, in which the tile will remain securely packed in place when laid.

4. Laying the Tile. The laying of the tile must begin at lower end and proceed up-stream. The tile must be laid as closely as practicable, and in lines free from irregular crooks, the pieces being turned about until the upper edge closes, unless there is sand or fine silt which is likely to run into the tile, in which case the lower edge must be laid close, and the upper edge covered with clay or other suitable material. When in making turns, or by reason of irregular shaped tile, a crack of one-fourth inch or more is necessarily left, it must securely covered with broken pieces of tile. Junctions with branch lines must be carefully and securely made.

5. Binding the Tile. After the tile have been laid and inspected by the employer or his representative, they must be covered with clay to a depth of six inches, unless, in the judgment of the employer or his representatives, the tile are sufficiently firm, so that complete filling of the ditch may be made directly upon the tile. In no case must the tile be covered with sand without other material being first used.

6. Risk During Construction. The ditch contractor must assume all risks from storms and caving in of ditches, and when each drain is completed it must be free from sand and mud before it will be received and paid for in full. In case it is found impracticable, by reason of bad weather or un-

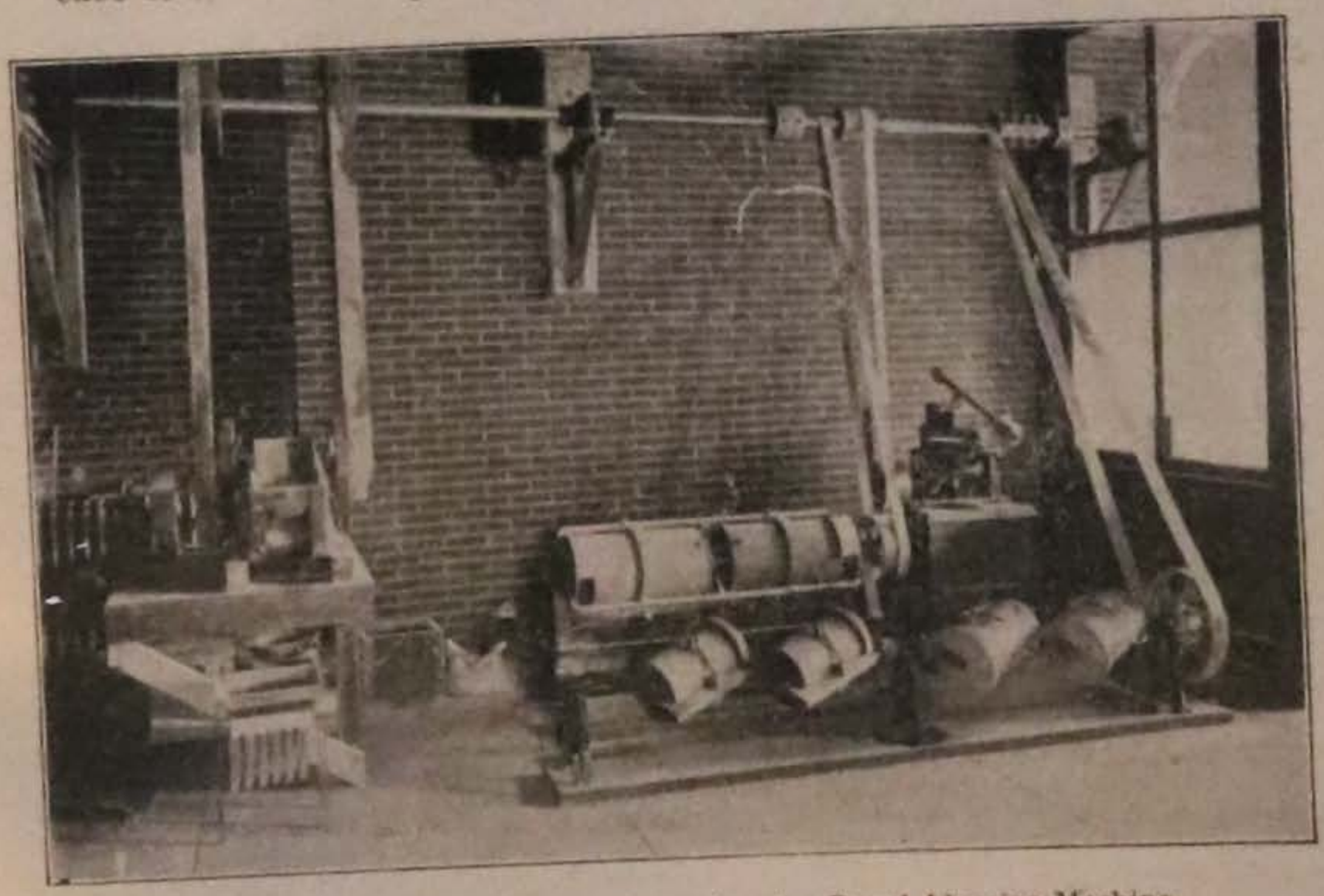


Fig. 43—Road Materials Laboratory, showing Deval Abrasion Machine.

looked for trouble in digging the ditch, or properly laying the tile, to complete the work at the time specified in the contract, the time may be extended as may be mutually agreed upon by the employer or contractor. The contractor shall use all necessary precaution to secure his work from injury while he is constructing the drain.

7. The Tile to be Used. Tile will be delivered on the ground convenient for the use of the contractor. No tile must be laid which are broken, or soft, or so badly out of shape that they cannot well be laid and make a good satisfactory drain.

8. Prosecution of the Work. The work must be pushed as fast as will be consistent with economy and good workmanship, and must not be left by the contractor for the purpose of working upon other contracts, except by permission and consent of the employer. All survey stakes shall be preserved and every means taken to do the work in a first-class manner.

9. Subleting Work. The contractor shall not sublet any part of the work in such a way that he does not remain personallly responsible, nor will any other party be recognized in the payment for the work.

10. Plant and Tools. The contractor shall furnish all tools which are necessary to be used in digging the ditches, grading the bottom, and laying the tile. In case it is necessary to use curbing for the ditches, or outside material for covering the tile where sand or slush is encountered, the employer shall furnish the same upon the ground convenient for use.

11. Payments for Work. Every.....weeks during the persecution of the work the contractor may claim and the employer shall pay 75 per cent. of the value of the work completed satisfactory, the engineer being the arbiter in case of dispute as to the amount of work satisfactorily completed. The remaining 25 per cent. will be retained until the entire work is completed satisfactorily, as certified by the engineer, after a final inspection, at which time the whole amount due shall be paid. Prior to any payment the employer may require a correct statement of all claims incurred by the contractor for labor, materials or damages on account of the work, and the employer may withhold payments until proof has been presented by the contractor of release of all liens against the employer on account of such claims.

12. DUTIES OF ENGINEER. The engineer shall have authority to lay out and direct the work and to inspect and supervise the same during construction and on completion, to see that it is properly done in accordance with the contract. His instructions shall be fully carried out.

13. FAILURE TO COMPLY WITH SPECIFICATIONS. In case the contractor shall fail to comply with the specifications, or refues to correct faults in the work as soon as they are pointed out by the engineer or other person in charge, the employer may declare the contract void, and the contractor, upon receiving 75 per cent. of the value of the completed drains at the price agreed upon, shall release the work and the employer may let it to other parties.

2. SPECIFICATIONS FOR MACADAM ROAD.

Clinton County, 1905

DESCRIPTION

For furnishing the necessary tools, labor and material for grading and macadamizing a portion of the public road from the northwest corner of the southwest 1-4 of Sec. 12, Twp. 82, Range 5, East of the 5th Principal Meridian to the Ten Mile House.

LOCATION.

Sec. 1. The proposed work will extend from the northwest corner of the southwest 1-4 of Sec. 12, Twp. 82, Range 5, north 7705 feet to the east and west public road. Said road to be graded to an even and true surface according to the profiles and stakes of the county surveyor.

ORDER OF WORK.

Sec. 2. To make necessary excavation and grading.
2nd. To make ditch for draining.
3rd. To place macadam.

GRADING.

Sec. 3. As far as possible the earth removed from cuts will be used in making fills and in grading up approaches. Where the macadam is on a filled grade it shall be backed up with three (3) feet of earth.

UNSUITABLE MATERIAL.

Section 4. All material for grading shall be put on in layers not over ten (10) inches thick, and all sod and unsuitable material out of the main roadbed.

FINISHING AND ROLLING.

Section 5. The sub-grade shall then be finished so that the outline of the sub-grade shall be smooth and even and conform to the outline of the completed road, and the surface rolled until compact.

MACADAM

Sec. 6. The wearing surface of the road shall consist of hard, durable lime rock, broken before brought into the road into pieces from one (1) to two (2) inches in diameter (longest way) free from dust and dirt, and deposited on the road in such places as the engineer or his authorized agent may direct, in layers six (6) inches in thickness.

FIRST ROLL MACADAM.

Sec. 7. Said macadam shall then be raked to a true surface of the same shape as the finished road and thoroughly rolled with a heavy iron roller; the contractor shall then cover said macadam with the necessary material for top dressing, consisting of crushed rock not exceeding one-half to three-fourths (1-2 to 3-4) of an inch in diameter, of satisfactory quality and of sufficient amount to fill all interstices and leave a one-half (1-2) inch layer over the entire surface so that no stones will show after the roadway is finished.

FINISHING MACADAM.

Sec. 8. The whole shall then receive a finishing wetting and rolling until well and thoroughly compacted and until the surface becomes smooth.

GENERAL CONDITIONS.

Sec. 9. It is expressly understood and agreed that all material delivered on the road must be to the entire satisfaction of the board of supervisors of Clinton county or their authorized agent, and will at any and all times be subject to their inspection.

UNSATISFACTORY MATERIAL.

Sec. 10. Material not satisfactory in the opinion of said board must be at once removed from the road and replaced by proper material at the expense of the contractor.

3. ABRIDGED SPECIFICATIONS FOR HIGHWAY BRIDGES

From American Bridge Company's Standard Specifications

TYPE OF BRIDGE

For spans 25 to 40 feet—Rolled beams or plate girders.
For spans 40 to 80 feet—Plate or lattice girders.
For spans 80 to 140 feet—Lattice girders.
For spans over 140 feet—Lattice girders or pin connected trusses.

GENERAL DESCRIPTION

WIDTH. The width of the structure shall be not less than 16′ center to center of trusses and shall in no case be less than 1-2 of the span between centers of pin.

HAND RAIL. All boidges except plate girders shall be constructed with a strong suitable hand rail rigidly attached to structure.

FLOOR BEAMS. "All floor beams and through bridges shall be rivited to the main girders."

STRINGERS. "Steel stringers shall be preferably riveted to the web of the floor beams. Wooden joists shall be not less than 3″ thick. Space not more than 2½″ between centers."

WHEEL GUARDS. Wheel guards of a cross section not less than 3″ thick, shall be laid transfersely with ¼″ openings.

WHEEL GUARDS. Wheel guards of a cross section not less than 6″ x 4″ shall be provided. These shall be blocked up from the floor with 2″ blocks not less than 12″ long 5′ feet center to center, held in place with ¾″ bolts.

FOOT WALK PLANK. Foot walk planks shall not be less than 2″ thick and spaced with 1-2″ openings.

DRAINAGE. Provision shall be made for drainage clear of all parts and metal work.

LOADS

CLASS C. OF THE COUNTRY HIGHWAY BRIDGE. "For the load and its support on any part of the roadway concentrated loads on two axles 10′ centers and 5′ gauge or on each street car track concentrated load on two axles 10′ centers. On the remaining portion of the floor including foot walks a load of 100

lbs. per square foot. For the trusses for spans up to 100′ will be 1200 lbs. and for spans of 200′ and over 1000′ per lineal foot and 60 lbs. per square foot for floor.

Class D. Ordinary Country Highway Bridges. For the floor and its support a load of 80 lbs. per square foot of total floor surface or six tons on two axles 10′ centers and 5′ gauge. For the trusses a load of 80 lbs. per square foot of total floor surface for spans up to 75′ and 55 lbs. for spans of 200′ and over proportionally for intermediate spans.

PROPORTION OF PARTS

The minimum thickness of material No material except for lining shall be less than ¼″ thick.

Tensile Strains. Maximum loads shall not cause greater tensile stresses in soft steel than 15000 lbs. per square inch and no medium steel more than 17000 lbs. per square inch.

Compressive Strains. No compression member shall have a length exceeding 120 times its least radius of gyration excepting those for wind bracing.

Shearing and Bearing Strains. Shearing strains on rivets, bolts or pins shall not exceed 11000 lbs. for soft steel, 12000 lbs. for medium steel per square inch of section.

Field Connections. Number of rivets or bolts shall be increased 25 per cent driven by hand, 10 percent for rivets driven by power.

Bending Strain on Pins. Bending strain shall not exceed 22000 lbs. per square inch for soft steel and 25000 lbs. per square inch for mild steel.

Floor Timber. Fiber strain on floor timber from dead and live load without impact shall not exceed 1000 lbs. for the following details of construction.

DETAILS OF CONSTRUCTION

"Adjustable members shall be avoided."

"Lateral and sway bracing shall preferably be made of shapes which can resist compression as well as tension."

All through spans with top lateral bracing shall have portals at each end of span connected rigidly to end posts.

All bridges exceeding 100 ft. in length shall have at one end nests of turned friction rollers between planed surfaces. Bridges less than 100 ft. in length shall be free to move upon smooth surfaces.

Bed plate pressure shall not exceed 400 lbs. per square inch upon masonry.

Pitch or rivets and the direction of the strain shall never exceed 6 inches nor 16 times the thickness of the thinnest outside plate connected.

In the ends of compression members pitch shall not exceed 4 diameters of the rivet for length equal to twice the width of the member.

Distance from the edge of any piece to the center of the rivet hole shall not be less than 1½ times the diameter of the rivet or exceed 8 times the thickness of the plate and the distance between centers of rivet holes shall not be less than 3 diameters of the rivet.

The butt joints of compression members shall be connected by splices to hold them truly in position.

All segments of compression members connected by latcing only shall have tie plates placed as near the ends as practicable.

Size of rivets shall vary from ½" for 5 and 6 inch channels to ⅞" rivets for 15 inch channels or built section with 3½ and 4 inch angles.

Lattice bars shall vary from 1¾ inches in width for 5 and 6 inch channels to 2½ inch for 15 inch channels.

WORKMANSHIP

All rivet work shall be punched accurately with holes 1-16" larger than the size of the rivet. No drifting to distort the metal will be allowed.

Holes for field rivets in floor beams and stringer connections and splices in tension members shall be accurately drilled to an iron template or reamed while the connecting bars are temporarily put together.

Medium steel of ¾" thickness or sheared edges shall be planed or holes shall be drilled to the diameter of ⅛" larger than the punched holes.

The rivet heads must be of approved shape, or uniform size, and neatly finished throughout the work. Wherever possible rivets shall be driven with power riveters.

All portions of work exposed to view must be neatly finished. All surfaces in contact shall be planed before they are put together.

All abutting surfaces in compression members shall be truly faced to even bearings.

All workmanship shall be first class in every particular.

STEEL

All steel shall conform to Manufacturers Standard Specifications or to the American Bridge Company's Standard Specifications.

TIMBER

All timber shall be strictly first class spruce, white pine, Douglas fir, Southern yellow pine or white oak bridge timber, sawed true, suitable size and free from all defects impairing strength or durability.

PAINTING

All iron work before leaving shops shall be thoroughly cleaned from rust and scale and shall be given one coat of pure linseed oil.

Pieces not accessible for painting after erection shall have two coats of paint.

The paint shall be of good quality oxide of iron paint mixed with pure linseed oil and after the structure is erected it shall have two coats of this paint of such quality and color as may be specified. Finished surfaces shall be coated with white lead and tallow before being shipped.

INSPECTION

All facilities for inspection of material and workmanship shall be furnished by the contractor to competent inspectors.

Contractors shall furnish without charge such prepared specimens of material to be used as may be required to determine their character.

4. STANDARD SPECIFICATIONS FOR REINFORCED CONCRETE CULVERTS

Iowa Highway Commission

(1) PLANS.

These general specifications shall become a part of, and shall be regarded as applying to, the Standard Plans put out by the Iowa Highway Commission, Ames, Iowa.

(2) FORMS.

All forms centering are to be made preferably from pine or fir, surfaced on one side, made and fitted together by a competent carpenter. The joints and contact surfaces shall be dressed smooth and even. The numebr and size shall be painted upon all the pieces comprising each standard form.

When set in place the forms shall be true to grade and alignment and shall be securely wired together and braced externally.

CONCRETE MATERIAL.

CEMENT

BRAND. The cement used shall be of a first class quality Portland cement of a brand approved by the Board of Supervisors (or Trustees) or their representatives.

TESTS. On delivery it shall be subject to the standard tests (Am. Soc. for Testing Materials or U. S. Army Specifications). Any cement failing to pass these tests shall be rejected and promptly removed without expense to the county (or township).

WEIGHT. The weight and condition of the cement on delivery shall be in accordance with the specifications for purchase of cement. (Section Seven).

STORAGE. The cement shall be stored in a weather tight building with the fioor properly raised above the ground.

SAND

SIZE. Sand shall pass a No. 10 (or No. 8) mesh sieve and shall be clean, sharp and coarse.

KIND. River sand shall perferably be used but not at the sacrifice of coarseness.

SCREENED GRAVEL

SIZE. Gravel shall be screened over a No. 10 (or No. 8) mesh sieve. All stones larger than 2 1-2 inches in largest dimensions shall be rejected.

UNSCREENED GRAVEL

If unscreened gravel is used, it shall be tested with a No. 10 (or No. 8) sieve and the amount used per unit of cement shall contain over three parts sand passing this size sieve.

PROPORTIONS. The following proportions shall be observed:

Culvert tops.
1 part cement, 2 parts sand, 4 parts crushed stone, or
1 part cement, 1 1-2 parts sand, 4 parts screened gravel.

Sides and wing walls.
1 part cement, 3 parts sand, 6 parts crushed stone.

MORTAR. Where mortar is used it shall consist of
1 part cement, 2 parts sand.

REINFORCEMENT

PER CENT. OF REINFORCEMENT. Unless other wise specified, a one per cent. (1 c-o) by area of reinforcement shall be used for all standard plans.

SIZES. No sizes larger than those shown on the plans shall be used. Smaller sizes may be substituted but the same area shall be retained.

PLAIN BARS. Plain bars used as reinforcement shall have an elastic limit of at least 25,000 lbs. per sq. in. and an ultimate strength of at least 50,000 lbs.

CORRUGATED BARS. Patented reinforcing bars shall have an elastic limit of 33,000 lbs. per sq. in. and an ultimate strength of not less than 60,000 lbs. per sq. in. If mild steel bars are used the area shall be increased 1-4 of the area specified on the plan for high elastic steel with mechanical bond.

PLACING OF STEEL

The steel reinforcing material shall be carefully placed as shown on the standard plans.

The reinforcement for the top shall be bedded in a layer of the mortar one inch thick as shown on the plans, and for the bottom, shall be covered with the same material. The reinforcement in the sides shall be carefully spaced and care shall be exercised during the tamping to leave it undisturbed.

MIXING AND LAYING THE CONCRETE

The materials shall be carefully proportioned by measure. When hand mixing is employed a tight platform shall be used. Upon this the sand and cement shall be thorougly mixed dry, then the previously wetted stone and water shall be added. This material shall be turned at least three times, and more, if necessary, to produce a uniform mixture. A moderately wet concrete shall be used. The cement shall be measured as packed by the manufacturers and the aggregate loose.

The concrete shall be placed in the forms in layers not exceeding six inches, each layer to be thoroughly tamped, and all exposed surfaces are to be "spaded" to produce smooth outside finish. If the forms cannot be entirely filled before the cement sets, the last layer shall be well cleaned and then wet with a neat cement grout and every precaution taken to secure a perfect bond.

SECTION NINE.

TRACTIVE RESISTANCE.

The resistance that a vehicle moving uniformly offers to that motion or the traction may be classed under three heads: (1) "Grade Resistance," (2) "Axle Friction," and (3) "Rolling Resistance."

1 GRADE RESISTANCE

The influence that grade has upon the tractive effort required to move any vehicle may be accurately computed and is entirely independent of the condition of the surface. A horse can not pull so much on a grade as on the level surface because he has his own weight to lift and because the inclination of the surface does not allow as good footing, especially when the roads are wet and slippery, but the tractive resistance depends only on the per cent. of inclination.

It is readily shown by a simple mathematical solution that G (the resistance due to the grade)=W P in which W=the load and P the grade in percent.

In words we may say:

The total grade resistance equals 20 times the number of tons times the per cent. of grade.

The total grade resistance for a load of 1½ tons hauled up a 50% grade is

20x1½x5=150 lbs.

2 AXLE FRICTION

Can be made so very small by proper lubrication that it can be neglected in this condition. Few dynamometers will register the axle friction produced with bearings, so that in comparing road surfaces or broad and narrow tires this factor need be considered, only by using similar vehicles.

3. ROLLING RESISTANCE

There are three principle elements which produce rolling resistance and each one of these is modified by specific factors as may be seen in the following outline:

IMPACT.

- Speed.
- Irregularities on the surface.
- Effect of springs.
- Kind of tires.

COMPRESSION OF THE SURFACE.

Character of the road surface.
Width of tires.

FRICTION BETWEEN WHEELS AND SURFACE.

Character of road surface.
Width of tires.

IMPACT.

If a ball is thrown against a wall, it rebounds to a distance depending upon the speed with which it was thrown and the rigidity of the wall. In the same manner a wheel when it strikes an irregularity in a road tends to rebound. Most of these obstructions are so small that the wheel does not rebound but receives a momentary check. Its own momentum is usually sufficient to carry it on but with diminished speed which must be regained by additional tractive effort.

The diameter of the wheel also affects the tractive resistance. In general the greater the diameter of the wheel the less is the force required on account of the greater leverage.

Springs are of service in lessening the resistance due to an uneven surface. The shock of the impact of the wheels is absorbed by the springs instead of being transferred to the load. Their effect is greater the higher the rate of speed because the force of the impact increases with the speed.

All that is said here in regard to impact assumes that the wheels have metal tires; with rubber tires the shock is greatly lessened and with pneumatic tires it is still less. It will be noticed that reference here is made only to such impact as results from projections on the surface and not to depressions which will be discussed in a succeeding paragraph.

COMPRESSION OF THE SURFACE. The character of the surface as regards elasticity is of prime importance in this connection. If the road material compresses under the wheels, the load has to be drawn continually up an inclined plane, the slope of which depends upon the depth of the depression and the diameter of the wheels. This explains the difference between the asphalt and brick pavements in favor of brick pavements, though asphalt is smoother.

If the road material is elastic, the depression under each wheel will vary with the load on it and the traction will be lessened by the use of wide tires.

FRICTION BETWEEN THE WHEELS AND THE ROAD SURFACE. The amount of friction will depend, first of all, upon the relative hardness of the road material. With the road in such a condition that the wheels would have to cut through a layer

of loose material or mud to a hard bottom, the narrow tires would be expected to give the lighter draught, but in all other cases the wide tires would be preferable, as is shown by traction tests.

This discussion indicates that traction or tractive resistance is subject to a large and complex number of influences. Its amount is measured with an instrument variously known as a tractometer, dynograph or dynometer. The results obtained will be the total resistance as has been said due to grade, axle friction, and rolling resistance, and for different results to be at all comparable they must be reduced to the same conditions. The effects of grade may be eliminated by taking tests on level stretches or by compensating for the grade when the degree of rise is known. Tests on roads thought to be level should always be made in each direction and the average taken.

The rolling resistance will then be an accurate measure of the value for traction purposes of different kinds of pavement, and of the various conditions which affect them.

4. RESULTS OF TESTS. For the past three years the Civil Engineering Department of the State College has been carrying on tests of the traction of different kinds of surfaces used on the public roads and streets of Iowa. In addition to these a series of tests was conducted at Pittsburg, Pa., by Mr. A. B. Chattin, a graduate of the College. The State Highway Commission during the past year also has made a large number of traction tests in various places in the state.

TRACTOMETER. The tractometer used in these tests was made by the Mechanical Engineering Department of the College. The direct pull of the team is taken by a horseshoe shaped spring and registered by means of a pencil connected to this spring by a multiplying device. This pencil plays on a strip of profile paper which is moved beneath it by clock-work. After calibrating the instrument in a testing machine, the number of pounds pull, maximum, minimum or average may be read directly from the record.

OUTFITS USED. The aim in this work being to get as near to the actual conditions as possible, care was taken to get an ordinary wagon and team. The teams were of the average size and weight used for draught purposes, and the wagons were in most cases the kind generally used on farms.

TABLE 1. TRACTION TESTS COMPARATIVE OF EARTH AND GRAVEL ROADS

NO.	CONDITION OF ROAD SURFACE	AVERAGE (IN POUNDS) PULL PER TON	
		Mch. 22-23, 1905	May 19, 1905
	GRAVEL ROADS	Worst Spring Condition	Ordinary Dry Condition
1	Old resurfaced..	112 lbs.	68 lbs.
2	Well graded, drained	170	35
3	Old, very dirty, poor	201	114
4	Good condition	195	78
5	Same as No. 4	193	102
6	New, soft	327	78
7	New, well packed	159	58
8	Old, well graded	135	45
9	Same as No. 8	135	56
10	Graded, good	154	52
11	Old, dirty on top	193	70
12	New, well crowned	318	74
	EARTH ROADS Average	191	69
1	Graded	288	110
2	Poorly graded	389	186
3	Clay, very poor drainage	531	215
4	Black loam, graded	286	148
5	Same as No, 4	236	99
6	Flat, poor drainage	234	87
7	Well graded	258	91
8	Sandy	365	87
9	Gravelly	262	83
10	Gumbo, little grade	408	139
11	Poor drainage	346	124
	Average	328	124

Diameter of wheels, 42 inches and 52 inches.
Width of tire 1¾ inches—farm wagon.

TABLE 2. TRACTION TESTS

COMPARATIVE OF TRACTIVE RESISTANCE OF WIDE AND NARROW TIRED WAGONS

DATE	DESCRIPTION OF ROAD SURFACE	RESISTANCE lbs. per ton Width of Tires	
1905		1⅝ in.	3⅛ in.
	AN EARTH ROAD, GOOD GRADE BUT FLAT. WELL DRAINED BY TILE SIDE DRAINS.		
Feb. 17	4 inches snow well packed	260	------
" 18	4 inches snow well packed	------	228
" 21	¾ inches slushy snow	134	175
" 28	Snow gone. Frost out in places	178	198
Mar. 4	Well dried and fairly smooth on top	162	162
" 21	2 inches to 3 inches thick mud	238	238
" 25	3 inches to 4 inches thick mud; dryer	315	289
Apr. 1	Dry, fairly smooth. Some dust	135	120
" 13	Dry, worn smooth. Some loose dirt	84	72
" 21	Thin loose mud on top, 1½ inches	140	121
May 12	Cut up 2 inches deep	------	178
" 22	Smooth track worn; ¼ inch loose dirt	85	86
	EARTH ROAD, POOR GRADE, POORLY DRAINED, HEAVY TRAVEL.		
Feb. 28	Thick mud	------	198
Mar. 4	Dryer track, fairly smooth	192	141
" 25	3 inches thick mud	287	289
April 1	Dry, very rough	228	211
" 13	Dry, wearing smooth	116	90
" 21	Ruts 1 inch to 3 inches; thin mud, water in places.	113	127
May 12	3 inch to 8 inch ruts full of loose mud and water	------	157
" 22	Deep ruts wearing smooth	105	99
	A WELL BUILT DEEP BED GRAVEL ROAD, WELL DRAINED.		
Feb. 22	1 inch loose wet gravel on top	220	144
Mar. 4	Smooth. A little loose gravel	121	101
" 21	Slightly damp	------	111
" 25	Moist. Hard	110	96
April 1	Dry. Some loose gravel	94	108
" 13	Dryer. Some loose gravel on top	59	62
" 21	Smooth, a little loose gravel on top	73	84
May 12	Smooth and dry on top	------	58
" 22	Smooth and dry, a little loose gravel	56	56
	A REPRESENTATIVE SAND ROAD. FINE SAND, DEEP SURFACE FLAT WITH GROUND.		
Feb. 28	Frozen 1½ to 2 inches slush	170	132
Mar. 4	Wet loose sand, 2 inches	170	164
" 21	Moist	------	184
" 25	Slightly moist	195	172
April 13	Sand loose and dry on top	93	92
" 21	Damp and solid beneath	------	110
May 12	Well defined ruts 1 inch to 2 inches. Moist	------	89
" 22	1 inch loose dry sand on compact surface	91	90

TABLE 2. TRACTION TESTS—CONTINUED

COMPARATIVE OF TRACTIVE RESISTANCE OF WIDE AND NARROW TIRED WAGONS

DATE	DESCRIPTION OF ROAD SURFACE	RESISTANCE Lbs. per Ton	
		Width of Tires	
1905	GRAVEL ROAD, CLAY BINDER, WELL CROWNED, WELL DRAINED	1⅝ in.	3⅛ in.
Feb. 28	1½ inches thin mud	146	136
Mar. 4	1½ inches to 2½ inches, ruts, well surface	172	138
" 25	1 inch soft slush	157	141
April 1	Dry, slightly dusty	100	82
" 13	Smooth, dry, no loose material	47	47
" 21	Wet, some slush in places	116	104
May 12	A little soft, but smooth	------	63
" 22	Smooth and dry, a little dust	46	58
	CINDER DRIVE, LOW, WELL DRAINED GRADE, HEAVY TRAVEL		
Feb. 28	Cut up 1 inch deep	152	125
Mar. 4	Dry, smooth, a little loose dirt	103	65
" 21	2 inches to 3 inches thick cinder mud	------	275
April 13	Dirty, smooth, some worn hollows	61	54
" 21	Fairly smooth, thin slush in holes	100	121
May 12	Hard and smooth, some wet places	------	84
" 22	Hard and smooth	65	68

INDEX

INTRODUCTORY PAGES

SECTION ONE

General Data Relating to the Public Roads

1. MILEAGE AND CLASSIFICATION 5
2. ANNUAL EXPENDITURE 6
3. THE ROAD CENSUS 7
4. RELATIVE PRICES OF AGRICULTURAL PRODUCTS AND CONDITIONS OF PUBLIC ROADS 10

SECTION TWO

The Topography of Iowa

1. GENERAL TOPOGRAPHY 11
2. DRIFT AREAS 16
   - The Loess 16
   - The Kansan Drift 16
   - The Iowan Drift 16
   - The Wisconsin Drift 18

SECTION THREE—IOWA'S ROAD LAWS

History and Development of Road Legislation in the State

1. ROAD LEGISLATION 1838-1857 20
   - Territorial Road Laws 20
   - County Commissioners 21
2. EARLY STATE ROAD LAWS 22
   - Constitutional Limitations 23
   - Laws of Seventh General Assembly 23
   - Board of Supervisors 24
3. NEW ROAD LAWS 24
   - Township Road Laws 25
   - Additional One Mill Levy in County Road Fund on Petition 26
   - New Drag Act 26
   - New Wide Tire Act 28
4. ORGANIZATION UNDER PRESENT ROAD LAWS 29
   - County Supervisors 29
   - County Auditor 29
   - Board of Trustees 29
   - Township Clerk 30
   - The Road Superintendent 30

SECTION THREE—IOWA'S ROAD LAWS—Continued

5. Administration of Road Funds 30
County Bridge Fund 31
County Road Fund 31
The Township Road Fund 32
County Financial Report 34

SECTION FOUR

The Iowa Highway Commission

1. Law Establishing the Commission 36
2. Organization of the Commission 37
3. Work of the Commission 37
The Road School 37
Plans and Publications 37
Demonstration Work 38
Experimental Work 38
4. Testing Laboratory 38
Road Material 38
Concrete 39

SECTION FIVE

Road Construction in Iowa

1. Road Location 40
2. Road Drainage 41
District Drainage 41
Local Drainage 46
Sub-drainage 46
Side Ditches 49
The Crown 50
3. Construction of an Earth Road 50
Cross Section 50
Clearing 52
Selection of Material 54
Cost of Earth Work 54
4. Construction of a Gravel Road 55
Material 56
Cross Section 58
5. Construction of a Broken Stone Road 59
Material 59
6. Road Machinery 60
Drag Scrapers 60
Wheel Scrapers 60
Road Machines 61
Elevating Graders 62
Stone Crusher 62

SECTION SIX

Road Maintenance

1. The Drag Method 65
   History and Developement of this Method. 65
   New Laws Enacted Relating to its Use... 68
   General Topography 68
   Theory of Road Dragging 69
      The Cross Section of a Dragged Road 74
      Methods of Making Drags 77
      Time to Drag 79
2. Maintenance of Side Ditches and Sub-drains 84
3. Weeds 84

SECTION SEVEN

Highway Bridges and Culverts

1. General Status 88
   Administration of Bridge Funds 89
   Forms of Construction Recommended for Adoption 90
      Size of Water Way Required 90
2. Pile Bridges 91
   Materials 91
   Design 91
   Construction 92
   Bearing Power of Piles 92
3. Steel Bridges 92
   Standard Plans for Ordinary Spans 92
   Standard Specifications 92
4. Concrete Culverts and Bridges 94
   Development of the Work in the State 94
   Cost of Concrete Work 96

Concrete Materials 99
   Portland Cement 100
   Sand 103
   Screened Gravel and Broken Stone ... 104
   Unscreened Gravel 105
Concrete 105
   Definition 105
   Proportion 106
   Quantities of Materials for Concrete .. 108
   Mixing 108
   Placing 109
   Specifications 110

SECTION SEVEN—Continued

Reinforced Concrete 110
Theory 110
Materials 111
Standard Plans 112
Foremen and Inspectors for County and Township Work 113

SECTION EIGHT

Specifications

1. Tile Drains 120
2. Macadam Roads (Clinton Co.) 123
3. Steel Bridges (Abridged) 125
4. Concrete Construction of Culverts and Bridges 128
5. Purchase of Cement 129

SECTION NINE

Tractive Resistance

1. Grade Resistance 131
2. Axle Friction 131
3. Rolling Resistance 131
Impact 132
Compression of the Surface 132
Friction Between Wheels and Surface 132
4. Results of Tests 133

Republican Printing Company, Cedar Rapids, Iowa