
# Building the Lincoln Highway: Early 20th Century Road Construction

Ernest Schirmer, New Jersey Chapter, Lincoln Highway Association
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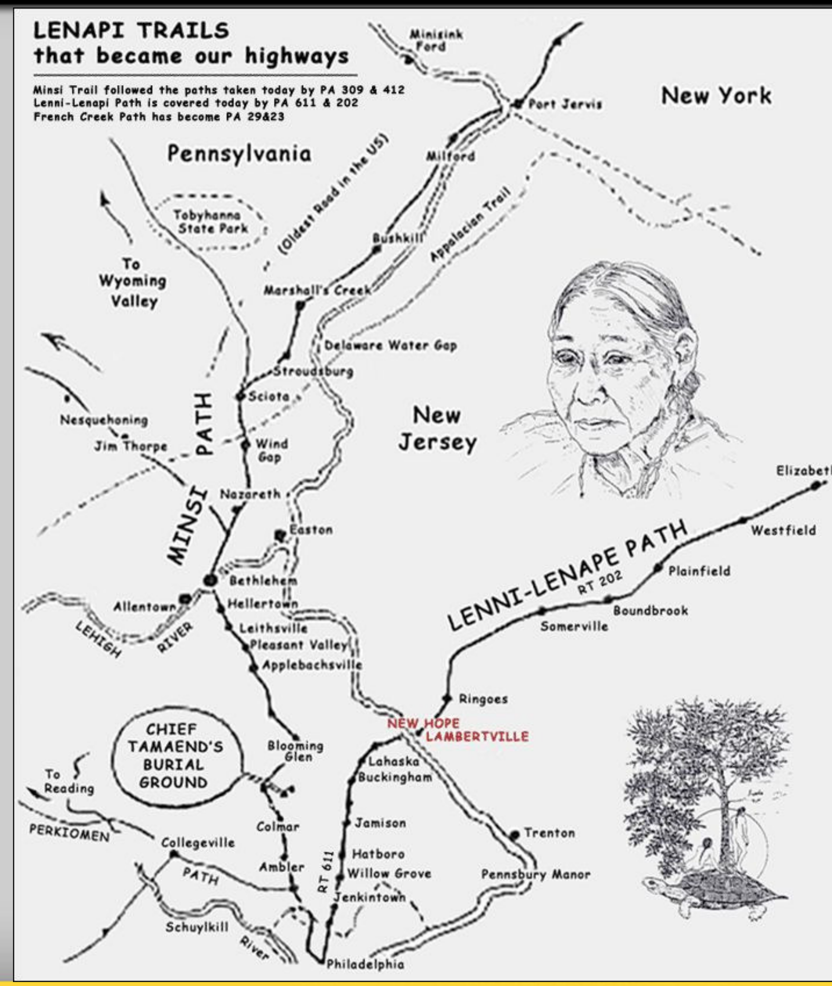
# Road Construction: techniques, method and means

- From footpaths to Interstates
  - Foot paths: it is what it is
  - Interstates: engineered transportation


# Footpaths

- Hunting
- Food, water
- Animal grazing
- Migration
- War
- Disease
- Trade



# Roadway Enthusiasm


ENTHUSIASM IN A TYPICAL EASTERN CITY

The Lincoln Highway Association is a wonderfully efficient organization that has been the means of arousing intense public interest in the stupendous undertaking of building a highway from the Atlantic to the Pacific.

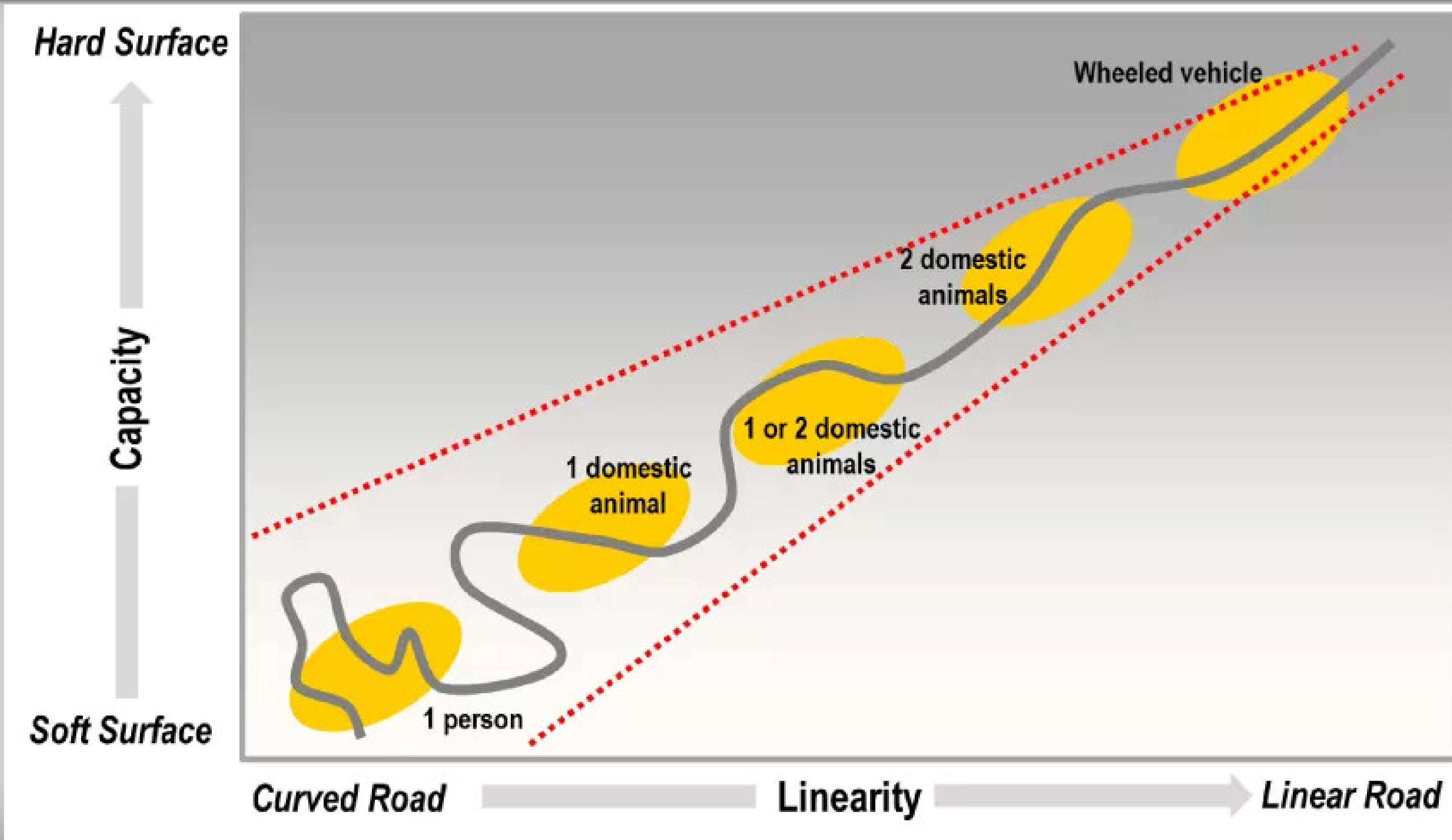
# Civil Engineering & Road Construction

- Critical components when designing a road:
  - Cost
  - Cost
  - Cost because the most important result is:
  - Return on investment
  - Return on investment
  - Return on investment

# Civil Engineering & Road Construction

- Critical components when designing a road:
  - Route (follow the river, valley, etc.)
  - Location (where to place the road – soil conditions)
  - Ancillary infrastructure (grading, fill, culverts, embankments, bridges, tunnels, etc.)
  - Slope (every degree of grade reduces efficiency)
  - Drainage
  - Surface (based on traffic and load)
  - Cost

# Civil Engineering & Road Construction



# Motivation for Road Construction

"The profits of such improvements are not confined to the proprietors of a road, (whether towns, or companies remunerated for these expenditures by tolls) but are shared by all who avail themselves of the increased facilities; consumers and producers, as well as road-owners. If wheat be worth in a city a dollar per bushel, and if it cost 25 cents to transport it thither from a certain farming district, it will there necessarily command only 75 cents. If now by improved roads the cost of carriage is reduced to 10 cents, the surplus 15 cents on each bushel is so much absolute gain to the community, balanced only by the cost of improving the road. Supposing that a toll of 5 cents will pay a fair dividend on this, there remains 10 cents per bushel to be divided between the producer and the consumer, enabling the former to sell his wheat at a higher price than before, while at the same time the latter obtains it at a less cost."

# Civil Engineering & Road Construction

- **Slope**
  - **"One important difference lies in the grades or longitudinal slopes of a road. Suppose that a road rises a hundred feet in the distance of two thousand feet. Its ascending slope is then one in twenty, and (as will be hereafter proven) one-twentieth of the whole load drawn over it in one direction, must be actually lifted up this entire height of one hundred feet. But upon such a slope a horse can draw only one half as much as he can upon a level road, and two horses will be needed on such a road to do the usual work of one."**

# Civil Engineering & Road Construction

- **Surface**
  - "On a well-made road of broken stone, a horse can draw three times as much as he can upon a gravel road. By making, then, such a road as the former in the place of the latter, the expenses of transportation will be reduced to one-third of their former amount, so that two-thirds will be completely saved, and two out of three of all the horses formerly employed can then be dispensed with."

# Civil Engineering & Road Construction

LOCATION AND GRADES OF COUNTRY ROADS.

## Considerations Governing Location.

THE considerations which should govern the Engineer in locating the line of an ordinary wagon road are (1) the present and prospective amount of traffic over the road; (2) its general character, whether light or heavy; (3) the convenience and necessities of the community tributary to the line; and (4) the natural features of the country through which the road must pass. The labor of the preliminary examination of the ground will be considerably lessened by keeping in view a few elementary principles, viz: (1) that the natural water courses are not only the lowest lines, but the lines of the greatest longitudinal slope in the valleys through which they flow; (2) that the direction and position of the principal streams give also the direction and approximate position of the high ground or ridges which lie between them; and (3) that the positions of the tributaries to the larger streams generally indicate the points of greatest depression in the summits of the ridges, and there-

# Civil Engineering & Road Construction

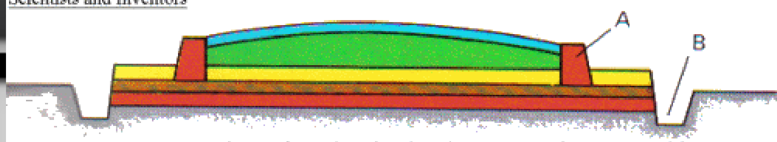
**Classification of Roads.**

*Country roads*, as distinguished from *paved streets* in cities and towns, may be classified with respect to their coverings as follows :

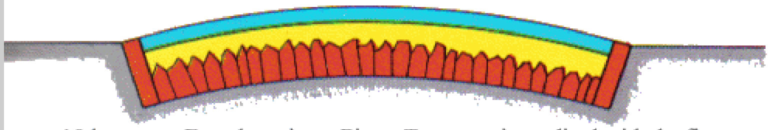
1. Earth roads.
2. Corduroy roads.
3. Plank roads.
4. Gravel roads.
5. All broken stone (or Macadam) roads.
6. Stone sub-pavement, with top layers of broken stone (Telford).
7. Stone sub-pavement with top layers of broken stone and of gravel.
8. Stone sub-pavement with top layers of gravel.
9. Rubble-stone bottom with top layers of broken stone, gravel, or both.
10. Concrete sub-pavement with top layers of broken stone, gravel, or both.

# Early 20th Century Road Construction

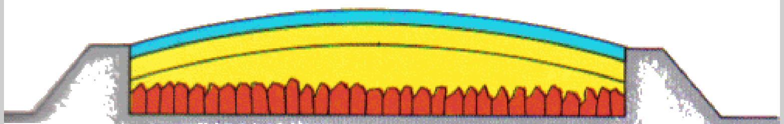
Scientists and Inventors



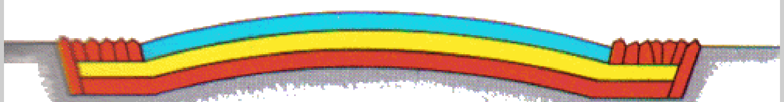

Roman pavement in section, showing local-stone wearing course (blue), cambered hard filling (green), Roman concrete (yellow), waterproof layer of stones (brown), compacted earth footing (red), retaining stones (A) and drainage ditch (B).



18th-century French engineer Pierre Tresaguet is credited with the first modern pavement design. Its 3-1/4 inch surface of small stones (blue) covers a 6-3/4 inch course of large stone (yellow), resting on a foundation of heavy stone (red) placed on a cambered footing.



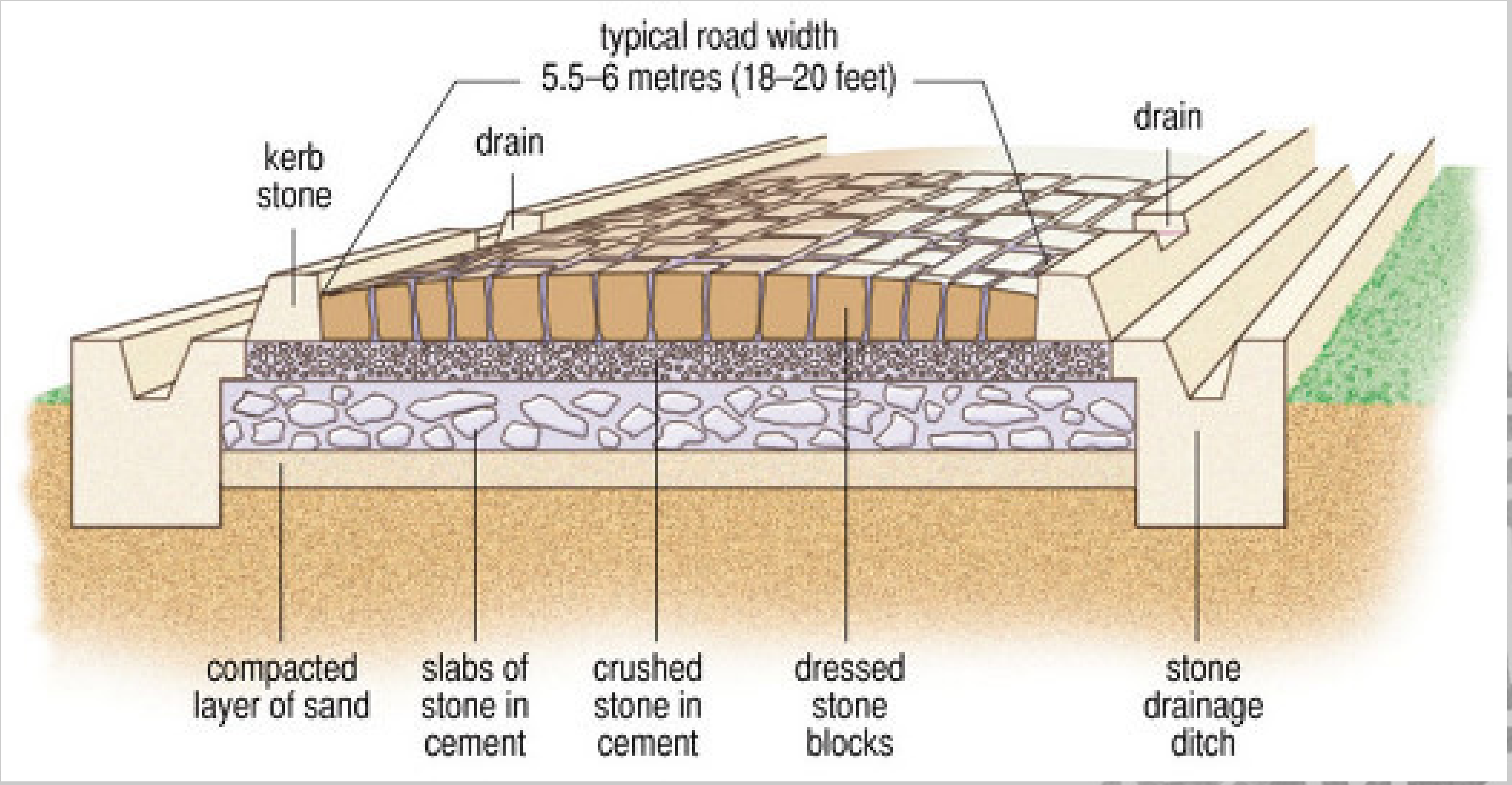
A road pavement design by British engineer Thomas Telford. Its 2-inch-thick gravel wearing surface (blue) rests on two layers of 2-1/2 stones, forming a base course 20 inches deep in the middle (yellow). It rests on 6-3/4 inches of heavy stones (red).



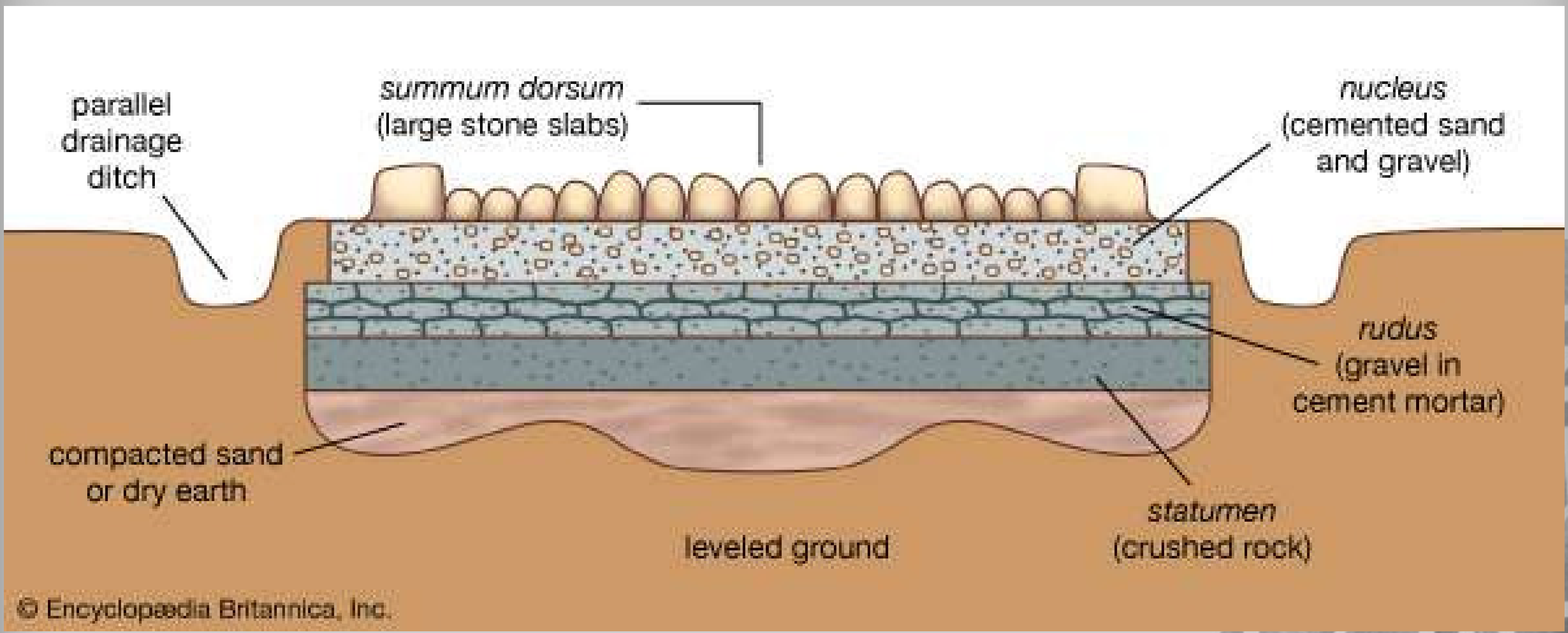
MacAdam's road pavement was simpler than some other versions, but very effective. It comprised three layers -- wearing surface (blue), base course (yellow), and footing (red) -- the first two of 2-inch stones resting on a footing of compacted cambered earth.

The advantages and disadvantages of the sub-pavement or "bottoming," which forms the characteristic difference between the Telford and the Macadam roads, have been the subject of lengthy discussion between the advocates of these two methods of road construction.

# Roman Road Construction



# Roman Road Construction



# Civil Engineering & Road Construction

In France, four classes of roads are prescribed as follows: *First*, 66 feet wide of which 22 feet in the middle are paved or stoned. *Second*, 52 feet wide of which 20 feet are stoned. *Third*, 33 wide of which 16 feet in the middle are stoned; and *fourth*, a width of 26 feet of which 16 feet in the middle are stoned.

Telford's Hollyhead road, which runs through a hilly country, is 32 feet wide between the fences on flat ground, 28 feet on side cuttings not exceeding three feet deep, and 22 feet along steep and precipitous ground.

The Cumberland or National road in the United States has a prescribed width of 80 feet, but the prepared road-way is only 30 feet wide.

The Roman Military roads were narrow, being only 12 feet wide on the straight portions, and 16 feet upon curves.

# Civil Engineering & Road Construction

Opinions differ as to whether that portion of the carriage way to be finished and maintained as a dirt road, should be at the sides or in the middle. Heavy loads are apt to seek the sides, in order that the driver may walk upon the foot path, which favors metaling the wings rather than the middle.

# Civil Engineering & Road Construction

The following table, resulting from trials made with a dynamometer attached to a wagon moving at a slow pace upon a level, gives the force of traction in pounds upon several kinds of road-surfaces, in a fair condition; the weight of wagon and load being one ton of 2,240 pounds.

| | |
|---|---|
| 1. On best stone trackways | 12½ pounds. |
| 2. A good plank road | 32 to 50 pounds. |
| 3. A cubical block pavement | 32 to 38 " |
| 4. A Macadamized road of small broken stones | 65 pounds. |
| 5. A Telford road, made with six inches of broken stone of great hardness, laid on a foundation of large stones set as a pavement | 46 pounds. |
| 6. A road covered with six inches of broken stone laid on concrete foundation | 46 " |
| 7. A road made with a thick coating of gravel laid on earth | 140 to 147 pounds. |
| 8. A common earth road | 200 pounds. |

# Civil Engineering & Road Construction

TABLE I.

COST OF TRANSPORTATION BY HORSES AND WAGONS PER TON-MILE ON DIFFERENT ROAD-COVERINGS.

| | | | |
|---|---|---|---|
| Iron rails | 1.28 | cents | per ton-mile |
| Asphalt | 2.70 | " | " |
| Stone, paving, dry and in good order | 5.33 | " | " |
| " " ordinary condition | 12.00 | " | " |
| " " covered with mud | 21.30 | " | " |
| Broken stone, dry and in good order | 8.00 | " | " |
| " " moist " " " | 10.30 | " | " |
| " " ordinary condition | 11.90 | " | " |
| " " covered with mud | 14.30 | " | " |
| " " ruts and mud | 26.00 | " | " |
| Earth, dry and hard | 18.00 | " | " |
| " ruts and mud | 39.00 | " | " |
| Gravel, loose | 51.60 | " | " |
| " compacted | 12.80 | " | " |
| Plank, good condition | 8.80 | " | " |
| Sand, wet | 32.60 | " | " |
| " dry | 64.00 | " | " |

# Civil Engineering & Road Construction

TABLE V.

ABSORPTIVE POWER OF STONES, ETC.

| | Percentage of water absorbed. |
|---|---|
| Granites | 0.066 to 0·155 |
| Marbles | 0.08 " 0.16 |
| Limestones | 0.20 " 5.00 |
| Sandstones | 0.41 " 5.48 |
| Brick, common | 2.00 " 25.00 |
| " paving | 0.15 " 8.00 |
| Mortars | 10.00 " 50.00 |
| Wood | 0.16 " 9.00 |
| Asphalt | Impervious |

# Civil Engineering & Road Construction

TABLE IX.

SPECIFIC GRAVITY, WEIGHT, AND RESISTANCE TO CRUSHING OF VARIOUS SANDSTONES.

| Localities. | Specific Gravity. | Average Weight, pounds per cubic foot. | Resistance to Crushing, pounds per square inch. |
|---|---|---|---|
| Potsdam (red), N. Y. | 2.60 | 162.28 | 42,804 |
| Medina, N. Y. | | | 17,725 |
| Malden (bluestone), N. Y. | 2.75 | 171.47 | |
| Warsaw (bluestone), N. Y. | 2.68 | 167.10 | |
| Albion, N. Y. | | | 13,500 |
| Craigleith, Scotland | 2.45 | 153 | 5,287 |
| Belleville, N. J. | 2.56 | 159.67 | 11,700 |
| Kasota, Minn. | | | 11,675 |
| Seneca, Ohio | | | 10,500 |
| Berea, Ohio | 2.57 | 160.06 | 10,250 |
| Little Falls, N. Y. | | | 9,850 |
| Dorchester, New Brunswick | | | 9,412 |
| Vermilion, Ohio | | | 8,850 |
| Massillon, Ohio | | | 8,750 |
| Cleveland, Ohio | | | 7,910 |
| Abroath (pavement), England | 2.47 | 155 | 7,884 |
| Marquette, Mich. | 2.53 | 158.17 | 7,450 |
| Middletown (Portland), Conn. | 2.62 | 163.48 | 6,950 |
| North Amherst, Ohio | | | 6,650 |
| Oxford (bluestone), N. Y. | 2.71 | 168.9 | 13,472 |
| Fond du Lac, Wis. | | | 6,250 |
| Bristow, Va. | 2.61 | 163 | |
| Yorkshire, England | 2.51 | 157 | 5,714 |
| Warrensburg, Ohio | | | 5,000 |
| Haverstraw, N. Y. | | | 4,350 |
| Derby Grit, England | 2.4 | 150 | 3,100 |
| Cheshire (red), England | 2.15 | 133 | 2,185 |
| Nova Scotia. | 2.62 | 163.50 | |

# Civil Engineering & Road Construction

TABLE X.

Production and Value of Sandstone for Street Uses in 1889, by States and Territories.*

| States and Territories. | Cubic Feet. | Value. | Value per cubic foot. |
|---|---|---|---|
| Arkansas | 27,160 | 8,215 | 0.30 |
| California | 100 | 200 | 2.00 |
| Colorado | 1,926,464 | 509,955 | 0.26 |
| Connecticut | 40,500 | 2,250 | 0.06 |
| Idaho | ........ | ........ | ... |
| Illinois | 3,200 | 50 | 0.02 |
| Iowa | 8,840 | 880 | 0.10 |
| Kansas | 452,015 | 132,188 | 0.29 |
| Kentucky | 13,900 | 1,600 | 0.12 |
| Maryland | 40,320 | 2,045 | 0.05 |
| Massachusetts | 501,221 | 40,471 | 0.08 |
| Michigan | 2,496 | 550 | 0.22 |
| Minnesota | 51,930 | 38,200 | 0.74 |
| Missouri | 6,533 | 2,512 | 0.38 |
| New Mexico | 10,000 | 3,000 | 0.30 |
| New York | 2,864,366 | 459,158 | 0.16 |
| Ohio | 1,603,614 | 430,552 | 0.27 |
| Pennsylvania | 854,907 | 175,062 | 0.20 |
| West Virginia | 42,075 | 23,274 | 0.55 |
| Florida, Georgia, Nevada, Rhode Island, Vermont | 13,865 | 2,660 | 0.19 |
| Total | 8,463,506 | $1,832,822 | $0.22 |

# Civil Engineering & Road Construction

TABLE VI.

SPECIFIC GRAVITY, WEIGHT, AND RESISTANCE TO CRUSHING OF VARIOUS GRANITES.

| Localities. | Specific Gravity. | Average Weight, pounds per cubic foot. | Resistance to Crushing, pounds per square inch. |
|---|---|---|---|
| Kirtland Rocks, Conn. | 2.66 | 166 | 35,000 |
| Lord's Island, Conn. | | | 24,000 |
| Chaumont Bay, N. Y. | 2 65 | 162.2 | 22,700 |
| Mystic River, Conn. | 2.63 | 164.4 | 22,250 |
| Sharkey's Quarry, Me. | 2.72 | | 22,125 |
| Richmond, Va. | | | 21,250 |
| Huron Island, Mich. | | | 20,650 |
| Rockport, Mass. | 2.61 | 163.2 | 19,750 |
| Port Deposit, Md. | | | 19,750 |
| Quincy, Mass. | 2.66 | 166.2 | 19,500 |
| Duluth, Minn. | | | 19,000 |
| Hurricane Island, Me | 2.67 | 166.9 | 15,000 |
| Mount Sorrel, England | 2.67 | 167 | 12,800 |
| Bay of Fundy, Canada | | | 11,916 |
| Aberdeen, Scotland (gray) | 2.62 | 163 | 10,900 |
| " " (red) | 2.62 | 165 | |
| Dublin, Ireland | | | 10,450 |
| New Haven, Conn. | | | 9,750 |
| Cornish, Wales | 2.66 | 166 | 6,300 |
| Patapsco, Md. | 2.64 | 163 | 5,340 |

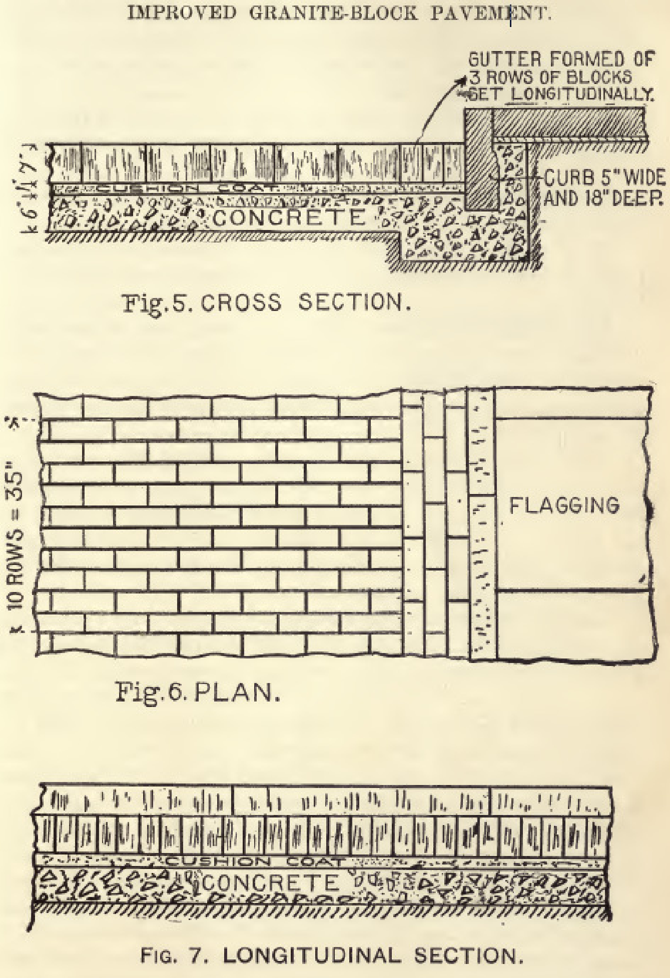
# Civil Engineering & Road Construction

TABLE VII.

PRODUCTION AND VALUE OF GRANITE FOR STREET USES IN 1889.*

| States. | Cubic feet, including Paving-blocks. | Value, including Paving-blocks. | Value per cubic foot. | Number of Paving-blocks. | Value of Paving-blocks. | Value per thousand. |
|---|---|---|---|---|---|---|
| California....... | 3,284,232 | $551,613 | $0.17 | 7,303,321 | $297,236 | $40.70 |
| Colorado........ | 1,100 | 230 | 0.21 | .......... | .......... | ...... |
| Connecticut..... | 567,860 | 109,261 | 0.19 | 761,100 | 40,683 | 53.45 |
| Delaware....... | 155,500 | 67,202 | 0.43 | 104,333 | 8,208 | 78.67 |
| Georgia......... | 658,603 | 250,634 | 0.38 | 1,599,952 | 84,951 | 53.10 |
| Maine.......... | 3,736,541 | 927,949 | 0.25 | 17,704,915 | 824,113 | 46.55 |
| Maryland....... | 1,051,010 | 125,958 | 0.12 | 286,950 | 10,310 | 35.93 |
| Massachusetts... | 1,475,093 | 466,147 | 0.32 | 6,106,016 | 378,627 | 62.01 |
| Minnesota....... | 338,640 | 141,554 | 0.42 | 1,239,000 | 68,045 | 54.92 |
| Missouri........ | 871,209 | 216,986 | 0 25 | 4,323,130 | 216,986 | 50.19 |
| New Hampshire. | 1,157,992 | 252,256 | 0.22 | 2,043,739 | 87,569 | 42.85 |
| New Jersey..... | 2,089,796 | 236,310 | 0.11 | 3,999,912 | 168,555 | 42.14 |
| New York...... | 247,902 | 51,062 | 0.21 | 587,120 | 26,962 | 45.92 |
| North Carolina.. | 221,820 | 42,605 | 0.19 | 775,000 | 34,200 | 44.13 |
| Oregon......... | 117,400 | 30.200 | 0.26 | 587,000 | 30,200 | 51.45 |
| Pennsylvania.... | 1,996,486 | 368,323 | 0.18 | 3,836,127 | 241,793 | 63.03 |
| Rhode Island.... | 213.477 | 65,817 | 0.31 | 781,765 | 45,817 | 58.61 |
| South Carolina.. | 94,489 | 34,016 | 0.36 | .......... | .......... | .... |
| South Dakota... | 601,000 | 170,695 | 0.28 | 3,017,500 | 170,694 | 56.57 |
| Vermont........ | 231,128 | 48,323 | 0 21 | 883,096 | 45 643 | 51.69 |
| Virginia ....... | 286,946 | 75,925 | 0.26 | 342,895 | 18,505 | 53.97 |
| Wisconsin ..... | 1,285,000 | 223,825 | 0.17 | 5,540,000 | 179,075 | 32.32 |
| Total....... | 20,683,244 | $4,456,891 | $0.22 | 61,822,871 | $2,978,172 | $48.17 |

# Civil Engineering & Road Construction



# Civil Engineering & Road Construction

**170. Method of Paying for Granite-block Pavements.**—The present system of paying for granite-block paving is erroneous. The contractor buys his blocks at so much a thousand, and sells them at so much a square yard laid; thus it is his interest to have as few blocks to the square yard as possible and joints as large as he can. Or he may purchase them from the stone man at so much a square yard: in this case the stone man is interested in having as few blocks as possible; as is also the contractor, for the fewer blocks to be laid to the yard the more yards of paving will the pavior lay in a day, thus increasing the profits of the contractor. In some cases the pavior is paid by the square yard of paving; then it becomes his interest to have as few blocks to handle as possible and as wide joints as he may, thus increasing the number of square yards of paving he can lay in a day, and thereby increasing his wages. No matter how looked at, all parties concerned in furnishing and laying the blocks are deeply interested in having as few blocks and as wide joints as possible to the square yard. As both of these are serious defects, the temptation to adopt them should be removed.

# Civil Engineering & Road Construction

EXTENT AND COST OF GRANITE-BLOCK PAVEMENTS IN SEVERAL OF THE PRINCIPAL CITIES OF THE UNITED STATES IN 1890.

| Cities. | Extent. Miles. | Cost of Construction per square yard. |
|---|---|---|
| New York, N. Y. | 140 00 | $2.50 to $4.50 † |
| Boston, Mass. | 62.00 | 2.75 " 4.00 † |
| Brooklyn, N. Y. | 55.30 | 2.75 |
| St. Louis, Mo. | 43.71 | 3.52 |
| Atlanta, Ga. | 33.00 | 1.50 |
| Cincinnati, Ohio | 30.00 | 4.25 |
| Washington, D. C. | 23.20 | 2.85 to 3.47 † |
| Chicago, Ill. | 20.48 | 3.13 |
| Richmond, Va. | 16.58 | 2.48 |
| Albany, N Y. | 16.39 | 2.78 to 3.45 † |
| Newark, N. J. | 13.36 | 2.75 |
| Lowell, Mass. | 10.00 | 1.80 to 2.25 |
| Providence, R. I. | 9.20 | 2.50 " 4.00 † |
| Troy, N. Y. | 9.12 | |
| Milwaukee, Wis. | 7.50 | 2.15 to 2.45 |
| Worcester, Mass. | 7 00 | 2.25 |
| Omaha, Neb. | 6.00 | 1.98 |
| New Haven, Conn. | 4.25 | 2 50 |
| Minneapolis, Minn. | 4.16 | 1.80 to 2.57 |
| Cambridge, Mass. | 3.63 | 2.20 |
| Trenton, N. J. | 3.50 | 3.00 |
| Los Angeles, Cal. | 1.50 | 2.52 |
| Wilmington, N. C. | 1.25 | 2.50 |
| Nashville, Tenn. | 1.25 | 3.15 |
| Waterbury, Conn. | 1.10 | 2.75 to 2.95 |
| St. Paul, Minn. | 0.39 | 2.10 |

# Civil Engineering & Road Construction

**181. Wood Pavements and Death-rate.**—A comparison of the death rate in cities using wood pavements with that in cities where little or no wood is employed seems to show that wood pavements do not cause an increase in the death-rate.

| Death-rate per 1000. | City. | Percentage of Wood Pavements. |
|---|---|---|
| 17.48 | Chicago | 80 |
| 25.19 | New York | 0 |
| 23.31 | Boston | 0 |
| 19.74 | Philadelphia | 0 |
| 14.70 | Detroit | 91 |
| 16.90 | Milwaukee | 48 |
| 23.70 | Nashville | 0 |
| 19.87 | Atlanta | 0 |
| 9.17 | Duluth | 95 |

# Civil Engineering & Road Construction

220. The cost of preparing the different varieties of asphaltum for street pavement is nearly the same; and as all appear to be about equally durable, the exclusive use of any one of them is due merely to the advantage in freights.

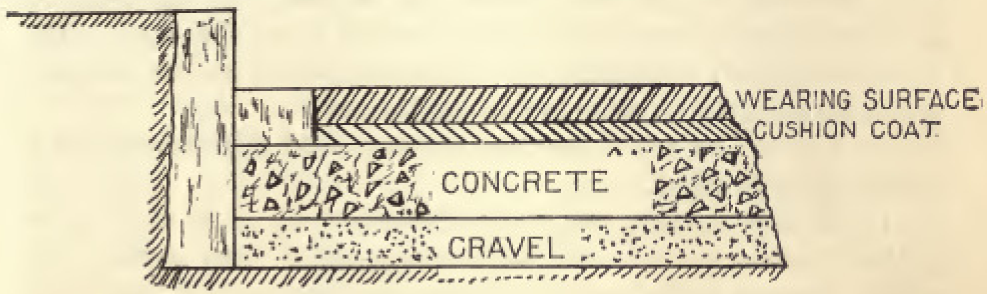



FIG. 14.—SECTION OF TRINIDAD ASPHALT PAVEMENT.

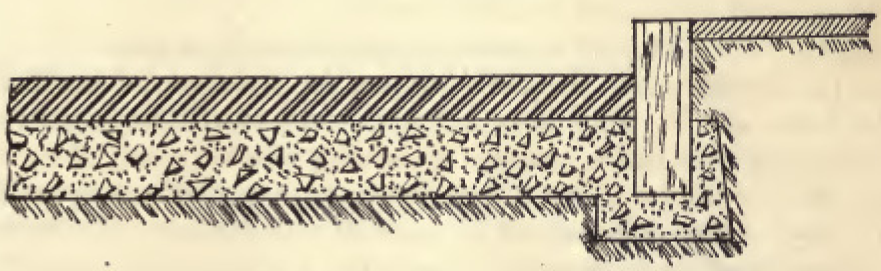


FIG. 15.—SECTION OF TRINIDAD ASPHALT ON BITUMINOUS BASE.

# Civil Engineering & Road Construction

Extent and Cost of Asphalt Pavements in the Principal Cities of the United States in 1890.

| Cities. | Extent. Miles. | Cost of Construction per square yard. |
|---|---|---|
| Buffalo, N. Y. | 83.00 | $3.00 |
| Washington, D. C. | 49.70 | |
| Philadelphia, Pa | 24.60 | 2.50 |
| Omaha, Neb. | 15.75 | 2.98 |
| Brooklyn, N. Y. | 8.82 | |
| Rochester, N. Y. | 8.00 | |
| Detroit, Mich. | 6.86 | 3.30 |
| Utica, N. Y. | 6.14 | |
| St. Joseph, Mo. | 6.00 | 2.80 |
| Erie, Pa. | 5.58 | 3.00 |
| Chicago, Ill. | 5.09 | 3.00 |
| Toledo, Ohio | 4.50 | 2.58 |
| St. Paul, Minn | 4.04 | 2.75 |
| St. Louis, Mo. | 3.95 | 2.97 |
| New York, N. Y | 3.36 | 3.25 to 4.50 |
| Boston, Mass | 2.70 | 3.50 |
| Harrisburg, Pa. | 2.50 | 2.78 |
| Syracuse, N. Y. | 1.79 | 2.70 |
| Minneapolis, Minn. | 0.98 | 2.75 |
| Providence, R. I. | 0.84 | 2.50 |
| Schenectady, N. Y. | 0.75 | |
| Newark, N. J. | 0.57 | 2.80 |
| Troy, N. Y. | 0.50 | |
| Albany, N. Y. | 0.46 | |
| Los Angeles, Cal | 0.30 | 2.56 |
| New Haven, Conn. | 0.25 | 2.75 |
| Grand Rapids, Mich. | 0.21 | 2.95 |
| Milwaukee, Wis. | 0.16 | 2.65 |

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# Civil Engineering & Road Construction

**261. Omaha, Neb.**—"Our temperature varies as much as 150 degrees Fahr., between the extremes of summer and winter. We are subject to rapid changes of temperature, which in the winter season occasionally are as high as 60 degrees in twenty-four hours. Douglass Street, which was paved in the fall of 1882 and spring of 1883, has experienced a range of temperature of from 120 degrees in the summer to 34 degrees below zero in the winter. . . . Our experience is very favorable to asphalt pavements on all grades ranging from 6 inches to 4 feet rise per 100 feet, and I am not sure but that as high as 5 or 6 feet per 100 feet may be favorably overcome. The asphalt pavement is not as cheap as wood, but, in my opinion, a preferable pavement upon permanently established and well-improved streets. It is not quite as easy for horses as wood, but more comfortable for those who ride, is more cleanly, and from a sanitary standpoint far superior."

# Civil Engineering & Road Construction

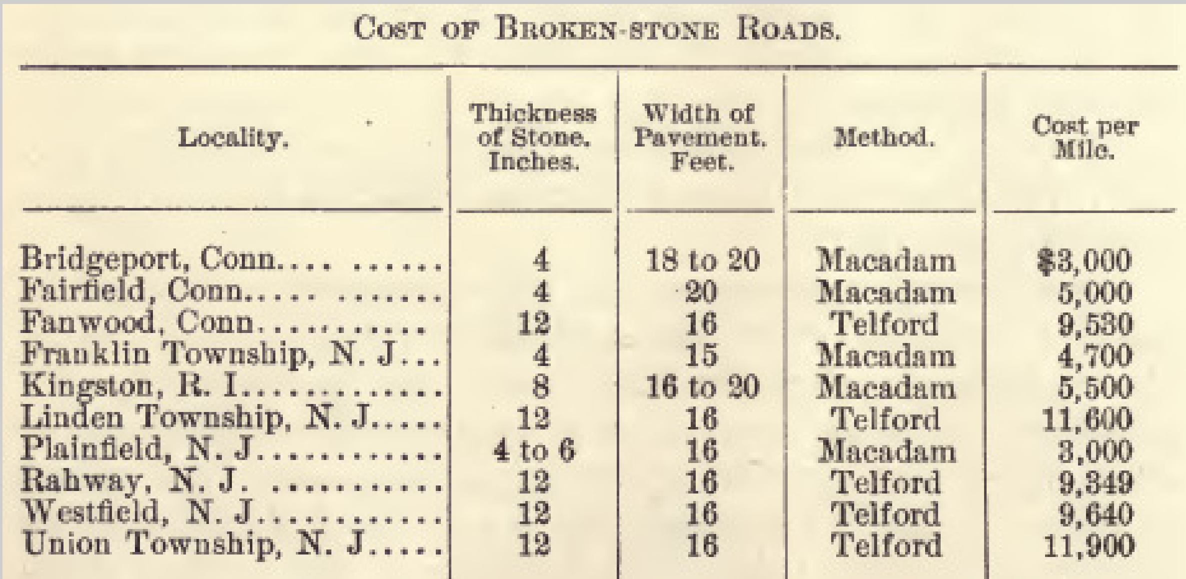
BRICK PAVEMENTS.

**304.** Brick, although one of the oldest materials used for paving, was not employed for this purpose in the United States until about twenty years ago. The first brick pavement laid in the United States was in Charleston, W. Va., in 1872. Since then the use of brick as a paving material has extended over a wide section of country; and in localities with moderate traffic such pavements appear to give satisfaction.

Extent and Cost of Brick Pavements in several Localities in the United States in 1890.

| Cities. | Extent. Miles. | Cost of Construction per square yard. |
|---|---|---|
| Columbus, Ohio | 21.00 | $1.75 to $2.35 |
| Philadelphia, Pa. | 19.80 | 2.05 |
| Decatur, Ill. | 10.00 | |
| Bloomington, Ill. | 6.00 | 1.62 |
| Toledo, Ohio | 4.70 | 2.10 |
| Omaha, Neb. | 3.00 | 1.75 to 2.14 |
| Parkersburg, W. Va. | 2.20 | 1.09 to 1.40 |
| Quincy, Ill. | 2.00 | 1.80 |
| Springfield, Ill. | 1.50 | 1.50 |
| Bucyrus, Ohio | 1.25 | 2.30 |
| Rochester, New York | 1.25 | 2.25* |
| Trenton, N. J. | 1.00 | 2.00 |
| Nashville, Tenn. | 0.75 | 1.35 |
| Detroit, Mich. | 0.61 | 2.80 |
| Chicago, Ill. | 0.38 | 2.00 |
| St. Paul, Minn. | 0.34 | 2.00 |
| Cumberland, Md. | 0.33 | 1 25 |
| Wheeling, W. Va. | 10.00 | 1.00 to 1.41 |

# Civil Engineering & Road Construction



Cost of Broken-stone Roads.

| Locality. | Thickness of Stone. Inches. | Width of Pavement. Feet. | Method. | Cost per Mile. |
|---|---|---|---|---|
| Bridgeport, Conn.... ...... | 4 | 18 to 20 | Macadam | $3,000 |
| Fairfield, Conn..... ....... | 4 | 20 | Macadam | 5,000 |
| Fanwood, Conn........... | 12 | 16 | Telford | 9,530 |
| Franklin Township, N. J... | 4 | 15 | Macadam | 4,700 |
| Kingston, R. I............. | 8 | 16 to 20 | Macadam | 5,500 |
| Linden Township, N. J..... | 12 | 16 | Telford | 11,600 |
| Plainfield, N. J............ | 4 to 6 | 16 | Macadam | 3,000 |
| Rahway, N. J. ........... | 12 | 16 | Telford | 9,349 |
| Westfield, N. J............ | 12 | 16 | Telford | 9,640 |
| Union Township, N. J..... | 12 | 16 | Telford | 11,900 |

# Civil Engineering & Road Construction

EXTENT AND COST OF BROKEN-STONE PAVEMENTS IN SOME OF THE PRINCIPAL CITIES OF THE UNITED STATES IN 1890.

| Cities. | Extent. Miles. | Cost per Square Yard. |
|---|---|---|
| St. Louis, Mo. | 271.76 | $0.51 |
| Chicago, Ill. | 226.67 | 0.90* to 1.70† |
| Boston, Mass. | 172.00 | 0.75 to 1.25 |
| Nashville, Tenn. | 111.00 | 0.45 |
| Providence, R. I. | 110.00 | |
| Philadelphia, Pa. | 90.80 | |
| Hartford, Conn. | 64.00 | 1.00 |
| Syracuse, N. Y. | 50.00 | 0.69 to 1.08 |
| Rochester, N. Y. | 46.00 | 1.25 |
| Paterson, N. J. | 38.00 | 0.45 |
| New Haven, Conn. | 28.50 | 0.50 to 1.25 |
| New York, N. Y. | 25.34 | 1.00 to 1.50‡ |
| Worcester, Mass. | 20.00 | |
| Cambridge, Mass. | 20.00 | 0.70 |
| Harrisburg, Pa. | 20.00 | |
| Toledo, Ohio. | 10.39 | 1.23 |
| Burlington, Vt. | 7.74 | |
| Washington, D. C. | 6.00 | |
| Richmond, Va. | 5.72 | 0.75 § |
| Utica, N. Y. | 2.62 | |
| Oswego, N. Y. | 2.18 | |
| Albany, N. Y. | 1.71 | |
| Milwaukee, Wis. | 1.16 | |
| Los Angeles, Cal. | 1.00 | 1.17 |
| Schenectady, N. Y. | 0.75 | |
| Cincinnati, Ohio. | | 1.25 ¶ |
| Duluth, Minn. | 44.00 | |
| Jersey City, N. J. | 1.50 | |
| East Saginaw, Mich. | 1.00 | |
| Springfield, Mass. | 15.00 | |
| Chelsea, Mass. | 5.00 | |
| Dubuque, Iowa. | 34.60 | |
| Toronto, Can. | 37.27 | |
| Mobile, Ala. | 20.00 | |
| Lowell, Mass. | 10.00 | |
| St. Louis, Mo. | 18.33 ‡ | 0.84 |
| Newark, N. J. | 10.84 ‡ | 1.75 |
| Kingston, N. Y. | 4.50 ‡ | |
| Toledo, Ohio. | 1.11 ‡ | |
| Trenton, N. J. | 0.50 ‡ | |

# Civil Engineering & Road Construction

This method of drainage has been very successfully applied in reclaiming the "Jersey Flats" between the cities of Newark and Jersey City, New Jersey, a large tract of marsh land with its natural surface not higher than the level of ordinary high tide, and in large part some inches below that level. These Flats were formerly subject to twice daily overflow, from the Passaic and Hackensack rivers, in which the mean rise and fall of the tide is about 4 feet. The tract was surrounded by a dike or levee formed along the margin of the stream, of the material excavated from a wide open ditch parallel to it on the inside. Numerous broad cross ditches, dividing the marsh into parallelograms, lead into this main ditch. The sluices are located at suitable intervals so as to drain from the main ditch into both the Hackensack and the Passaic rivers. The pipes are usually placed in pairs, and are of various sizes, in only a few instances exceeding two feet in interior diameter. It has been found that a difference of one inch in the inside and outside water level, will open or close the sluice-gates.

# Civil Engineering & Road Construction

Small drains placed close together will drain the

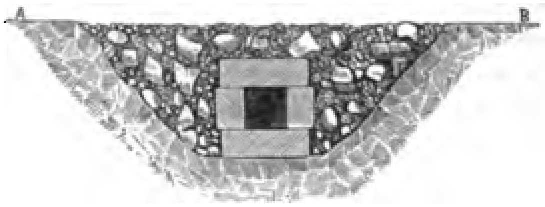


FIG. 20.

road bed much more efficiently than larger ones of the same aggregate water-way placed farther apart. A water-way of 2.5 to 4 inches sectional area, such as may be obtained with

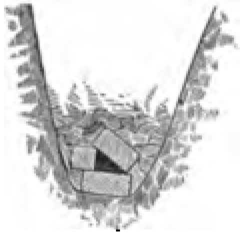


FIG. 21.

FIG. 22.

three lines of whole bricks placed end to end as in Fig 22, will generally be ample. The full lines show one method of

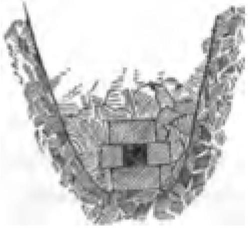


FIG. 23.

arranging the brick, and the dotted lines another.

# Civil Engineering & Road Construction


Fig. 17.

# Civil Engineering & Road Construction

The following estimates of the cost per rod of these several kinds of drains, is believed to be fair, with labor at $1.75 per day, in stiff clay soils :

| | Tile drain, 2-inch pipe tiles. | Brick triangular drain. Fig. 21. | Brick drain. 3 courses end to end. Figs. 22, 23. | Brick drain. 4-in. x 4-in. Fig. 20. |
|---|---|---|---|---|
| | $ cts. | $ cts. | $ cts. | $ cts. |
| Cutting and filling per rod.......... | .25 | .30 | . 30 | . 35 |
| Cost of tiles, or bricks | .23 | .55 | .594 | 1.188 |
| Total cost per rod... | .48 | .85 | .894 | 1.538 |

# Construction Equipment


**IN THE DAYS OF ELEVATING GRADERS, "TURNPIKING" DESCRIBED EXCAVATION** and embankment placement without using haulers. Here are two Stroud Road Machinery Heavy Duty graders turnpiking a road embankment for an unidentified county in Kansas. Photo courtesy of the Historical Construction Equipment Association (www.hcea.net).

# Civil Engineering & Road Construction

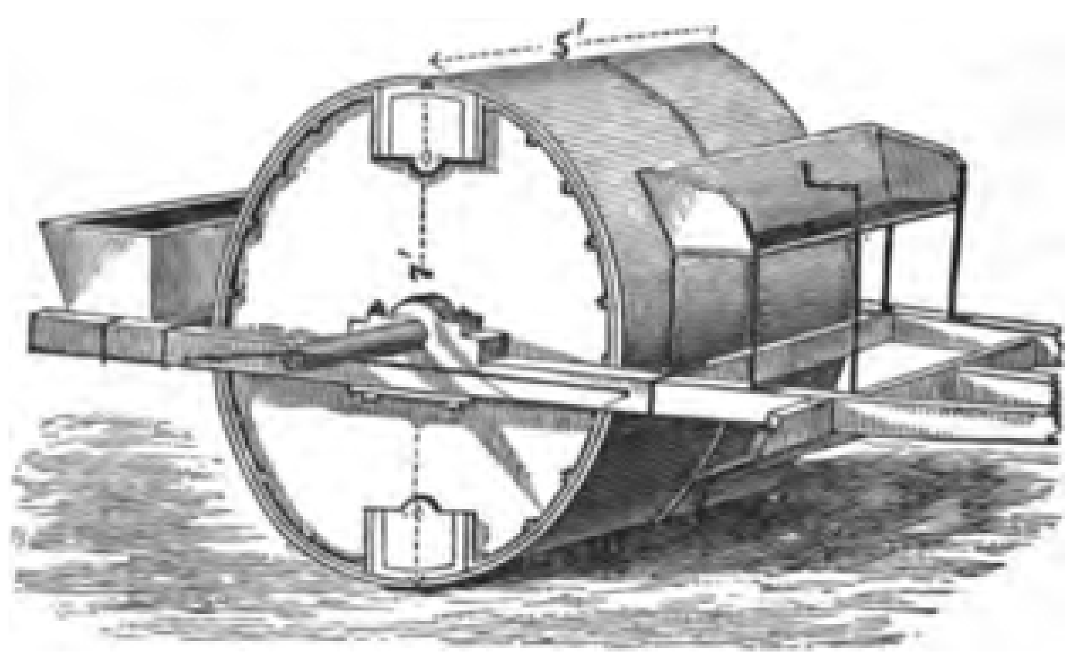


Fig. 34.

# Civil Engineering & Road Construction

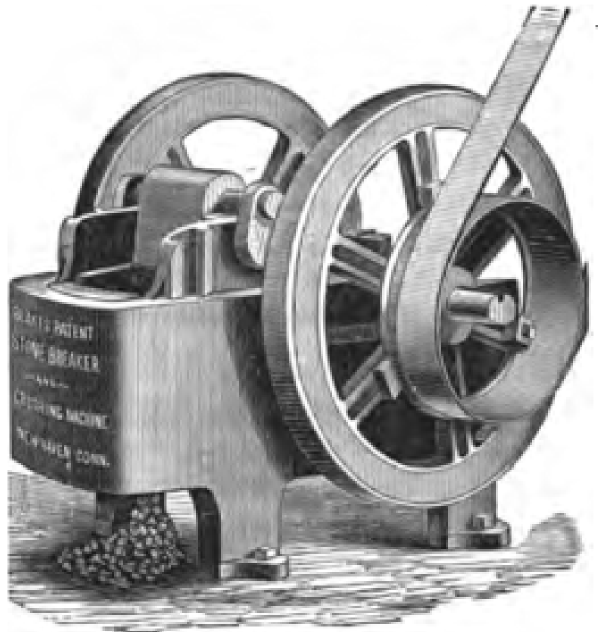


Fig. 87.

The proper speed of these machines is about 200 revolutions of the crank per minute. They are made of several sizes, requiring engines of 4 to 12 horse power, and their working capacity varies correspondingly from 3 to 7 cubic yards of broken stone per hour. The best size for breaking road material is one having a capacity to receive stones 8 to 9 inches thick and 14 to 15 inches wide.

# Civil Engineering & Road Construction

**The Cubical Concrete Mixer.**

This mixer, Fig. 64, consists of a cubical box made of hard-wood plank or boiler iron, measuring about four feet on each edge in the interior, rigidly mounted on an iron

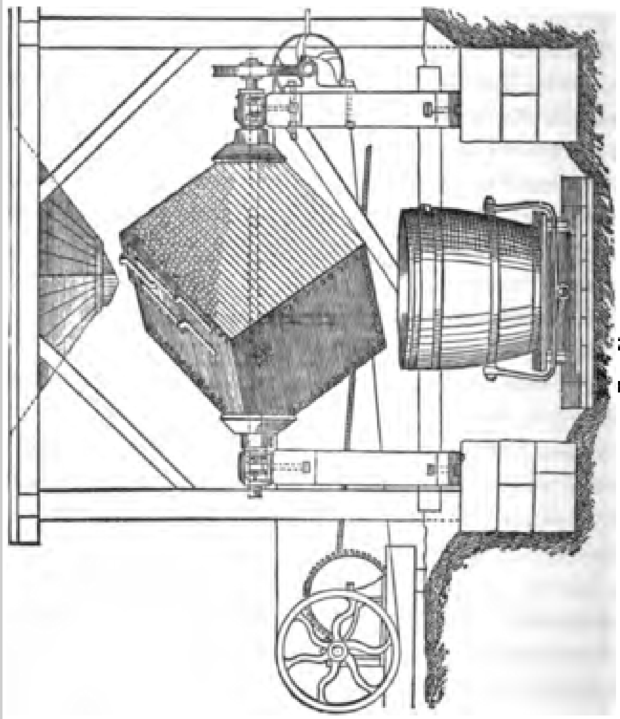


Fig. 64.

axle passing through opposite diagonal corners. It is provided with a trap door about two feet square, close to one of the six angles farthest from the axle, for charging and emptying the box.

# Civil Engineering & Road Construction

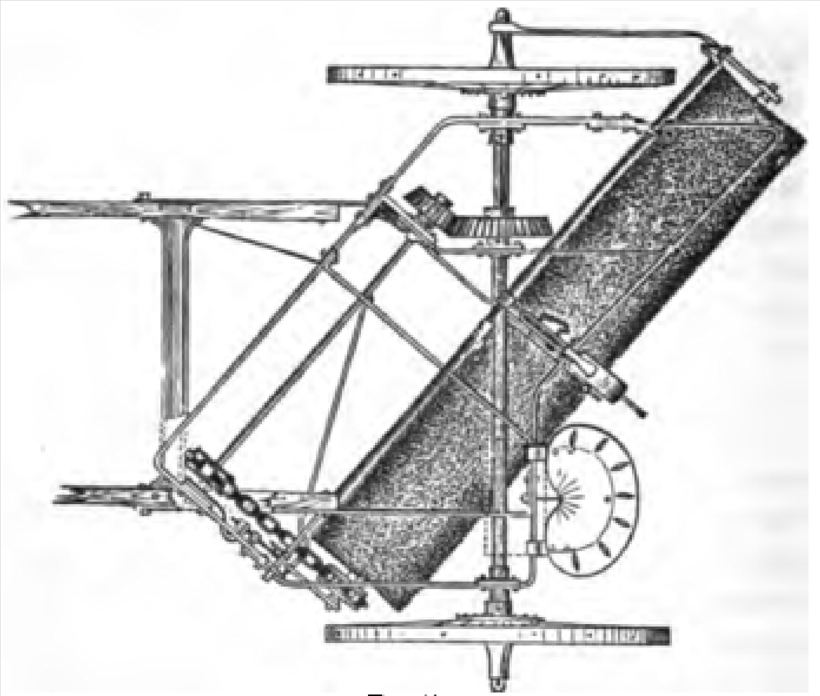


Fig. 44.

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# Civil Engineering & Road Construction

In Macadam's matured practice upon the Bath and Bristol roads, England, he did not allow any stone above three ounces in weight (equal, with the material he had, to cubes of 1½ inches or 2 inches in their longest diagonal length) to be used. He caused splinters and thin slices and spalls to be excluded as far as possible, and laid considerable stress upon uniformity of size, and perfect cleanliness or freedom from dust, sand, or earthy matter. The French engineers, on the contrary, are indifferent as to cleanliness,

# Civil Engineering & Road Construction

### Thickness of the Road-covering.

The thickness of the covering need not exceed 10 or 11 inches of well consolidated materials on a good road bed, for roads in cold climates subjected to the heaviest traffic. The French road engineers consider ten inches sufficient in France, upon the most important roads, and 6, 7, and 8 inches where the traffic is comparatively light. Macadam considered 10 inches of well compacted materials enough for very heavy traffic, and generally advocates less thickness than most English constructors. Six inches for the minimum and ten for the maximum thickness appear to have been his limits. In one instance he speaks of a road which "having been allowed to wear down to only three inches, this was found sufficient to prevent the water from penetrating, and thus to escape any injury from frost," and in another, states that "some new roads of six inches in depth were not at all affected by a very severe winter."

# Civil Engineering & Road Construction

### Shell Roads.

Upon the South Atlantic and the Gulf coasts of the United States, stone suitable for road coverings does not exist, and in most localities good coarse gravel or pebbles cannot be procured except at such an outlay for transportation as to practically exclude their employment for road construction. Oyster shells, however, can generally be had at from 4 to 5 cents per bushel, exclusive of land haulage, and when applied directly upon sandy soil, as a covering, 8 to 10 inches in thickness, they form an excellent road for pleasure driving or light traffic. They wear much more rapidly, of course, than broken stone or gravel of good quality, and require more constant supervision to keep them in good order. When properly maintained they possess most of the essential requisites of a good road.

# Civil Engineering & Road Construction

**Charcoal Roads.**

The novel expedient of using charcoal for road coverings is not likely to be resorted to except in newly settled, heavily wooded districts, where the standing timber has no market value, and must be gotten rid of before the land can be devoted to agricultural pursuits. A case is mentioned in Michigan where a good road was made through a swampy forest in the following manner:

"Timber from six to eighteen inches through is cut twenty-four feet long, and piled up lengthwise in the centre of the road, about five feet high, being nine feet wide at the bottom and two at top, and then covered with straw and earth in the manner of coal pits. The earth required to cover the pile, taken from either side, leaves two good sized ditches, and the timber though not split, is easily charred; and when charred, the earth is removed to the side of the ditches, the coal raked down to a width of fifteen feet, leaving it two feet thick at the centre and one at the sides, and the road is completed." The material was found to pack well, not form into ruts, nor get soft and spongy in wet weather, although the water was not drained from the ditches. Its cost was $660 per mile, and contracts for two such roads were given out in Wisconsin at $499 and $520 per mile, respectively. (See Gillespie on Roads and Railroads.)

# Civil Engineering & Road Construction

With suitable appliances, labor at $2.00 per day, natural American hydraulic cement at $1.50, or Portland cement at $4.00 per barrel, and refined asphaltic cement at 1¼ cents per pound, an asphalt pavement of the kind described on page 183, and following, can be laid for $2.70 to 2.80 per square yard, exclusive of profit to the contractor, as follows :

| | |
|---|---|
| Concrete foundation 6 inches thick (labor and material), | $1.40 to $1.45 |
| Asphalt covering 2 inches thick do do..... | 1.30 to 1.35 |
| Total........................................ | $2.70 $2.80 |

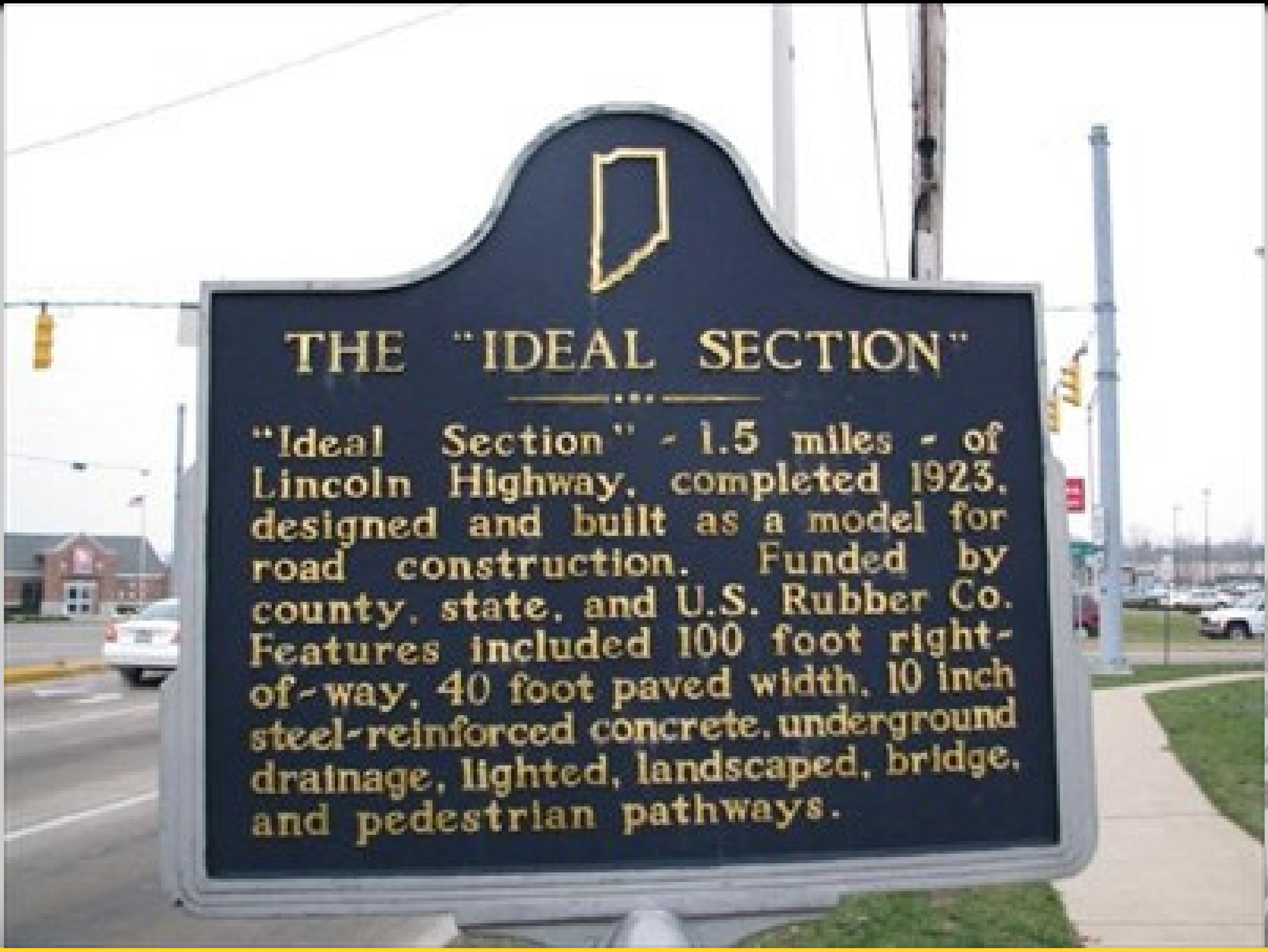
This includes nothing for earth work, but supposes the road bed to have been suitably excavated or filled in, as the case might be, in readiness for the minor adjustments of, grade and cross section, preparatory to laying the foundation.

# Civil Engineering & Road Construction

"2. The Qualities essential to a good pavement may be stated as follows :
(1) It should be impervious.
(2) It should afford good foothold for horses.
(3) It should be hard and durable, so as to resist wear and disintegration.
(4) It should be adapted to every grade.
(5) It should suit every class of traffic.
(6) It should offer the minimum resistance to traction.
(7) It should be noiseless.
(8) It should yield neither dust nor mud.
(9) It should be easily cleaned.
(10) It should be cheap."

Austin Bryne

# Early 20th Century Road Construction



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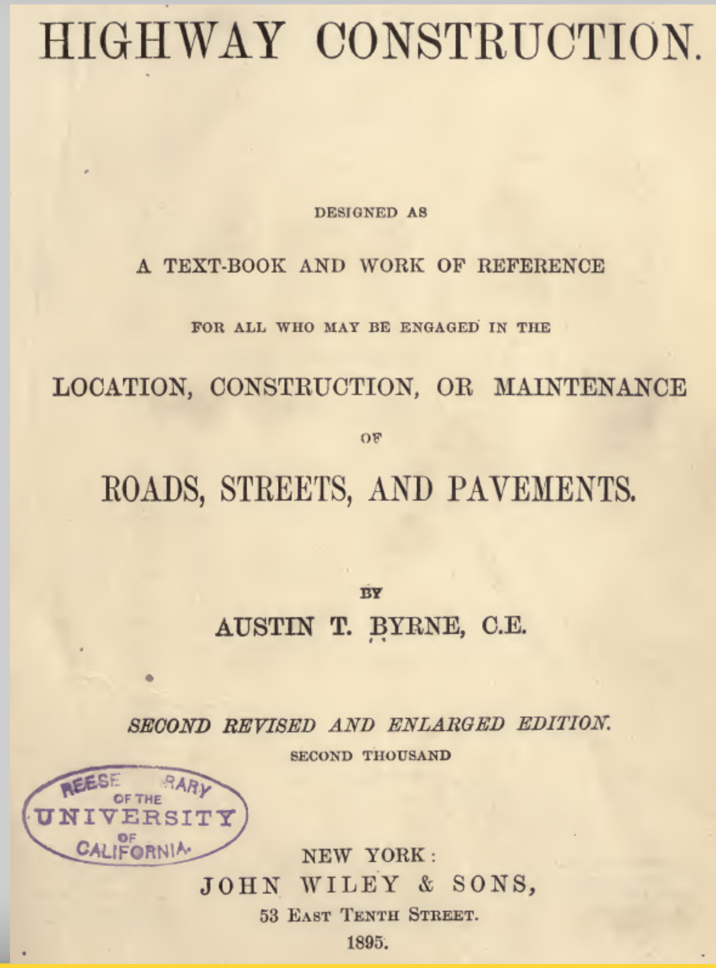

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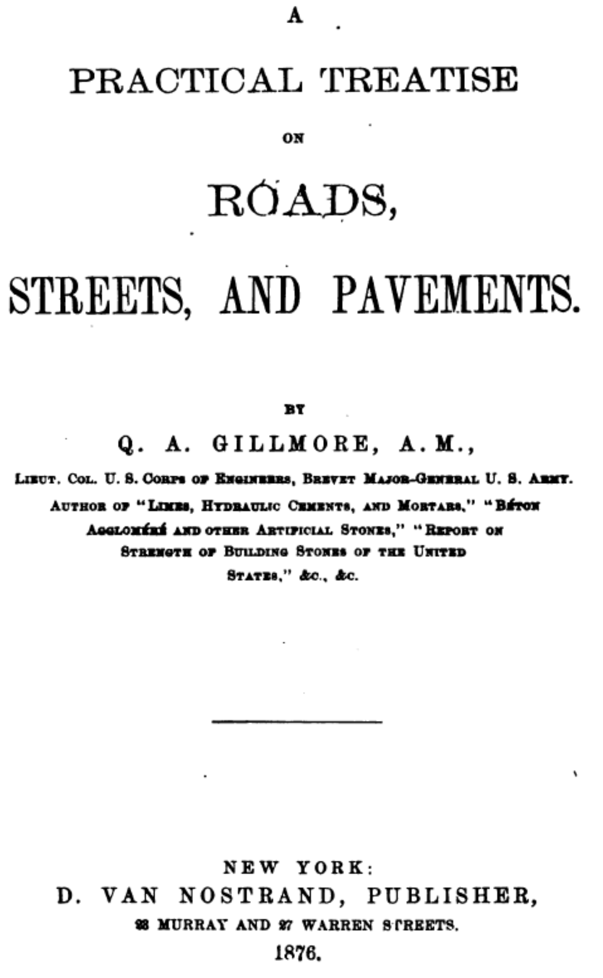

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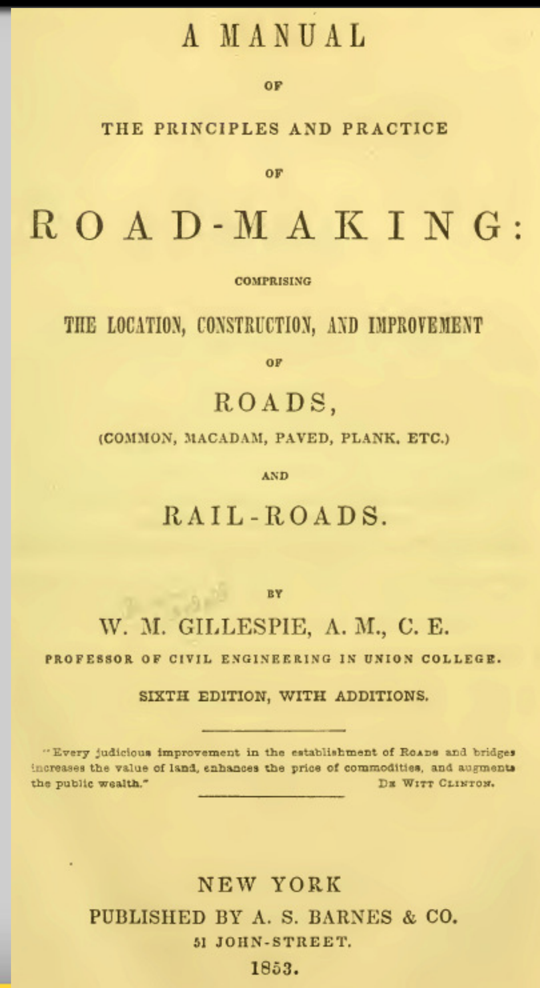
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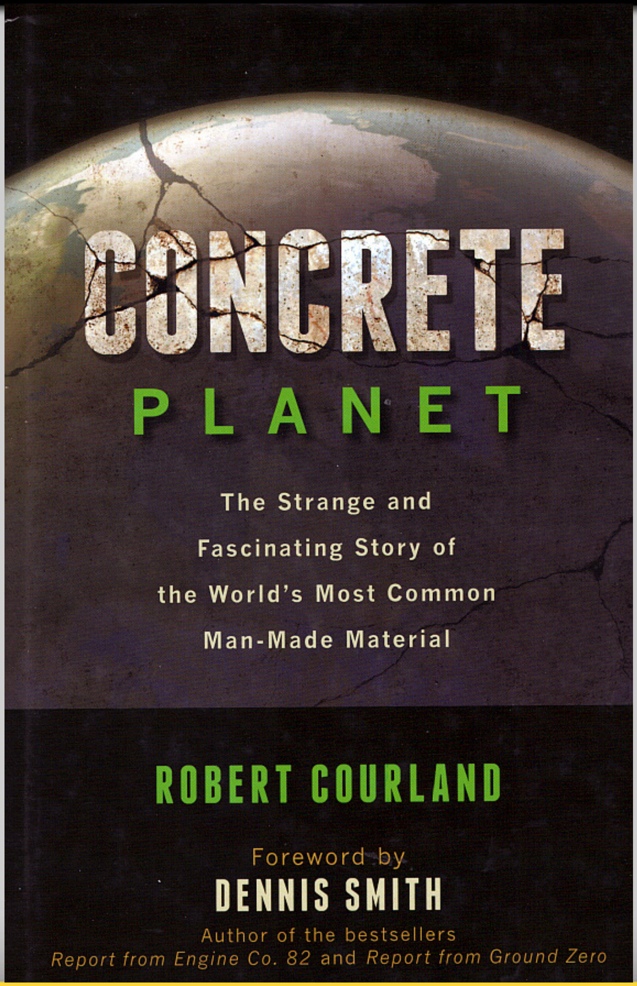

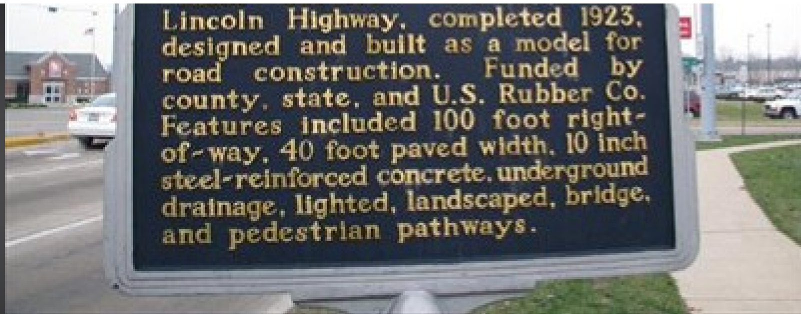


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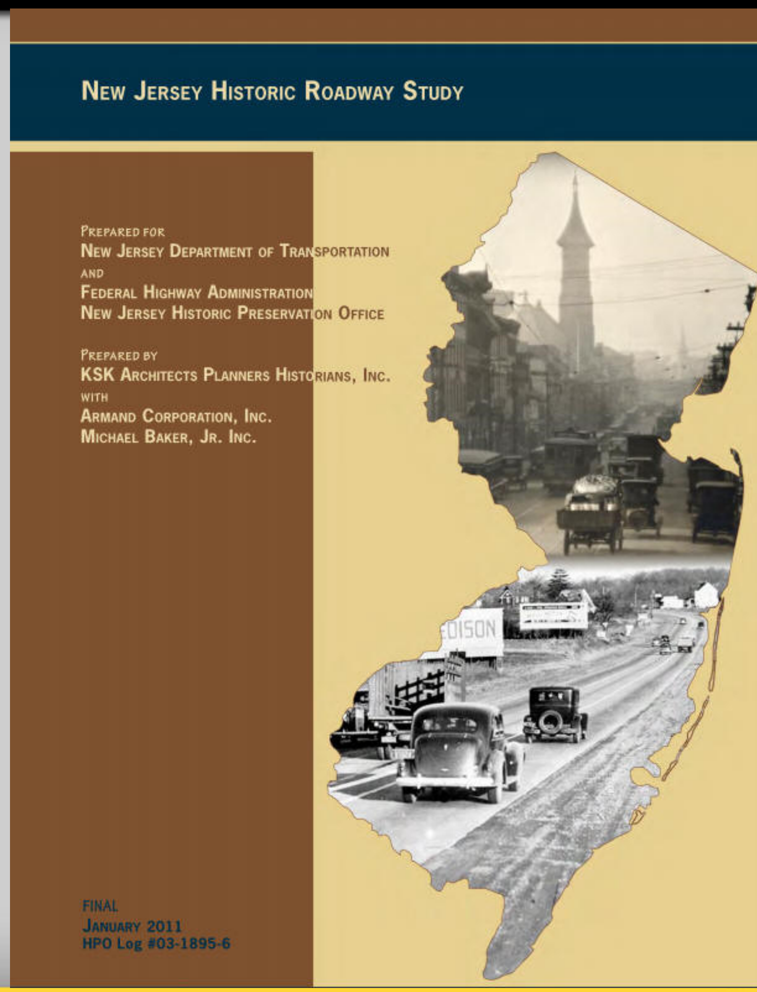
New Jersey Historic Roadway Study

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New Jersey Historic Preservation Office

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