Screenings from the Soil Research Lab

IOWA ENGINEERING EXPERIMENT STATION
IOWA STATE UNIVERSITY of Science and Technology
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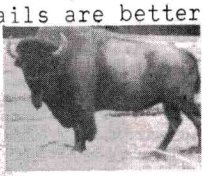
A CONDENSED HISTORY OF ROADFARE

From Pristine Bog to 10¢ per Gallon

Highway engineering is a primordial art, probably starting with the ant.[1] Larger animals literally let the roads grow under their feet,[2] their relentless pitter-patter compacting the soil to form trails.

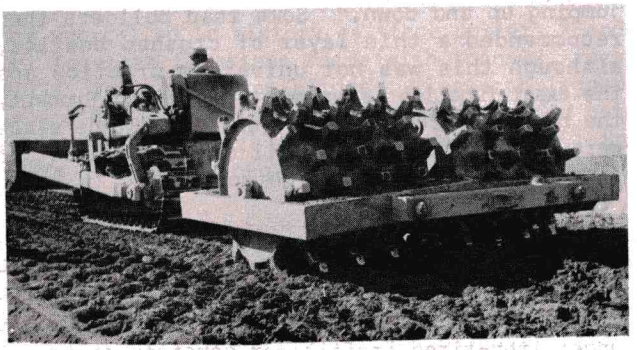
Pedestrian-pounded roadways can be rather indelible, as anybody knows who tries to grow grass in a neighborhood full of paper boys. Stone Age "Ridgeways" are still traceable in England. Other prehistoric trails are better kept up, to the extent that they now wear highway markers. Many roads and railroads in the central U.S. follow stage coach routes, which in turn followed buffalo trails.



Trail boss.

The first roads of man were probably game trails until man objected to the way other predators played the game. He then took off for the highlands, and the Ridgeways were truly ridge ways. Trails in Africa often run high and avoid lurking appetites in the valleys.

Next, man gradually turned from hunting to agriculture as women got the upper hand and wanted somebody to stay home nights and do the dishes. Because valleys were better for growing and closer to dishwater, homes and roads relocated downward. "Hillside Ways" therefore superceded the Ridgeways in the late Stone and early Bronze Ages. Lower routes could not avoid wetter and softer soils, and already people were looking around for somebody to take charge and call himself a highway engineer.



Soil compaction devices often copy the pre-eminent tread of animal feet. Above, a sheepsfoot roller. Right, a kind of bouncing bump-thumper used in Europe.

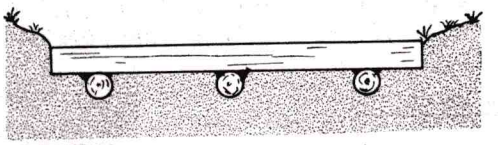
All aboard

Literally the first major step towards road improvement was to find a tree in the right place, push it down, and walk on it.

According to the widely quoted anthropologist, Et Al, the log road was invented because some aboriginal chief's sister-in-law objected when her feet got muddy. The men were not happy to halt their native interpretive dancing and lay the logs, and they stood aside and braced themselves for an uproarious laugh should sister-in-law happen to slip and fall in.

The ensuing catastrophe caused future log roads to be built with logs laid in pairs for better stability. Sometimes they were laid on boughs to retard sinking.

Some time later, Stone Age man realized he had clear title on the government timber concession, and there was no stopping him. Log pairs or trios were spread apart to act as longitudinal girders which supported a continuous blanket of other logs laid cross-wise and even pegged in place. Such prehistoric roads have been dug up in Holland.



The log method is still the best for roads crossing a marsh or swamp. American "corduroy" is a simplification from the Stone Age acme, in that longitudinal members are not used.

[1]Ants wisely pooled their not too copious brains to form committees. Unfortunately, it is practically impossible to dissolve a committee. That's why there are so many ants, always hurrying.

[2]They also stepped on the committees.

Return to Table of Contents

Omanray ariotchay utray in an avalay urfacedsay oadray. (Roman chariot rut ...)

Merrily we roll the wheel

Throughout history, highway engineers have been forced to roll with the punch of each new innovation in travel. For example, about 3500 B.C. the Babylonian Research Council got hot rockets to invent the wheel before somebody else got it, without so much as a wisp of worry about what this would do to local dirt roads. As a result roads were rutted, and hard pavement was needed.

Unfortunately paved highways are not built with need but with cold cash, which usually means a strong central government to collect the loot through war or taxes. Egypt was strong enough and had the cash and slaves, but the Pharaohs' religious integrity dictated that all major engineering effort be expended on monuments to themselves. Roads were used mainly for sliding stone blocks into conspicuous piles hither and yon.

Meanwhile Babylonians were building sun-dried mud brick streets laid up with soil-asphalt or gypsum mortar, but the bricks were soft and intended only for foot traffic. A few were stone-paved, with ruts intentionally made for wheels. Invasion by Persians about 540 B.C. did something to initiative, and nothing new developed. The Persians, a rowdy lot always in a hurry, took a dim view of road improvement. The Persian view was that you could pull through anywhere if you didn't spare the horses.

India and China

Away from the western main stream, India and China made some notable roadbuilding achievements which were lost or superceded before they could become known and woven into the general evolutionary fabric. An Indian road dated at 800 B.C. appears to be soil burnt in situ, a technique still untried in modern times. China's trade routes to the west were paved with stone slabs, and traversed elegant cantilever, arch, and suspension bridges. However, by the time of communication with Rome, Rome had superior pavement designs of its own.

THE MASSIVE SCHOOL (2000 B.C. - 1775 A.D.)

The thick, massive school of road engineering, best exemplified by the superb highway system of the Romans, lasted about as long and served as well as any incorrect idea should. It probably had its roots in the Minoan stone-paved streets of ancient Crete. Greeks picked up some pointers from Minoans but were all wrapped up in local politics and philosophy, and lacked a strong central authority to build many roads.

Rome was the first mighty empire and built the first mighty roads, unexcelled until the present century. Colonization of Italy began about 500 B.C., and the first of 23 great highways radiating from Rome was started in 312 B.C. This, the Appian Way, took almost 70 years to complete, which is understandable when you see how they built it. By the second century A.D. the highway system in Italy and European and African provinces totaled 50,000 miles, or 20 percent more than in the new interstate system under destruction in the U.S.

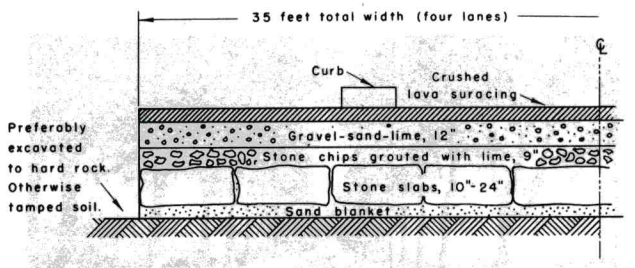
Pompeii street paved with slabs of lava. Street was preserved under hot ashes from Vesuvius in A.D. 79; note how tops of buildings are weathered and long gone.

Main Roman highways were four lanes, $3\frac{1}{2}$ to $4\frac{1}{2}$ feet thick, and are best described as "walls laid flat." First the soil subgrade was prepared by compaction by nine or more slaves jumping up and down.[3] Some road builders then recommended a thin layer of crushed beetles, although this was not universal practice and the exact function is somewhat in doubt. Probably the beetles were a nuisance anyway. Stone slabs were laid either on the soil or on a blanket of sand and grouted with lime mortar.

On top of the stone slabs was a layer of cobbles or broken stone grouted with lime mortar, then a layer of gravel concrete. The topmost layer could be stone slabs for durability under iron-tired traffic, or concrete or gravel grouted with mortar. Sometimes loose sand or gravel was spread on top to reduce wear.

[3]They also used rollers and wooden rams, but these are hardly as picturesque.

Return to Table of Contents



Typical section in the Appian Way

Total thickness, 3-5 feet.

The Roman roads were about three or four times as thick as modern highways and would have been vastly more expensive except for cheap labor of the foreign draftees. The load limit for wagons was set at about half the weight of a modern automobile, and an average road lasted maybe 30 to 40 years, high class ones 80 to 100.

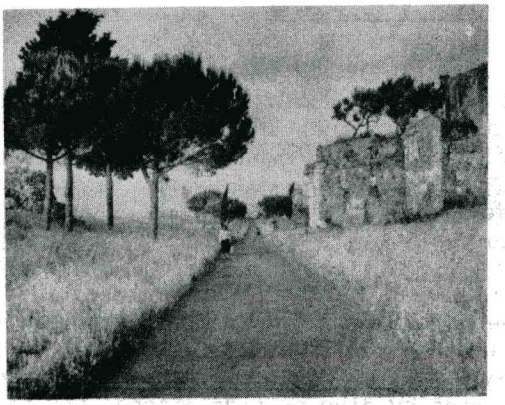
Roman concrete dates from about 150 B.C., when some pioneer chemist discovered that a volcanic ash from near Pozzouli could replace part of the lime in mortar and give more strength. Later other ash deposits were also exploited and given the name Puzzoulana. A common mortar was one part lime, three parts ash, and about three parts sand, the proportions varying depending on the quality of the sand.

When Romans invaded the soggy North they had to either adopt local practice and use log roads or watch their massive ledges of stone and concrete sink slowly out of sight. Some roads were set on vertical logs, or pile, another very cogent idea. Roman log roads gave fanciful attention to detail, longitudinal girders being of split fir or oak, and cross members being hand-hewn overlapping planks.

The Americas

Incan roads in Equador, Peru, and Chile ran some 10,000 miles across the most difficult mountainous terrain, an engineering feat rivaling the road system of the Roman Empire. The Incas are unexcelled in history as stone cutters,[4] and put together flagstone roads with tunnels, rock fills, and suspension bridges. Research lagged in another field, however, and the Incas did not have the wheel. This may be one reason their roads lasted so long.

In 1532 Pizarro and his bandits swung a bold sword in Peru but took little notice of roads or architecture, having sustained a peculiar blindness caused by close proximity to somebody else's gold. In Mexico, Aztec and Mayan civilizations also had built stone roads of considerable merit, but in the glitter of gold these too were forgotten.



In most places the Appian Way now wears a new, stylish coat of asphalt. Note how straight runs the road.

The Middle Ages

Curiously enough, at the time the Spanish came to America, roads in Europe had reached an all-time miserable low. When the Roman Empire deteriorated so did the roads, and many of the stones were dug up to be put in houses, castles, or catapults. Twelfth century kings took a dim view of improving roads because nobody traveled much except to invade and plunder, and why make it easy? Overland travel was restricted to walking or horseback, and the secrets of Roman cement had been thoroughly forgotten.

The Crusades gave a new outlet for boyish enthusiasms, and with the delinquents off for Palestine interest was renewed in roadbuilding. Streets were paved with cobblestones, until in 1550-1750 statute labor laws required every man to put in some time on the road gang. By 1600 wheels came back but had a rough time, roads at best being an inferior copy of those of the Romans.

A flagstone street on the isle of Elba, where Napoleon used to hang out. (Laundry in the background.)

The first instinct when one encounters mud is to lay logs or sprinkle gravel. As early as 1737 Robert Philips noticed that gravel usually sank after a few years and became ineffective. He therefore suggested better drainage, but he was an idealist and ignored.

[4]The Incas also made bronze and worshipped the sun, as many a modern lass is prone to do.

Return to Table of Contents

Blind Jack's turnpikes

By the late 1700's coach travel was going by leaps and bounds, which was a little rough on the passengers and ushered in the era of the turnpikes. In 1765 John Metcalf, popularly known as Blind Jack, left his dry goods business to become England's first turnpike road contractor.

Metcalf was blind but shrewd and no idealist, and he pecked and probed along a proposed route like a fawn exploring the universe. He instinctively tried improving drainage, raising the road grade by digging side ditches and heaping the soil up between, then shaping the road and giving it crown so the rain would run off. Then he spread the gravel.

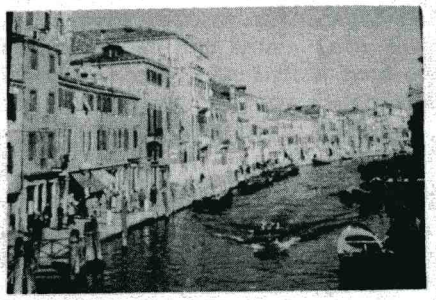
DIRT ROAD METCALF HIGHWAY

Metcalf's gravel-surfaced turnpikes formed a startling contrast in a world used to mudholes and ruts. His design is still copied for much modern secondary road construction in the U.S. and elsewhere. But Blind Jack was a man of action, and had no patience for describing his methods to others who might compete. Therefore other designs took over.

Trésaguet-Telford departures

At the same time as the intuitive designs of Metcalf, a French engineer named Pierre Trésaguet was wondering if the Romans were entirely right.

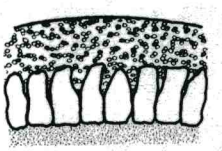
Trésaguet shaped his roads with a 20° crown to improve drainage, so much so that one wonders that the carriages didn't slide off. Then Tresaguet noticed that stone slabs laid flat after the manner of the Romans might readily tilt or shift under pushing from wheeled traffic. He therefore tried laying stones on edge with the thick edge down, crevices between the stones being filled with crushed stone hammered tight.



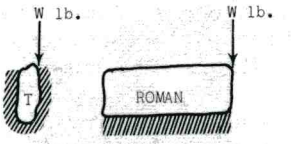
Blind Jack rediscovered what Romans had learned earlier and the Venetians learned later, that proper drainage is a must, or you may have to go to market in a motor boat. Venice.

The telford hand-laid road base is still widely used in Europe, as in this beauteous secondary road in Germany. On top is asphalt.

The edge-wise slabs could not tip or shift, and were all keyed together to react to a point load en masse. Furthermore, pounding from traffic should fill the chinks tighter and improve the road, which was rather radical. On top Tresaguet spread 3 inches of crushed stone for a wearing surface.



TRÉSAGUET-TELFORD ROAD



WHICH ROCK WILL ROCK?

Trésaguet's brilliance reduced Roman thickness by one-half and made a better road. In 1775 Louis XVI named him Inspector General of Roads and Bridges, which was no small plum to a struggling engineer. This allowed him to see to it that his roads were maintained and not thoughtlessly allowed to go to pot.

In the early 1800's Britain's first professional road engineer independently came upon the same design principles. Thomas Telford was authorized by an Act of Parliament to build roads to encourage commerce with hungry Scotland. Telford's Scottish integrity allowed him to view with alarm the incredible waste of the Roman design, and he ended up using a 7 inch layer of stone slabs laid on edge and chinked, covered by 7 inches of crushed stone and an inch of gravel.

Telford's most famous effort is the 194-mile Holyhead road to North Ireland. Started in 1815 and completed in 1830, it was at that time acknowledged to be the finest road in the world. The telford type of construction is still widely used in areas of plentiful rock and cheap labor, but already by 1830 Telford's design was up for grabs.

Return to Table of Contents

The Renegade

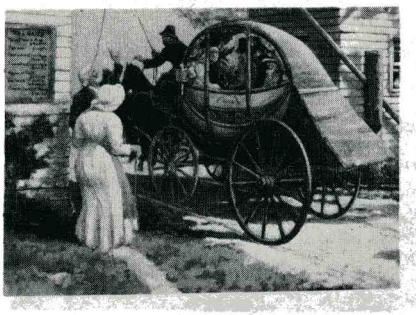
The ultimate heresy to Roman road doctrine came from another Scot, John Loudan Macadam. Even his name reflects a certain familial impudence; actually descended from the outlawed clan MacGregor, the family name was changed to Macadam because nobody could deny they were descendants of Adam.

The fine Telford roads in Scotland and Ireland gave a dismaying contrast to the sorrowfully inadequate English roads of the early 1800's. The House of Commons reacted to the problem with characteristic political insight by sharply limiting traffic. Finally public clamor was so terrifying that elected officials invited suggestions.

One respondent was Macadam, whose letter caused a sensation and overnight made him the popular expert on roads.

Macadam scoffed at limiting traffic, insisting that roads be designed to fit the traffic, not the traffic to fit the roads. (He could still raise some heat with that one.) He discarded the idea of large foundation stones, insisting that large stones merely formed an anvil upon which smaller surface stones were crushed and destroyed. Macadam's stones all passed a 1-inch ring, selected on the basis of contact area of the iron tire. Furthermore large stones settling unevenly would pocket water within the road.

Macadam's design was deceivingly simple; roads were usually 6 to 12 inches of crushed limestone placed on the drained, shaped, and compacted soil subgrade. Pounding from traffic created dust which infiltrated and with the aid of water cemented the road tight and solid. Macadam held that the stone surface had only two major functions, neither of which was strength: Stone inhibited wear, and after cementation it served as a "roof" to keep subgrade soil dry and firm.



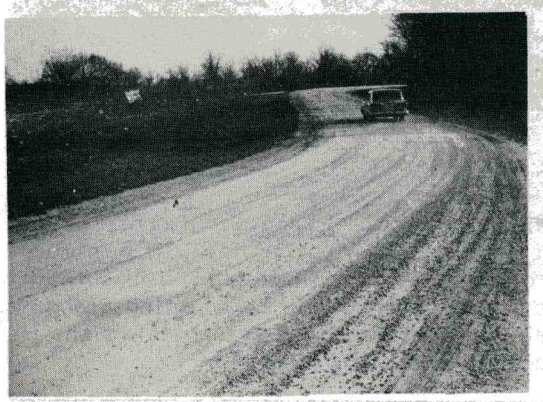
Tollgate on the Maysville-to-Lexington (Kentucky) Turnpike, 1830. Fares, 6¼¢ per horse, 2¢ per person, 16¢ per four-wheeled carriage, 6¼¢ per 10 head of cattle or 20 head of sheep.

Professional trespasses easily provoke proffessional jealousies, whether from trade unions, acrobats, or department heads, and the controversy over Macadam vs. Telford styles of road building was the hottest item since the medieval cure for witchcraft. The fact that Macadam was a popular hero didn't help, and his zeal for reform led him to overstate his case, which didn't help either. For example, he claimed his roads were best on a weak, boggy, "elastic" soil, since this formed the poorest anvil for destructive breakage. This view led to much critical buffoonery.

Eventually criticisms faltered in the face of success, and macadam roads became widely adopted and remain so. Unquestionably Macadam's unlettered audacity literally paved the way for the Industrial Revolution.

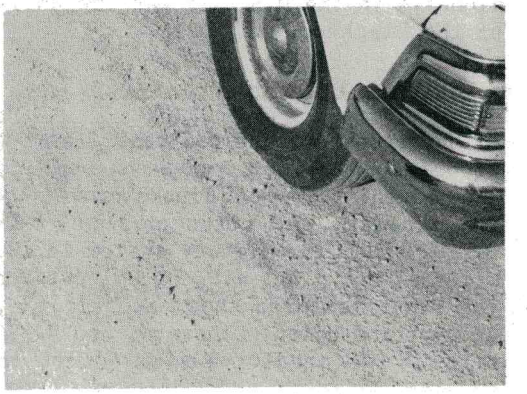
The turnpikes: boom and bust

By 1830, highway systems had reached their highest development since the time of the Romans. This was also the year a stage coach was outrun by an American train called the Tom Thumb, a grim foreboding of more thumbs to come. The train came in as rapidly as it is fading out now, and within 20 years the stage coach was completely extinct except in frontier areas. Turnpike trusts had also collapsed and were gone, and maintenance of existing roads fell on local governments.

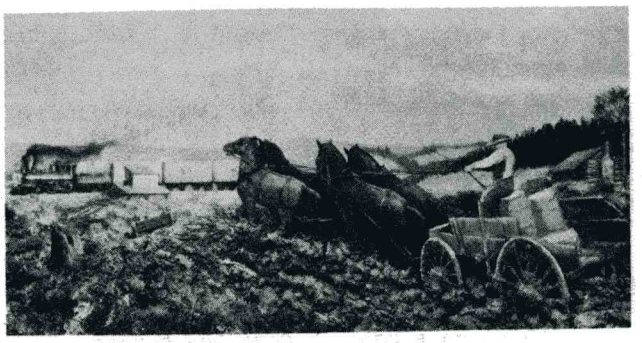


Macadam or crushed rock road.

The most important feature of the macadam is cementation by moisture and traffic dust. See the hard, natural surface of the traffic-bound macadam. Cementation may be hastened by artificially adding limestone dust and water to make a so-called "water-bound" macadam.



Return to Table of Contents



From 1850 to 1900 were very dark ages for the road. Only feeder lines to the railroads were maintained, and overland travel in bad weather was impossible except by foot, horseback or rail.

THE TWENTIETH CENTURY

The present century swirled in with a cloud of dust and a cacophonous beep and clatter, the sign, song and signal of a morbid little beast called the automobile. Soon macadam and gravel road building revived but rubber tires and fantastic speeds made goggles and dusters a matter of good sense. Roads also "ravelled" or made washboard as fines were blown out.

Merrily the world began rolling along and the dust clouds began rolling bigger until Sunday driving in the country was too literally in the country, and people objected to driving by braille. Women also fidgeted, believing the dust to be inedible, and in 1908 an international conference met to try and solve the dust problem.

Soon all manner of tar, asphalt, salt, or sea water were being spread to lay the dust. Asphalt treatments in particular showed promise of giving a higher type of pavement, and a common construction became the "asphalt penetration macadam," made by spraying hot asphalt on fresh crushed stone macadam. The decade 1904-1914 saw construction of over 10,000 miles of bituminous highways in the U.S. It was the undisputed era of the blacktop.

Trucks and highways

Unfortunately the delicate flavor of victory lingered only long enough to be mangled under the onrushing truck. Trucks proved too much for the macadam, and stronger roads were needed. By 1924 the U.S. highway system included 10,000 miles of hot plant mix, bituminous concrete and the finer textured sheet asphalt, 31,000 miles of portland cement concrete, and 4,300 miles of brick. (We predict a slow future for brick.)

Currently portland cement concrete highway slabs are usually 8 to 10 inches thick, with or without internal reinforcement of steel, and resting on a thin granular sand, gravel, or crushed stone subbase to prevent soil from pumping. Bituminous concrete thickness is usually less but more variable, the difference being made up by the underlying material. The New Jersey Turnpike, for example, is $4\frac{1}{2}$ inches of asphaltic concrete over $7\frac{1}{2}$ inches of macadam over $6\frac{1}{2}$ inches of gravel. Competition between the two major classes of construction is fierce.

Secondary roads are still gravel or macadam or telford (in Europe), but garden spots such as Iowa are running out of rock. Therefore a late research aim is to stabilize or harden soil for a substitute, a search fairly well assured of success. Satisfactory stabilized soil roads have been built with portland cement, lime, lime-pozzolan, asphalt, clay, or lignins. Further improvements are in the works.

ACKNOWLEDGMENTS AND REFERENCES

Foreign photos are from color photographs by Dr. E. A. Rosauer; paintings on p. 5 and 6 are reproduced courtesy of the U.S. Bureau of Public Roads.

For more information with less deformation see The Story of the Road by J. W. Gregory, MacMillan 1931; Public Roads of the Past and Historic American Highways by the Old Roadbuilder (Albert C. Rose), American Association of State Highway Officials, 1952 and 1953.

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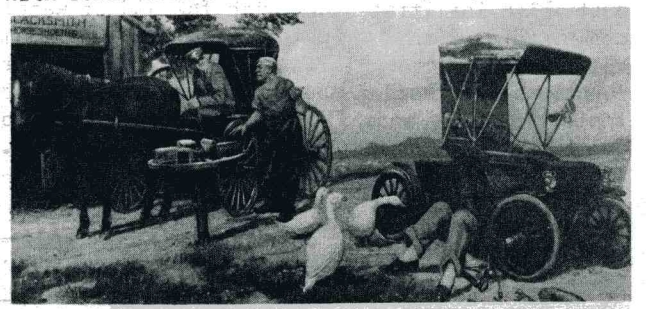

TO MARIAN THE LIBRARIAN:

With this issue Screenings degenerates to a quarterly to give Ye Olde Editor time for other pursuits such as golf. Thus the next lively issue should be bouncing along three months from now. Meanwhile to the hammock, to contemplate.

RLH

Return to Table of Contents