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CONSTRUCTION OF COUNTRY ROADS.

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HIGHWAY DEPARTMENT

CONSTRUCTION OF COUNTRY ROADS.

The consideration of the construction and improvement of roads may be properly divided into four subjects: Location, Drainage, Foundation and Surface, and may be treated from two standpoints: One, that of a general discussion of the principles upon which the modern methods are based, and the other, the more detailed and specific description of appliances and processes in carrying out these methods in the work of construction. It would be most desirable in this bulletin to treat the subject from the latter standpoint, were it possible. It is hoped in the future, with more funds at the command of the Department, to take up the latter treatment more fully. The treatment referred to cannot be satisfactorily accomplished without the aid of illustrations, portraying machines, processes and progress of construction. As there are no funds available for such illustrations, it is deemed best to take up the latter treatment in a future bulletin, and confine this to a discussion, in the briefest manner possible, to the principles that underlie modern road improvement.

LOCATION.

Primarily, the most important question is that of location. It is the first one that must be considered, and is especially of urgent consideration for the reason, that the improvement of the surface of any road with faulty location stands as a bar to the early and, perhaps even the final, construction of a road that will best serve travel and use by the public. Any road improvement worth' while is expensive, and the expenditure of money for drainage or surfacing but tends to cause hesitation on the part of authorities and tax payers, to the adoption of new location and construction that will lead to the abandonment of results that may have been secured at a considerable expenditure of public funds, and thus hinder the adoption of a new location that will be necessary to secure the best road attainable. A faulty or erroneous location of a road that is to be improved is to be especially avoided. After a large sum of money has been expended, people are loth to abandon the resultant there from to secure proper location. The pioneers in the hilly parts of Ohio located their trails or roads so as to secure a road at all passable, for the least expenditure of money and labor. The plan followed was to reach the top of a ridge by the most direct line, which was up a point, thence along the top of the ridge. On this location the side cutting was at a minimum and the location, the one requiring the least movement of material, but without any consideration whatever for future utility or serviceability, nor for the economical conveyance of loads and comfort of travel. Along these faulty locations farm houses, barns and other improvements were made, and having been made, the owners most naturally strenuously object to re location that will leave their buildings without direct access to the public way, or interfere with their existing fences and arrangements of fields or other enclosures. In rough and hilly sections a proper location cannot be made without using the methods and equipments of the civil engineer in order that undue

percentage of grade may be eliminated. A preliminary instrumental survey at least, if not a topographical survey, should be made before the final location is determined.

The location of a road in a level country in many cases is but that of the laying down of a straight line connecting the initial and objective points; but where great irregularities of surface interfere, the question of grade is the dominant one in location, requiring the highest engineering skill for its solution.

The railroads expend immense sums of money to improve the gradation of their lines as a matter of economy. The locomotive is limited in its adaptability to overcome grade, and there are certain limits beyond which its use cannot go, and below which the comparative cost of transportation must be considered in economical management. The horse has a larger degree of adaptability; but the question of economical transportation applies as fully in the one case as in the other.

There are two things to be considered in the matter of grade in public highways: The effect on durability of the road, and the other, ease of traction. The bicycling craze, so called, did more to stimulate road building and especially to arouse interest in the minds of the public in the improvement of grades, than anything else in the history of our country.

The uncomplaining, patient dumb brutes toiled and panted; tugged and wore out their tired muscles to drag loads up steep grades and through quagmires; unappreciated and uncared for as to their comfort and well being, so far as the majority of the unthinking drivers were concerned. When men and women, however, started out to supply their own motive power, they realized the need of improvement and insisted on more rational and businesslike treatment of the question of better location of roads. The increase of grade, by even one or two per cent. impressed itself most strenuously upon the tired human muscles in such a manner that conclusions as to the needs along the lines under discussion were reached; that, compared with the old line of scientific argument or proof, seemed almost as intuitions.

As to the matter of durability, observation fully proves that a permanent macadam surface cannot be maintained on a grade above a certain limit, that limit being variable from two elements: Climate and cementing quality of material. In such climate as that of Ohio and with material of the character of the limestone occurring in Ohio, the limit for grade on which a fair macadam surface may be maintained is about eight and three fourths per cent., or in other words, five degrees. In approaching this limit, the cost of maintenance increases very rapidly, and above that limit, a fair macadam surface of limestone cannot be maintained at a reasonable cost. The washing of violent rains, the action of horses' hoofs in drawing loads tip hill, and the effect of locked wheels on a down grade disturbs the bond of the surface. Anyone can see the loosening of the constituent parts of the surface on heavier grades as evidenced by the loose and rounded stones occurring on the heavier grades of any well constructed road.

Section 4759 of the Revised Statutes of Ohio, referring to construction of County Turnpikes; closes: "In no case shall the grade of ascent or descent on the road be greater than seven degrees," that is, nearly twelve and one quarter per cent. I have found that many, in endeavoring to sustain their claim as to the advisability of constructing macadamzied roads of such grade, use the above section

as an argument to support their case. . Section 3477, referring to turnpike companies, says: "And in no case shall the ascent in any such road be greater than five degrees," recognizing that there is a limit, at about five degrees, above which the cost of transportation over roads of heavy grade is such that toll should not be charged. A grade of, five degrees can only be admissible in the most extreme cases, due to conditions that must be exceptional, and do not in any manner obtain in the much larger proportion of the area of the State of Ohio, and are confined entirely to the immediate vicinity of the Ohio river and a few localities along some of the other streams.

Especially with macadamized roads is the necessity of good location and easy grade very evident. The fine or binding material so essential to the best surface condition of a macadam road, is on a heavy grade, washed out by the action of violent, dashing rains, and the surface is soon destroyed. The method of procedure in the laying out of a road under Ohio laws, is by what are termed viewers, who by the eye pick out a location, or perhaps after partial trial with the vertical circle on a surveyor's transit. determine the alignment of a road that is to stand for a generation and be subjected to constant travel and wear. There is need of preliminary surveys and care in location in every road; the final location should only be made after careful investigation and study.

It should be understood that the same principles of road location and construction apply to every class of roads, no difference what may be the kind of road constructed, be it of earth, gravel, macadam, brick or the higher classed and more costly roads and pavements constructed for suburban and city streets. The above remarks, although especially applicable to macadam roads, which are considered the type of country roads, apply to any road of any construction.

The last report of the Commissioner of Public Roads of New Jersey, for the year 1904, in the description of roads being improved in that state during that year, reports one grade on such roads, when completed, as seven and one quarter per cent., and instances of more than five per cent. are exceptional. In the state of Connecticut, the standard grade adopted for state roads is five per cent., which is only exceeded in exceptional cases, where conditions are such as to absolutely prevent the choice of the standard adopted by Commissioner Macdonald. These states, standing in the front rank of the matter of improvement of their roads, and with their continued and extensive experience, adopting such standard, but confirms the views of the writer founded on his experience, the fact, that under all ordinary conditions five per cent. may be well established as a maximum grade, and when exceeded through stress of conditions, it is well established that it is not good business nor engineering policy, to attempt to maintain a macadam road on a grade exceeding eight and one half to nine per cent.

DRAINAGE.

The next important consideration after that of location is drainage, and in a great proportion of the counties of Ohio, on account of the level or rolling surface, the question of drainage is of greatly more importance than that of location. The amount of money squandered in endeavoring to construct roads of every kind without providing for proper drainage is one of the most wasteful processes of expenditure known. Many try the method of improving a road by placing upon its

surface materials of different kinds, without providing for drainage, and of necessity fail. No amount nor, any kind of a surface material can make a permanently good road that has not been provided with proper drainage, especially in the latitude of Ohio, with its extreme variance of temperature and alternate deep freezing arid thawing. If water is allowed to stand or accumulate under the surface material, and that surface material is not deep enough to prevent frost action on its foundation, the freezing of the water, expanding the foundation and raising the surface material, will leave the road in such condition that the road surface will be porous, and the foundation will be saturated with moisture and allow settlement that will break up the cohesion of the surface material and destroy its efficacy as a roof and traffic bearer.

In providing for surface drainage, open ditches are necessary. From the road where there is absolutely no attempt at surface drainage, which is the condition in quite a large mileage of the roads of the state, to the attempt in some locations to provide both surface and sub drainage by the use of open ditches, there is every grade of work. The unsafe ditches unsafe on account of their depth and the steep slope of their sides that are found in some localities, extreme in their construction, and especially in their depth, are not evidences of good road construction. Different soil and conditions call for a wide difference in construction of open ditches, but the attempt to provide for subdrainage by the construction of open ditches of extreme depth and width, are not along lines of goad economy, good taste and effectiveness. It may, in some localities, be necessary, in order to secure proper fall, to construct one deep ditch, but it does not necessarily follow that the other ditch should be deep. Advantage should be taken of the lowest side of a road in extremely level localities to provide for drainage of the road. There is, except in very rare cases, a low side to the location of the road, and that law side, even if having the advantage of a very few inches, should be utilized for securing the prompt carrying away of the water in the longitudinal direction of the road. Having secured the one ditch as indicated above, the other, an the higher side of the. road location, need not be of equal depth. More effective results will be secured by using a small ditch and carrying the water at frequent intervals to the deeper ditch on the lower side by cross drains. This system is vastly better than deep ditches on both sides, especially as it gives better fall for cross sewers from side to side of road. For subsurface, it is useless to attempt to substitute surface drainage, and although under some conditions subsurface drainage ,may be. entirely emitted, in the great majority of roads it is needed in at least places to provide for the removal of water from the foundation derived from waterbearing strata opening under the road. In locations of exceptional character, where there is an impervious subsoil and waterbearing strata combined, it may be necessary to place two lines of tile along the entire distance of the road. This treatment has been found efficient even under the worst conditions, provided proper outlet is secured. In the case of a country road improved by paving at Empire in Jefferson County, Ohio, the conditions were: The location of the proposed road improvement on what is called the first bottom of the Ohio river; the material being loam and subjected each year, and sometimes several times each year, to river floods that covered the entire road for hours and sometimes two or three days, and completely soaking the loamy foundation of the proposed road. Such conditions required the prompt removal of the water left in the road and its foundation, in order that travel might not entirely destroy it. Two lines of four inch tile were laid in trenches at each side of the paving, three feet below the surface, and the trenches were filled with refuse from the adjacent sewer pipe factories, consisting of the broken and rejected sewer pipe. This treatment so well accomplished the result of securing prompt and

thorough drainage, that the pavement, after four winters, shows very satisfactory indications of permanency. A single line of four inch tile, in all except extreme cases, provides complete drainage and secures the foundation of a first class road. In all cases where longitudinal sewers are used, branch side sewers must be placed at frequent intervals to carry the water to open drains or other proper conveyance for the accumulated water. Trenches V shaped where there are local quagmires or surface springs, placed longitudinally under a road, are often most effective, and where the stone needed for filling them is convenient and abundant, are advisable in many localities. The Massachusetts Highway Commission, which stands in the forefront as to construction of first class country roads, used in many cases a V shaped drain under the center of the road for its entire length. The drain is made about three and one half feet deep, and is filled with stone from the smallest size up to eight inches in diameter, placed in a general way at random, but with the largest at the bottom. These drains are wide and practically form a foundation for, as well as secure efficient drainage of the road. As to culverts for carrying water from one side of the road to the other, vitrified tile and iron pipe are used. Where conditions are such that a good cover can be obtained, and the weight of cover is not too great, well burnt vitrified pipe of good quality will serve every purpose. Where the pipe are manufactured near the road and can be supplied at low cost, they are the best to adopt because of their cheapness. They, however, must be at such depth below the surface that in a clay road they will be entirely and completely below the most extreme depth to which the travel may cut the road, and in the case of macadam or other stone roads, should have at least twelve inches of earth or clay between their extreme top and the bottom of the material of which the road surface is constructed. The clay or earth forms a cushion to prevent the action of the roller during construction, and of travel afterward, from producing an unequal strain on any part of the pipe. Many failures of vitrified pipe under roads are due to improper treatment in the manner of laying. A trench being cut with a flat bottom instead of having the form of the outside of the pipe, causes the entire weight of the pipe and the filling over it to rest on the lowest point of the pipe. If the pressure is distributed equally on all parts of the surface, the pipe is an arch that most effectively resists pressure. The placing of all weight on one point of the circumference of the pipe adds largely to the tendency to rupture by cracks longitudinal to the drain and at about one eighth of the circumference from the lowest point of circumference of the pipe, because at such distance there is no external support from the surrounding material. In covering pipe, large boulders are often placed next the pipe, and these boulders carrying at their immediate point of contact with the pipe more than the share due at such point, produce unequal strain, very destructive to the resisting power of the pipe. Finer material that will distribute the pressure should always be placed in immediate contact with the pipe. Where culverts are under heavy fills, only iron pipe should be used.

In locations where the surface is level, every inch of height, or if you please, depth, is often an important element and must be conserved, and the placing of an eighteen inch cushion between the top of the pipe and the surface of the earth road, or twelve inches between the bottom of the macadam material of the stone surface road and the top of the pipe, often requires more leeway as to perpendicular quantities than is available if drainage is to be secured. Under such conditions iron sewers are a necessity, irrespective of their cost. The matter of capacity of sewers in relationship to rainfall and slope is too broad a subject to be even touched upon within the limits of this bulletin.

Where large sewers are required, concrete is now being generally adopted and appears to be taking its place in the front rank for large sewers and small bridges.

Another question that may properly be considered under the topic of drainage is that of prevention of destruction of the surface of the road, on moderate and heavy grades, from the water from rainfall following the wheel tracks or impressions made lengthwise of the road by travel. Water breaks are used to counteract this trouble, being placed across the road to carry the water to the side drains and prevent it from flowing along the line of travel. These are effective and desirable if properly constructed, but are often constructed in such a manner as to prove to be wagon and carriage brakes, rather than water breaks. They should have large base in proportion to their height, so that there may be no abruptness that will cause jolting, nor unpleasant rolling to vehicles passing over them. They should begin in the center of the road and slope outward as to the center of the road, and downward as to grade of road. The practice of carrying them directly across does not secure as effective work as at an angle of forty five degrees. Continuing breakers entirely across the road, sloping continuously from one side of the road to the other, gives a twisting motion that is very destructive to vehicles and does not take advantage of the crown of road to add to the effectiveness of the work.

Some engineers follow the plan of forming the break in the foundation, the intention being to save material, as the road metal is thus of equal thickness at the breaker as on the remainder of the road; whilst the construction, by adding the thickness of road metal to constitute the breaker, requires that an extra amount of material, equal to the height of the breaker, be added to the ordinary thickness of the surface material to secure the result. The saving in material by this construction of the breaker in the foundation is largely or entirely counteracted by the extra cost of preparing the foundation. The greatest fault, however, to this method of forming the breaker in the foundation is, that there is no way by which in the future the exact original location of the breaker can be determined. The gradual change of the location of the breaker, by adding repair slightly above or slightly below the exact original position, eventually changes the location and results in a weak spot in the road at' the original location immediately above or below the new location of the breaker, as the case may be, whether or not the repair for the breaker is placed a little farther above or below where it was originally placed. At the original location the height of the form in the foundation is deducted by the process of wear from the depth of the surface material on other parts of the road.

FOUNDATION.

An important division of the subject has reference to foundation. Any construction, be it in the line of engineering or architecture, must be preceded by securing proper foundation, which is in fact the essential part of any structure.

It must be borne in mind that it is not the surface of asphalt, brick, macadam or slag, as ordinarily used, that bears the load, although the current idea is that this is the case. The fact is that the load is supported by the foundation on which the surface construction rests, the surface material mainly serving the purpose of a roof to keep the foundation dry, and in its less important service, is

intended to resist the impact of hoofs and wheels. It is therefore evident that the condition and nature of the foundation is a very important and essential matter to consider: The supporting power of the foundation is dependent on the conditions in which it is constantly and permanently kept, and that condition is mainly determined by. its primary construction, as the covering prevents access by which any remedies may be applied. This suggests that everything should be done prior to placing the metal that will provide conditions that will not require the digging up or disturbing the surface, such as laying or repairing pipes or sewers. Many brick and other roads are in a measure destroyed as to their usefulness and comfort by digging up the surface which can never, short of reconstruction, be placed in good condition again. Frost acts on a wet foundation, and especially by unequal lifting and settlement of the surface material destroys its usefulness. Some soils are such as to provide a natural foundation. Along the Ohio and other rivers of the state are found what are called second bottoms, located above extreme highwater mark and consisting of sand and gravel, affording the best of drainage and a firm, permanent foundation in their natural condition, upon which it is useless to attempt an improvement. Ordinarily, however, except when the sand is in excess or the gravel too coarse to provide a smooth and easy surface, these locations are not the ones demanding so rigidly as in other localities expensive processes of improvement. The conditions may not be such as to easily secure the best natural road surface, yet the roads are not in their natural condition very bad. Over the greater part of the state of Ohio, if proper drainage is secured, the question of foundation is not a dominant one and can in a measure be given only cursory consideration. Where the earth upon which a road rests does not have proper cohesiveness to act as a unit in sustaining the pressure placed thereon, some method must be adopted to secure proper foundation. In the construction of the ordinary country road the item of expense, limited by restricted funds available for construction, will prevent the use of a concrete foundation advocated by some authorities. The expense of such foundation of itself bars its use in the road that comes under consideration in this bulletin. The question of use of concrete foundation also brings to mind a debated question of methods in road construction, and that is, Telford foundation. The best foundation upon which to construct a lasting macadam surface must be firm, but not rigid. The foundation may be firm, yet in one sense in a measure pliant, so that it does not act as does the anvil, in reference to what is placed upon it, in that the latter receives the entire force of the impact of the blows of the hammer. The latter condition being intended to effect the existing condition of the object of the stroke, whilst it is intended that the stroke of the wheel or hoof should not act upon the macadam surface in such a manner as to change the condition of or destroy the macadam. The shock should be transmitted through the macadam surface to the firm yet not rigid foundation. The concrete or Telford foundation acts as the anvil, under ordinary conditions, tending to the destruction of the macadam surface that would not result in the case of the dry foundation composed of mixed clay, loam and sand, a mixture that is not rigid in the sense of being of an absolutely unyielding nature, yet firm in the sense of resisting permanent change of form. There are cases of unstable subsoil that require the intervention of the Telford foundation to give the proper firmness, that, in connection with the unstable subsoil give the proper degree of firmness without the rigidity resulting from placing the Telford foundation on a firm subsoil. These remarks show the road visability of the use of a rigid foundation of concrete on which to construct a macadam surface.

Waste products are available in many localities that provide all the essential qualities needed for foundation. The writer has used slag from iron furnaces for foundation where the supply is adjacent

to construction, and, if used properly, this waste product makes a solid, permanent and effective foundation of high grade. I have examined such foundations after being down several years that were so solid that it was with the greatest difficulty that a breaking up of the foundation was accomplished by the use of a pick. This result was secured by a thorough mixture of all the waste, so as to secure uniformity of texture. The slag is not resistant to wheels and hoof action, and does not produce a permanent surface, yet as a foundation is admirable, and may be substituted for lower part of the macadam material. Its economical use is entirely dependent upon its accessibility, and its use as a surface material, where better cannot be had, is advisable in many cases where some material of higher grade as to resisting the abrasion of travel, cannot be secured.

For one road constructed tinder the supervision of the writer, the waste of manufactories of sewer pipe and fire clay brick was used very effectively and. satisfactorily as a foundation. The material as a waste product had to be carted away from the plants and cost very little delivered on the road. It consisted of broken bats and waste of fire brick works, and broken and condemned sewer pipe. The material was broken by sledges so that the finer part, resulting from breaking, filled as much as possible the voids formed by the larger pieces of brick and pipe hubs. Cinder from steam engines was used to fill all the smaller spaces and to secure a solid mass after rolling. A foundation of high grade was the result. The depth of the finished foundation was twelve inches. This thickness might be considered excessive, except for the small cost of the material delivered on the road and conditions were such as required care.

The screenings from coke that may be secured from some furnaces is an excellent foundation material, and the cinder from coal combustion at extensive steam boilers often serves an excellent purpose under some conditions. It will appear from the above that the search for, and test of the many waste products of our mills, factories and modern operations, are matters worthy of study and trial. They are often allowed to remain unused and unrecognized.

In the construction of a road foundation one consideration must not be lost sight of, and that is, thorough compaction of the material of the foundation, whether it be common earth, waste product or any other artificial or natural material. In this work the use of the roller is essential. The weight of the roller and the continuance of its use should be such that the material of the foundation is made firm, of equal consistence and even surface. If the foundation be such as to yield through time or use, the road itself cannot be substantial and permanent.

All that has been said so far applies in a general way to all roads whatever may be their construction or surface, and may be taken to refer, and be applicable to any of the classes of roads considered below. These fundamental principles apply to every class of road, from the ordinary clay road to the asphalt pavement of the residential streets, or the granite block of the wholesale districts of our cities.

SURFACE CLAY.

In considering the last division of our subject, that is, surface, it is important to remember that the surface of clay or earth is the most important of any. This arises from the fact that for many years to come, the great percentage of our road mileage must be of these materials, and no difference what

may be the status of the movement for stone roads, the condition and construction of the earth or clay road is the dominant one in this division of our subject.

This department is now endeavoring to secure reliable data from all counties of the state as to the mileage of all roads throughout the state. It is hoped to secure reliable data as to these matters, but for the present, the two items of mileage of earth roads and the cost of improvement of the same must be assumed. An estimate of one thousand miles of road for each county is certainly a conservative one, and the' actual' figure will probably exceed that. With this assumption, we have for our basis of mileage eighty eight thousand miles. Cost of construction would probably range from $1,000 to $6,000 per mile. We may assume an average cost per mile of $3,000. Eighty eight thousand miles, at the above figure gives us $264,000,000 as a conservative estimate of the cost of improving the roads of the state. Distributing the work over twenty years would require an annual expenditure of $13,200,000, requiring an annual appropriation of $3,300,000 by the state, the same amount by localities, and double that amount by the counties. All the above is. upon assumed data. I only desire to use it in order to impress the fact that for many years to come the greater part of the roads of the state must be of clay and earth and thus insist upon the importance of proper construction and condition of such roads.

The improvement of the main highways by macadam or other hard surface, tends to improve the by roads of clay and earth by relieving the latter of part of the travel during the season in which frost is going out of the ground, and the surface of the roads saturated with the water, released by the thawing of the soil. The placing of a stone surface on any leading road drains the travel from those that are parallel, or in a measure parallel thereto. The farmer or traveller during the season when the clay road is in bad condition takes the shortest route to the improved road, according to the law of least resistance. This is a universal law not only in mere material questions, but also in those that carry with them the interference of mind.

This relief of the clay road during the season when travel works the greatest injury, tends to keep them in better condition for the remainder of the year. This relief is another and potent argument for the expenditure of money in the improvement of the main highways in that the benefit of the improvement reaches farther than the road improved and is a benefit to every contributing road.

No treatment of a clay road can prevent it from becoming a mortar bed when subjected to heavy travel at a period when the frost is going out of the ground. The frozen soil underneath prevents the drainage of the moisture released by the thaw, forming an impervious strata that prevents the moisture from reaching any under drainage that may be provided. The tenaceous nature of the material prevents seepage laterally to a sufficient extent, to cause saturation of the road surface.

The relief of the road surface from travel by adjacent stone surface roads, together with proper crown and drainage which will provide for carrying off the water released by the thaw at the first possible moment ameliorates conditions and adds vastly to the usefulness of the by road for a large portion of the year.

Sand roads are sometimes greatly improved by the use of clay that renders the surface more cohesive. Sand and clay represent the extremes as to cementing qualities, and mutually improve

roads that are extreme in the opposite constitution. They are often used to great advantage where other material is too expensive for road surface. They improve conditions; sand from its want of cohesiveness being greatly improved by admixture of clay. The condition of a road too sandy or non cohesive, is almost an nonexistent one in the greater part of Ohio; but the opposite condition of the cohesive clay road is widely, almost universally, present.

Where sand is of convenient access it may be used to improve the clay road. When used, the sand should be thoroughly incorporated with the clay material of the natural surface.

Brush and trees rowing along side of a clay road are very detrimental. The shading of clay roads prevents the drying effect of sunshine as well as of winds upon their surface, and should be prevented by the only method effective, and that is, the removal of the trees and brush. Whatever may be said of the beauty and picturesqueness of the road overarched by trees and bordered by bramble and bush, the serviceableness and comfort of travel requires that the wind and sun be admitted to the road, as that in many cases determines the difference, for months in each year, between a good road and a bad road. The clay or earth road, when in good condition, that is not so moist as to be muddy and not so dry as to be dusty, is the model road; not only is it easy to travelers and is traversed with comfort, it is also noiseless and best for the horse, except for heavy traffic.

One condition of construction that is important in any road, but especially so in the earth road, is that of giving proper crown which is most essential and in the majority of cases neglected. The ordinary earth road in many parts of the state is well calculated for a drain, but extremely poorly constructed for a road. In many localities the larger proportion of the roads are concave as to their surface, and with borders of grass, weeds and bramble, collect water upon their surfaces and prevent it from being removed in any other manner than by the slow method of evaporation. Proper drainage should be secured by construction of open ditches along the sides of the road, yet the efficiency of the ditch is sometimes well nigh nullified by the concave surface of the road and its border of sod higher than the traveled surface. This prevents the flow of water from the surface of the road to the open ditch. In every case the road surface should 'be so constructed as to give a continuous fall, from the center to the side, of sufficient slope to secure the rapid lateral flow of any water that may fall thereon, and not permit it to remain to the destruction of the surface. The lateral slope or crown of the road from center to side should be about one in twelve. Some builders adopt a continuous curve for the surface; others. a curve at the center whilst the sides have an even slope. The exact form is not essential, but sufficient crown is. The slope from center to side of one in twelve is sometimes designated as one in twenty four. If each side slopes downward one inch to the foot, the center of a road twenty four feet wide will be twelve inches higher than the sides, that is, a crown of one foot in twenty four. An unvarying standard cannot be adopted on account of the different quality and conditions of the material of the road surface, but the above is considered the best average and permits the rapid flow of water from the surface. My observation is that next to drainage, the need of the average road of Ohio is proper crown. In securing such crown the modern road machine,' called by some the "side wipe" scraper, is an effective agent. The old method of using the ordinary dump scraper to fill up the center of the road in securing crown and leaving the surface uneven and alternately compact and loose, is too well known and too objectionable to the ordinary traveler to require discussion. Between successive deposits are low places which are also

more subject to settlement than the center of the deposit, giving an uneven and progressively more uneven surface, vexatious to travelers, destructive to vehicles, wearing to horses. An uneven condition of surface produces results that absolutely prevent the passage of water from the surface of the road, but retains it in the depressions of the surface to its absolute destruction. The above will suggest that another implement of effectiveness in finishing a road is the roller, to solidify the surface and make it more impervious to water. The use of the modern machines in conjunction with the roller secures results as to the condition of the surface that will repay the outlay and accomplish the most desirable results. The discussion of the proper construction of clay or earth roads is one covering a wide range and requires more space than is at command in this bulletin; but it is hoped that the above remarks will he suggestive and add somewhat to the movement for better roads in Ohio.

GRAVEL.

The next material for use in the surface of country roads to be considered is gravel. It is recognized that when the good roads advocate speaks' of .improved country roads, he has in mind roads of broken stone, and that the macadam road is at the present stage of improvement the typical road, and by many considered the ideal road. A certain ideal should not be set up arid all conditions and circumstances forced to conform to such ideal. Civil engineering is the profession that makes use of available materials that nature has provided, in the most economical manner, to provide in the most effective way for the comfort, convenience and service of man. In many counties of the state material for the construction of macadam roads is absolutely nonexistent, and in fact, typical macadam material, such as the traps of some of the eastern states, where road improvement has been given the most encouragement, is absent. In many counties where limestone is not found its use is not to be considered by reason of cost of transportation. It does not therefore follow that because a road of highest or ideal standard cannot be constructed in a certain locality, consistent with funds that may be available, that therefore that locality should not receive all the benefits that may be derived from the use of materials at hand, even though the result may not be an ideal road, if it is one that will in proportion to its cost serve to improve the condition of travel. In fact, the locality deficient in materials, and whose' conditions are the worst, deserves the most careful attention and closest investigation in order that its deficiencies may be remedied in the most effective manner.

In many places in Ohio where limestone is absolutely absent and which are so far from deposits of that material as to exclude its use for road surface by reason of cost of transportation, nature has provided a substitute that although not taking the place of limestone and trap as a material for constructing a model road surface, does make a road of fair grade and low cost. In some localities the gravel is graded as to size as well as could be accomplished by the best modern screen. In other localities through the action of the forces resultant from the conditions in the glacial age, as known to geologists, immense terraces of mixed gravel, clay and sand have been spread over the entire surface. Recent action of existing streams has removed the finer material and left in pockets supplies of gravel fairly well adapted for road surface. These deposits, of both kinds as described above, when properly selected and applied provide an excellent, if not typical, surface for improved roads.

The act passed by the Seventy sixth General Assembly, providing for state aid in building highways, very wisely provides for roads "constructed of gravel." In gravel roads, as well as macadam, all the conditions given above in reference to drainage and foundation apply and need not be repeated here, except to emphasize the necessity of care to secure the best results, and utmost importance of thorough rolling, compaction and evening of the surface of the foundation and giving it proper crown, which should be at least nearly as great, but never greater than that of the proposed surface of the completed road. In the selection and use of gravel it should be screened or prepared so as to exclude all fine material that is not necessary to provide for a mass with the voids completely filled and to give proper cementing quality or condition. If material consists only of round pebbles, without any finer material of quantity or quality to cement them together, the road surface cannot be firm and durable on account of the movement of the component parts among themselves under travel.

Gravel beds are often covered with surface material that is very detrimental if it is not carefully removed, because its presence interferes with properly securing a solid surface and also produces, through the action of travel, a great deal of mud in wet weather and dust in dry.

From such gravel as found in many places it is necessary to remove by screening any surplus fine material that may be mixed with the gravel in its bed or from the surface. If gravel requires screening it is well to grade the material in the same manner as is recommended for macadam roads; if there is not enough fine material to fill the voids it should be supplied. The method of applying the clean gravel, that has not enough ;fine with it to produce a solid mass, and allowing the crushing and grinding effect of travel to produce fine material to fill the voids is an unwise proceeding. In some cases where there are boulders too large for use in the road in their natural condition the best method is to crush them, thus securing sharp edges that are so effective in securing the best bond in the best classes of stone surface roads. Gravel should always be applied in layers and thoroughly rolled. The gravel surface ordinarily should average ten to twelve inches thick when completed.

BROKEN STONE.

The broken stone road is what is referred to at the present stage of the work when an improved country road is mentioned. The reason for the adoption of the broken stone road is not that it is a road of the highest type, but because of its cheapness of construction. The broken stone road, no difference how well constructed, will in a measure be dusty in dry weather and have during the continuance of rain a surface sloppiness that is not pleasant. One of the essential constituents of any modern broken stone road is binder of fine material that, under the action of wheels and hoofs, will be reduced to powder which will be of sufficient lightness to be caught up and carried by the wind and when wet with rain, will be of such lightness 'as to be picked up by the wheels of vehicles and thrown off by their centrifugal action, with unpleasant results to the traveler. With these drawbacks a well constructed stone road will, during all times of the year, when not covered by snow, afford a firm and solid surface that serves well the purpose of a country road. As stated above, the item that

especially rates the broken stone surface road as desirable is that of cheapness of construction in most localities. In many cases it does not follow that it is the cheapest in the end, for although of cheap construction, its cost of maintenance, under any considerable amount of weight of travel, is high. The typical road material, desirable from all points of view, is not known, and is probably as difficult of attainment as any other perfect condition in this world of imperfection and progressive discovery. Like every other material problem. the financial phase is the dominant question. In other words, wherever we turn in material progress the question "Does it pay?" is the one we meet face to face at every turn, and the one that must be answered in a practical way or the promoter faces defeat. With its detects the broken stone road, when wisely constructed with reference to cost, available material and use, has proven to be the solution of the question of local transportation over country roads, and wherever adopted and properly cared for, has led to urgent demand for future extension. The demand for extension comes with more and more urgency with the experience that follows use and observation. Good object lesson roads have proved themselves effective and have affirmatively answered the question "Does it pay?"

There is one error widely prevalent as to the real fundamental service or office of the surface of broken stone roads, and that is, that its main intention and use is to support the load and bear the effect of traction.

These are essential uses, but not the one of prime importance, which is, to act as a roof to keep the foundation of the road dry. When properly constructed, a stone surface road acts as a roof that effectively prevents rainfall or moisture from passing downward and softening the foundation.

The foundation, when dry, of any ordinarily constructed road will carry any load whatever.

The first lesson, therefore, in the construction of a broken stone road is to fully comprehend the fact, that the first dominant and essential condition required, is such construction as will provide for the foundation an impervious roof.

There has been a great deal of discussion, especially in former years, as to the comparative merits of macadam and Telford construction. For quite a number of years macadam has been adopted almost to the exclusion of Telford, but of late there has been more attention given to the latter. In the construction of Telford the lower layer of material consists of a pavement of stone on edge. This pavement is constructed of stones set by hand to form a foundation for the broken stone, which, as in macadam, forms the surface. Sometimes the sub foundation is crowned. The other treatment is to form a level sub foundation and construct the paving of stones having greater depth in the middle of the road and less toward the sides; for example, seven or eight inches in the center, decreasing to three or four inches at the sides so as to form the crown of the road. The stones are set on the broadest edges and lengthwise across the road, the stones not to be over four inches wide. After being thus placed carefully and closely by hand, all projections are broken off and all spaces filled with spalls or broken stone; the whole after rolling forming a solid mass. There is no doubt that, in some cases, especially when the foundation is of such nature as to be deficient in firmness, and when such firmness is not attainable by ordinary means, it is advisable to adopt the Telford construction. In most cases the macadam construction is the one most likely to prove satisfactory. What is said below in regard to construction of macadam applies fully to Telford, except, so far as

indicated above, where reference applies to the lower or hand placed layer. The roof principle referred to above should be kept in mind as the important result to be accomplished. In its attainment certain things are essential. One is the filling of all voids and the thorough firming of the material.

The use of the crusher and screen are essential in the construction of the modern macadam road. There is little doubt that in the use of a very large proportion of available material, knapped stone is more durable than crushed. This arises from the action of the crusher and its effect upon the texture of the material and also to the more cubical form of the knapped stone. With this fact in mind, yet in the twentieth century it is almost absurd to consider the comparative merits of methods, that are essentially distinguished by the one using the power of human muscle in competition with another method using the power of steam. In order to secure the impervious roof, which is the aim in modern construction, knapped stone does not provide the finer material required to completely fill the voids and to provide a smooth surface for travel immediately upon completion. Macadam insisted on knapped stone of uniform size and the rejection of any fine material that did not arise from the process of knapping. He depended upon the crushing and abraiding process of travel, to provide the fine material to secure thorough filling of voids and an impervious surface. The question is often asked: "Why do you not construct macadam roads to day according to the methods adopted by Macadam?" In the first place, because of the fact of the step from muscle of his time to steam of the present, indicated above; and second, because the experience of the last hundred years has led road builders to see the defects in Macadam's methods, although they recognize him as the father of road improvement and give him the praise due to a pioneer in discovery. His plan of securing compact, impervious cover by travel, instead of the roller, is not the method that is taught by the experience of the past score of years.

A mistake that is made in many instances is the use of unsuitable material for the lower portion of a macadam construction. It is not necessary to use a material of equal grade as to toughness or cementing quality for the lower course, but it is essential that no soft material should be used that will be devoid of. firmness and constancy. Soft sand stone is unsuitable for the lower layer, but hard sandstone or other rock that is unfit for the surface, may be used where material is difficult to obtain in sufficient quantity for both layers. This introduces another phase of the question of material, and that is, hardness, toughness and cementing value. Some granites have hardness in a high degree, yet are not good material because lacking in toughness and cementing value. Clay stands at the head of materials when graded as to their cementing value, but from its lack of toughness and hardness, is the road material of lowest grade, and the question of substitution of some other material in its place is in the great majority of cases the problem that presents itself to the road builder as the one most difficult of solution. The combination of the three essential qualities indicated above is found in the highest degree in some of the traps, and they are the best type of macadam material and give character and quality to the improved roads of New Jersey, Massachusetts and others of the states that have the best roads in our country. Trap, except in scattered boulders in our glacial terraces, is not found in Ohio, and can only be secured at a cost for transportation that is prohibitive. This circumstance removes this material from the list of those to be considered in this bulletin.

The limestones that are found in such abundance in parts of Ohio, and in moderate quantities over a considerable part of the state, have not, especially the softer ones, the hardness and toughness characteristic of the traps, but from their cementing value, combined with a measure of hardness, are adopted as the typical macadam road material of Ohio. These will be understood to be the material in use in the consideration of the method of construction below.

It is assumed that the precedent requirements of drainage, foundation and crown have been provided. The mistake is general of neglecting to provide a berme or shoulder to retain the macadam firmly in place. Sometimes boards are placed along the sides of the proposed location of macadam, and the material dumped from wagons to the height of the boards. The latter are removed and the material allowed to assume its. own slope. The effect of travel in the work of compaction is largely nullified by this method because of the shifting laterally of the material. Shoulders should be so formed and so compacted that they will prevent lateral movement of the macadam either under the roller or traffic. When completed they should be of even surface and crown with the completed surface of the macadam. In the construction all material over the size that will pass through a two and one half to a three inch screen, as the material is hard or soft, should be rejected. From that size down to what will pass through a one and one half inch screen, should be used to secure five to seven inches of thickness of stone when completely rolled. Rolling will compact the stone one fourth or more, the exact amount can be determined only by trial, since it varies with the material used. The layer should then be thoroughly rolled with a roller of ten tons or more in weight, and unless the weather is very dry, water should not be used. Some toad builders water this layer, but on account of the tendency to soften the foundation, it is not considered good management to use water on the lower layer. The Massachusetts Highway Commission especially insist that the water should not be used on the foundation course only under exceptional conditions. When the layer is spread and during the process of rolling, enough fine material should be used to fill all voids. This is essential to the making of a good road, but the quantity of fine used should not be so great as to more than fill the voids, for each of the larger pieces of stone should come in contact with and bind on those adjoining, to secure a stable road. In rolling this or subsequent layers, the roller should be passed over the side of the macadam first, in order that the sides may be compact and resist lateral thrust when the center is rolled. Rolling the center first inevitably decreases the crown, and it can only be restored by the use of additional material. Upon the first should be placed a second layer of stone that will pass through a one and one half inch screen and from which has been rejected all fine material that will pass through a half inch screen, except so much as may be necessary to fill voids. The same remarks as given under first layer apply to fines to the second layer. In placing the material for any layer, especially the one under consideration, it should not be dumped directly on the road froth wagons, for the reason that this method will cause the material to be irregular as to compactness and size of pieces, and good work with the roller cannot be done. If it is necessary to dump on the road, then the entire load should be removed by shovels to produce a uniform layer as to the depth and compactness. This is necessary in order that the roller may have equal force upon all parts of the surface, and that there be no spots with an excess of fines where travel will produce soft spots and hales. As the material may be hard or soft, the thickness of this second layer may be from three to five inches. It should be treated in the same manner as the first, except that water should be used to keep the stone in a moist condition, unless the weather is such as to accomplish the same result. In rolling this layer the

berme or wings, or in the case where constructed, the summer or side road of earth should be rolled and formed and made to crown with the macadam. Upon the surface of the second layer should be placed a light layer of the chips or screenings and the final work of watering and rolling be carried on until there is produced a flushing of mixed water and fines before the roller. In putting on the finishing chip and fine layer, care should be used not to use mare than is required to fill up and smooth the surface; more than is needed for that purpose is a detriment, especially when limestone is used that contains a considerable per cent of clay. I have in mind a macadam road constructed of limestone in which were soft, clayey layers, which layers, although of small proportion to the whole body of stone, were of such a nature that the tendency was to fracture under the crusher along the lines of clay, to such an extent that the screenings contained an undue amount of fine clay. An excess of this fine clayey material was used as a top dressing, probably two or three inches. When wet weather occurred the surplus fine material became a sticky mud. The wheels picked up this mud in spots and deposited it again m such a way that the surface of the road became a series of hills and hollows, resulting in a condition about as disagreeable for travel as the original road.

Considerable advertising and attention is devoted to bitulithic pavement at the present time. The most disagreeable thing about the macadam road constructed of limestone arises from the comparatively tender or soft nature of the rack as generally occurring in Ohio. As referred to above, the results, under travel of its abrasion, is a dusty surface in extremely dry weather, and a sloppy mud during rains. The bitulithic treatment almost entirely prevents this condition, and, were it not for the cost, would certainly lead to its adoption in many places, especially in suburban localities where the expense of asphalt pavements places them beyond consideration. The comparative cheapness of the limestone in construction, in spite of the dust and slush, constituting it the most popular surface for country roads.

In Ironton, Lawrence county, a number of squares of a residence street has been covered with bitulithic at a cost of $1.76 per square yard for surface. The average cost of macadam surface in that locality is about 6o cents per square yard. This gives for a mile of road twelve feet wide, for bitulithic surface, $12.30, and for macadam surface, $4,224.

These figures for the present will not permit the bitulithic pavement to be placed m the class of available materials for country road construction. It is probable that in the future reduction in the cost of material and application of the bitulithic, will require that it be considered as an available material.

The principle in the bitulithic is to use trap or limestone broken to about a half inch screen; this to be graded, and the grades to be mixed in such proportion that the next smaller size will just fill the voids of that next larger, so as to provide a mixture in which there are only ten to fifteen per cent. of voids and that these voids be filled with the patented bitulithic material so as to make a solid and impervious surface, forming a perfect roof, a solid, smooth and dustless surface.

On level or nearly level location a macadam road is exceedingly hard to maintain. In certain localities, where brick of good quality are manufactured under favorable conditions as to cost and accessability, they have been used to construct country roads. Under such combination of

conditions as above, brick are coming into use and are proving exceedingly satisfactory on account of freedom from dust and mud and because they require much less expense for maintenance than macadam. A country road fifty six hundred feet long, referred to under foundation, was constructed under the supervision of the writer four years ago at Empire, Jefferson county. The cost of construction was a minimum for brick paving, by reason of the abundance and accessibility of waste material and brick. In many other localities brick is coming to the front for the surface of rural roads.

The construction of good roads in some parts of northwestern Ohio, where the black, rich prairie soil covers deeply all material now in use for road surface, is a problem justifying careful investigation and the indications are, from present prospects, that the solution may be found in the use of brick whenever the fact is fully appreciated that a brick pavement properly constructed is a durable road surface, and one maintained at small cost. When people once realize the full importance of good roads, that may be traveled with ease and comfort during twelve months of the year, they will be willing to pay for roads of good quality.

Clay or soil vitrified by burning leas been used satisfactorily for railroad ballast, and to a slight extent for common road surface, but by reason of the difficulty of securing complete vitrification, has not given very great satisfaction. It is considered as being advisable in localities where nothing better is available, but at the most, in the light of the experience of the past, is but a temporary and not a permanent improvement.

The use of oil for the improvement of the roads of California has brought that material into prominent consideration as a material that might be available for road improvement in the east. The writer has traveled over a considerable number of miles of the oiled roads of Southern California and can most heartily assent to the benefit derived from the use of oil on the roads in that locality. Two or three conditions there conspire to the result that has given locally so much satisfaction. First, the nature of the oil having an asphalt base as distinguishing it from Ohio and Pennsylvania oils with a naphtha base. Second, the exceedingly low price at which the Los Angeles anal Bakersfield oils can be secured and applied. Third, the climatic conditions which are, dryness of climate and freedom from alternate freezing and thawing.

Experiments in a small way have been tried with oil in the moist climate and with alternate freezing and thawing, of the east. Among the trials has been that in Washington City. The results at Washington, and in fact, at any place in the east, have not been satisfactory, and it follows that at present oil cannot be classed as a satisfactory and valuable material for use on our public roads where the soil is saturated with moisture and subjected to deep and heavy alternate freezing and thawing.