seminated by the federal government, Pennsylvania led all the states in highway employment for four months with a daily average of 24,500 men employed. The peak of such employment during 1931 was reached during the week ending December 26, when 28,383 men were employed. The mildness of the winter has permitted us to continue this work and last week (January 20, 1932) the number of men employed on our highway work was increased to 30,360.

PREPARATION OF ROAD PLANS
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The outstanding characteristics of a bad road are abrupt curves, steep grades, and uneven surface. The first two are permanent, because of bad location, but might have been eliminated by the proper application of engineering principles. A good set of plans can be prepared only when the field surveys, designing, estimating, and field inspection have been good. The slighting of any one of these preparatory operations in the name of economy will be reflected in error, higher costs, and greater expense for maintenance.

There are six steps necessary in collection of the data and compiling the plans:
(a) careful field surveys, (b) mapping the surveys, (c) designing the roadway, (d) estimating the quantities, (e) careful field inspection of the design, and (f) final completion of the plans.

Care and skill are necessary that the center line as located will be the best possible, with respect to appearance as well as usefulness, so that what is done will be permanent and a part of any future improvement. The selected alignment is not only the basis of an improvement built with taxpayers' money to serve traffic, but it will stand subject to condemnation or commendation as a monument to the incompetence or the skill of the locating engineer. The center line selected may in the future serve as the center of a pavement widened to two or three times the original width.

The field survey follows in general a route tentatively established. It may be along an existing road or over an entirely new route, but the route should have been examined with certain definite ideas in mind by the locating engineer or the chief of party acting under instructions.
Transit notes will show: distances between deflection points, the deflection angles, bearings on tangent lines, P.C., P.I., and P.T. stations, horizontal curve data, and reference ties for the P.I. and P.O.T. points.
Level notes will show: elevations at all stations and prominent breaks of the ground surface, stream edges, top and bottom of banks, center points in ditches and small streams, bench mark elevations and descriptions, and intersections of the center line with the center line of cross roads or with railroad lines.

Topography notes will show: location of buildings, drainage structures, fences, field and private entrances, stream angles and direction of flow, angle of railroad crossings, sidewalks, section corners, probably clearing and grubbing, road intersections, pole lines, mile posts, stream and marsh boundaries, trees in right-of-way to be preserved, railroads and streams adjacent to the right-of-way, and detailed topography at bad situations.

Drainage notes will show: detailed sketch with angle of stream crossing and all information which will affect the design of the road or structure at that point, proposed channel changes, direction of drainage flow at cross roads and culverts, detailed description of structures in place, inlet and outlet elevations with side shots in the field to indicate discharge possibilities, notation as to head room, soundings in larger streams, structure recommendations, etc.

Right-of-way notes will show: boundary lines, property owners' names, location of buildings, boundaries of fields, classification of lands, areas of land cut off, location of water affecting pasture rights, stations and pluses at property lines, names of owners whose lands encroach on the right-of-way with areas of encroachment, length of centerline across property, monument ties, etc.

Soil and material notes will show: character of soil at all points along the survey; classification of materials such as rock, hardpan, loose rock, gravel, earth; location of available materials for construction, gravel pits, stone quarries; distances and kinds of roads for haulage.

Bridge survey notes will show: conditions which will make construction difficult, foundation conditions, transportation conditions, high water indications, kind of local materials close by, velocity of stream, normal high water, normal water stage, low water, character and amount of drift if any, profile of stream bed with information as to liability of scour, location data as to test holes and soundings, careful notes on investigation of foundation conditions, alignment and grades on approaches, and photographs of site and of any bridges on the stream near by.

Cross section notes will be taken at all stations and at prominent breaks of the ground and at any additional places where necessary to get more accuracy in computing the volumes of excavation and embankment. It is important that sections be taken at cross roads, ends of bridges, culverts, and railroad crossings.
Note books should be indexed and kept up to date. All notes should be carefully entered, so that they may be worked up by others who are not familiar with the survey: the draftsman who makes the map may never get into the field. A permanent bench mark should be set near Station 0+00 and a description of it entered in each note book. Each day's work should be dated. Upon the front page opposite the fly leaf should appear the name of the survey, the names of the survey party, and any general information relative to the purpose of the survey.

SURVEY MAP

Mapping the survey involves reproducing on the plan-profile sheet the information obtained in the field by the field survey parties. If this information has been fully and carefully taken, then the office draftsmen will find their difficulties are few in building this base upon which the road design is constructed. All notes should be checked before any plotting of plan, profile, or sections is started.

Three views of the roadway are shown: the horizontal alignment, the vertical section along the center line, and cross sections showing the ground surface at right angles to the center line at the stations where taken. For plan and profile the standard plan-profile sheet is recommended.

The plan sheet represents one-half mile of roadway. The center line is laid down to a scale of 1" = 100'. The deflection angles are laid off using the natural tangent of the deflection angle. The plan serves as a picture to present to the eye the relative position of the various topographic features with respect to the center line. The hundred foot station points should be marked on the center line and the full station number shown at every fifth station increasing from left to right. All natural and artificial features which might have any bearing upon the design should be shown upon the map, located by a station plus and a right angle offset. These features will be fences, (both right-of-way and line), buildings, cultivated fields, wooded areas, streams, rivers, lakes, culverts, bridges, information as to side slopes, nature of the soil, bad drainage, etc. Reference ties should be shown for all P. I. and P. O. T. points, the P. I. and the P. O. T. station point being shown on the map as a small circle. The bearing of survey lines, the elements of the horizontal curves, right-of-way lines, direction of runoff flow, etc., should be properly shown. The center line should be inked about 1/32" weight; other lines light weight.

The most usual mistake in plotting is using wrong station numbers, or reversing the direction of the center line deflections, or plotting the topography reversed. The lettering used should be neat and plain. The smallest letter in lower case should be not less than 1/10" high. Conventional signs for
topography should be used so far as possible. Only the information as received from the field, referring to structures and natural topography as they exist, should be placed on the plan in the first drafting operation.

The profile of the center line is plotted on the lower part of the plan-profile sheet, the profile being of the same one-half mile as shown in the plan layout above the profile. The horizontal scale is $1'' = 100'$ and the vertical scale is $1'' = 10'$. Plot only those points at which elevations were taken. Connect the plotted points by straight lines of about $1/64''$ weight. The plotting can be done to 0.1 foot, which is as close as the field elevations were taken. Stations for the profile points should be shown on the vertical lines and across the bottom of the sheet. The stationing of one sheet should lap four stations with the next sheet; that is, the last four stations upon one sheet should be the first four stations upon the next sheet which follows.

The cross sections should be most carefully plotted, for upon this plotting depends the closeness of the computed yardage quantities to the actual yards moved in the field. The section paper is 5 x 5 feet to the inch. From the center elevation determine the section reference elevation and mark this elevation and the section station number upon the sheet at the left of the section. The reference elevation line should be assumed at an elevation number divisible by 5 and that one nearest to the center elevation of the section. The section is plotted right and left of the center line to the nearest 0.1 foot in elevation and these plotted points connected by straight lines. The sections are plotted beginning at the lower left and working to the top of the sheet; this allows 2 columns per sheet, average sections. The profile should be observed as the sections are plotted, and vertical allowance can be made between sections so that the final plotting of construction sections will not overlap. The ground line should be inked about $1/64''$ weight.

**ROAD DESIGN**

The mapping of data which has been accumulated by the field surveys furnishes the base upon which to build the design. First consideration should be given to the requirements of the future road. What kinds and what density of traffic must the road serve?

The road design consists of several parts: type of metal for the surface, width and shape of section, proper drainage system, correct grade line, determination of quantities, culverts and bridges needed, and miscellaneous details.

The type of metal, or wearing surface used, should be that which is economically adapted to the quantity and classification of the traffic which it is presumed will operate over the road. This surfacing will be determined in conference and
will be approved by the commissioners, or other proper au-
thority. The width of the roadway surfacing, the shape of
the section, the width of the shoulders, the slope, width, and
depth of ditches, are determined; and this information is
furnished to the drafting force who will then complete the
design in accordance with the tentative specifications and re-
quirements as set up for the road.

Drainage is of major importance. The roadway is made
permanent only when it is properly drained. The nature of
the soil influences the selection of size and shape of ditches.
The surface, in order to perform its function with the least
maintenance cost, must be provided with a dry subgrade.
This requires that the bottoms of the side ditches be placed
sufficiently below the bottom of the pavement metal to drain
the ground water away and lower its elevation to a safe
distance below the pavement. In porous soils, such as sand,
gravel, loam, and light clay, there will be slight difficulty.
The dense clays have such high capillarity factors that ditches
cannot be depended upon to give satisfactory subdrainage.
For this soil condition it will be necessary to use bleeder lines
of tile laid in gravel under the metal and leading to the ditch.
Several lines of small tile will prove more efficient in drying
up the roadbed than fewer lines of larger tile. The designer
must consult all sources of information to determine how the
drainage can be handled best. Special drainage may be re-
quired at some places. A road cannot be said to be a road
unless properly drained.

A proper grade must be selected, for upon this grade de-
pends the cost of excavation, appearance of the road, riding
and hauling qualities, and economical operation of motors in
highway transport.

The designer, in order to lay a grade intelligently must
know the location of this road with respect to its position
in the state, its relation to other local and state roads, the
quantity and kind of traffic carried and estimated, the maxi-
mum gradient allowable, and the vertical curve requirements.

Keeping these things in mind, the designer should observe
that the maximum gradient having been determined, it is un-
economical and unwise to make heavy and extensive cuts to
secure a lower grade at points on the road where the traffic
conditions remain the same. It is undesirable to use short
choppy grades; they not only spoil the appearance of the
road, but it is very seldom that a more uniform grade can-
not be found which will not materially change the excavation
volumes. If the road is following the general slope of the
country, it is desirable to avoid adverse grades. Flat grades
are not desirable; they require independent special ditches.
The most economical grade line is one whereon the cuts and
fills just balance with a minimum of excavation. This is never
attained, but can be closely approached. Economy of grad-
ing should never extend to the point where it overlooks safety, convenience, or roadway appearance. Some thought should be given to esthetics. Certain features will control the grade, such as cross roads, railroads, swamps, bridges, established grades in villages, flat country requiring elevation of grade line, excessive cuts or fills which would result in property damages. The controlling features of the grade must be satisfied. Short haul is desirable but not at the expense of waste and borrowing.

The maximum grade is dependent more on the nature of the topography traversed by the road than it is upon the traffic, but the traffic must be considered. An investigation should be made of traffic on connecting roads, cross roads, between centers of distribution, and on various parts of the road to be improved. The minimum grade would be a zero grade, but this should not be used except where necessary, for it requires special work on the ditches for drainage. The economic design will make use of rolling grades. Highway traffic does not require long stretches of uniform grade. However, it is unwise to cut a 3 per cent grade to 2.5 per cent if the ruling grade is 5 per cent. Small minor rises and hummocks should be cut through to get a pleasing grade line and avoid the unsightly appearance of dips in the pavement. There is small economy in rolling the grade over these minor rises and depressions.

Riding qualities of curves are improved by raising the outer edge of the pavement and widening the inner side at the same time. Curves of 1,000 feet or less radius should be super-elevated and widened. The super-elevation and widening should be a function of the allowable speed and the degree of the curve. Super-elevation and widening affect the quantities of the earthwork and should be taken into consideration in the yardage computations.

In computing the yardages and balancing the earthwork, shrinkage of the materials placed in embankment must be taken into account. The ordinary ratios given in handbooks do not usually apply, for they do not take into account the various vegetable matters in the soil which are not suitable for fill and should be wasted. The allowance for shrinkage will vary from 15 per cent to 35 per cent, depending on the amount of sod and surface mulch.

To determine the economic grade line a template cut to the road section is placed over the plotted ground cross section and adjusted to make the side cut and fill balance. The elevation of grade as shown for this position of the template is marked upon the profile at the proper station. Through these plotted points a straight line curve is drawn which will be an economic grade line; that is, the earthwork quantities will be balanced both for side casting and for longitudinal movement. The line must be adjusted to take account of the
various vertical control points along the line, such as railroads, bridges, culverts, and cross roads. The first line drawn is a trial grade. From this trial grade a preliminary estimate of the earth quantities is run off and the grade line is adjusted to make the cuts and fills balance.

The straight grades are connected by vertical curves, so computed that the sight distance along the pavement will be not less than 400 feet. The minimum curve is 300 feet long, except at bridges and railroads where less distance must frequently be used. For hard surface work a change of grade of 0.5 per cent should have a vertical curve; for gravel a change of 1.0 per cent or less does not need a vertical curve. The highway curve is a parabola and the mid-offset is given by the equation

\[ e = \frac{(G_1 - G_2) L}{8} \]

and any other offset is given by

\[ o = \frac{(x^2)}{(l^2)} e \]

where
- \( e \) = the mid-offset,
- \( G_1 \) and \( G_2 \) = the grade percentages,
- \( L \) = the length of curve in stations,
- \( x \) = the distance from the nearer end of curve to point,
- \( l \) = half length of the curve,
- \( o \) = the offset at any point on the curve.

All offsets are applied to the grade tangent and are plus or minus depending on whether the construction grade is above or below the grade tangents in passing through the curve.

**QUANTITY OF EARTHWORK**

The cubic quantities of earth may be computed from the areas of the cross-sections using the average end area method. For each station determine the net quantity, that is, the excess or deficiency in the cut or fill yardage. If these excess quantities per station, considered plus when representing excavation and minus when representing fill, are summed algebraically, beginning at the zero station and progressing through the survey, and these summation numbers are plotted station by station to some vertical scale of cubic yards and horizontal scale of stations the resulting curve is called a mass diagram, and it graphically represents the movement of earth in a direction parallel to the center line. This curve does not represent the total excavation or fill, but represents only those yards of excavation which move from one station in excavation to position in fill in another station.
A rising curve represents excavation and a falling curve represents fill. If any section of the curve which is in the form of a loop has this loop cut by a line parallel to the base from which the curve was plotted, the section cut represents a balance of excavation and fill. Loops convex upward show haul in the direction of the increasing station numbers, and loops convex downward show haul in the opposite direction. Haul is always from cut to fill, from the rising line to the falling line. Each loop is comprised of two equal parts, cut and fill, and the volume of each part is represented by the length of the maximum ordinate which divides them, computed from any horizontal line drawn across the loop. The intersections of this horizontal line with the loop determines the stations between which the quantities balance.

If the curve is a continuously rising line, then there will be waste, for the curve is representing excavation; and if it is continuously falling there will be borrow, for the falling line represents fill. When this occurs, the grade line, if possible, should be adjusted to equalize the cut and fill. The mass diagram checked against the profile and grade line will show the balanced sections, location of wastes, borrow pits, and the overhaul sections. If these represented units of work are not satisfactory, the grade line must be relaid.

FIELD INSPECTION OF DESIGN

The plans as first prepared may and usually do contain inconsistencies and omissions which must be corrected. This is best done by a field inspection of the design. It can only be done properly by taking preliminary prints from the drawings. On these blueprints are marked recommendations for the drainage structures, special notations and questions relative to information needed by the designer. With these blueprints the inspector walks over the line and carefully checks the details. He should check the grade to see that the fills are adequate in swampy places; that guard rail is specified at all places where essential; that the cuts do not unnecessarily interfere with private property. He should not criticise a grade because at that particular point it does not appear to fit the ground properly; if a desirable grade has been properly laid, the cuts and fills as shown on the plan are necessary to produce that grade. He should, however, criticise the grade with regard to the general topography, the importance of the road, the road's relation to the road system, the kind and the amount of traffic, and the total money involved. If he suggests a change, he should furnish the designer with a clear and concise statement of his reasons, setting forth the extent and amount of the change proposed.

The general drainage conditions should be given careful consideration; inspection of bridges and culverts on the same stream should be made to see that proper sizes are specified.
The inspector should carefully note that all required drainage locations are shown upon the plans. Bleeder lines of tile for springy places, outcroppings of waterbearing strata, special work in boggy and swampy places, should be noted, the extent and amount of the special work required being specified. Notations as to farm entrances and drives, cross-roads intersections, and railroad crossings, should be made. The inspector should endeavor to visualize the road as it will be in the future and in this manner check the work of the designer at all points. All his suggestions and criticisms should be constructive and not destructive. A statement should accompany the field-checked blueprints setting forth all changes, additions, etc., and the reasons therefor. All markings on the blueprints should be carefully and legibly made; no statement should be ambiguous; every question asked by the designer should be answered.

**FINAL PLANS**

The field-inspected plans are gone over by the designer to see what changes are pointed out by the inspector. These are carefully studied with reference to the general idea of the grade and line. Recommended changes in grade must be given a very careful consideration, the designer keeping in mind that the inspector's recommendations are but approximations and that it is the designer's duty to work out the best grade consistent with all the information available. The yardage quantities are recomputed. The elevations of all stations along the grade line are now placed along the bottom of the sheet. Elevations of other essential points are shown, bench marks are noted, guard rails computed, length of vertical curves shown, and special drainage details described. The whole profile is carefully checked.

Across the bottom along a convenient line collective figures are shown giving the quantities of cut, fill, borrow, waste, and overhaul, if any, in such a way that the contractor is given a comprehensive idea of the amount of work between certain stations and the direction of the earthwork haul. The stations between which these units of work are shown are obtained from the mass diagram, and the units of work shown are between balancing points. The length of these working sections will be variable, but in general they should not be greater than 1,000 to 1,500 feet in length.

The plan is checked carefully to see that all notations are entered, that special details are shown, that nothing of the slightest detail but of relative importance is omitted.

New culvert information should be most carefully studied and the proper kind, size, and shape of culvert specified, and the quantities upon which the contractor will base his bid should be shown. Bridges should be handled under the bridge engineer, and are not considered as a part of the road plans.
The bridge location, name of stream, and description of the bridge should be shown. The elevation of the flow line, upper and lower, should be shown for all pipe culverts, and the elevation of the top of footing for box culverts. Culverts for driveways should be specified. Notation should be shown as to width of widening and amounts of metal or extra pavement required for this widening.

Special details and designs should be worked out on separate sheets and included in the set of plans. These extra details will cover special culverts, baffle walls in ditches, cobble gutters, concrete gutters, subdrainage structures, bleeder drains, catch basins, inlets, manholes, special driveways, channel changes, riprap, and special construction of any kind which is not covered in the usual standards and regularly specified for the road.

The set of plans when completed should be collected in folio form, and contain in order: the cover sheet showing the general location of the project with respect to shipping points by rail or water, and the roads leading from these shipping points to the job; one or more sheets showing the standard cross-sections for the road construction; the plan-profile sheets for the entire layout; quantity sheets consolidating and summarizing all the quantities of work of every kind upon the project; sheets showing the special details; cross-section sheets, and mass diagram sheets. For the use of the contractor, a folio for his inspection should contain: general location sheet, typical road sections, plan-profile sheets, quantity sheets, and special detail sheets.

If the surveys have been carefully made and all essential data collected, the designer will have little difficulty in preparing a very comprehensive preliminary sheet from which the blueprints are made for the field inspector. If the field inspection is carefully done, the final sheets can be put in shape in a very short time by the office draftsman. This set of well prepared plans will enable a contractor to estimate and make a bid for the work on the project, which should be at a figure economical for the taxpayer and affording the contractor a reasonable profit upon his investment in time and capital.

MICHIGAN'S TOWNSHIP ROAD PROBLEM

By L. J. Rothgery, Field Engineer, Engineering Experiment Station, Michigan State College, Lansing, Michigan

At the opening of the college term in the fall of 1925, the Engineering Experiment Station, after considerable urging from several sources, began a study of the township road