Having derived formulæ for body and truck bolsters of specified shape and loading, and having explained a graphical method for finding the deflection of such bolsters of any shape and any loading, it re-

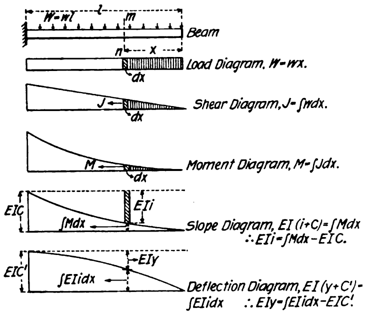


Fig. 2.—Graphical Methods for Bolster Computations.

mains to compare the results of the application of the formula to certain beams with the results of tests on the same beams, and to examine the stiffness of certain forms of beams.

Applying the formula (A) to a body bolster where $I^1 = 115$, $I_0 = 28$, $l = 53$ in., n for the side bearing $= \frac{23}{53}$, and $E = 30,000,000$, we find, for $w = 750$ lbs. per running inch, that the deflection at the side bearing equals 0.117 in., and that at the end of the bolster the deflection equals 0.268 in. By the graphical method the side bearing and end deflection are respectively 0.108 in. and 0.266 in. as compared with

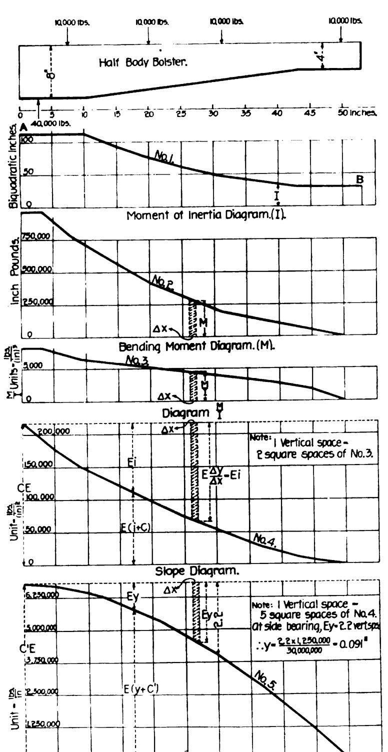


Fig 3.—Diagrams for Deflection of a Body Bolster.

0.117 in. and 0.268 as above. The agreement is thus quite close.

The question arises: Will the assumption of uniform loading give results very different from those obtained with the actual concentrations? A graphical process applied to the beam described above, using actual concentrations of 10,000 lbs., each spaced as shown in Fig. 3, gave deflections of 0.106 in. and 0.256 in. at the side bearings and end respectively, as compared with 0.108 in. and 0.266 under a uniform load of the same total amount.

Another question: Does the assumption that $I = I_0 + \left(\frac{I^1 - I_0}{l}\right) x$, or the assumption of a uniformly increasing moment of inertia, introduce much error? The assumption is equivalent to drawing a straight line between the points A and B of curve No. 1 in Fig. 3. The writer could detect no difference in deflection amounting to one-hundredth of an inch between the results from the true inertia curve and the assumed inertia curve for the case tried.

The same beam was placed in the testing machine, and loads of 10,000 lbs. each were successively placed at the points indicated in Fig. 3. One load was applied near the end, and the deflection at the side bearings was measured; the next load was applied at intermediate sill, and the deflection again measured. We are able to make the assumption that, within the elastic limit, the combined effect of the loads acting together is equal to the sum of their separate effects. This deflection at the side bearing by actual test was 0.115 in., not sensibly different from that computed by the formula. So close an agreement might not have been expected.

The following table summarizes the results:

	Deflection of body bolster in inches at		Conditions.
	Side Bearings	End	
By formula (A)	0.117	0.268	Uniform load; assumed I.
By actual trial	0 115	....	Concentrations; real I.
By graphical method	0 108	0.266	Uniform load; real I
" " "	0.108	0 266	Uniform load; assumed I.
" " "	0 091*	0.259*	Concentrations; real I.
" " "	0.106	0.256	Concentrations; assumed I.

The values marked * are smaller than the others, since the reaction at the center bearing was taken to act at a point 3 in. from the center.

If the beam considered above were of the same depth throughout, equal to the depth at the center, the deflection at the end would be $\frac{1}{8} \frac{w l^4}{E I^1}$, or 0.280 in. If we suppose the end depth to be zero, the end deflection would be $\frac{1}{8} \frac{w l^4}{E I^1}$, or 0.280 in. The real deflection is intermediate between these two values; it is about 95 per cent. of that given by the formula $\frac{1}{8} \frac{w l^4}{E I^1}$. The deflection at the side bearing is about 43 per cent. of the end deflection, and is thus about $\frac{1}{15} \frac{w l^4}{E I^1}$. The latter expression might be used for most practical purposes.

It may be remarked that the deflection by test of many forms of bolster will be greater than that computed from these formulæ, because of the looseness of parts of these bolsters. That is, the formula takes account only of the elastic deflection due to bending, and not of the in-elastic deflection. In the case of built-up bolsters of I section there will be a slight additional deflection due to shear; that is, due to the vertical sliding on each other of the vertical sections. This latter would not be more than one-fifth the deflection given by the above formula. Because of the in-elastic deflection we may find that the method of putting together the material of the section will influence the deflection as well as the size of the section. There would be no appreciable in-elastic deflection in the case of a bolster made of I beams; whereas, in the case of a bolster composed of parts riveted together, this in-elastic deflection may amount to one-third the total deflection. A review of the stiffness of the body and truck bolsters now in use discloses the fact that these parts, designed for the same service, differ in their capacity to withstand the loads put upon them to such a large extent that their design would seem to be controlled by the judgment of the designer rather than by any formal computation. The same thing is true of brake beams, which vary in stiffness (extreme range), as fifteen to one; and in strength as thirty-five to ten.

The Block System on the Atchison.

The Atchison, Topeka & Santa Fe now has about 750 miles of its lines equipped and manned for running trains by space interval, and 167 miles more will soon be equipped. General Superintendent H. U. Mudge has given us the following details of the regulations under which trains are run, with facts of interest concerning the apparatus and the results of the change.

The Atchison, Topeka & Santa Fe is now equipped with the telegraphic block signal system from Double Track Junction, 11.5 miles west of Chicago, to Sheffield, 8 miles east of Kansas City Union Depot; from Holliday, Kan., to Newton, via Topeka and main line, and from Holliday to Emporia Junction, on Emporia branch, which runs via North Ottawa. The double track from A. T. & S. F. junction, in Kansas City, to Holliday, 12 miles, is equipped with Hall automatic electric block signals, and the Raton tunnel, in New Mexico, is also equipped with the Hall automatic electric absolute block. The line between Bee Creek Junction and Terminal Yard, on the St. Joseph branch, 7.7 miles, is operated under the staff system, this track being used by two tenant lines, having an average service of 30 trains a day. The mileage worked under the telegraph block signal system is as follows, with cost of construction of signals, etc.:

	Miles.	Block. Offices.	Cost.
Chicago Division:			
Double Track Jct. to Sheffield	439.4	98	$16,000
Eastern Division:			
Holliday to Emporia, via Main Line...	114.7	21	2,226
Holliday to Emp. Jct., via Emporia Br.	98.4	20	2,838
Middle Division:			
Emporia to Newton	72.1	14	2,027
Totals	725.6	153	$23,091

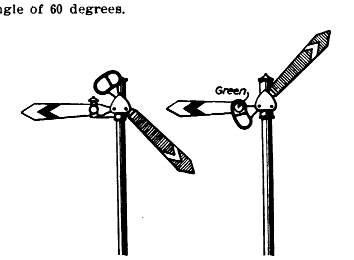
The Chicago Division is equipped with three-position signals, the arms for both eastbound and westbound on the same post. The Eastern and Middle divisions are equipped with two-position signals. Of the total 153 block offices, 14 have telephone connection only. These fourteen are located at unimportant passing tracks and are run the same as telegraph offices, except that telephones are used instead of telegraph instruments.

In establishing the block system it was necessary to open 23 new offices, and 21 additional day operators and 45 additional night operators were employed. At present there are 10 day offices that are closed at night. This will vary according to the business. All of the night offices are day offices also. The average pay of telegraph operators is $45; telephone operators, $35. The increases in payrolls to operate the telegraph block were as follows:

Chicago Division	$2,620	monthly
Eastern Division	1,300	"
Middle Division	450	"
Total	$4,370	"

The average length of the blocks on all three divisions is five miles. The longest block is eight miles, although when business is dull some intervening offices may be closed at night, making blocks as long as 10 miles; but ordinarily the longest block does not exceed seven miles.

The standard signal post is of iron pipe, 32 ft. long, set in a concrete base, which is inclosed in a 12 in. vitrified sewer tile, making the structure as permanent as possible. The Chicago Division is equipped with these posts. West of Kansas City wooden posts were erected in the beginning. Fittings for the home signals were furnished by the Union Switch & Signal Company, of Swissvale, Pa., and are the design of that company's Chief Engineer, Mr. J. P. Coleman. The standard semaphore blade is used, two blades on each post, governing trains in either direction. Pipe connections are used. The signal is so designed that should any connection break or become disconnected the arm will go to horizontal or stop position from either the clear or the caution position. With the three-position signal the permissive signal is indicated by inclining the semaphore blade upward at an angle of 60 degrees.



Three-Position Semaphore for Block Signaling—Atchison, Topeka & Santa Fe.

At stations where the view of the home signals is obscured by curves or obstructions distant signals are used. These distant signals are of standard type, such as are employed at interlockings, and all the fittings are made at the company's shops at Topeka. The iron posts for both home and distant signals are furnished by the Pennsylvania Tube Works, of Pittsburgh, Pa. When no distant signal is used the signal is operated by a short lever on the operator's desk. Where distant signals are used all the signals are operated by long levers similar to those used to handle interlocking signals.

The rules provide for permissive blocking for freight trains following one another and for passenger trains following freight trains (but this only in a few cases where blocks are long and grade ascending), but never for passenger trains to follow each other or for freight trains to follow passenger trains. Permissive blocking is practiced only where the traffic is so heavy that it cannot be avoided. Where three-position signals are used permission to follow another train in the block is given by the upward inclination of the semaphore or by green light at night. Where two-position signals are used permissive cards are issued. The dispatcher controls the giving of permissive cards or signals, but does not give the operator specific orders in each case.

In addition to the signals here described, the Atchison expects within the next three months to erect three-position signals at 30 stations on the Oklahoma Division, from Winfield to Purcell, a distance of 167 miles. There will be six distant signals.

The heaviest freight traffic on any single track line of the Atchison is that on the Emporia branch, where as many as 60 freight trains have been moved in 24 hours. On the whole, it is believed that trains are not delayed any more under the block system than under the time interval, and in a number of cases collisions have been prevented. The permissive system has been successfully managed thus far, with no accidents. Responsibility for collision rests with the following train. During snowstorms and fogs the instructions are to use the absolute block. It is believed that the fast passenger trains make time easier under the block system than before it was adopted.

Revised rules for the block signals were issued by Superintendent Mudge in October last. There is a chapter of definitions, like that in the Standard Code of the American Railroad Association. A clear block signal indicates that the track is clear to a point 1,000 ft. before reaching the next "home block signal." Rule 17 says that the use of the block system does not in any way relieve trainmen from flagging at all times, according to the general rule. Rule 23 reads: "A home block signal must be restored to the 'stop' indication after having been changed for a train, as soon as the rear car carrying the markers has passed the signal, if the train stops, and if it does not stop, as soon as the markers are 300 feet beyond the signal." A distant signal must not be restored to the caution indication until after the rear car carrying the markers has passed the signal. To send forward an eastbound train a block signal operator must simply see that the block is clear and that he has no order on hand to hold eastbound for westbound trains. To send forward a westbound train he must say to the operator at the other end (for example): "B. E. for No. 1," which means block all eastbound trains for westbound train No. 1. The operator receiving this order enters train No. 1 on his register and then responds: "I 13 B. E. for No. 1," signing his personal and office call.

From Trade to Profession—Advances in American Railroad Location.

By William G. Raymond.*

IV.—EQUATING VALUES.

In this paper it will not be attempted to introduce new principles, but rather to restate some old ones in concise form, and to furnish late and what is hoped are reliable figures for comparing various routes.

The two considerations that practically determine the general route are business and ruling grade. Cost of construction, climatic differences, length of line, amount of curvature, and rise and fall, all, theoretically, enter into the problem; but it is a fact that under ordinary circumstances the first two named elements control the selection. The other items enter to confirm or to show total differences in value of different lines, or to decide when differences in business or ruling grade are very small.

Bearing this in mind: 1. Of two or more lines of the same ruling grade, select that of most business in sight. 2. Of two or more lines of approximately the same apparent business, select that having the lowest ruling grade. 3. If both business and ruling grade vary, consider proportionate additions to business as worth three times an equal proportionate increase in train load due to lower ruling grade. This does not mean, as intimated in one text-book, an equal proportionate decrease in number of trains. It means that if one line seems to offer 1 per cent. more business than another which affords grades on which 3 per cent. heavier loads can be hauled than on the first line, the two lines are of approximately equal value. The rule is a rough one, and probably errs in attaching too little importance to business. On the other hand, if the bulk of the business immediately available is to be through business, which will undoubtedly become, if it is not at once, competitive, ruling grade at once becomes a vastly more important item. In such matters definite figures can not be given applicable to even a few cases, and individual judgment must be exercised.

It must also be remembered that by the ruling grade is not meant the single steepest grade, which may possibly be operated by assistant power, nor the ruling grade of a single division of the line, if the line is long enough to have several divisions, but the grade that fixes the weight of train that can be hauled over the entire road, breaking the train occasionally, if necessary, or using helpers.

To find the load in net tons that a given locomotive can haul up a given grade of r per cent. at ordinary freight speed, the following equation is used. In this equation L is the load in net tons that can be hauled behind the tender, E is the weight in net tons of the locomotive and tender, and W is the weight, also in net tons, on the drivers.

$$L = \frac{100\,W}{1 + 4\,r} - E$$

This equation is based on a rolling resistance of 5 pounds per ton on straight level track, which is probably an ample allowance for ordinary summer weather. An allowance of about 20 per cent. must be made in winter in northern latitudes for working loads, because the coefficient of adhesion, taken at one-fourth in the equation, probably often drops to one-fifth. One text-book says that such a load as is obtained from the foregoing equation may not always be considered, because the steam-making power of the locomotive may be insufficient if the hill be a long one. With modern notions of locomotive design the steam-making power of the machine is not likely to be deficient.

The same rules that apply to the line as a whole apply to single divisions.

If two lines seem to be about equally worthy, measured by business and ruling grade, the final decision may be reached by considering the other elements of the problem, as indicated in what follows.

When the general route is determined, the location must be put on the ground and studied in detail. Since the cheapest possible line, mile for mile, is that line which lies at all points on the surface of the ground, and since such a line is manifestly impossible, it becomes necessary, in order to compare details of location, to know the cost of earthwork and superstructure, of rise and fall, curvature and distance. Figures for estimating cost of construction are plentiful, and hence there will be given here only those less frequently seen in print. As a basis for comparison, the locating engineer formulates a statement showing how much may be expended to throw out one foot, or one mile, of distance, one foot of rise and fall, or one degree of curvature, on the particular line adopted. To do this he first estimates the probable traffic in daily trains, and the cost of handling a train mile, as a basis to work from. He then applies his own knowledge, derived from experience, or from such a set of figures as will presently be given, and determines the required values.

Thus, at a cost of one dollar per train mile, the annual cost of one degree of curvature per daily train both ways may be fairly estimated at $0.355, which sum, multiplied by the probable number of daily trains both ways, that is by 10 if there are 10 trains each way, and capitalized at the rate of interest that must be paid for money, gives the gross cost of one degree of curvature on the particular road under consideration, or the sum beyond which it is improper to spend to save one degree of curvature.

The value of distance is not independent of the amount saved. For small savings, say under 3 miles of single track, the estimated cost is $0.40 per mile per train, or about $290.00 per annum per daily train round trip. For distances greater than 2 or 3 miles, but less than 8 or 10 miles, the cost is estimated at $0.45 per mile per train, or about $330.00 per annum per daily train round trip. For distances between 10 miles and, say, 50 miles, $0.75 may be estimated per mile per train, or about $550.00 per annum per daily train round trip. For greater distances than this, possibly necessitating an extra operating division, nearly the whole average cost, or, say, $0.90 per train mile, about $660.00 per annum per daily train round trip, must be estimated. But for any such additional length as 20 or more miles there would almost certainly be some offsetting advantage in increased revenue, which would very likely equal or exceed the extra cost attributable to it. At any rate this must be carefully considered in any particular case.

Rise and fall, like distance, is not constant in cost per foot. Its cost will, notwithstanding statements to the contrary, depend both on the amount in a single place and the rate of grade on which it occurs. On grades under 0.25 per cent., which is the grade of repose for five pounds resistance, there will be no appreciable cost of rise and fall, no matter how long the grade. If the grade is steeper than this, but the hill is short, making a rise of not more than 40 or 50 feet, and is worked by stored energy, that is, is approached with high velocity, which is partly converted into potential energy in climbing the hill, and is reconverted into velocity in descending, the hill not being long enough to require the use of brakes, there is no apparent loss of power, and little expense results from such a grade. As such a grade cannot always be worked by stored energy, and as brakes must sometimes be applied, and as there is some little extra expense in caring for roadbed and track, it will be fair to assign to such a hill a cost somewhere between that due to working it by stored energy and that due to working it entirely by extra fuel on the hill, and applying brakes on the descent.

*Professor of Geodesy and Road Engineering in the Rensselaer Polytechnic Institute.

TABLE II.

Distribution of Operating Expense of American Railroads. At $1.00 per Train Mile These Figures Become Cents per Train Mile.

Item.	Per cent. of whole expense.	
Maintenance of way and structures:		
Repairs of roadway	10.54	
Renewals of rails	1.43	
Renewals of ties	2.95	
Repairs and renewals of bridges and culverts	2.22	
Repairs and renewals of fences, road crossings, signs and cattle guards	0.55	
Repairs and renewals of buildings and fixtures	1.76	
Repairs and renewals of docks and wharves	0.27	
Repairs and renewals of telegraph	0.13	
Stationery and printing	0.03	
Other expenses	0.37	
Total		20.25
Maintenance of equipment:		
Superintendence	0.63	
Repairs and renewals of locomotives	5.65	
Repairs and renewals of passenger cars	2.09	
Repairs and renewals of freight cars	6.83	
Repairs and renewals of work cars	0.15	
Repairs and renewals of marine equipment	0.17	
Repairs and renewals of shop machinery and tools	0.50	
Stationery and printing	0.01	
Other expenses	0.41	
Total		16.50
Conducting transportation:		
Superintendence	1.77	
Engine and roundhouse men	9.80	
Fuel for locomotives	9.80	
Water supply for locomotives	0.70	
Oil, tallow and waste for locomotives	0.39	
Other locomotive supplies	0.24	
Train service	8.00	
Train supplies and expenses	1.59	
Switchmen, flagmen and watchmen	4.23	
Telegraph expenses	2.03	
Station service	7.90	
Station supplies	0.81	
Switching charges—balance	0.37	
Car mileage—balance	2.10	
Hire of equipment	0.33	
Loss and damage	0.79	
Injuries to persons	0.87	
Clearing wrecks	0.[illegible]3	
Operating marine equipment	0.84	
Advertising	0.43	
Outside agencies	1.57	
Commissions	0.17	
Stock yards and elevators	0.13	
Rents for tracks, yards and terminals	1.79	
Rents for buildings and other property	0.52	
Stationery and printing	0.[illegible]3	
Other expenses	0.57	
Total		58.50
General expenses:		
Salaries of general officers	1.25	
Salaries of clerks and attendants	1.45	
General office expenses and supplies	0.32	
Insurance	0.46	
Law expense	0.75	
Stationery and printing (general offices)	0.17	
Other expenses	0.35	
Total		4.75
Grand Total		100.00

TABLE I.

Annual Cost, per Daily Train Round Trip, of One Unit of Distance, Curvature, and Rise and Fall. Cost of Train Mile assumed at $1.00.

Distance. Cost per Mile.				Curvature Cost per Degree.	Rise and Fall. Cost per Foot.				
0 to 3 Miles.	3–10 Miles.	10–50 Miles.	Over 50 Miles.		Grades under 0.25%.	Grades over 0.25%. Under 50 ft. total rise in one place.	Grades bet. 0.25% and 0.75%. Over 50 ft. rise in one place.	Grades Exceeding 0.75% Over 50 ft. in one place. Under 2%.	Grades Exceeding 0.75% Over 50 ft. in one place. Over 2%.
$290.00	$330.00	$550.00	$660.00	$0.355*	0.00	$0.50	$1.80 × rate %.	$1.80	$2.00–$2.50

* Based on ½ pound curve resistance. With 1 pound resistance the cost is $0.408.

TABLE III.

Showing Portion of Several Expense Items that is assumed to vary more or less directly with Distance, Curvature and Rise and Fall. The amount varying is shown in cents per train unit and in per cent. of the whole item. Train mile $1.00.

Item.	Total cost of item (per train mile).	Distance (per train mile). 0–3 miles. Cents.	0–3 miles. %.	3–10 miles. Cents.	3–10 miles. %.	10–50 miles. Cents.	10–50 miles. %.	Over 50 miles. Cents.	Over 50 miles. %.	Curvature (per train degree). Cents.	Curvature %.	Rise and Fall (per train foot). Under 50 feet in one place. Cents.	Under 50 feet in one place. %.	Over 50 feet in one place. Grades bet. 0.75% and 2%. Cents.	Over 50 feet … %.
Maintenance of Way and Structures	20.25	12.34	61.0	16.50	81.5	19.00	93.9	20.25	100.00	0.0155	0.075	0.015	0.075	0.070	0.346
Maintenance of Equipment	16.50	5.30	32.2	5.30	32.2	14.00	85.0	15.00	91.00	0.0224	0.134	0.017	0.103	0.028	0.170
Conducting Transportation—Fuel	9.80	4.20	42.9	4.20	42.9	5.00	51.1	8.50	86.8	0.0084	0.086	0.037	0.378	0.148	1.512
Transportation, other Expenses	48.70	18.16	37.2	19.00	39.1	37.00	76.1	45.50	93.6	0.0024	0.005	..	.....	.....	.....
General Expenses	4.75	...	...	.	.....		.....	.75	0.159	...		...	...		...
Total	100.00	40.00	...	45.00	.....	75.00	.....	90.00	...	0.0487	....	0.069	....	0.246	.....