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PUBLIC ROADS

A JOURNAL OF HIGHWAY RESEARCH

FEDERAL WORKS AGENCY
PUBLIC ROADS ADMINISTRATION

VOL. 23, NO. 10 ▽ OCTOBER-NOVEMBER-DECEMBER 1943

A SECTION OF THE THREE-STATE HIGHWAY

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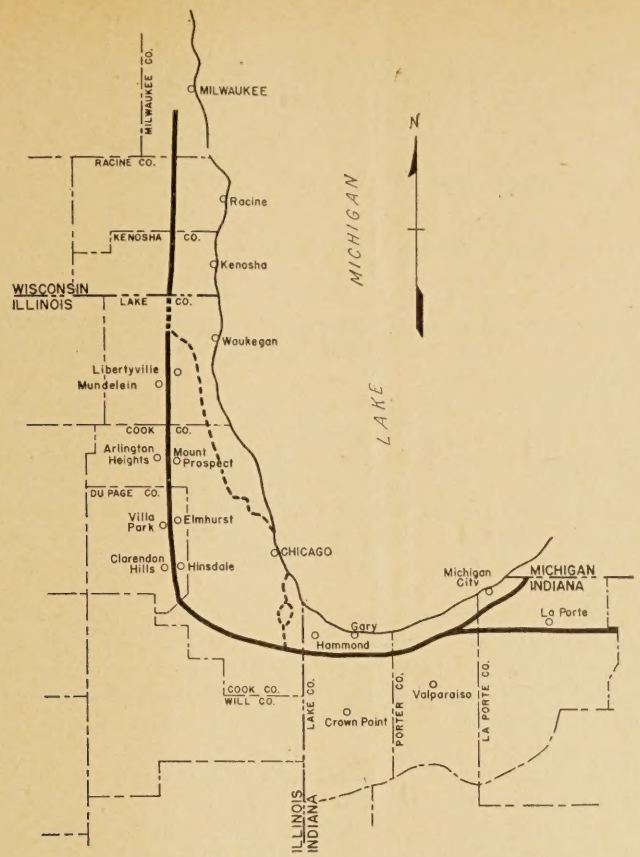


FIGURE 1.—THE THREE-STATE HIGHWAY AS ORIGINALLY PLANNED IN 1925. DATA TAKEN FROM FILES OF CHICAGO REGIONAL PLANNING ASSOCIATION.

tage values. In general, the device of marginal land acquisition was used quite successfully in Du Page County.

Highway widening versus highway relocation.—Analysis of costs on several widened or relocated sections of the highway indicates that land acquisition costs for widening are considerably greater than for relocation. Kenosha County, Wis., and Du Page County, Ill., provide striking illustrations.

INVESTIGATION COVERED ALL PHASES OF LAND ACQUISITION COSTS

The Three-State Highway, when completed, is to be a through route extending from Milwaukee south and east around Chicago to a point somewhere in the eastern part of Indiana. It was conceived of as a connecting artery between the larger metropolitan areas in the region, conveniently passing along the outskirts of proximate cities shown in figure 1. Radial routes are to extend from the cities to the highway. Plans for ultimate improvements, formulated in 1926 by the Chicago Regional Planning Association and the highway engineers of Illinois, Indiana, and Wisconsin, designate a motorway of the parkway type built on a 200-foot right-of-way, and having at least four lanes, as indicated in figure 2. By September 1939, the land for 72 miles of this 161-mile route had been obtained. Negotiations are under way for right-of-way on additional mileage.

Problems involved in the construction of the Three-State Highway are typical of those which must be solved in any major highway improvement. The section of the highway studied is located in two States,

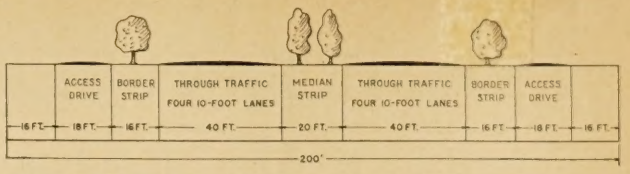


FIGURE 2.—CROSS SECTION OF THE THREE-STATE HIGHWAY AS ORIGINALLY PLANNED IN 1925. DATA SUPPLIED BY CHICAGO REGIONAL PLANNING ASSOCIATION. TWO OF THE FOUR STRIPS OF PAVEMENT ULTIMATELY ARE TO BE 18 FEET WIDE, THE OTHER TWO 40 FEET WIDE. THE LATTER WOULD CONSTITUTE THE CENTER STRIPS, DIVIDED BY A 20-FOOT MEDIAN STRIP, EACH CENTER STRIP CONSISTING OF FOUR LANES OF PAVEMENT AND SERVING THROUGH TRAFFIC. ON THE OUTER SIDE OF THESE THROUGH-TRAFFIC LANES, A 16-FOOT BORDER STRIP WOULD BE DEVELOPED TO SEPARATE THEM FROM 18-FOOT ACCESS DRIVES; ALONG THE OUTER EDGE OF THESE DRIVES, 16 FEET WOULD BE PROVIDED FOR SHOULDERS AND FOR FUTURE DEVELOPMENT. THIS WOULD GIVE ADJACENT PROPERTY OWNERS THE RIGHT OF ACCESS WITHOUT INTERFERING WITH THROUGH TRAFFIC, SINCE THE DRIVES WOULD BE CONNECTED WITH THE THROUGH LANES AT HALF-MILE INTERVALS. IT WAS PLANNED THAT THE THROUGH-TRAFFIC LANES WOULD BE PAID FOR OUT OF GENERAL STATE OR COUNTY FUNDS, WHILE THE ACCESS DRIVES WOULD BE FINANCED BY SPECIAL ASSESSMENTS.

three counties in one State and three in the other. It traverses urban, suburban, and rural territory in which commercial and residential property and agricultural lands are represented.[5] Right-of-way was acquired by donation, purchase, and condemnation. Some marginal or "excess" land was taken, considerably more in Illinois than in Wisconsin. Certain portions of the highway made use of existing roadway. Other portions are relocations.

Local conditions have forced a modification of the original plan of having a uniform 200-foot right-of-way throughout the length of the Three-State Highway. At the time of this investigation, Milwaukee County, Wis., had completed the widening of its portion from an existing 66-foot right-of-way to 160 feet, by acquiring land on either side of the highway to a depth of 47 feet. The right-of-way in Racine and Kenosha Counties, Wis., was limited to 120 feet, but a considerable amount of land was taken for drainage channels and earthwork extending beyond the 120-foot limit. In Lake County, Ill., the highway is built on a 160-foot right-of-way. In Cook and Du Page Counties, Ill., the right-of-way is 200 feet. The plans for ultimate development on each of these widths are shown in figure 3.

Three-State Highway as of September 1939.—The Three-State Highway is a composite of many existing routes, as well as of new sections of roadway, as indicated in figure 4. The highway follows U S 41 south from Milwaukee city limits, through Milwaukee and Racine Counties, Wis., a distance of 25.8 miles to State Highway 43 running east and west across the northern part of Kenosha County, Wis. From this point south to the Wisconsin-Illinois State line, a distance of 8.2 miles, U S 41 was relocated on Bond Issue Route 68 in northern Lake County, Illinois. From the State line, the Three-State Highway proceeds south on U S 41 to and along Bond Issue Route 63, a distance of 13.4 miles. At present, it proceeds southeasterly parallel to and 2½ to 3 miles west of Lake

[5] A large portion of the area traversed by the highway is suburban-rural fringe area. East, north, and south of the route lie highly developed urban regions in which are located the cities of Milwaukee, Racine, and Kenosha in Wisconsin and Chicago in Illinois. In such fringe areas, new land uses tend to encroach upon former uses, with the result that agricultural, commercial, residential, semipublic and public uses exist side by side.

HIGHWAY LAND ACQUISITION COSTS AND PRACTICES IN ILLINOIS AND WISCONSIN

A STUDY OF THE THREE-STATE HIGHWAY

Reported by DAVID R. LEVIN, Transportation Economist

PUBLIC AUTHORITIES, particularly those concerned with highway transport, have known for some time that the construction of new highway facilities and the modernization of existing roads have been impeded by prohibitive costs of land acquisition and almost insurmountable legal and administrative obstacles. Yet until recently,[1] little organized effort had been directed toward the investigation and elimination of these difficulties which, in the aggregate, constitute the so-called right-of-way problem. In 1939, the Public Roads Administration undertook a brief investigation of the Three-State Highway,[2] with the dual objective of ascertaining highway right-of-way costs and revealing such land acquisition difficulties as may be expected to occur on a long stretch of highway traversing rural, suburban, and urban areas devoted to a variety of land uses. It is the purpose of this report to present the findings of this pioneer study.[3]

FACTS AND CONCLUSIONS SUMMARIZED

The problems involved in the construction of the Three-State Highway are typical of those encountered in any major highway improvement. The portion of the highway studied is located in six counties of which three are in Illinois and three are in Wisconsin. It traverses urban, suburban and rural territory representing a wide diversity of land uses.[4]

Mileages, areas, number of parcels.—As of September 1939, the right-of-way for 72 miles of a proposed 161-mile highway improvement had been obtained, involving 1,065 acres of land of which 83 percent was rural, 9 percent suburban, and 8 percent urban. A total of 835 parcels was acquired, averaging 11.6 parcels per mile of road. Of the total area acquired, 67 percent consisted of agricultural lands, 21 percent was residential, and the remaining 12 percent was devoted to other uses. Although commercial property represented but 2 percent of the area acquired, it accounted for 20 percent of the entire cost ($1,228,281) of the acquisitions.

Condemnation, donation.—In acquiring more than a thousand acres of land, 6 percent had to be condemned. Resort to court proceedings is likely to add a minimum of from $300 to $400 to the costs of a given acquisition. Donations were few, except in Milwaukee County, Wis., where the practice seems to prevail of offsetting the benefits accruing to property from an improvement against the value of land acquired, one invariably canceling the other.

Wisconsin award system.—The so-called statutory award system in Wisconsin seems to expedite the acquisition of lands and the construction of highways. The State or a county makes an award for the value of land and damages and tenders that amount to the property owner. Construction may commence immediately afterward. Illinois has no such summary procedure.

Total acquisition costs.—The average total cost of land acquisition per mile of the Three-State Highway was $17,124; of this total, 29 percent represents the cost of "bare" land, 69 percent the amount of damages, and 2 percent the out-of-pocket expenditures for services incidental to acquisition.

Population density.—Although only 8.7 percent of the area acquired was in suburban territory, 16.0 percent of the total cost of $1,228,281 was incurred therefor; 8.4 percent of the area, located in urban sections, was assigned 19.3 percent of the total cost; and 82.9 percent of the area was in rural places and accounted for 64.7 percent of the total cost.

Costs per mile and per frontage-mile.—The average cost per frontage-mile for all property acquired was $9,812. The average cost in rural areas was $7,580 per frontage-mile, in suburban areas almost twice as much, and in urban places more than four times the rural average. These frontage mileages translated into ordinary mileage costs indicate that the cost of acquiring property necessary for the Three-State Highway was approximately $15,000 per mile through rural areas, $29,000 per mile in suburban territory, and $67,000 per mile in urban places.

Costs of "bare" land.—The purchase of 718 acres of "bare" agricultural land entailed an expenditure of $90,763, or $126 per acre. A frequency distribution of unit land costs shows that the average land cost was $145 per acre for all farm lands, $774 per acre for residential lands in rural areas, and $2,033 per acre for residential lands in urban areas.

Damages and incidental fees.—Damage costs averaged $11,801 per mile of highway. Out-of-pocket incidental fees averaged $330 per mile of road.

Marginal land acquisition.—Forty-two parcels of marginal or so-called "excess" land, aggregating 25.6 acres, were purchased at an estimated total cost of $30,823. The parcels are largely in Du Page County, Ill. Of this land, 14.7 acres were traded for other lands needed for highway purposes, 0.6 of an acre was sold, 2.7 acres were transferred to other governmental agencies, and 7.6 acres still remain in county ownership. Some surplus land was purchased in order to avoid the payment of large amounts of consequential damage because of severance and destruction of plot-

[1] The Defense Highway Act of 1941 authorizes the Public Roads Administration to extend Federal aid to the States in the acquisition of lands for the strategic system of highways, for access roads, for flight strips, and for off-street parking facilities.

[2] So called because the plans for ultimate development indicate it will traverse portions of Wisconsin, Illinois, and Indiana.

[3] The investigation was undertaken by the Public Roads Administration under a cooperative agreement with the University of Wisconsin. It was directed by Dr. Henry R. Trumbower, Senior Agricultural Transportation Economist, Public Roads Administration, and Professor of Transportation, University of Wisconsin, Madison, Wisconsin. H. R. Briggs, assisted by the author, supervised the project.

[4] See Glossary of Terms for definitions of technical words.

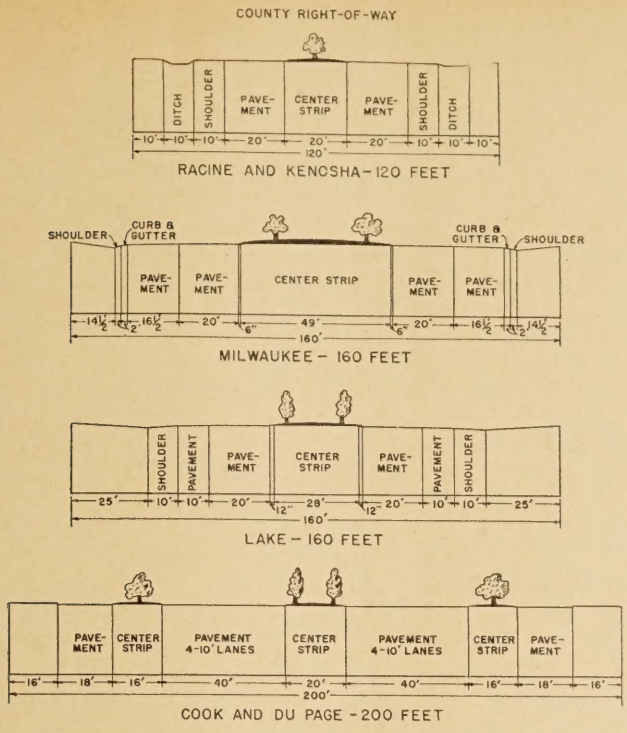


FIGURE 3.—PLAN OF ULIMATE DEVELOPMENT FOR VARYING RIGHT-OF-WAY WIDTHS.

Michigan to Niles Center, Ill., and then southeast and east into Chicago's newly developed Outer Drive at Foster Avenue, about 6.5 miles north of the Chicago Loop.

The Three-State Highway, at its intersection with Bond Issue Route 63, begins a belt route which is still incomplete. In September 1939, the alignment from a point one-half mile north of U S 45 in central Lake County, Ill., southward to a point in the southern part of northern Cook County, had not been surveyed. From the end of the unsurveyed section in the town of Elk Grove, the belt route is constructed along the section lines of Elk Grove to the Cook-Du Page County line, a distance of 2 miles. From the county line, the route proceeds along the section lines of the town of Addison; then follows Bond Issue Route 54 from its junction with Bond Issue Route 64 to the southern Cook-Du Page County line, a distance of 20.4 miles. Beginning at the county line, 1 mile of the belt route is constructed on Bond Issue Route 54 through the Sanitary District of Chicago.[6]

[6] In this study information was obtained from the following sources:
I. Wisconsin:
Milwaukee County.—Wisconsin Highway Commission, Madison; Wisconsin Highway Commission, District Office No. 2; Milwaukee County Highway Department; Milwaukee County Regional Planning Department; Milwaukee County Clerk and Register of Deeds; an official appraiser for Milwaukee County; all at Milwaukee.
Racine County.—Wisconsin Highway Commission, Madison; Wisconsin Highway Commission, District Office No. 2, Milwaukee; Racine County Highway Department; Racine County Clerk and Register of Deeds; all at Racine.
Kenosha County.—Wisconsin Highway Commission, Madison; Wisconsin Highway Commission, District Office No. 2, Milwaukee; Kenosha County Highway Department; County Clerk; Register of Deeds; all at Kenosha.
II. Illinois:
Lake County.—Illinois State Department of Public Works and Buildings, Division of Highways, District Office, Elgin; Lake County Highway Department; County Clerk; and Register of Deeds; all at Waukegan.
Cook County.—Illinois State Department of Public Works and Buildings, Division of Highways, District Offices, Elgin and Chicago; Chicago Regional Planning Association, Chicago; Cook County Highway Department; County Clerk; Register of Deeds; all at Chicago.
Du Page County.—Illinois State Department of Public Works and Buildings, District Office, Elgin; State's Attorney's Office; Du Page County Highway Department; Register of Deeds; County Clerk; County Court Clerk; all at Wheaton.

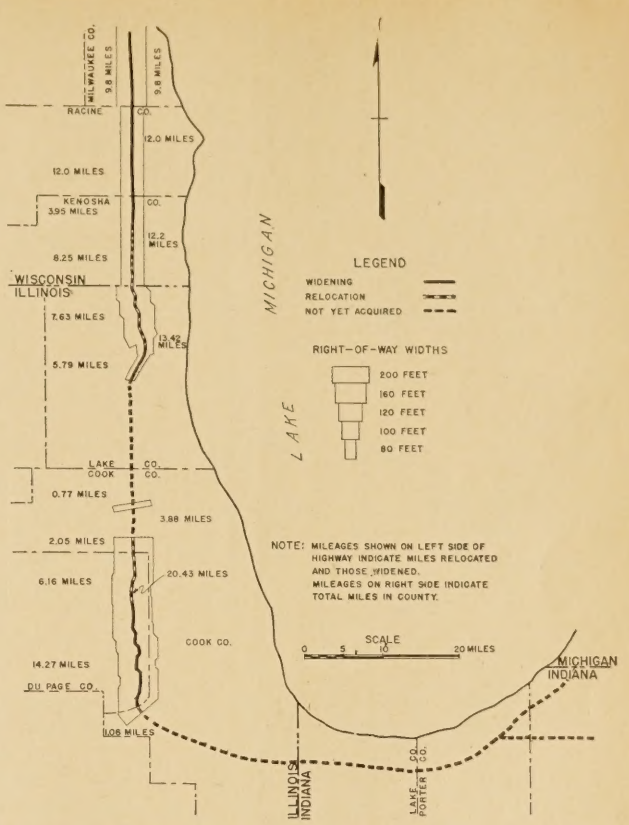


FIGURE 4.—THREE-STATE HIGHWAY RIGHT-OF-WAY ACQUIRED AS OF SEPTEMBER 1939. DATA TAKEN FROM FILES OF HIGHWAY DEPARTMENTS OF THE RESPECTIVE COUNTIES.

TABLE 1.—*Number of parcels acquired*

County	Number of parcels	County	Number of parcels
Grand total	835	Kenosha	51
		Lake	82
Milwaukee	212	Cook	27
Racine	91	Du Page	372

In September 1939, only 72 miles of the originally planned 161-mile route had been completed. The southern terminus was about five-sixths of a mile north of the intersection of State-aid routes 126 and 178 in the northern portion of southern Cook County.

Number of parcels acquired.—By September 1939, right-of-way for 72 miles of the highway had been obtained. This necessitated the acquisition of 835 parcels of real estate, as indicated in table 1, or an average of 11.6 parcels per mile of road. In rural areas, the acquisitions per mile were 4.2 parcels in Kenosha County, 6.1 in Lake County, 7.0 in Cook County, 7.6 in Racine County, and from 4.2 upwards in Milwaukee County.[7] In the urban fringe areas the acquisitions per mile ranged up to 21.6 parcels in Milwaukee County and 18.2 in Du Page County. The properties were largely residential and commercial.

The number of parcels acquired per mile has considerable influence upon acquisition costs, for incidental and condemnation costs vary directly with the number

[7] In Racine and Kenosha Counties, more than two-thirds of the land needed for the highway was acquired on one side of the existing highway to avoid excessive damage costs; this practice reduced the number of parcels acquired in these counties.

TABLE 2.—*Total area of all acquisitions*

County and classification according to population density	Land use										
	Total	Agricultural		Commercial		Industrial		Residential		Public and semipublic	
	Area	Area	Percent	Area	Percent	Area	Percent	Area	Percent	Area	Percent
	Acres	*Acres*		*Acres*		*Acres*		*Acres*		*Acres*	
Grand total	1,064.71	718.49	67.48	23.84	2.24	3.63	0.34	224.96	21.13	93.79	8.81
Rural	881.88	657.46	74.55	12.28	1.39	3.63	0.41	129.08	14.64	79.43	9.01
Suburban	92.92	61.03	65.69	11.07	11.91	----	----	18.29	19.68	2.53	2.72
Urban	89.91	----	----	0.49	0.54	----	----	77.59	86.30	11.83	13.16
Milwaukee: Total	110.75	68.32	61.69	5.30	4.79	----	----	33.96	30.66	3.17	2.86
Rural	69.87	50.18	71.82	3.23	4.62	----	----	15.67	22.43	0.79	1.13
Suburban	40.88	18.14	44.37	2.07	5.06	----	----	18.29	44.75	2.38	5.82
Racine: Total	116.49	93.41	80.19	13.05	11.20	----	----	3.58	3.07	6.45	5.54
Rural	64.45	50.52	78.39	4.05	6.28	----	----	3.58	5.55	6.30	9.78
Suburban	52.04	42.89	82.42	9.00	17.29	----	----	----	----	0.15	0.29
Kenosha: Rural (also total) [1]	136.11	135.68	99.68	0.42	0.31	----	----	0.01	0.01	----	----
Lake: Rural (also total) [1]	166.01	161.89	97.51	0.33	0.20	----	----	0.94	0.57	2.85	1.72
Cook: Rural (also total) [1]	78.88	50.56	64.10	2.09	2.65	----	----	13.57	17.20	12.66	16.05
Du Page: Total	456.47	208.63	45.70	2.65	0.58	3.63	0.80	172.90	37.88	68.66	15.04
Rural	366.56	208.63	56.92	2.16	0.59	3.63	0.99	95.31	26.00	56.83	15.50
Urban	89.91	----	----	0.49	0.54	----	----	77.59	86.30	11.83	13.16

[1] No urban or suburban lands acquired.

of acquisitions. Every acquisition, regardless of the size of a tract, requires negotiation, verification of description and title, recording of the conveyances, etc. If condemnation is necessary, legal costs and disbursements, witness fees, appraisal charges, and other expenditures are in proportion to the number of parcels.

Area, land use and population density analysis.—Of the total of 1,065 acres of land acquired, 82.9 percent was rural land, 8.7 percent was suburban territory, and 8.4 percent was within the limits of incorporated villages and cities, as shown in table 2.

The greatest portion of land, both in area and linear frontages, acquired for the highway consisted of agricultural property. Of the total 1,065 acres acquired, 67 percent consisted of agricultural land and 21 percent of residential property. Moreover, of the total highway frontage of 125 miles, 73.4 percent consisted of agricultural and 17.8 percent of residential lands. Commercial, industrial, public and semipublic properties therefore constitute only small percentages of the total. It is significant that commercial property, although it represented but 2 percent of the area acquired, accounted for 20 percent of the entire cost of the acquisitions.

An analysis of population density in terms of land use is of interest. Of the total right-of-way acquired for the Three-State Highway, 83 percent was rural land, 9 percent suburban, and 8 percent urban. Agricultural property is practically confined to rural territory but 61 acres out of the total of 718 acres acquired was in suburban areas. Likewise, land predominantly devoted to residential usage was not restricted to urban and suburban areas. Of a total of 225 acres of land classed as residential, 57 percent was acquired in rural areas, chiefly because of platted property in suburban-fringe districts.

TABLE 3.—*Area of land acquired by purchase, donation, and by condemnation*

County	Total	Purchase		Donation [1]		Condemnation	
	Area	Area	Percent	Area	Percent	Area	Percent
	Acres	*Acres*		*Acres*		*Acres*	
Grand total	1,064.71	955.39	89.73	44.78	4.21	64.54	6.06
Milwaukee	110.75	99.60	89.94	7.38	6.66	3.77	3.40
Racine	116.49	105.65	90.69	----	----	10.84	9.31
Kenosha	136.11	136.11	100.00	----	----	----	----
Lake	166.01	154.32	92.96	11.69	7.04	----	----
Cook	78.88	65.92	83.57	10.85	13.76	2.11	2.67
DuPage	456.47	393.79	86.26	14.86	3.26	47.82	10.84

[1] Neither land nor damage costs were involved.

LAND ACQUIRED BY A VARIETY OF METHODS

Table 3 shows the amount of land acquired by donation, purchase, and condemnation.[8] The amount donated is of particular interest in this study because efforts to obtain a large portion of the right-of-way through donation had been made at the outset of negotiations for this improvement. Only 13 percent of the total area involved was acquired by donation. In Milwaukee County 93 percent of the total land acquired was donated, in Lake County 7 percent, in Cook County 14 percent, and in Du Page County 38 percent. No land was donated in Kenosha County or in Racine County. The relatively high percentage of donations in Milwaukee County is accounted for by the county's practice of offsetting the benefits accruing to property as the result of an improvement against the value of the land acquired, one invariably canceling the other. The percentage for Cook County is unreliable because of the comparatively small amount of land involved.

In acquiring more than a thousand acres of land, 6 percent had to be condemned. Milwaukee County made the best showing by acquiring only 3.4 percent through court proceedings. The Cook County sample is inadequate and may be ignored.

Outstanding differences characterize the methods for acquiring rights-of-way in Illinois and Wisconsin. Wisconsin utilizes the so-called statutory award system under which the State or a county awards an amount

[8] Table 3 is based upon the concept of a donation as involving neither land nor damage cost. In the text discussion, the term "donation" means the conveyance of "bare" land without compensation, even though damages to improvements may be involved.

that is deemed to be the value of land and compensation for damages and tenders it to the property owner. Construction may commence immediately afterwards. If a tender is not accepted, the award is deposited with the county clerk or other designated officer to be held by him in trust for the property owner until accepted or until the procedure is terminated by a formal settlement consummated through other proceedings. In Illinois the State constitution prohibits the taking of private property for public use without just compensation. Such compensation must be ascertained and paid the owner before a property is taken or construction started. The Wisconsin statutory award system expedites the construction of highways and may well serve as a model procedure in the acquisition of lands for public purposes.

The constitution of Wisconsin [9] also permits highway authorities to condemn marginal or "excess" lands. Illinois lacks such an organic legal sanction. It is an interesting side light that local units in Illinois acquired much more marginal lands (through voluntary purchase) than did Wisconsin counties. (See p. 264).

ACQUISITION COSTS REPORTED

Land, once the cheapest thing in all the world, is now worth millions of dollars an acre in some areas. Since highway facilities are most urgently needed in the more densely populated sections of our country, where land values are relatively high, it becomes important to know what the rights-of-way for motorways are likely to cost. While sweeping generalizations about land acquisition costs should be avoided, a detailed analysis of the expenditures for the lands acquired for the Three-State Highway is enlightening, and may be indicative of probable costs under similar conditions in other sections.

Three elements constitute the total cost of property acquired by a public authority for a public purpose. These are, the cost of the bare land, the payments for damages resulting from acquisition, and the various incidental fees paid to others than the property owners. Table 4 summarizes these elements of cost on a per-mile basis. Figure 5 presents the data in graphic form.

Various units of measure, the acre, for example, which is a unit of area, and the mile, a unit of length, may be used effectively in presenting comparable data

TABLE 4.—*Summary of costs of land, damages, and incidental fees per mile of highway*

County	Miles of highway	Cost per mile			
		Total	Land	Damage	Incidental
Grand total	71.7	$17,124	$4,993	$11,801	$330
Milwaukee	9.8	41,025	1,015	39,053	957
Racine	12.0	16,185	2,464	13,287	434
Kenosha	12.2	4,426	1,124	3,215	87
Lake	13.4	4,079	1,220	2,810	49
Cook	3.9	18,080	4,680	12,941	459
Du Page	20.4	22,180	13,235	8,671	274

[9] Wisconsin Constitution, Article XI, Section 3a, provides that "the State or any of its cities may acquire by gift, purchase or condemnation lands for establishing, laying out, widening, enlarging, extending, and maintaining memorial grounds, streets, squares, parkways, boulevards, parks, playgrounds, sites for public buildings, and reservations in and about and along and leading to any or all of the same: and after the establishment, layout, and completion of such improvements, may convey any such real estate thus acquired and not necessary for such improvements, with reservations concerning the future use and occupation of such real estate, so as to protect such public works and improvements and their environs, and to preserve the view, appearance, light, air and usefulness of such public works."

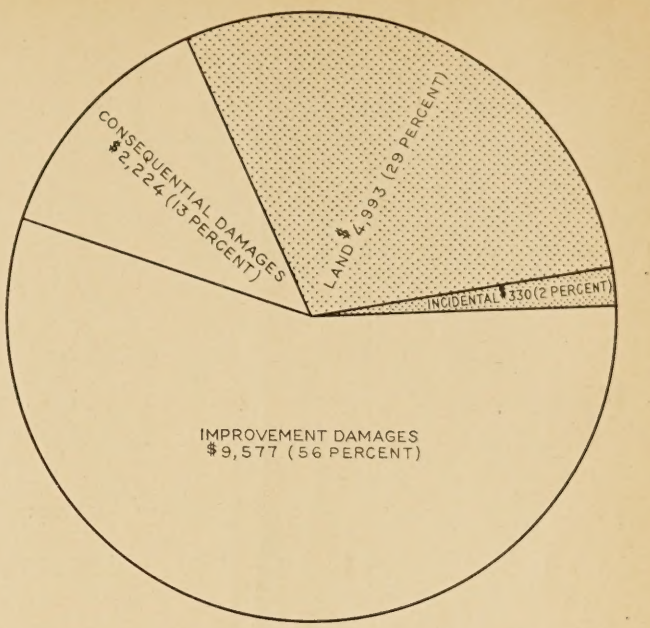


FIGURE 5.—AVERAGE COST PER MILE OF LAND, DAMAGE, AND INCIDENTAL ITEMS.

on highway land acquisition. Two linear units have been utilized in this study, the mile and the frontage-mile. The mile represents 5,280 feet of the length of the highway including cross roads and streets. The linear feet of properties fronting on the highway measured along the highway, excluding the frontage of cross roads and streets, is the basis for the frontage-mile. The two sides of the road are considered separately, 1 mile of highway (without cross roads and streets) being equivalent to 2 frontage-miles. Some 72 miles of roadway were acquired for the Three-State Highway, representing the acquisition of 125 miles of frontage.

The average total acquisition cost per mile for the entire 72 miles was $17,124. Of this total cost, 29 percent represents the cost of bare land, 69 percent the amount of damages, and 2 percent out-of-pocket expenditures for services incidental to the acquisition. The average total cost ranged from $4,079 per mile in Lake County, Ill., to $41,025 per mile in Milwaukee County, Wis. The comparatively high cost of the Milwaukee County acquisition is due to the rather intensive development that fronted the existing roadway in that county, affirmed by the fact that the damage item alone—$39,053—was almost three times the cost of damage per mile in any of the other counties. The extremely small land cost in Milwaukee County, averaging $1,015 per mile, is the result of a practice of offsetting the potential benefits resulting from a highway improvement against the value of the land taken. Payments for land as such were made to public organizations when the benefits were expected to be of negligible value and to owners of lands condemned when claims of benefits to be offset were apparently not sustained. Table 5 is an analysis of the total cost per acre of all acquisitions according to land use and population density. Figure 6 illustrates right-of-way land and damage costs per mile. Study of this figure will reveal much about Three-State Highway acquisition costs.

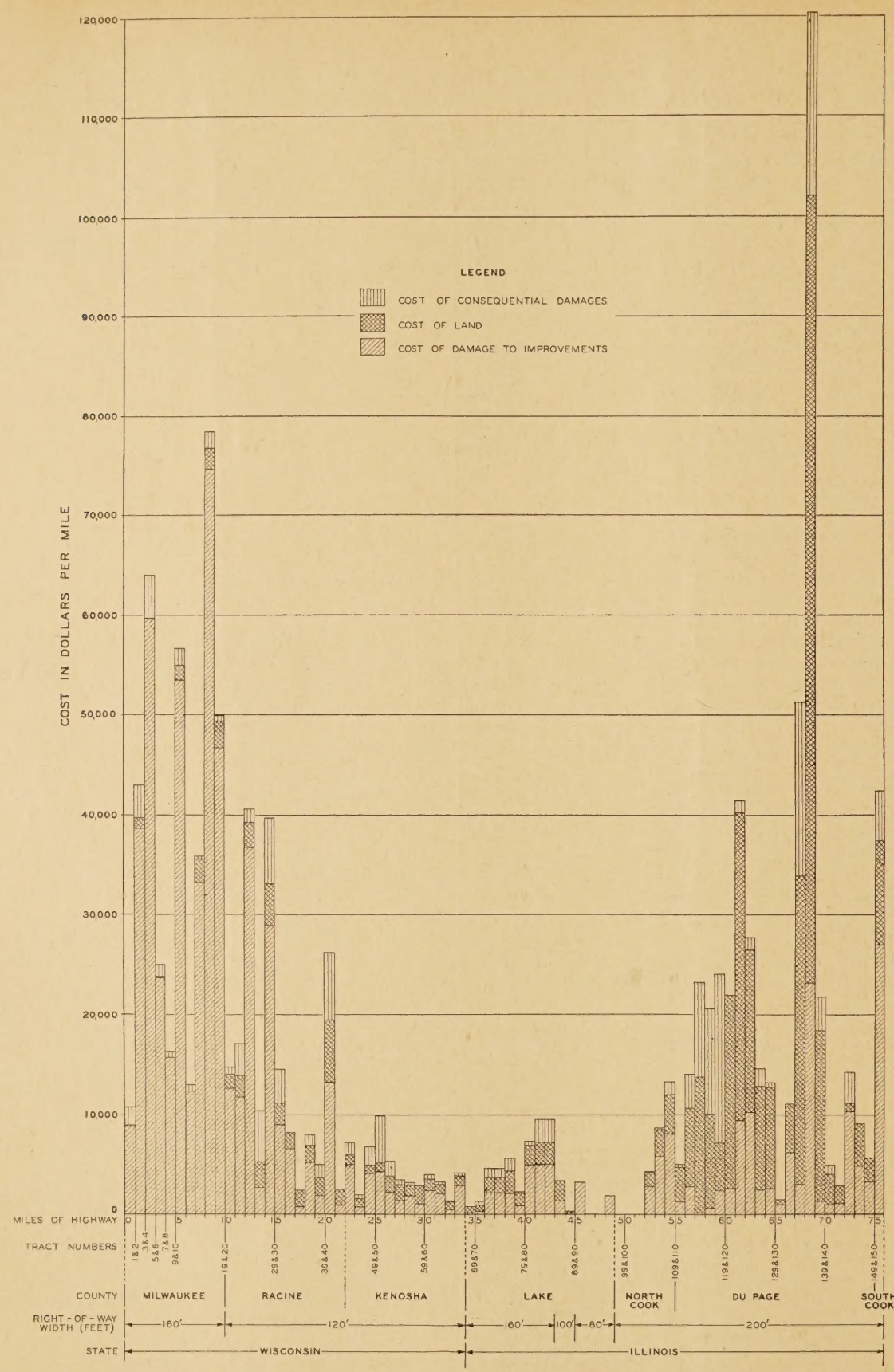


FIGURE 6.—LAND AND DAMAGE COSTS PER MILE.

TABLE 5.—*Total cost per acre of all acquisitions*

County and classification according to population density	Total		Agricultural		Commercial		Industrial		Residential		Public and semi-public	
	Area	Cost per acre	Area	Cost per acre	Area	Cost per acre	Area	Cost per acre	Area	Cost per acre	Area	Cost per acre
	Acres		*Acres*		*Acres*		*Acres*		*Acres*		*Acres*	
Grand total	1,064.71	$1,154	718.49	$677	23.84	$10,145	3.63	$875	224.96	$1,787	93.79	$1,007
Rural	881.88	901	657.46	633	12.28	14,536	3.63	875	129.08	1,081	79.43	723
Suburban	92.92	2,112	61.03	1,156	11.07	5,555			18.29	2,425	2.53	7,838
Urban	89.91	2,638			0.49	3,787			77.59	2,812	11.83	1,452
Milwaukee: Total	110.75	3,630	68.32	2,745	5.30	21,807			33.96	1,705	3.17	12,945
Rural	69.87	3,703	50.18	2,691	3.23	27,538			15.67	865	0.79	26,842
Suburban	40.88	3,506	18.14	2,895	2.07	12,863			18.29	2,425	2.38	8,332
Racine: Total	116.49	1,667	93.41	893	13.05	6,732			3.58	3,599	6.45	1,563
Rural	64.45	2,193	50.52	1,294	4.05	13,083			3.58	3,599	6.30	1,600
Suburban	52.04	1,016	42.89	420	9.00	3,874					0.15	
Kenosha: Rural (also total) [1]	136.11	397	135.68	358	0.42	12,531			0.01	12,975		
Lake: Rural (also total) [1]	166.01	330	161.89	330	0.35	758			0.94	691	2.85	160
Cook: Rural (also total) [1]	78.88	889	50.56	690	2.09	5,653			13.57	1,557	12.66	183
Du Page: Total	456.47	993	208.63	378	2.65	7,960	3.63	875	172.90	1,789	68.66	591
Rural	366.56	589	208.63	378	2.16	8,907	3.63	875	95.31	957	56.83	412
Urban	89.91	2,638			0.49	3,787			77.59	2,812	11.83	1,452

[1] No urban or suburban lands acquired.

TABLE 6.—*Total cost per mile of frontage of all acquisitions*

County and classification according to population density	Total		Agricultural		Commercial		Industrial		Residential		Public and semi-public	
	Frontage	Cost per mile	Frontage	Cost per mile	Frontage	Cost per mile	Frontage	Cost per mile	Frontage	Cost per mile	Frontage	Cost per mile
	Miles		*Miles*		*Miles*		*Miles*		*Miles*		*Miles*	
Grand total	125.18	$9,812	91.87	$5,298	2.73	$88,590	0.30	$10,585	22.27	$18,054	8.01	$11,792
Rural	104.86	7,580	83.28	4,998	1.66	107,530	0.30	10,585	12.42	11,233	7.20	7,979
Suburban	13.29	14,763	8.59	8,210	0.99	62,116			3.30	13,439	0.41	48,364
Urban	7.03	33,744			0.08	23,198			6.55	33,312	0.40	42,938
Milwaukee: Total	19.32	20,810	11.85	15,826	0.89	129,859			6.05	9,571	0.53	77,423
Rural	11.94	21,669	8.52	15,847	0.53	167,826			2.75	4,929	0.14	151,464
Suburban	7.38	19,420	3.33	15,771	0.36	73,964			3.30	13,439	0.39	50,844
Racine: Total	16.13	12,041	13.53	6,164	1.35	65,077			0.50	25,770	0.75	13,442
Rural	10.22	13,830	8.27	7,907	0.72	73,591			0.50	25,770	0.73	13,810
Suburban	5.91	8,947	5.26	3,424	0.63	55,346					0.02	
Kenosha: Rural (also total)[1]	16.94	3,188	16.89	2,878	0.05	105,261						
Lake: Rural (also total)[1]	27.08	2,021	26.15	2,042	0.05	5,000			0.14	4,643	0.74	616
Cook: Rural (also total)[1]	7.26	9,662	4.96	7,034	0.15	78,764			1.11	19,032	1.04	2,232
Du Page: Total	38.45	11,785	18.49	4,269	0.24	87,896	0.30	10,585	14.47	21,380	4.95	8,194
Rural	31.42	6,872	18.49	4,269	0.16	120,245	0.30	10,585	7.92	11,512	4.55	5,140
Urban	7.03	33,744			0.08	23,198			6.55	33,312	0.40	42,938

[1] No urban or suburban lands acquired.

COST PER MILE VARIED WITH LAND USE AND POPULATION DENSITY

The investigation affirms the principle that over-all cost of property does not vary directly with quantity of land acquired. This is largely because of variations in land use and population density. Although only 8.7 percent of the area acquired was in suburban territory, 16.0 percent of the total cost of $1,228,281 was incurred for suburban land; 8.4 percent was in urban areas and was responsible for 19.3 percent of the cost; and 82.9 percent was in rural sections and accounted for 64.7 percent of the total cost.

Because a mile of the highway may have required lands devoted to various uses and may include portions where no lands at all were taken, a more accurate measure of acquisition costs is the cost per frontage-mile, as indicated in table 6. Although the average cost per frontage-mile for all property acquired was $9,812, the average cost in rural areas was $7,580 per frontage-mile, in suburban areas almost twice as much, and in urban places more than four times the rural average.

The cost varied to an even greater extent with the nature of land use. Costs ranged from $616 per frontage-mile for semipublic property in rural areas in Lake County to $167,826 for a half-mile of commercial property in a rural area of Milwaukee County. The average cost per frontage-mile for all agricultural property was $5,298. Although agricultural property in rural areas was obtained for $4,998 per frontage-mile, agricultural lands acquired in suburban areas were almost double that rate.

The same tendency applies to acquisitions of residential property of which the average cost per frontage-mile was $18,054. Notwithstanding that the cost was $11,233 per frontage-mile for residential lands in rural areas, it amounted to approximately three times as

much in urban areas. Residential property was twice as expensive per frontage-mile as agricultural property, and even though the Three-State Highway traverses the undeveloped sections of cities and villages, the cost of residential property in urban localities was approximately three times the cost of residential property in rural areas.

Right-of-way was not acquired through commercial, industrial, public, and semipublic properties in sufficient quantities to justify conclusions concerning cost relationships. The acquisitions analyzed, however, do indicate that cost of lands devoted to such uses may have a decided influence upon total costs. Although but 2.7 frontage-miles of commercial property were acquired, the cost per frontage-mile was $88,590, or more than four times the cost of an equal amount of residential frontage, and more than 17 times the cost of agricultural lands.

These frontage-mile sums when translated into ordinary mileage costs indicate that the cost of acquiring the property necessary for one mile of the highway through rural areas was approximately $15,000, in suburban territory $29,000, and in urban places $67,000. Furthermore, the data indicate that 1 mile of right-of-way through agricultural property averaged approximately $10,500 on the whole route but that its cost in rural areas was about $10,000, and in suburban regions approximately $16,000. The cost per mile of residential property was $22,000 in rural areas, $26,000 in suburban places, and approximately $66,000 in urban centers. Acquisitions of commercial, industrial, public, and semipublic lands were highly dispersed and not in sufficient amounts to warrant extensive analysis.

COSTS OF "BARE" LAND ANALYZED

Expenditures for "bare" land amounted to $358,140 or 29 percent of the total expended for rights-of-way. The land cost was lowest in Milwaukee County—but 2 percent of total expenditures in that county—because of the practice, previously mentioned, of offsetting benefits accruing to property as the result of an improvement against the value of the lands taken. On the other hand, 60 percent of the total was cost of land in Du Page County, Ill., due in large measure to the great amount of platted but unimproved property in that region.

Purchase of 718 acres of agricultural "bare" land entailed an expenditure of $90,763, or a per-acre cost of $126, as shown in table 7. Average cost ranged from $94 per acre in Lake County to $213 per acre in Cook County. The general average cost is somewhat influenced by the Milwaukee County land policy. If acquirements in Milwaukee County are omitted from the aggregate, the land cost averages $137 per acre for relatively high-grade farm lands in "rurban" territory. Excluding Milwaukee County, residential lands averaged $1,107 per acre, the highest cost being $1,871 per acre in urban places in Du Page County, Illinois. Rural lands devoted to all uses, excluding Milwaukee County, averaged $233 per acre, while suburban lands averaged $281 per acre, and urban property $1,708 per acre.

The range in rural land costs per frontage-mile, excluding Milwaukee County, was from $605 in Lake County to $3,713 in Du Page County, as shown in table 8. In residential areas, the cost per frontage-mile, omitting Milwaukee County, ranged from $3,929 in Lake County to $22,162 in Du Page County. The least expensive bare lands in urban and suburban areas cost approximately twice as much as the most expensive land in rural territory. However, since the depth factor has been ignored entirely in this study, all frontage-mile measures of value are of limited significance.

An analysis of unit costs of bare land acquired by purchase, excluding all donations and condemnations, is summarized in table 9. Only lands devoted to agricultural and residential uses were considered because lands put to other uses were acquired so sparingly as to make the resulting sample unreliable. The analysis shows that the average land cost was 3 cents per square yard or $145 per acre for all farm lands; 16 cents per square yard or $774 per acre for residential lands in rural areas; and 42 cents per square yard or $2,033 per acre for residential lands in urban areas.

TABLE 7.—*Cost of bare land per acre*

County and classification according to population density	Total		Agricultural		Commercial		Industrial		Residential		Public and semipublic	
	Area	Cost per acre	Area	Cost per acre	Area	Cost per acre	Area	Cost per acre	Area	Cost per acre	Area	Cost per acre
	Acres		*Acres*		*Acres*		*Acres*		*Acres*		*Acres*	
Grand total	$1,064.71	$336	718.49	$126	23.84	$1,012	3.63	$569	224.96	$943	93.79	$310
Rural	881.88	214	657.46	125	12.28	1,367	3.63	569	129.08	518	79.43	259
Suburban	92.92	170	61.03	139	11.07	571			18.29		2.53	395
Urban	89.91	1,710			0.49	2,084			77.59	1,870	11.83	637
Milwaukee: Total [1]	110.75	90	68.32	20	5.30	645			33.96	19	3.17	1,419
Rural	69.87	126	50.18	25	3.23	1,057			15.67	40	0.79	4,429
Suburban	40.88	28	18.14	8	2.07	2			18.29		2.38	420
Racine: Total	116.49	254	93.41	197	13.05	594			3.58	634	6.45	180
Rural	64.45	231	50.52	199	4.05	355			3.58	634	6.30	184
Suburban	52.04	281	42.89	194	9.00	702					0.15	
Kenosha: Rural (also total) [2]	136.11	101	135.68	101	0.42	100			0.01	200		
Lake: Rural (also total) [2]	166.01	99	161.89	94	0.33	758			0.94	585	2.85	116
Cook: Rural (also total) [2]	78.88	230	50.56	213	2.09	801			13.57	335	12.66	95
Du Page: Total	456.47	592	208.63	150	2.65	4,145	3.63	569	172.90	1,180	68.66	319
Rural	366.56	318	208.63	150	2.16	4,612	3.63	569	95.31	618	56.83	253
Urban	89.91	1,710			0.49	2,084			77.59	1,871	11.83	637

[1] See discussion and footnote 8 on page 256, concerning donations of bare land.
[2] No urban or suburban lands acquired.

TABLE 8.—*Cost of bare land per mile of frontage of all acquisitions*

County and classification according to population density	Total		Agricultural		Commercial		Industrial		Residential		Public and semipublic	
	Frontage	Cost per mile	Frontage	Cost per mile	Frontage	Cost per mile	Frontage	Cost per mile	Frontage	Cost per mile	Frontage	Cost per mile
	Miles		*Miles*		*Miles*		*Miles*		*Miles*		*Miles*	
Grand total	125.18	$2,861	91.87	$988	2.73	$8,837	0.30	$6,886	22.27	$9,523	8.01	$3,635
Rural	104.86	1,799	83.28	988	1.66	10,109	0.30	6,886	12.42	5,388	7.20	2,859
Suburban	13.29	1,189	8.59	987	0.99	6,386			3.30		0.41	2,439
Urban	7.03	21,865			0.08	12,762			6.55	22,162	0.40	18,824
Milwaukee: Total [1]	19.32	515	11.85	118	0.89	3,842			6.05	104	0.53	8,489
Rural	11.94	737	8.52	147	0.53	6,443			2.75	230	0.14	24,993
Suburban	7.38	156	3.33	44	0.36	12			3.30		0.39	2,564
Racine: Total	16.13	1,833	13.53	1,359	1.35	5,744			0.50	4,534	0.75	1,547
Rural	10.22	1,460	8.27	1,216	0.72	1,996			0.50	4,534	0.73	1,589
Suburban	5.91	2,478	5.26	1,583	0.63	10,029					0.02	
Kenosha: Rural (also total) [2]	16.94	809	16.89	809	0.05	840						
Lake: Rural (also total) [2]	27.08	605	26.15	583	0.05	5,000			0.14	3,929	0.74	446
Cook: Rural (also total) [2]	7.26	2,501	4.96	2,166	0.15	11,162			1.11	4,091	1.04	1,152
Du Page: Total	38.45	7,032	18.49	1,694	0.24	45,767	0.30	6,886	14.47	14,104	4.95	4,430
Rural	31.42	3,713	18.49	1,694	0.16	62,269	0.30	6,886	7.92	7,440	4.55	3,164
Urban	7.03	21,865			0.08	12,762			6.55	22,162	0.40	18,824

[1] See discussion and footnote 8 on page 256, concerning donations of bare land.
[2] No urban or suburban land acquired.

DAMAGES FOUND TO BE LARGE

Unlike land costs, damages paid for injury to improvements and betterments because of right-of-way acquisition are not susceptible of unit measurement, and each individual parcel acquisition is a separate problem. Figure 6 indicates the wide variation in damage costs per mile on the Three-State Highway. More than two-thirds of the total amount, $1,228,281, expended for rights-of-way was incurred for damage payments. The average damage cost was $11,801 per mile (table 4).

Damages for legal injuries may be divided into various categories. The principal classifications in highway land acquisition are improvement or betterment damages and consequential damages. Improvement or betterment damages are amounts of money paid for direct damage to structures, trees, fences, lawns, crops, etc., resulting from the acquisition of property. Consequential damages are amounts of money paid a property owner for injury to the remainder of his land as a result of decrease in site value, deprivation of lateral support, grade change, loss of access, severance, etc., caused by a highway development. There is a third category of damages for which no compensation need be made because, in general, the law does not recognize the validity of damage claims for noise, inconvenience, inesthetic arrangements, and the like. This type of damage is called damnum absoque injuria.

TABLE 9.—*Frequency distribution of unit land costs in agricultural and residential areas, excluding donations and condemnations*

Land cost per square yard	Agricultural land		Land cost per square yard	Residential land			
				Rural		Urban	
Cents	*Square yards*	*Percent*	*Cents*	*Square yards*	*Percent*	*Square yards*	*Percent*
0–0.9			0–4.9	207,445	49.24	13,981	4.02
1–1.9	21,524	0.75	5–9.9	45,807	10.87	26,842	7.72
2–2.9	1,468,234	51.28	10–19.9	69,632	16.52	118,388	34.06
3–3.9	162,807	5.69	20–29.9	37,625	8.93	38,599	11.11
4–4.9	982,553	34.32	30–39.9	14,214	3.37	19,490	5.61
5–5.9	181,034	6.32	40–49.9	17,997	4.27	22,406	6.45
6–6.9	222	0.01	50–59.9	12,110	2.87	9,408	2.71
7–7.9	39,073	1.36	60–69.9	3,347	0.79	43,384	12.48
8–8.9	774	0.03	70–79.9	769	0.18	4,134	1.19
9–9.9			80–89.9	234	0.06	9,639	2.77
10 and over	6,959	0.24	90–99.9	1,802	0.43	7,508	2.16
			100–109.9	1,736	0.41	16,080	4.63
			110–119.9	5,198	1.23	5,112	1.47
			120–129.9	265	0.06	888	0.26
			130–139.9	3,070	0.73	57	0.02
			140–149.9			927	0.27
			150–159.9			189	0.05
			160–169.9			881	0.25
			170–179.9			1,207	0.35
			180–189.9				
			190–199.9				
			200–209.9			888	0.26
			210 and over	149	0.04	7,513	2.16
Total	2,863,180	100.00	Total	421,400	100.00	347,521	100.00
Average cost per square yard, cents	2.92		Average cost per square yard, cents	15.58		41.98	

Table 10 shows the various elements of the two classes of injuries for which payments were made. Damages to structures constituted the largest single element, aggregating almost half a million dollars, the range being from $10,619 to $74,569 per mile (figure 6). Milwaukee County accounted for over half of the damages to structures because of the "shoestring" nature of the existing highway development in that county. It is alleged that these damages would have been considerably greater but for the existence in Milwaukee County of the Highway Widening Ordinance which in 1926 established an extended highway width.[10] The only other large item was damage to trees. This amounted to almost $100,000 on the 72 miles of highway. The highest amounts were incurred in Milwaukee County where tree damage was approximately $7,000 per mile of highway. It should be noted that acquisitions in Racine County and Kenosha County, Wis., were largely confined to the east side of the existing highway in order to avoid large damage payments. Damage costs per frontage-mile are shown in table 11.

[10] See Ray E. Behrens, "Highway Widening Procedure Saves Millions," The American City, December 1938, volume 53, No. 12.

TABLE 10.—*Analysis of improvement and consequential damages for all acquisitions*

County	Grand total	Improvement damages					Consequential damages			
		Total	Structures	Fences	Trees	Other [1]	Total	Severance	Grade change	Other [2]
Grand total	$846,470	$686,963	$475,030	$27,323	$97,676	$86,934	$159,507	$70,543	$44,933	$44,031
Total Wisconsin	581,400	525,225	359,687	15,646	88,069	61,823	56,175	15,582	11,229	29,364
Milwaukee	382,723	367,189	255,946	5,972	68,799	36,472	15,534	6,393	2,568	6,573
Racine	159,448	130,077	92,195	4,092	11,547	22,243	29,371	4,736	7,879	16,756
Kenosha	39,229	27,959	11,546	5,582	7,723	3,108	11,270	4,453	782	6,035
Total Illinois	265,070	161,738	115,343	11,677	9,607	25,111	103,332	54,961	33,704	14,667
Lake	37,711	28,960	9,824	2,426	2,010	14,700	8,751	8,316	----------	435
Cook	50,208	43,664	39,445	406	2,224	1,589	6,544	6,401	----------	143
Du Page	177,151	89,114	66,074	8,845	5,373	8,822	88,037	40,244	33,704	14,089

[1] Includes payment for injuries to miscellaneous improvements such as culverts, driveways, grading, lawn, sidewalks, etc.
[2] Includes payments for damage to site value, proximity, etc.

TABLE 11.—*Damage cost per mile of frontage of all acquisitions*

County and classification according to population density	Total		Agricultural		Commercial		Industrial		Residential		Public and semi-public	
	Frontage	Cost per mile	Frontage	Cost per mile	Frontage	Cost per mile	Frontage	Cost per mile	Frontage	Cost per mile	Frontage	Cost per mile
	Miles		*Miles*		*Miles*		*Miles*		*Miles*		*Miles*	
Grand total	125.18	$6,672	91.87	$4,211	2.73	$76,893	0.30	$3,667	22.27	$8,273	8.01	$8,032
Rural	104.86	5,592	83.28	3,903	1.66	93,180	0.30	3,667	12.42	5,586	7.20	5,024
Suburban	13.29	13,470	8.59	7,196	0.99	54,973	----------	----------	3.30	13,404	0.41	45,245
Urban	7.03	11,531	----------	----------	0.08	10,210	----------	----------	6.55	10,783	0.40	24,042
Milwaukee: Total	19.32	19,810	11.85	15,514	0.89	119,262	----------	----------	6.05	9,336	0.53	68,396
Rural	11.94	20,197	8.52	15,454	0.53	150,070	----------	----------	2.75	4,455	0.14	126,421
Suburban	7.38	19,183	3.33	15,670	0.36	73,905	----------	----------	3.30	13,404	0.39	47,566
Racine: Total	16.13	9,885	13.53	4,588	1.35	58,288	----------	----------	0.50	20,436	0.75	11,287
Rural	10.22	11,938	8.27	6,342	0.72	70,655	----------	----------	0.50	20,436	0.73	11,596
Suburban	5.91	6,336	5.26	1,831	0.63	44,156	----------	----------	----------	----------	0.02	----------
Kenosha: Rural (also total) [1]	16.94	2,316	16.89	2,014	0.05	101,660	----------	----------	----------	----------	----------	----------
Lake: Rural (also total) [1]	27.08	1,393	26.15	1,435	0.05	----------	----------	----------	0.14	714	0.74	129
Cook: Rural (also total) [1]	7.26	6,916	4.96	4,639	0.15	66,838	----------	----------	1.11	14,571	1.04	962
Du Page: Total	38.45	4,607	18.49	2,510	0.24	41,578	0.30	3,667	14.47	6,989	4.95	3,743
Rural	31.42	3,058	18.49	2,510	0.16	57,262	0.30	3,667	7.92	3,852	4.55	1,958
Urban	7.03	11,531	----------	----------	0.08	10,210	----------	----------	6.55	10,783	0.40	24,042

[1] No urban or suburban land acquired.

Consequential damages on the highway aggregated $159,507. The largest single item of consequential damage resulted from severance of property, which occurred when the highway divided a single owner's tract of land into two separate parts, thereby impairing the economic utility of the whole. In some places a farmhouse was separated from the barn and other farm buildings, thereby making movement between them more difficult. On this highway consequential damages were frequently estimated by a rule-of-thumb method, assuming them to be 50 percent of the value of the bare land acquired. The plottage value of subdivided, potential residential property was frequently diminished by the acquisition of the front 50 feet of lots originally 100 feet deep, as illustrated in figure 7. This figure shows a portion of the highway in the village of Bensonville, Du Page County, Ill.

Still another form of consequential damage resulted from changes in elevation of the roadway surface, impairing the means of ingress and egress, one of the fundamental rights incident to the ownership of property. A typical example is shown in figure 8.

INCIDENTAL COSTS AND ADDITIONAL PAYMENTS REPORTED

In addition to land and damage costs, there are other fees incidental to land acquisition. Among them are amounts paid to others than property owners for special services rendered in connection with a land acquisition. They include sums paid to appraisers, commissioners, registers of deeds, county clerks, title-search companies, and others. Out-of-pocket incidental fees averaged $330 per mile of highway and constituted 2 percent of the aggregate expenditures. Table 12 is an analysis of out-of-pocket costs.

Additional payments are sums paid to grantors of property and others for interests in property needed for the highway. They are in addition to amounts paid at the time of original settlement, and are generally the result of inadequate title searching by public authorities. As shown in table 13, more than $22,000 was paid in this fashion, chiefly in Du Page County, Ill. For example, one parcel in that county was acquired originally for what was supposed to be a very reasonable value, $500. Later the county had to pay an additional $4,000 for the partial release of a mortgage. Three

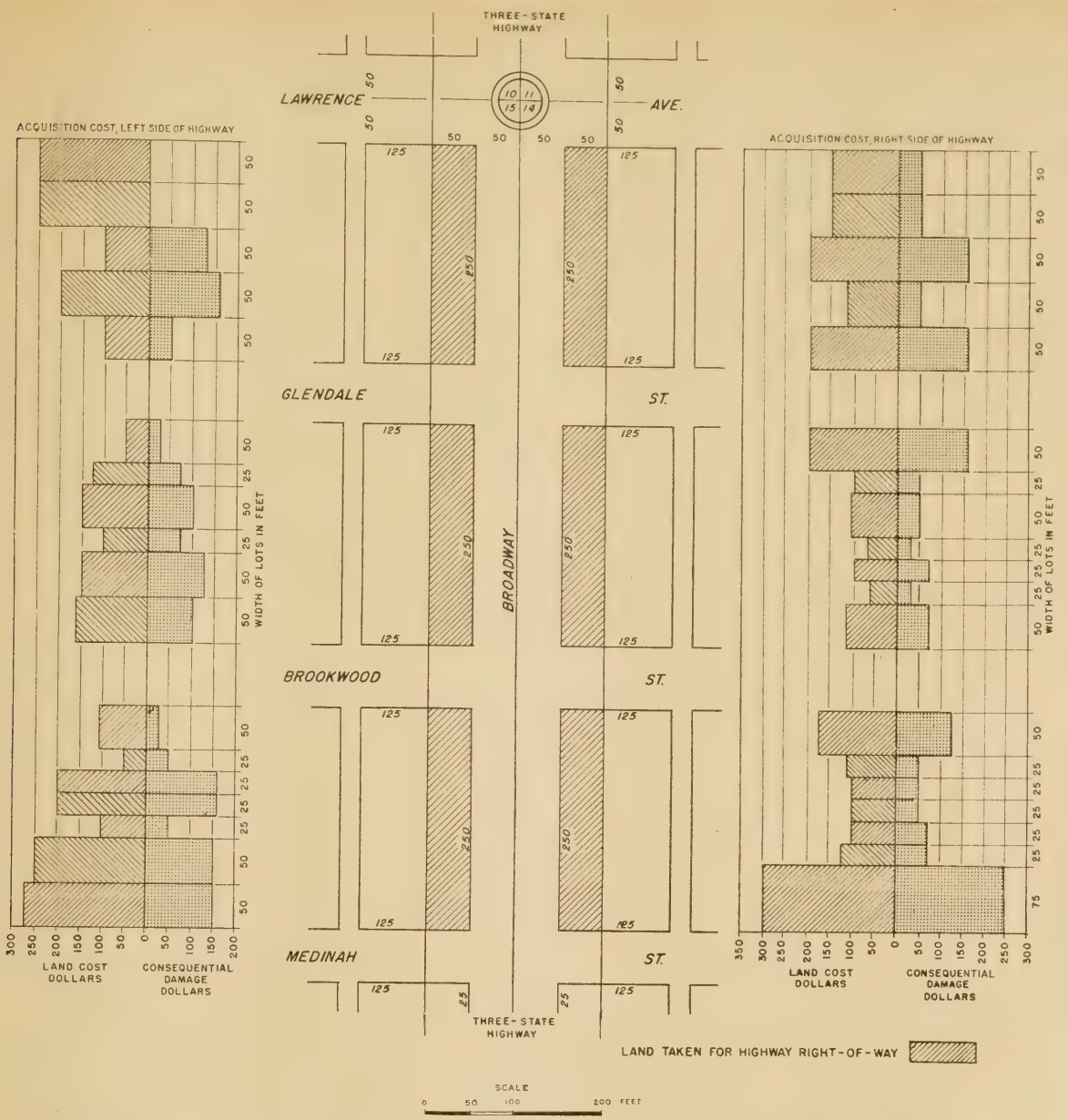


FIGURE 7.—EXTENT OF TAKINGS FROM FRONT OF LOTS AND COSTS OF LAND AND CONSEQUENTIAL DAMAGES ON 1,000 FEET OF HIGHWAY IN THE VILLAGE OF BENSONVILLE, DU PAGE COUNTY, ILLINOIS.

other parcels were acquired at an original total price of $556. After the highway was built, a mortgage holder started foreclosure proceedings and the county had to settle for an additional $4,500. These instances occurred before Du Page County inaugurated its present effective system of title searching. In isolated instances additional payments were made for damages not anticipated. County authorities were willing to give additional compensation as a matter of equity

CONDEMNATION PROCEEDINGS TO BE AVOIDED IF POSSIBLE

If lands cannot be purchased through voluntary negotiation, they must be acquired forcibly through court action. In acquiring more than a thousand acres of land for the Three-State Highway right-of-way, 6 percent had to be condemned. Milwaukee County made the best record by acquiring only 3.4 percent through court proceedings (table 3). Of the 835 parcels acquired, 31 or 3.7 percent had to be condemned. This proportion is not inconsistent with that found on other highway projects. Details concerning costs in condemnation cases are shown in tables 14 and 15.

The condemnation data show that the average condemnation proceedings are likely to add three or four hundred dollars [11] to the total costs of an acquisition. The costs include compensation for witnesses, experts, commissioners, court reporters, and publication services. If there is obstinacy in controversy over values it may be advantageous in some cases for highway authorities to compromise by offering an amount somewhat in excess of the appraised value of a property rather than resort to court action.

[11] This estimate is probably much lower than actual average costs. In many instances investigated, even approximate data on condemnation costs were unavailable.

TABLE 12.—*General and special incidental costs of all acquisitions*

State and County	Total	Cost per frontage mile	General [1]	Special [2]
Grand total	$23,669	$189	$14,369	$9,300
Wisconsin	15,639	299	7,651	7,988
Milwaukee	9,378	485	4,213	5,165
Racine	5,205	323	2,531	2,674
Kenosha	1,056	62	907	149
Illinois	8,030	110	6,718	1,312
Lake	657	24	657	
Cook	1,781	245	1,781	
Du Page	5,592	145	4,280	1,312

[1] Consists of title search, recording fees, and appraisal fees.
[2] Consists of commissioners' fees, witness fees, court costs, and other miscellaneous fees.

TABLE 13.—*Number and nature of additional payments*

County	Additional payments	
	Number of parcels	Amount
Grand total	[1] 43	$22,324
For damages	6	4,225
Additional interest	9	10,951
Taxes	29	6,748
Land	2	400
Milwaukee	6	1,875
For damages	4	1,725
Additional interest	2	150
Taxes		
Land		
Racine		
Kenosha		
Lake		
Cook		
Du Page	[1] 37	20,449
For damages	2	2,500
Additional interest	7	10,801
Taxes	29	6,748
Land	2	400

[1] This total is not derived by simple addition since there is overlapping of items.

MARGINAL LAND ACQUISITION USED TO ADVANTAGE

Marginal land acquisition, or "excess condemnation" as it is popularly called, is the acquisition of land and property exceeding the immediate physical needs for a highway improvement, but having definite economic utility in connection with the enterprise. In connection with the Three-State Highway, 42 parcels of marginal land were purchased, aggregating 25.6 acres, at an estimated aggregate cost of $30,823. The land was largely in Du Page County, Ill. Of this land, 14.7 acres were traded for other lands needed for highway purposes, 0.6 acre was sold, 2.7 acres were transferred to other governmental agencies, and 7.6 acres remained in county ownership, as indicated in table 16.

TABLE 14.—*Cost histories of condemnation cases*

County, tract and parcel number	Amount offered	Amount asked	Final settlement	Incidental cost	Aggregate cost
Milwaukee:					
15.1			$2,050	$572	$2,622
16.8	$250		320	295	615
16.9, etc	7,500	$20,000	8,423	1,695	10,118
17.10	6,500	14,000	7,940	1,609	9,549
17.11	7,500	15,000	8,919	2,676	11,595
20.2	3,500	9,000	3,450	1,453	4,903
Racine:					
21.6	300	1,000	484	355	839
21.7	2,098		2,750	20	2,770
23.8, 25.1	1,500	3,500	2,669	517	3,186
24.6	2,750		3,916	226	4,142
25.6	238	1,000	1,000	1	1,001
25.9, 27.1	4,214	8,320	5,499	469	5,968
27.2, 27.3	1,000	5,000	2,051	342	2,393
28.5	500	5,000	2,164	322	2,486
28.6	1,200	5,000	2,257	315	2,572
30.2	1,000		2,500	1	2,501
Cook, 109.5	317		422	89	511
Du Page:					
114.9			250	111	361
115.7			100	43	143
115.13	200		300	33	333
116.1, 116.2			250	43	293
117.19, etc	20,000	80,000	29,000	547	29,547
126.3			1,676	130	1,806
129.1B			4,875	30	4,905
135.4			3,999	80	4,079
135.6			3,665	80	3,745
137.23			2,300	20	2,320
138.22			2,500	22	2,522
139.1			4,956	205	5,161
146.1			3,747	30	3,777
147.6-148.3			2,826	230	3,056

Surplus lands were purchased for a variety of reasons. In Milwaukee County, Wis., marginal land was purchased and later traded to obtain a portion of a school district property needed for highway right-of-way. The county had purchased land contiguous to the highway and traded it for a portion of school district property lying within the proposed right-of-way.

In Du Page County, Ill., the highway damaged the sewage disposal plant of the city of Elmhurst. The county obtained a large tract of land near the city limits, retained the portion necessary for highway right-of-way and traded a portion of the balance for the land of the city's sewage disposal plant and for land being held for a potential city park. The county purchased another tract which it expected to trade for other lands needed for right-of-way, but the deal was never consummated and the county still retains this marginal land. Five other tracts were purchased because of the possibility of a future grade separation. A total of 2.7 acres of marginal lands was donated by the county to the Illinois State Forest Preserves. In five instances surplus land was sold to private individuals.

Some surplus land was purchased by Du Page County to avoid the payment of large amounts of consequential

TABLE 15.—*Area and cost of parcels acquired through condemnation*

County	Total			Elements of cost											
				Land	Damage			Incidental							
	Number of parcels	Area in acres	Cost	Total	Total	Improvement	Consequential	Total	Recording	Appraisal	Title search	Stenographer	Commissioner	Witness	Miscellaneous
Grand total	31	64.54	$129,813	$36,959	$80,298	$39,552	$40,746	$12,556	$126	$4,725	$99	$247	$2,695	$3,851	$813
Milwaukee	6	3.77	39,401	5,296	25,806	25,637	169	8,299	2	3,338	7		2,025	2,849	78
Racine	10	10.84	27,858	2,158	23,131	12,788	10,343	2,569	1	983	12	247	670	627	29
Kenosha															
Lake															
Cook	1	2.11	512	422				90	13	29	48				
Du Page	14	47.82	62,042	29,083	31,361	1,127	30,234	1,598	110	375	32			375	706

TABLE 16.—*Analysis of marginal land acquisition*

County, tract and parcel numbers	Aquisition		Disposition
	Area in square yards	Estimated cost	
Milwaukee:			
4.5	780	$360	Held.
12.6	3,652	1,499	Traded.
Racine: 28.3	431	18	Held.
Kenosha			
Lake: 89.1, 90.1	5,313	110	Held, remnant.
Cook: 151.12, etc	44	2	Held.
Du Page:			
116.19, 116.20	363	148	Held.
116.21	362	130	Held.
121, 122.11c	774	56	Held.
122.23, etc	3	2	Held for future grade separation.
122.24	181	196	Held for future grade separation.
122.25	130	117	Held for future grade separation.
122.26	155	149	Held for future grade separation.
122.27	782	1,018	Held for future grade separation.
123.12	1,310	129	Held.
123.13	66,792	7,529	Traded.
125.3	3,550	50	Held.
125.6	12,889	572	Donated to forest preserve.
136.26	329	331	Held.
136.27	953	330	Held.
136.29	953	300	Traded.
137.9	16	11	Held, remnant.
137.10	69	85	Held, remnant.
137.11	12,541	8,002	Held.
137.12	51	55	Held.
138.7	17	39	Held.
138.8	916	1,990	Held. offer to trade rejected.
138.10	314	330	Held.
138.11	407	665	Sold.
138.13	751	656	Sold.
138.14	731	644	Sold.
138.16	610	696	Sold.
138.17	596	571	Sold.
138.18	580	997	Held.
138.19	1,674	1,365	Held.
139.3	111	31	Held.
139.4	167	46	Held.
139.8	316	91	Held.
139.10	2,778	863	Held.
140.10	250	198	Held.
140.14	534	154	Held.
140.19	24	21	Held.
140.21	929	267	Held.
Grand total	124,121	30,823	

damage claimed because of severance and impairment of plottage values. In several instances where Du Page County felt that the probable cost of "bare" land plus the damages, including those for consequential injuries, approached the value of the entire tract or parcel, the county purchased the whole tract. Figure 9 shows examples of such takings. Because of the limitations of the sample and the many variables involved, it is unwise to draw conclusions from the marginal land activities in Du Page County. All marginal land was acquired through purchase.

HIGHWAY WIDENING VS. HIGHWAY RELOCATION

The attention of highway authorities has been focused for some time upon the economics of highway widening and highway relocation. Analysis of the cost of widening and relocating sections of the Three-State Highway seems to indicate that land acquisition costs of widening are considerably greater than those of relocation. The most striking illustrations of this difference in cost is found in Kenosha County, Wis., and Du Page County, Ill.

Four miles of the highway in northern Kenosha County coincided with the existing U S 41, which was widened from 66 feet to 120 feet. A 5-mile section in that county was on new location with a 120-foot right-of-way. The total cost on the widened portion averaged $6,404 per mile, of which $5,521 constituted damage payments. The total cost on the relocated portion averaged only $3,752 per mile, of which $2,260 constituted damage costs. It was expected that the

FIGURE 8.—AN EXAMPLE OF CONSEQUENTIAL DAMAGE RESULTING FROM A CHANGE OF GRADE. THIRTY-FOUR HUNDRED DOLLARS WAS ALLOWED AS DAMAGES TO THIS CORNER PROPERTY, IN THE SOUTHERN PORTION OF MILWAUKEE COUNTY.

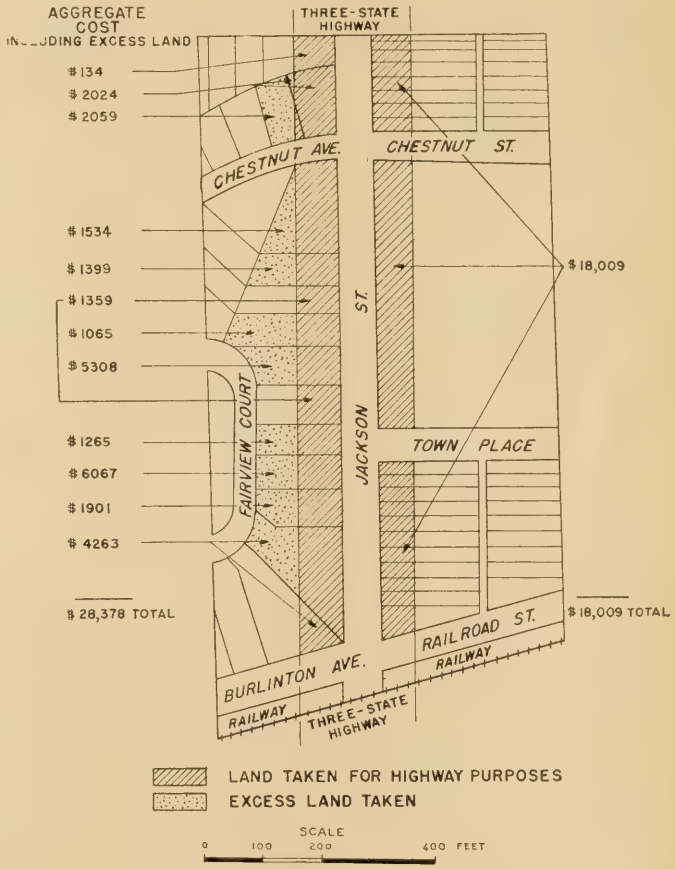


FIGURE 9.—LOCATION OF EXCESS LAND ACQUIRED ON 1,000 FEET OF HIGHWAY IN THE VILLAGE OF CLARENDON HILLS, DU PAGE COUNTY.

land costs for the 120-foot width required on new location would exceed those for the 54-foot width required for widening. The areas traversed by these sections of highway were similar in all essential respects, and the properties were acquired at the same time by the same agencies under similar conditions.

Another instance of the relative economy of relocation is found in Du Page County, Ill. Figure 10 shows the location and surrounding conditions. A considerable portion of the existing street, 100 feet wide, in the city of Bensonville, was widened to 200 feet, 50 feet

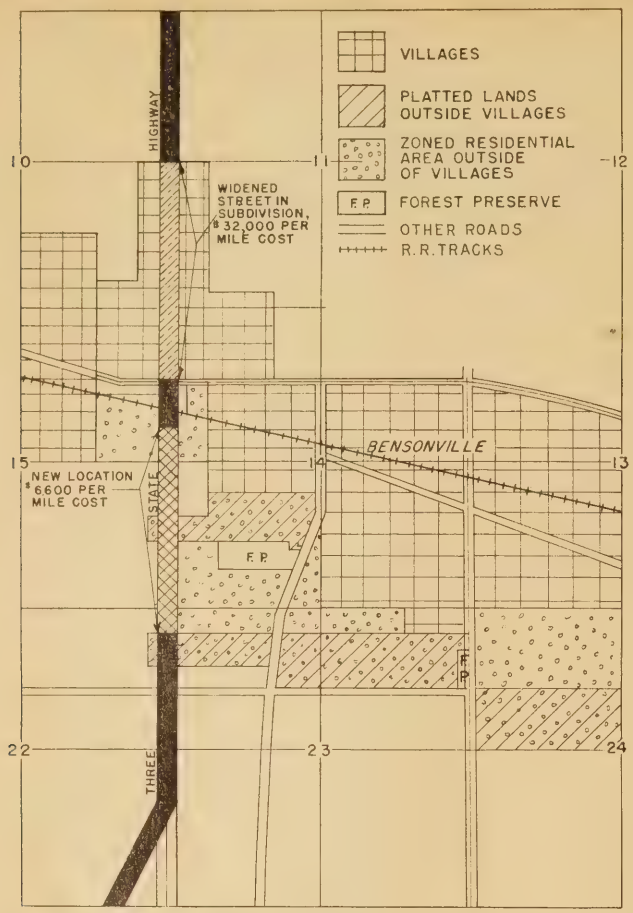


FIGURE 10.—COMPARISON OF COST OF SECTIONS OF THE HIGHWAY, ONE ON NEW LOCATION AND THE OTHER ON AN EXISTING ROAD THAT WAS WIDENED.

being taken on eah side, at a total cost of approximately $32,000 per mile. This was "raw" subdivision territory, without other development in the area than the startling presence of occasional fire hydrants in vacant lots. Immediately south of the tracks of the Chicago, Milwaukee, St. Paul and Pacific Railroad, the highway was relocated through unplatted territory for a distance of some 3,000 feet. A 200-foot right-of-way was obtained at an approximate total cost of $6,600 per mile. The nature of the land traversed by these two sections of highway was the same in all essential respects except that the property taken for widening was subdivided land and that taken for relocation was unplatted. Acquisition costs for widening, on a per mile basis, were almost five times as great as those for relocation.

GLOSSARY OF TERMS

Terms used in this study are defined as follows:

1. *Access, right of.*—The right of reasonable and convenient ingress to and egress from property to a given highway in addition to the public easement in that highway. This is a right incident to the ownership of abutting land and generally cannot be impaired or taken away without just compensation.

2. *Agricultural land.*—Land and structures used predominantly for farming or truck gardening.

3. *Commercial land.*—Land and structures used predominantly for retail or wholesale business.

4. *Commissioner's fees.*—Amounts of money paid a person acting as a member of a board in adjudicating the compensation to be paid a property owner as a result of land acquisition for a highway enterprise.

5. *Consequential damages.*—Amounts of money paid to a property owner for damages to the remainder of his land as a result of decrease in site value, deprivation of lateral support, grade change, loss of access, severance, etc., caused by a highway development.

6. *Decrease in site value.*—A consequential damage resulting from the acquisition of land in such a way as to prevent or hinder the continuation of a former land use.

7. *Deprivation of lateral support.*—A consequential damage resulting from the construction of grade separations or the excavation of deep cuts which may destroy natural support and cause earth to crumble, sink, or fall away.

8. *Donation.*—The voluntary conveyance of an interest or title in realty without the passing of any real consideration to the grantor.

9. *Grade change.*—A change in the elevation or level of a highway causing it to be above or below the elevation of an existing roadway or of abutting property.

10. *Improvement damages.*—Amounts of money paid for damage to structures, trees, fences, lawns, crops, etc., caused by a given acquisition.

11. *Incidental costs.*—Amounts of money paid to others than property owners for special services rendered in connection with an acquisition. Sums paid to appraisers, commissioners, registers of deeds, county clerks, title search companies, and others, are included.

12. *Industrial land.*—Land and structures used predominantly in the production of goods with labor and capital.

13. *Marginal land acquisition.*—Acquisition of land and property exceeding the immediate physical needs for a highway improvement but having definite economic utility in connection with such improvement. Popularly called "excess condemnation."

14. *Plottage value.*—That element of the worth of a tract of land which exists because of its suitability in size and quality for a given use.

15. *Population density.*—The number of persons per square mile of territory.

16. *Residential land.*—Plotted land and structures predominantly used for present or potential living purposes.

17. *Rural areas.*—Unincorporated areas having a population density of fewer than 100 persons per square mile.

18. *Rurban areas.*—Generally, rural lands enjoying urban services; the term is an amalgam of "rural" and "urban," and represents the infusion of urban culture and interest into rural life.

19. *Semipublic and public lands.*—Land and structures devoted to restricted or nonrestricted common or general use or enjoyment.

20. *Severance damage.*—A form of consequential damage resulting from the division of a tract of land by a highway enterprise in such a manner as to affect adversely the normal use of the residual areas.

21. *Structure damage.*—Amounts of money paid for the moving or destruction of any building or structure or portion thereof in connection with a highway enterprise.

22. *Suburban areas.*—Unincorporated areas having a population density of more than 100 persons per square mile.

23. *Urban areas.*—All incorporated villages and cities.

BENDING AND DIRECT STRESS IN REINFORCED CONCRETE

By W. P. LINTON, Senior Highway Bridge Engineer, and THOMAS P. REVELISE, Associate Highway Bridge Engineer [1]

Several methods for the design and analysis of rectangular sections of reinforced concrete subject to bending and direct stress are in current use. They require the use of diagrams, nomographic charts, and analytical procedures. Perhaps the most familiar method is that described in Hool and Johnson's "Concrete Engineers' Handbook" based on the use of diagrams. Each method has advantages in solving certain design problems but apparently none is sufficiently general for satisfactory use in solving all of the wide variety of problems presented in every day practice.

Most diagrams are useful mainly in analyzing, or checking, designs, rather than in original design. One must first assume the percentage of reinforcement and subsequently check this assumption. If the assumed percentage is found to be inadequate, or uneconomical, the procedure must be repeated. In checking sections containing reinforcement for tension and compression, it is generally necessary to refer to several diagrams for a complete solution. Most diagrams are further restricted in use to problems involving a few fixed proportions of reinforcement, such as equal amounts of steel in top and bottom of a section, and steel in compression one-half that in tension, etc. Often in actual practice the amount of steel required in tension is not an exact multiple of the amount in compression, and in many cases relatively small variations in the amount of reinforcement produce substantial variations in the stresses.

Heretofore analytical procedures have been much favored by engineers for designing sections with tensile and compressive reinforcement to carry bending and direct stress. They are used to some extent for analysis. The design procedure consists usually in the assumption of f_c, the compressive unit stress in the extreme fiber of concrete, and p', the ratio of the area of compressive reinforcement to the effective area of the section, bd, and computation of p, the ratio of the area of tensile reinforcement to the effective area of the section, and f_s, the tensile unit stress in the longitudinal reinforcement, such that $\Sigma H=0$ and $\Sigma M=0$ for the section. The limitation inherent in this and similar analytical procedures arises from the fact that with the dimensions of the section, the moment, the direct force and f_c fixed, an infinite number of consistent values of p, p', f_s, and f'_s exist. For example, suppose a rectangular section 18 inches wide and 20 inches deep were subjected to a bending moment of 800,000 inch-pounds and a direct force of 50,000 pounds, and that f_c were arbitrarily fixed at 1,000 pounds per square inch. The distance from centerline of steel to face of concrete is 2 inches. The following are three of the unlimited number of combinations that satisfy the given conditions:

(*a*) $p=0.0145$; $p'=0.0000$; $f_s=7{,}800$ pounds per square inch; $f'_s=0.000$ pounds per square inch.

(*b*) $p=0.0075$; $p'=0.0058$; $f_s=12{,}700$ pounds per square inch; $f'_s=7{,}750$ pounds per square inch.

(*c*) $p=0.0040$; $p'=0.0140$; $f_s=21{,}000$ pounds per square inch; $f'_s=6{,}900$ pounds per square inch.

Obviously, a rational design by conventional methods requires more than one determination to find the optimum combination, making the procedure tedious and time-consuming.

The diagrams presented as plates 1 to 5 are believed to provide a unique method for the design and analysis of rectangular sections of reinforced concrete subject to the following conditions:

(*a*) Simple bending, with tensile reinforcement only.

(*b*) Simple bending, with tensile and compressive reinforcement.

(*c*) Bending and direct stress, tension on part of the section, with tensile reinforcement only.

(*d*) Bending and direct stress, tension on part of the section, with tensile and compressive reinforcement.

These conditions cover most of the problems encountered in the design of rectangular sections of reinforced concrete, including simple beams, eccentrically loaded columns, rigid frames and arches (in which the usual procedure is to analyze an element of unit width) culverts, and other indeterminate type structures.

The diagrams have received extensive trial in the design of reinforced concrete highway bridges, and have been found to reduce by more than one-half the amount of time usually consumed in similar computations by other methods. It is believed that they will save considerable time for concrete designers and checkers, particularly those whose work occasionally involves making a number of determinations of this type.

Although there are numerous aids in solving problems in simple bending, including tables, diagrams and formulas, problems in this category may be solved so readily by use of the diagrams that illustrative examples will be given. The examples are arranged in the order of the conditions stated above, with an example in the design procedure followed by an example in the analytical procedure. To use the curves in design it is not necessary to go into the derivation of the formulas from which they were developed. The examples given illustrate methods of use. However, many readers will wish to trace the mathematical development of the methods in order to judge their accuracy.

DERIVATION OF GENERAL EQUATIONS

The major point of difference between this and other methods lies simply in the generalization of conventional formulas. The accepted theory of bending in reinforced concrete is adhered to without modification. Standard symbols are used throughout with the excep-

[1] The basic idea for the diagrams presented in this article was developed by W. P. Linton. Thomas P. Revelise collaborated in further improvements and prepared the diagrams and discussion for publication. Acknowledgment is due Logan L. Ratliff, associate highway bridge engineer, for valuable assistance with the computations and lay-out work.

tion of B and C which represent composite terms having no exact counterpart in current usage. The standard symbols are defined as follows:

f_c = compressive unit stress in extreme fiber of concrete, pounds per square inch.

f_s = tensile unit stress in longitudinal reinforcement, pounds per square inch.

f'_s = compressive unit stress in longitudinal reinforcement, pounds per square inch.

p = ratio of area of tensile reinforcement to effective area of section.

p' = ratio of area of compressive reinforcement to effective area of section.

n = ratio of modulus of elasticity of steel to that of concrete.

k = ratio of distance between extreme fiber of concrete in compression and neutral axis, to the effective depth, d.

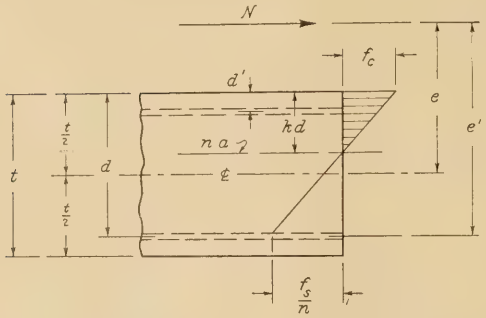


FIGURE 1.—DIAGRAM FOR USE IN DERIVING EQUATIONS.

Referring to figure 1, and utilizing two of the conditions of static equilibrium, $\Sigma M=0$ and $\Sigma H=0$, the following may be deduced:

$$\frac{1}{2}f_c bkd^2\left(1-\frac{1}{3}k\right)+nf_c p'bd^2\left(\frac{k-\frac{d'}{d}}{k}\right)\left(1-\frac{d'}{d}\right)=Ne'$$

$$\frac{1}{2}k\left(1-\frac{1}{3}k\right)+np'\left(\frac{k-\frac{d'}{d}}{k}\right)\left(1-\frac{d'}{d}\right)=\frac{Ne'}{f_c bd^2} \quad (1)$$

$$\frac{1}{2}f_c bkd+nf_c p'bd\left(\frac{k-\frac{d'}{d}}{k}\right)-nf_c pbd\left(\frac{1-k}{k}\right)=N$$

$$\frac{1}{2}k+np'\left(\frac{k-\frac{d'}{d}}{k}\right)-np\left(\frac{1-k}{k}\right)=\frac{N}{f_c bd} \quad (2)$$

Multiplying (2) by $1-\frac{d'}{d}$:

$$\frac{1}{2}k\left(1-\frac{d'}{d}\right)+np'\left(\frac{k-\frac{d'}{d}}{k}\right)\left(1-\frac{d'}{d}\right)-np\left(\frac{1-k}{k}\right)\left(1-\frac{d'}{d}\right)=\frac{N}{f_c bd}\left(1-\frac{d'}{d}\right) \quad (3)$$

Subtracting (3) from (1):

$$-\frac{1}{6}k^2+\frac{1}{2}k\frac{d'}{d}+np\left(\frac{1-k}{k}\right)\left(1-\frac{d'}{d}\right)=\frac{Ne'}{f_c bd^2}-\frac{N}{f_c bd}\left(1-\frac{d'}{d}\right) \quad (4)$$

from (1): $$p'=\frac{\frac{Ne'}{f_c bd^2}-\frac{1}{2}k\left(1-\frac{1}{3}k\right)}{n\left(\frac{k-\frac{d'}{d}}{k}\right)\left(1-\frac{d'}{d}\right)} \quad (5)$$

from (4): $$p=\frac{\frac{N}{f_c bd}\left(\frac{e'}{d}-1+\frac{d'}{d}\right)+\frac{1}{2}k\left(\frac{1}{3}k-\frac{d'}{d}\right)}{n\left(\frac{1-k}{k}\right)\left(1-\frac{d'}{d}\right)} \quad (6)$$

Let $\frac{Ne'}{f_c bd^2}=B$, and $\frac{N}{f_c bd}\left(\frac{e'}{d}-1+\frac{d'}{d}\right)=C$

from (5): $$p'=\frac{k}{n\left(k-\frac{d'}{d}\right)\left(1-\frac{d'}{d}\right)}\left[B-\frac{1}{2}k\left(1-\frac{1}{3}k\right)\right] \quad (7)$$

from (6): $$p=\frac{k}{n(1-k)\left(1-\frac{d'}{d}\right)}\left[C+\frac{1}{2}k\left(\frac{1}{3}k-\frac{d'}{d}\right)\right] \quad (8)$$

Equations (7) and (8) were used in the form given for plotting the curves, and five individual diagrams were prepared, based on the value of $n=10$, and values of $\frac{d'}{d}=0.05$, 0.10, 0.15, 0.20, and 0.25. This fixed the values of n and $\frac{d'}{d}$ for each diagram, leaving as variables p, p', k, B and C. Since the values of p, p', and k are interdependent, it was possible to plot a series of curves for various values of B with values of p' as abscissas and values of k as ordinates, and adjacent to this, a series of curves for C with values of p as abscissas and the k-axis common to both diagrams. This arrangement, with the related stress curves, results in a diagram of unusual versatility and simplicity of operation.

PROCEDURE IN DESIGN AND ANALYSIS

Using the known data in a given problem, assign the desired value of f_c and compute values of B and C using the simplified formulas given on each diagram. Select the diagram based on the proper value of $\frac{d'}{d}$ and place a straightedge (a transparent triangle is suggested) parallel to the horizontal grid lines and within the range of curves representing computed values of B and C. At the intersections of this horizontal line with curves representing computed values of B and C read the values of corresponding abscissas for values of p and p'. Locate the intersection of the

horizontal line with the ordinate through the assigned value of f_c at the right of the diagram. The curve passing through this point (actual or visualized as an interpolation) indicates the appropriate value of f_s. The value of f'_s is similarly determined using the ordinate for f_c at the left of the diagram. Shift the straightedge up or down, maintaining it parallel to the horizontal grid lines, and note by inspection the variations in the values, then select the desired group of values. In all uses of a straightedge on the diagrams the straightedge is kept horizontal or parallel to the x-axis.

When tensile reinforcement only is used, a diagram may be selected at random for solution of the problem without regard to the particular value of $\frac{d'}{d}$ on which it is based. This applies to problems in bending and direct stress as well as those involving only simple bending.

The procedure for problems in simple bending is exactly the same as that set forth for problems in bending and direct stress except that in all cases of simple bending, $B=C$, and the expression for B (or C) becomes

$$\frac{M}{f_c bd^2} \text{ instead of } \frac{Ne'}{f_c bd^2}.$$

The analytical procedure requires an approach differing from that used in design, but its application is no less simple and general. One of the factors sought, f_c, is also contained in the expressions for B and C, hence these terms cannot be evaluated as in the design procedure. It is evident, however, that since f_c has one value only in the design to be analyzed, the ratio, $\frac{B}{C}$, likewise can have but one value. This ratio may be evaluated from the simplified formula given on each diagram. For example, suppose a section is to be analyzed for which the value of $\frac{d'}{d}=0.10$. Looking at the top of the diagram based on this value we observe $C=B\left(\frac{e'-0.90d}{e'}\right)$. For bending and direct stress, therefore, the expression for $\frac{B}{C}$ would become simply the inverse of the expression in parentheses, or $\frac{e'}{e'-0.90d}$. Since $B=C$ in all cases of simple bending, the value of $\frac{B}{C}$ for problems in this category becomes unity.

Having evaluated $\frac{B}{C}$, place a straightedge parallel to the horizontal grid lines, shift vertically along the two ordinates through the given values of p and p', and, by trial, locate the position at which simultaneous values of B and C give the computed $\frac{B}{C}$ ratio. The value of B indicated at this position is inserted in the equation $B=\frac{Ne'}{f_c bd^2}$ (for bending and direct stress), or $B=\frac{M}{f_c bd^2}$ (for simple bending), and f_c is computed. Keep the straightedge in the same position and locate its intersections with ordinates through the computed value of f_c at the right and left of the diagram. The curves (actual or visualized) passing through these points indicate values of f_s and f'_s.

In applying this procedure, it will be observed that the values of $\frac{B}{C}$ converge rapidly in a continuous function, and that the desired ratio may be obtained quickly in all cases.

In using the diagrams to design sections requiring tensile reinforcement only, one occasionally finds a case in which the steel, rather than the concrete, controls the design, that is, having assumed f_c and evaluated B, f_s is observed to exceed the allowable value. For that reason, the following procedure is suggested for design involving tensile reinforcement only.

Assign the allowable value for f_c, and compute B, preferably on the slide rule. Manipulate the rule in such manner that the last operation in obtaining the value of B is division by f_c. Before evaluating C, place the straightedge horizontally so it will pass through the point where the curve representing the tentative value of B is intersected by the ordinate for the value of $p'=0$ and check f_s at the intersection of the straightedge with the ordinate through assumed value of f_c. If f_s is found to exceed the allowable value, shift the slide rule setting to a lower value of f_c, place the straightedge to pass through the point indicated by the new value of B and read f_s at the intersection of the straightedge with the ordinate through new value of f_c. In this manner, the diagram position for the desired steel stress is obtained rapidly. Now compute the value of C, and obtain p at the intersection of the straightedge in its final position with the curve corresponding to the computed value of C.

Values of k, which may be read on the center vertical axis, are not essential to the use of the diagram in either design or analysis, but are indicated as a convenience to the user who may require these data occasionally for special purposes.

The use of the diagrams is more clearly demonstrated by actual illustrative examples, several of which follow. A careful reading and comparison of these examples will show the simplicity of use and a general similarity of application to all cases. The most involved problems may be solved in approximately the same amount of time as that required for the simplest.

Example 1.—Simple Bending With Tensile Reinforcement Only; Balanced Design.—Given: A member is subjected to a bending moment of 1,000,000 inch-pounds. Design the section with tensile reinforcement only, such that $f_c=800$ pounds per square inch and $f_s=18{,}000$ pounds per square inch.

Solution: Since tensile reinforcement only is to be used any one of the diagrams may be selected.

Place a straightedge parallel to the horizontal grid lines so it will pass through the intersection of lines representing $f_c=800$ pounds per square inch and $f_s=18{,}000$ pounds per square inch. On the vertical line at which $p'=0$ (the center axis) read $B=.138$. For simple bending, $B=C$. Therefore follow back along

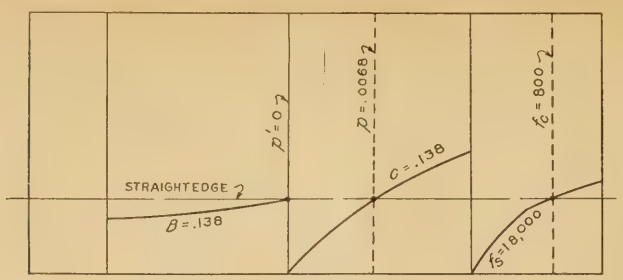


FIGURE 2.—DIAGRAM FOR USE WITH EXAMPLE 1.

the straightedge to the intersection with $C=.138$, and read vertically downward $p=.0068$.

From the formula for B for simple bending, given on each diagram, $B=\frac{M}{f_c bd^2}$ we obtain:

$$bd^2=\frac{M}{Bf_c}=\frac{1{,}000{,}000}{.138\times 800}=9{,}050$$

The section may now be proportioned as desired, and the area of reinforcement obtained by multiplying the value of effective area of the section, bd, by the value of p.

Example 2.—Simple Bending With Tensile Reinforcement Only; Analysis.—Given: A member 15 inches wide and 27 inches deep is subjected to a bending moment of 900,000 inch-pounds. Reinforcement consists of two 1-inch square bars. The distance from face of concrete to centerline of steel is 2 inches. Find f_c and f_s.

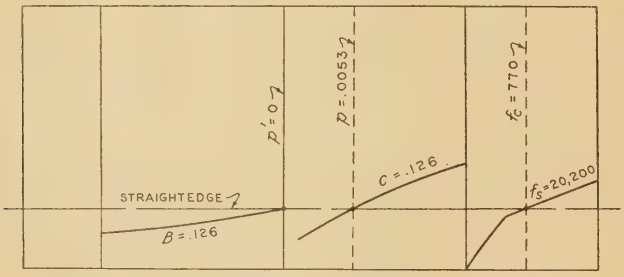


FIGURE 3.—DIAGRAM FOR USE WITH EXAMPLE 2.

Solution: Select any diagram. From the given data, $p'=0$ and $p=.0053$. For simple bending, $B=C$. Shift the straightedge along the vertical lines representing the values of p' and p, and, by trial, locate the position at which the value of B equals the value of C. This fulfills the condition that the ratio $\frac{B}{C}=1$ for simple bending. Using the given data, the value of B at this position is found to be .126. From the expression $B=\frac{M}{f_c bd^2}$ for simple bending, we obtain:

$$f_c=\frac{M}{Bbd^2}=\frac{900{,}000}{.126\times 15\times 25^2}=770 \text{ pounds per square inch.}$$

With the straightedge held in its last position note that it intersects the vertical line representing $f_c=770$ pounds per square inch at $f_s=20{,}200$ pounds per square inch.

Example 3.—Simple Bending With Tensile and Compressive Reinforcement; Design.—Given: A member 10 inches wide and 18 inches deep is subjected to a bending moment of 363,000 inch-pounds. The distance from face of concrete to centerline of steel is to be 3 inches. Allowable stresses, $f_c=850$ pounds per square inch, and $f_s=16{,}000$ pounds per square inch. Design the reinforcement.

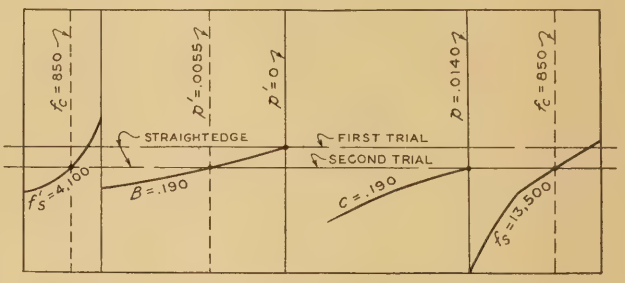


FIGURE 4.—DIAGRAM FOR USE WITH EXAMPLE 3.

Solution: $\frac{d'}{d}=\frac{3}{18-3}=0.20$. Therefore, use the diagram based on this value.

$$B=\frac{M}{f_c bd^2} \text{ (for simple bending)}=\frac{363{,}000}{850\times 10\times 15^2}=0.190$$
$$C=B \text{ (for simple bending)}=0.190$$

First investigate the section for tensile reinforcement only by placing the straightedge at the intersection of lines corresponding to $B=0.190$ and $p'=0$. Follow back along the straightedge to the intersection with the curve for $C=0.190$ and read vertically downward to obtain the value of p. It is evident that the value of p will be considerably in excess of .0140 as the required intersection lies well outside the limit of the curves for C. Now shift the straightedge downward to the intersection, say, of lines corresponding to $C=0.190$ and $p=.0140$. At the intersection with the curve $B=0.190$ read $p'=.0055$, and at the intersections with the ordinates representing $f_c=850$ pounds per square inch read $f_s=13{,}500$ pounds per square inch and $f'_s=4{,}100$ pounds per square inch.

By thus shifting the straightedge up or down, similar consistent values of p, p', f_s and f'_s may be obtained by inspection.

Example 4.—Simple Bending With Tensile And Compressive Reinforcement; Analysis.—Given: A member 12 inches wide and 15 inches deep is subjected to a bending moment of 300,000 inch-pounds. Reinforcement consists of two 1-inch square bars in tension and one 1-inch square bar in compression. The distance from face of concrete to centerline of steel is 3 inches. Find f_c, f_s and f'_s.

Solution: $\frac{d'}{d}=\frac{3}{15-3}=0.25$. Therefore use the diagram based on this value. From the given data, $p=.0139$ and $p'=.0070$. For simple bending, $\frac{B}{C}=1$. Shift the straightedge along the vertical lines representing the above values of p and p' and, by trial, locate the position at which $B=C$. The value of B at this

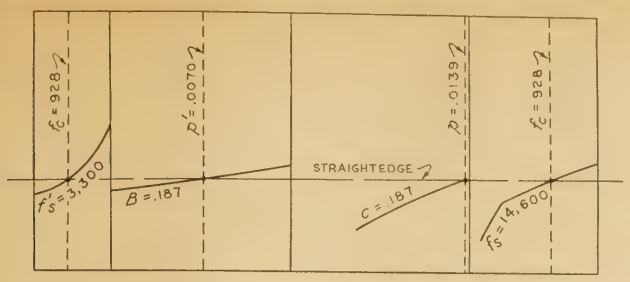


FIGURE 5.—DIAGRAM FOR USE WITH EXAMPLE 4.

position is found to be 0.187. From the expression for simple bending, $B=\frac{M}{f_c bd^2}$ we obtain

$$f_c=\frac{M}{Bbd^2}=\frac{300{,}000}{.187\times12\times12^2}=928 \text{ pounds per square inch.}$$

With the position of the straightedge unchanged, at the intersection with the vertical lines representing f_c= 928 pounds per square inch, read f_s=14,600 pounds per square inch and f'_s=3,300 pounds per square inch.

Example 5.—Bending and Direct Stress With Tensile Reinforcement Only; Design.—Given: A member 12 inches wide and 15 inches deep is subjected to a bending moment of 161,000 inch-pounds and a normal force of 7,160 pounds. The distance from face of concrete to centerline of steel is 3 inches. Allowable stresses, f_c=800 pounds per square inch and f_s=18,000 pounds per square inch. Design for tensile reinforcement only.

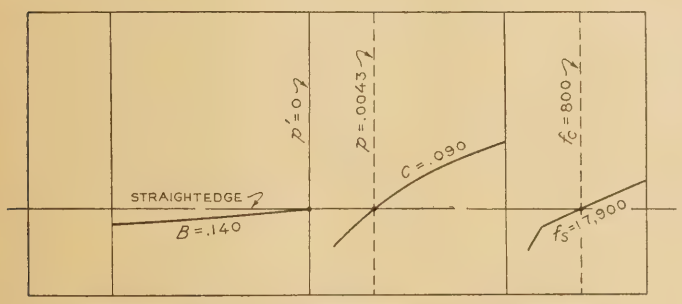


FIGURE 6.—DIAGRAM FOR USE WITH EXAMPLE 5.

Solution: Any one of the diagrams may be used. For this solution, the diagram based on $\frac{d'}{d}$=0.20 is selected.

From the given data, $e=\frac{M}{N}$=22.5 inches, d=12 inches and e'=27 inches.

$$B=\frac{Ne'}{f_c bd^2}=\frac{7{,}160\times27}{800\times12\times12^2}=0.140$$

$$C=B\left(\frac{e'-0.80d}{e'}\right)=0.140\left(\frac{27-9.6}{27}\right)=0.090$$

Place a straightedge on the diagram passing through the intersection of lines representing p'=0 and B=.140. Follow back along the straightedge to the intersection with the curve for C=0.090, and read vertically downward to obtain p=.0043. At the intersection with the ordinate for f_c=800 pounds per square inch read f_s=17,900 pounds per square inch.

Example 6.—Bending and Direct Stress With Tensile Reinforcement Only; Analysis.—Given: A member 15 inches wide and 22 inches deep is subjected to a bending moment of 500,000 inch-pounds and a normal force of 15,150 pounds. Reinforcement consists of 2 1-inch square bars in tension. The distance from face of concrete to centerline of steel is 2 inches. Find f_c and f_s.

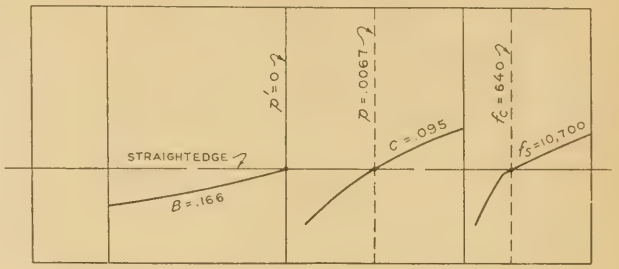


FIGURE 7.—DIAGRAM FOR USE WITH EXAMPLE 6.

Solution: Any one of the diagrams may be used. For this solution, the diagram based on $\frac{d'}{d}$=.10 is selected.

From the given data, $e=\frac{M}{N}$=33 inches, d=20 inches, e'=42 inches, p'=0 and p=.0067.

$C=B\left(\frac{e'-0.90d}{e'}\right)$, whence $\frac{B}{C}=\frac{e'}{e'-0.90d}=\frac{42}{42-18}=1.75$

Shift a straightedge along the two vertical lines corresponding to p'=0 and p=.0067, and, by trial, locate the position at which $\frac{B}{C}$=1.75, the computed value.

The value of B at this position is found to be 0.166.

Using this value in the equation, $B=\frac{Ne'}{f_c bd^2}$ we have:

$$f_c=\frac{Ne'}{Bbd^2}=\frac{15{,}150\times42}{.166\times15\times20^2}=640 \text{ pounds per square inch.}$$

With the straightedge in this position, at the intersection with the ordinate for f_c=640 pounds per square inch read f_s=10,700 pounds per square inch.

Example 7.—Bending And Direct Stress With Tensile And Compressive Reinforcement; Design.—Given: A member 12 inches wide and 18 inches deep is subjected to a bending moment of 550,000 inch-pounds and a normal force of 30,000 pounds. The distance from face of concrete to centerline of steel is 3 inches. Allowable stresses, f_c=1,200 pounds per square inch and f_s=20,000 pounds per square inch. Design the reinforcement.

Solution: From the given data, $\frac{d'}{d}$=0.20, d=15 inches, $e=\frac{M}{N}$=18.3 inches, and e'=24.3 inches.

$$B=\frac{Ne'}{f_c bd^2}=\frac{30{,}000\times24.3}{1200\times12\times15^2}=0.225$$

$$C=B\left(\frac{e'-0.80d}{e'}\right)=0.225\left(\frac{24.3-12}{24.3}\right)=0.114$$

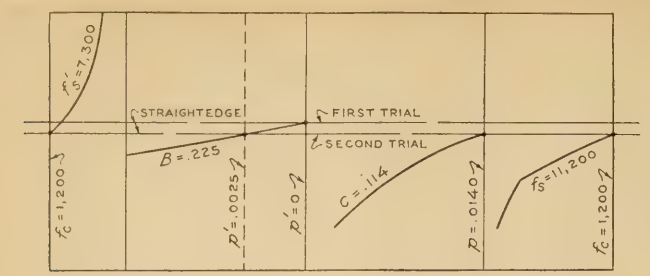


FIGURE 8.—DIAGRAM FOR USE WITH EXAMPLE 7.

First investigate the section for tensile reinforcement only by placing the straightedge at the intersection of the curve for $B=0.225$ and the ordinate $p'=0$. Follow back along the straightedge to the intersection with the curve for $C=0.114$, reading vertically downward to obtain the value of p. The required intersection lies outside the limits of the C-curves, indicating an excessive amount of tensile reinforcement. Shift the straightedge down to the intersection, say, of the curve for $C=0.114$ and the ordinate for $p=.0140$. At the intersection with the curve for $B=0.225$, read $p'=.0025$, and at the intersections with the ordinates for $f_c=1{,}200$ pounds per square inch read $f_s=11{,}200$ pounds per square inch and $f'_s=7{,}300$ pounds per square inch.

By thus shifting the straightedge up and down, similar consistent values of p, p', f_s and f'_s may be read by inspection, and the desired combination selected.

Example 8.—Bending and Direct Stress With Tensile And Compressive Reinforcement; Analysis.—Given: A member 12 inches wide and 24 inches deep is subjected to a bending moment of 600,000 inch-pounds and a normal force of 75,000 pounds. Reinforcement consists of four ⅞-inch round bars in tension and two ⅞-inch round bars in compression. The distance from face of concrete to centerline of steel is 3 inches. Find f_c, f_s and f'_s.

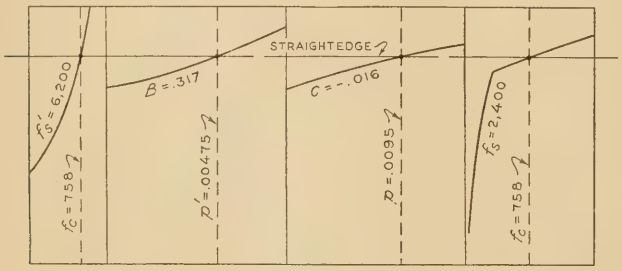


FIGURE 9.—DIAGRAM FOR USE WITH EXAMPLE 8.

Solution: From the given data, $e=\frac{M}{N}=8$ inches, $e'=17$ inches, $d=21$ inches, $p'=.00475$ and $p=.0095$.

$\frac{d'}{d}=0.15$.

$$\frac{B}{C}=\frac{e'}{e'-0.85d}=\frac{17}{17-17.85}=-20.0$$

Shift a straightedge along the two ordinates representing $p'=.00475$ and $p=.0095$, and, by trial, locate the position at which $\frac{B}{C}=-20.0$

The value of F at this position is found to be 0.317

Using this value in the equation $B=\frac{Ne'}{f_cbd^2}$ we have:

$$f_c=\frac{Ne'}{Bbd^2}=\frac{75{,}000\times17}{.317\times12\times21^2}=758 \text{ pounds per square inch.}$$

With the straightedge in this position, at the intersections with the ordinates for $f_c=758$ pounds per square inch, read $f_s=2{,}400$ pounds per square inch and $f'_s=6{,}200$ pounds per square inch.

Example 9.—Bending and Direct Stress With Tensile Reinforcement Only; Steel Controls.—Given: A member 30 inches wide and 70 inches deep is subjected to a bending moment of 876,765 foot-pounds and a normal force of 91,850 pounds. The distance from face of concrete to centerline of steel is 3 inches. Allowable stresses, $f_c=800$ pounds per square inch and $f_s=18{,}000$ pounds per square inch. Design for tensile reinforcement only.

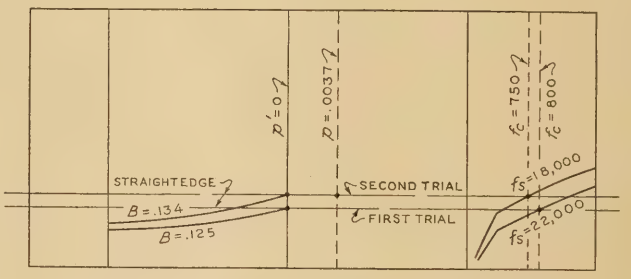


FIGURE 10.—DIAGRAM FOR USE WITH EXAMPLE 9.

Solution: Any one of the diagrams may be used. For this solution, the diagram based on $\frac{d'}{d}=0.05$ is selected. From the given data, $e=\frac{M}{N}=\frac{876{,}765}{91{,}850}\times12=115$ inches, $d=67$ inches, $N=91{,}850$, and $e'=147$ inches.

First compute B on the slide rule in such manner that the last setting is division by f_c. Place the straightedge so it will pass through the point on the curve for the value of B where the curve is intersected by the ordinate for $p'=0$, and check f_s as indicated by the intersection of the straightedge with the ordinate for $f_c=800$. If f_s is found to be excessive change the slide rule setting to a lower value of f_c and again determine the value of f_s using the ordinate for the new value of f_c. When a value of f_c giving a satisfactory value of f_s is determined, compute C and then read the value of p corresponding to the intersection of the straightedge with the curve for C.

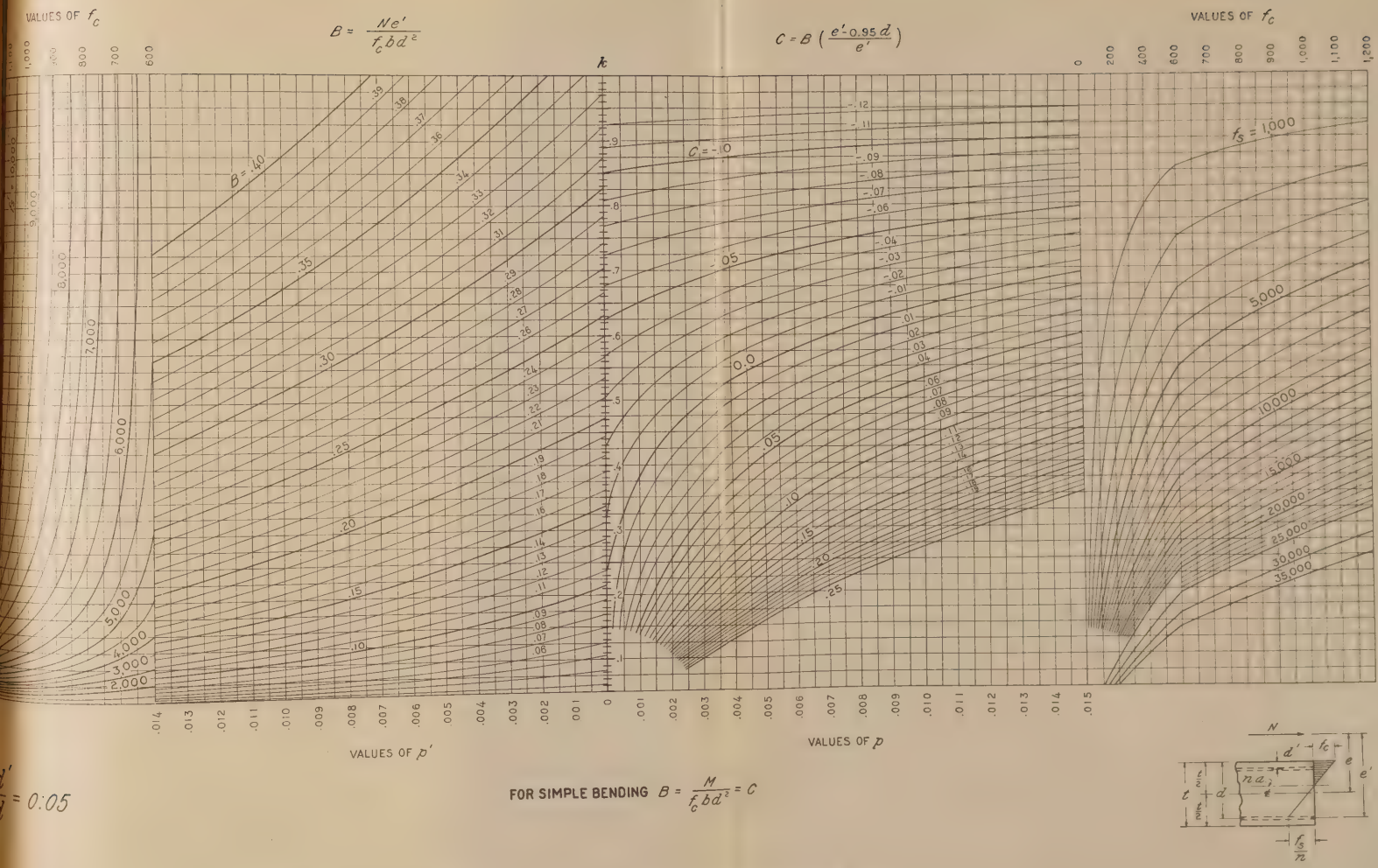
First assumption: $f_c=800$ pounds per square inch.;

$=\frac{Ne'}{f_cbd^2}=\frac{91{,}850\times147}{800\times30\times67^2}=.125$; $f_s=22{,}000$ pounds per square inch.

Second assumption: $f_c=750$ pounds per square inch.;
$B=.134$ $f_s=18{,}000$ pounds per square inch.

$$C=B\left(\frac{e'-0.95d}{e'}\right)=.134\left(\frac{147-64}{147}\right)=.076$$

At the intersection of the straightedge in its final position with the curve $C=.076$, read $p=.0037$.



$\frac{d'}{d} = 0.05$

FOR SIMPLE BENDING $B = \frac{M}{f_c b d^2} = C$

PLATE 1.—DIAGRAM FOR DESIGN AND ANALYSIS OF RECTANGULAR SECTIONS OF REINFORCED CONCRETE BASED ON $n = 10$ AND $\frac{d'}{d} = 0.05$.

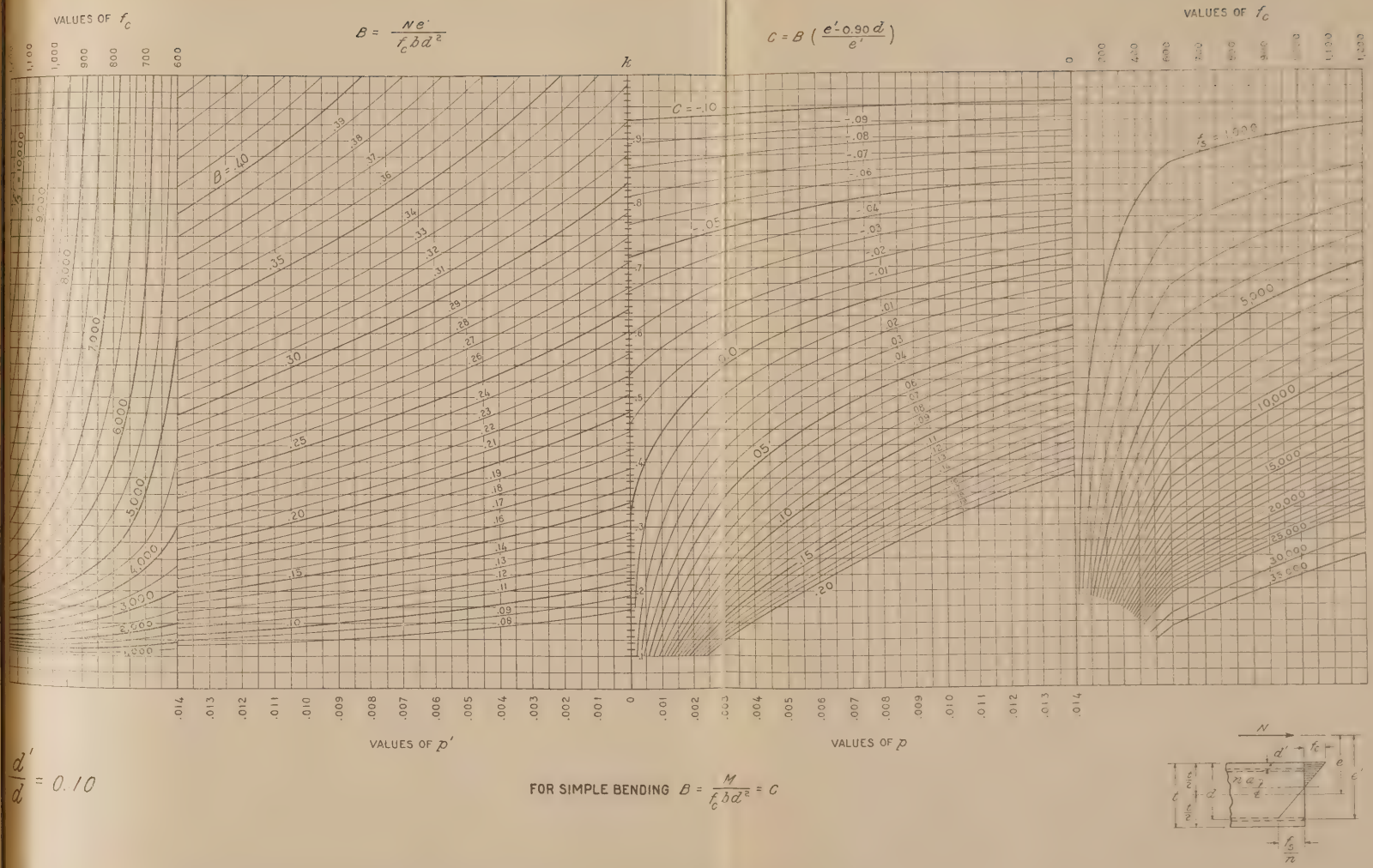
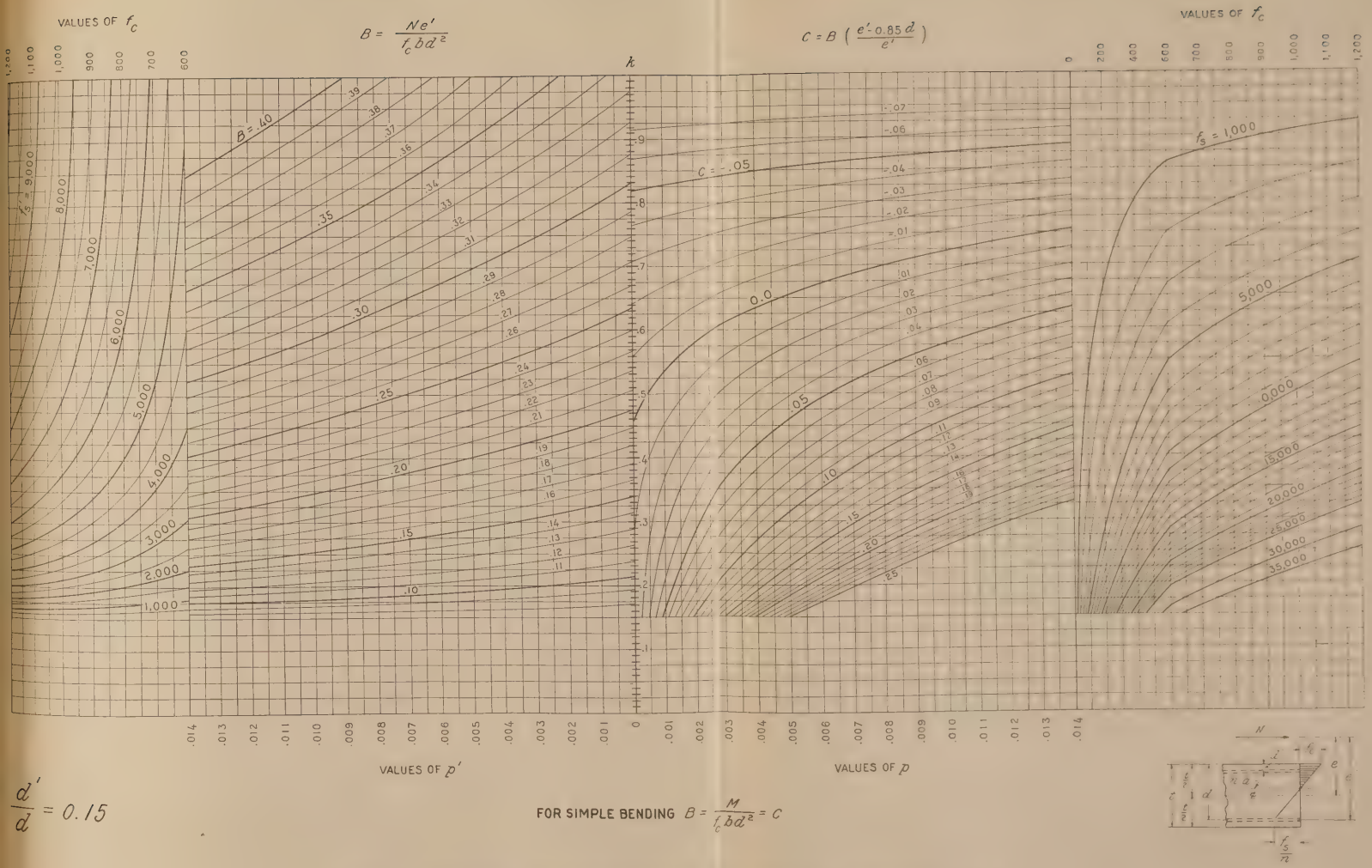


PLATE 2.—DIAGRAM FOR DESIGN AND ANALYSIS OF RECTANGULAR SECTIONS OF REINFORCED CONCRETE BASED ON $n = 10$ AND $\frac{d'}{d} = 0.10$.



$\frac{d'}{d} = 0.15$

FOR SIMPLE BENDING $B = \frac{M}{f_c b d^2} = C$

PLATE 3.—DIAGRAM FOR DESIGN AND ANALYSIS OF RECTANGULAR SECTIONS OF REINFORCED CONCRETE BASED ON $n = 10$ AND $\frac{d'}{d} = 0.15$.

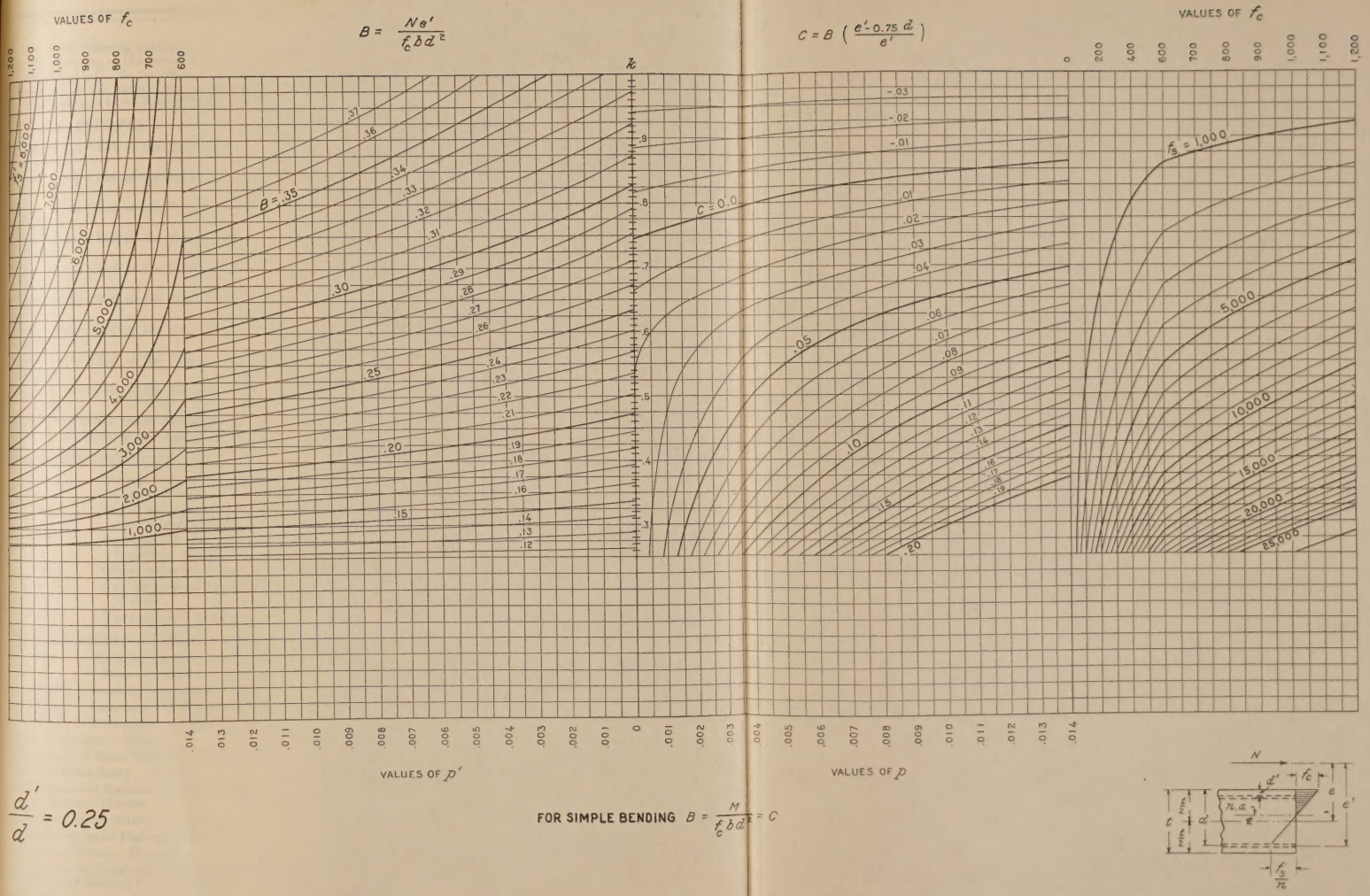


PLATE 5.—DIAGRAM FOR DESIGN AND ANALYSIS OF RECTANGULAR SECTIONS OF REINFORCED CONCRETE BASED ON $n=10$ AND $\frac{d'}{d}=0.25$.

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REPORTS IN COOPERATION WITH UNIVERSITY OF ILLINOIS

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No. 304. . . A Distribution Procedure for the Analysis of Slabs Continuous Over Flexible Beams.

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No. 314. . Tests of Reinforced Concrete Slabs Subjected to Concentrated Loads.

No. 315 . . Moments in Simple Span Bridge Slabs With Stiffened Edges.

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UNIFORM VEHICLE CODE

Act I.—Uniform Motor Vehicle Administration, Registration, Certificate of Title, and Antitheft Act.

Act II.—Uniform Motor Vehicle Operators' and Chauffeurs' License Act.

Act III.—Uniform Motor Vehicle Civil Liability Act.

Act IV.—Uniform Motor Vehicle Safety Responsibility Act.

Act V.—Uniform Act Regulating Traffic on Highways.

Model Traffic Ordinances.

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