# DEPARTMENT OF ECONOMICS, FINANCE, AND ADMINISTRATION

H. S. Fairbank, *Chairman*

# MILWAUKEE METHODS OF DETERMINING AND CONTROLLING LENGTHS OF BLOCKS AND INTERSECTIONS

Raleigh W. Gamble, *Superintendent,*
*Bureau of Street Construction and Repairs,*
*Milwaukee, Wisconsin*

## SYNOPSIS

A definite need for a positive, yet flexible, control section procedure for recording the lengths of pavements on city streets prompted the city of Milwaukee to initiate such a study in connection with its development of a simplified and systematic method of inventorying its present street system. As a result methods which are believed to be new in concept and scope have been developed for determining, controlling, computing, and recording lengths of blocks and intersections.

Before assembling data pertaining to construction features for existing streets, and historical data relating to past construction and retirement experience, it was necessary to select a method to divide the entire street system of approximately 824 miles into small, usable, basic units. The "block and intersection method," in which each block and each intersection constitutes a unit, was adopted as the most suitable. The development of this method of control sections and its application to the peculiarities of modern, city street patterns is closely linked to the development of length control procedures, and both are presented together in this discussion.

As pavement lengths and areas are the bases used in the preparation of all paving studies, reports, and construction and maintenance programs, care must be exercised to obtain accurate information, while maintaining rigid control for consistent results. However, sufficient flexibility is also desirable to obtain the length of a single street, and with the same basic set-up, to obtain a mass tabulation of the length of streets in a definite area with a preselected directional control, either east-west, north-south, or diagonal. All of the above requirements are met by the adopted length control procedures.

Two new descriptive terms are introduced, "through length" and "add length." As applied to a block, the through length is the overall length of the block, that is, the average distance between the extended property lines of intersections at either end of the block. Intersections have a similar through length, from property line to property line extended; and an additional add length, the distance from the property line to curb line (roadway line extended). While a block always has only one through length and no add length, an intersection may have two or more through and add lengths depending upon the number of streets involved in the formation of the intersection.

Procedures for delimiting intersections and methods of determining and computing the proper through and add lengths pose an interesting problem when applied to the following variety of intersections: (*a*) standard, two streets intersecting at a common point and both extending beyond the common intersection formed; (*b*) deadend, two streets intersecting at a common point but only one extending beyond the common intersection formed; (*c*) offset, two streets not intersecting at a common point but with both extending beyond the two intersections formed; (*d*) multiple, three or more streets intersecting to form a common intersection; (*e*) special or miscellaneous, intersections which do not conform to any of the previously explained groups.

During the fall of 1942 the City of Milwaukee began the development of a simplified and systematic method of inventorying its present street system. It was felt that paving construction and other related data should be assembled, at least for existing conditions. Later that same year the Wisconsin State Highway Commission requested more detailed reporting of the length of each street, within the city so that state-aid money could be apportioned on a mileage basis. Thus lengths were added to the other information being assembled. While length control procedures were not fully developed at this time, a separate card for each block and each intersection was prepared as the best method of entering and controlling these data.

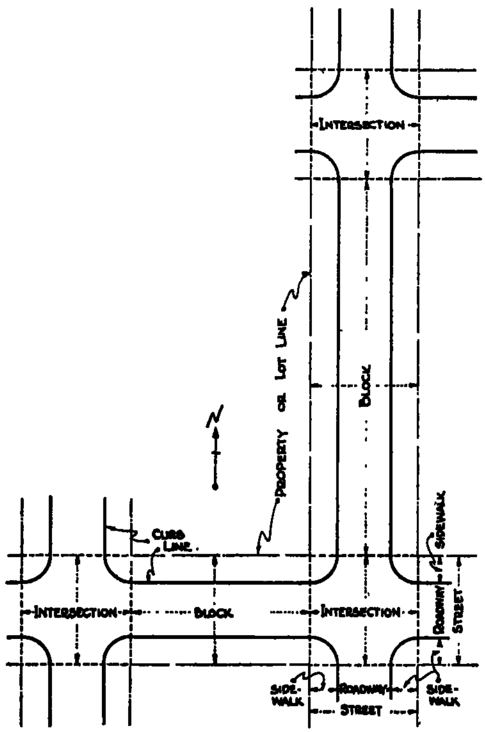


**Figure 1. Sample Street Layout Divided into its Component Blocks and Intersections**

This phase of the study was partially completed when it was absorbed, in November 1944, in a city-sponsored, Public Roads Administration project. The scope of the project was broadened to include a complete historical record from the first-known recorded improvement in 1861 to the present existing street system. The historical and other pertinent data are being placed on visual file cards for reference and will be in constant use, replacing some twenty sources of record. In addition the information is being punched on business machine cards for analyses of various problems including the development of pavement life studies.

### *Control Sections*

Before basic data could be recorded on the new project it was necessary to develop further the previously selected block and intersection method of control sections; a method which was adopted as the most suitable to divide the entire Milwaukee street system of 824 miles into a system of small, usable, basic units. The development of this method of control sections and its application to the peculiarities of modern city street patterns is closely linked to the development of length control procedures, and both are presented together in this paper.

For the purpose of this work, a "street" is defined as the entire right-of-way between the property or lot lines dedicated to public travel, and includes the pavement, walk, curb and gutter, and accessory structures (Fig. 1). An "intersection" is defined as that part of the street lying between the extended property lines of intersecting streets, while a "block" is that part of the street lying between intersections. The problems produced at intersections are the most difficult in the application of the block and intersection method to the breakdown of a selected street into its component parts. It is evident that after establishing the limits of intersections, blocks are merely the remainders between intersections.

### *Through and Add Length*

As pavement lengths and areas are the bases used in the preparation of all paving studies, reports, and construction and maintenance programs, care must be exercised to obtain accurate information, while maintaining rigid control for consistent results. However, sufficient flexibility is also desirable to obtain the length of a single street, and with the same basic set-up, to obtain a mass tabulation of the length of all streets in a definite area with a preselected directional control, either east-west, north-south or diagonal.

The manner in which basic lengths are defined is illustrated by a simple street layout consisting of three standard intersections with two intermediate blocks (Fig. 2). The overall length of the block, designated as "through" length, is the average distance between the extended property lines of intersections at either end of the block. Intersections have a similar through length, from property line to property line extended; and an additional "add" length, the distance from the property line to curb line (roadway line extended). While a block always has only one through length and no add length, an intersection may have two or more through and add lengths depending upon the number of streets involved in the formation of the intersection. Notice the similarity between Figure 2 and Figure 1. The only significant difference is the substitution of 'through length' for 'street' and 'add length' for 'sidewalk' at the intersections. This points to a definite relationship between through and add lengths on one street, and street and sidewalk widths on the intersecting street, a fact which will be amplified later.

The total length of a single street is the sum of the through lengths of the individual blocks and intersections, much the same as an actual linear field measurement is obtained. Thus in Figure 2, the length of the north-south street is the sum of the north-south through length at the top intersection, the through length of the north-south block, and the north-south through length at the bottom intersection. Similarly the length of the east-west street is the sum of the east-west through length at the left intersection, the through length of the east-west block, and the east-west through length at the right intersection. At the common intersection (lower right) different through lengths are used depending upon the general direction in which the length is wanted.

*Length Control*

However, in a mass length tabulation, which is the determination of the length of pavement on all streets in a given area, it is not possible to total the individual street lengths as described in the previous paragraph because of the duplication of intersection lengths. A definite procedure for length control at intersections had to be devised which permitted any preselected primary, secondary or tertiary control in any combination of east-west, north-south, or diagonal streets. Primary control at intersections determines the direction in which the through length is taken, secondary control the direction of principal add lengths, and tertiary control the direction of the remaining add lengths.

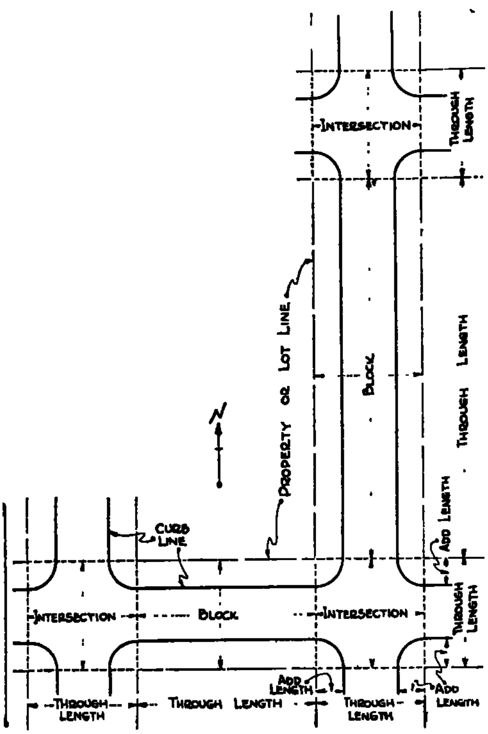


**Figure 2. Sample Street Layout Showing Through and Add Lengths for Blocks and Intersections**

maining add lengths. This principle is applicable only to intersections as it is evident that each block has a constant through length. Its application is illustrated in Figure 3, a sample east-west and north-south street layout having an east-west primary directional control and north-south secondary control. The total length of pavement is the sum of the through length of both blocks, the through length of all intersections in an east-west direction, and the add length of all intersections in a north-south direction.

The manner in which an intersection is divided into its through and add lengths is explained by using the lower right hand intersection as an example. It is first delimited by extending the four property lines across the two streets. With an east-west primary control, the curb lines of the east-west street are extended across the intersection. This portion of the intersection will have a pavement width equal to that of the adjoining east and west blocks, and its length will be the through length of the intersection. Note that in this instance the through length in an east-west direction is equal to the street width of the north-south street. In like manner, the remainder of the intersection is formed by extending the north-south curb lines to meet east-west curb lines extended. The resultant two areas have a pavement width equal to that of the adjoining north and south blocks and their lengths are the add lengths of the intersection. In this illustration the add lengths in a north-south direction are equal to the sidewalk widths of the east-west street

It is the introduction of the above mentioned add length, so often overlooked, which begins to take on added importance. Add lengths may vary from nothing to as much as 60 ft at one intersection but these distances are worthy of consideration when block lengths average only 400 to 600 ft. The problem of mass length tabulations is further complicated because the sum of the through length and add length at any one intersection may vary with a change of directional control. This is illustrated by using the same intersection with different directional control (Fig. 4). With an east-west primary control and north-south secondary control, the through length is 100 ft and the add length is 30 ft, a total of 130 ft; but with a north-south primary control and an east-west secondary control, the through length is 60 ft and the add length 40 ft, a total of 100 ft. It is this difference in length which produces varying results.

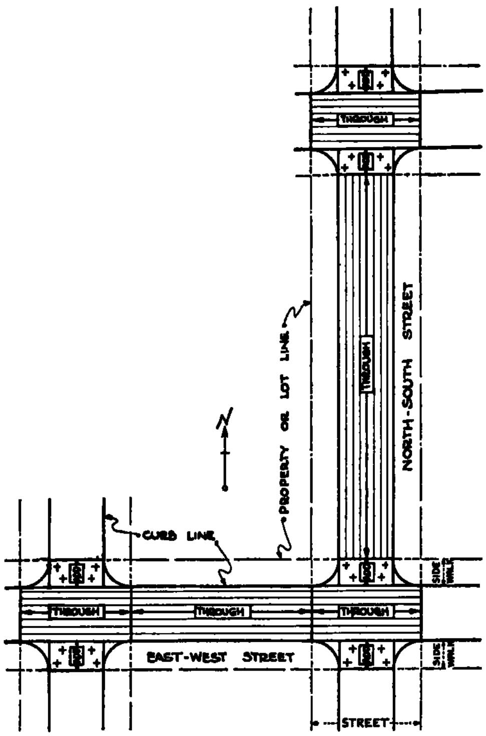


**Figure 3. East-West and North-South Street Layout with East-West Primary Directional Control and North-South Secondary Control**

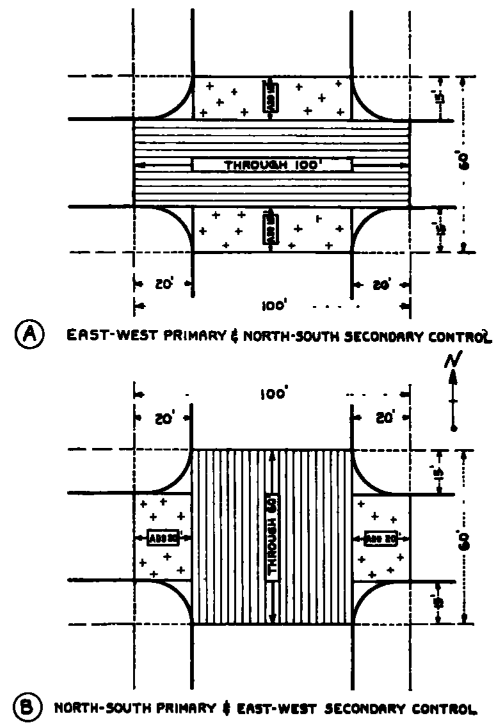


**Figure 4. Standard Intersection with Varying Directional Control**

*Intersections*

Having established the existence and necessity of through and add lengths at intersections, further consideration will be given to the detailed methods of delimiting the various types of intersections and determining their through and add lengths. For this purpose, all intersections are divided into the following general groups as indicated in Figure 5: Standard (A), two streets intersecting at a common point and both extending beyond the common intersection formed; Dead end (B), two streets intersecting at a common point but only one extending beyond the common intersection formed; Offset (C), two streets not intersecting at a common point but with both extending beyond the two intersections formed; Multiple (D), three or more streets intersecting to form a common intersection; Special or Miscellaneous intersections which do not conform to any of the previously explained groups. Various forms of blocks (E) are also indicated.

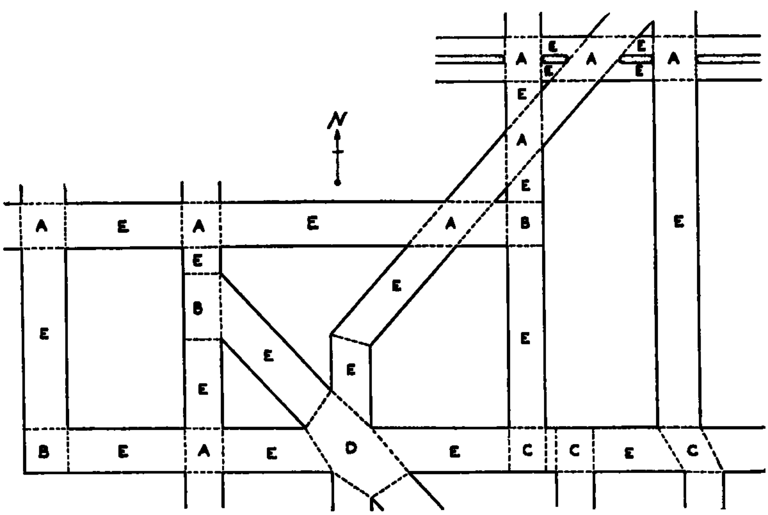


**Figure 5. Sample Street Layout Showing Various Types of Blocks and Intersections**

*Standard Intersection*

The methods of delimiting the standard right-angle intersection and developing the through and add lengths have been explained previously in conjunction with Figure 3. Similar methods are used when the two streets forming a standard intersection meet at an acute angle (Fig. 6). In this instance the lengths are taken along the center line of the street, so the north-south through length is not the same as the diagonal street width. Instead the through length is computed by multiplying the diagonal street width by the cosecant of the acute angle (D) formed by the intersecting streets. In the same manner the add length along the diagonal street is equal to the product of the sidewalk widths of the north-south street and the cosecant of the acute angle. Similar length calculations are made if the through length is taken in a diagonal direction and the add length in a north-south direction.

Another example of a standard intersection is one formed by a standard street with single roadway intersecting a divided lane street with two roadways separated by a parkway strip (Fig. 7). As the parkway strip ends at the property line instead of continuing through the intersection, the result is a standard intersection paved in its entirety and developed as explained previously.

*Dead-End Intersection*

The two streets intersecting to form a dead end intersection may meet at right angles to each other (Fig. 8) or at an acute angle (Fig. 9). In either instance, the intersection is outlined when the property line on the con-

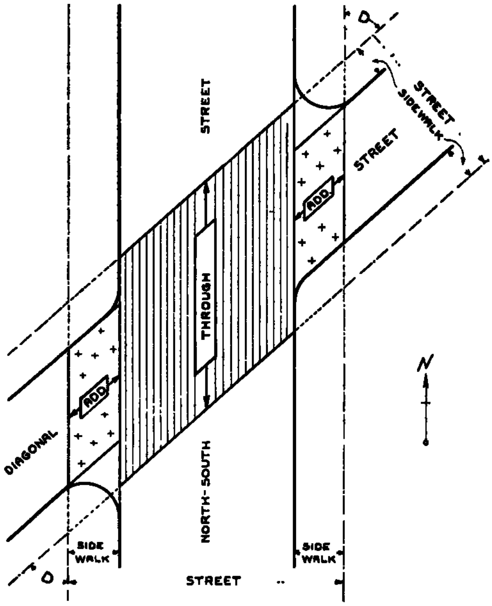


**Figure 6. Standard Intersection with Streets Meeting at an Acute Angle (D)**

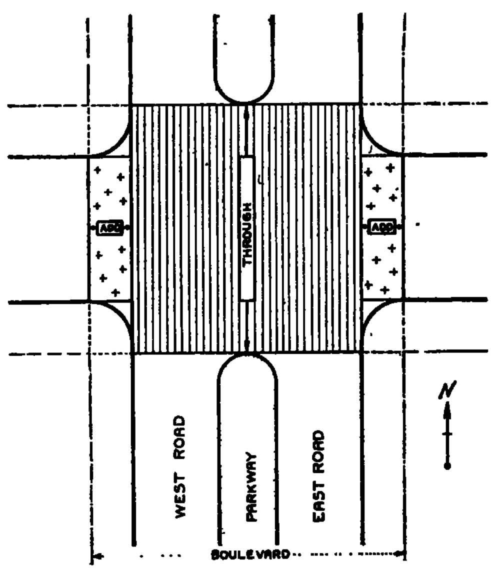


**Figure 7. Standard Intersection with Boulevard or Divided Lane Roadway**

tinuous street is extended from point A to B, and lines from A and B drawn perpendicular to the opposite property line on the continuous street to point C. As the pavement ends at

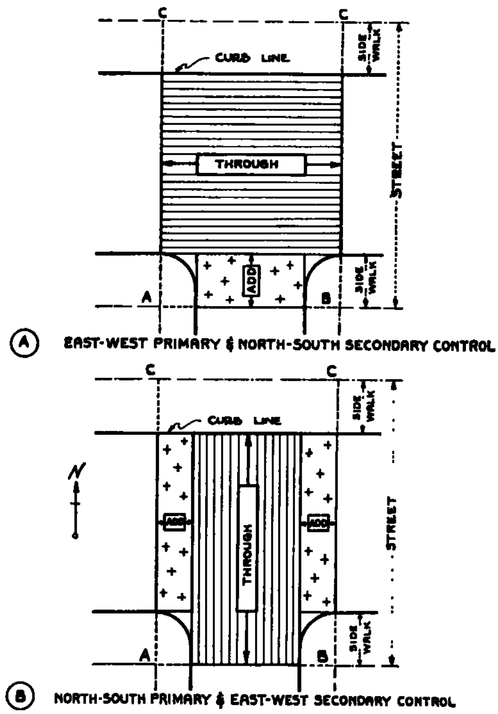


**Figure 8. Dead End Intersection with Streets Meeting at Right Angles**

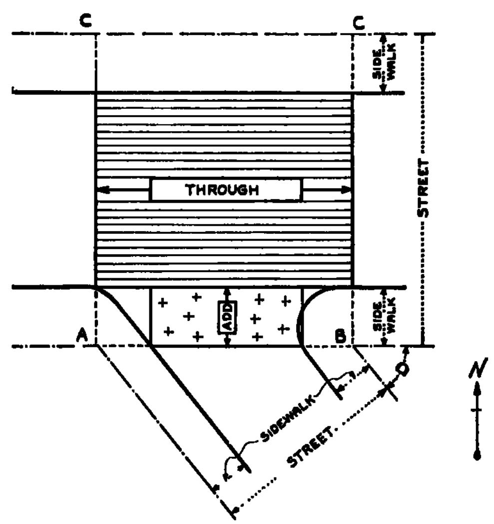


**Figure 9. Dead End Intersection with Streets Meeting at an Acute Angle (D)**

the curb line instead of the property line on the dead end (north side) of the street, the through length in a north-south direction can extend from the south property line to the north curb line only, a reduction in length equal to the sidewalk width on the north side of the street. There is no change in the method of determining the add length with this north-south control. With an east-west primary directional control the through length is obtained as for a standard intersection but there is only one add length to include, that on the south side.

A double dead end or L-shaped intersection is formed when two streets intersect as a common point and neither extend beyond the common intersection (Fig. 10). The intersection is formed with lines from point 'A'

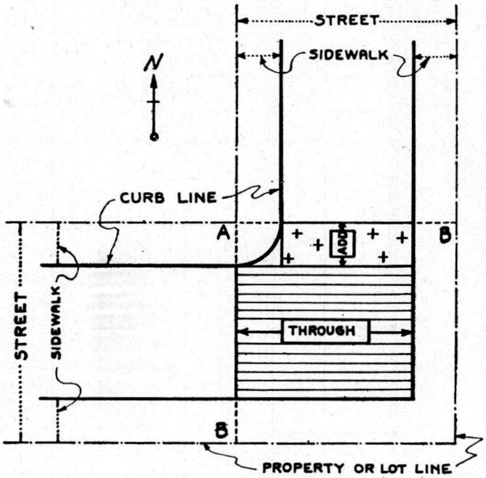


**Figure 10. L-shaped Intersection with East-West Primary and North-South Secondary Directional Control.**

drawn perpendicular to the opposite property line to points 'B'. The through length with an east-west primary directional control is taken from the west property line to the east curb line only. With the elimination of the add length on the south side of the street the remaining add length appears on the north side with north-south secondary control.

*Offset Intersection*

An offset intersection is developed either as a dead end or standard intersection depending upon the amount of the offset. The intersection is delimited by extending the property lines on both streets similar to the dead end intersection procedure. If the offset is sufficient to produce a distinct block between a pair of dead end intersections (Fig. 11), continue to use dead end intersection methods to obtain through and add lengths. When obtaining

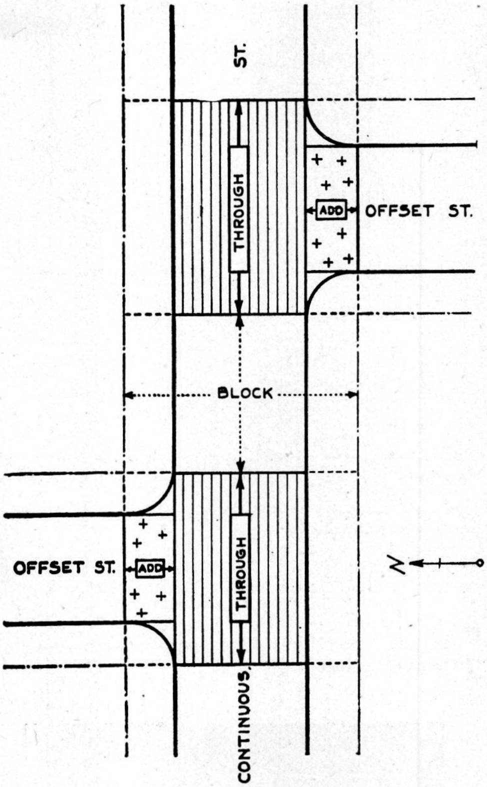


**Figure 11. Offset Intersection with Block between Offset Streets**

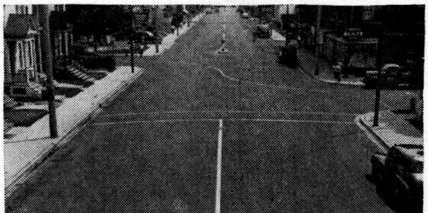

**Figure 11a. Offset Intersection with Block Between Offset Streets—Note painted driving guide line along offset street.**

the through length along the offset street, use the distance from the property line to the opposite curb line at both intersections rather than the distance from property line to center line of the through street.

If the offset is not sufficient to form a distinct block between dead end intersections, but instead produces an area of overlap (Fig. 12), the offset intersection is further developed as a standard intersection which has been shifted off center along the center line of the continuous street (Fig. 13).

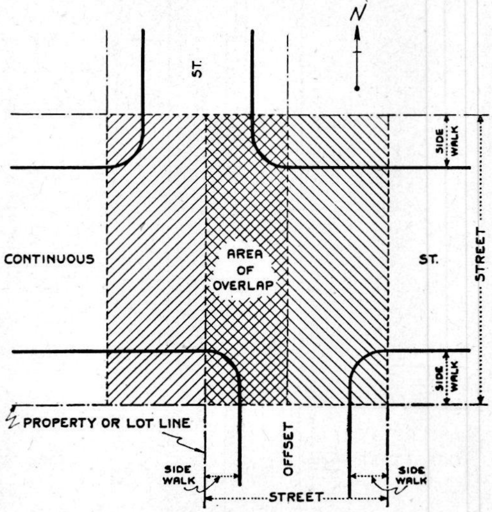


**Figure 12. Offset Intersection with Area of Street Overlap**

**Figure 12a. Offset Intersection with Area of Street Overlap**

*Multiple Intersection*

A multiple intersection is formed when three or more streets intersect to form a common intersection. As in the case of offset intersections, it is necessary to determine whether or not an area of overlap, which is an area of street common to all intersecting streets, is produced when property lines are extended through the intersection. If an area common to all intersecting streets is not formed, the apparent multiple intersectional area must be divided into smaller blocks and intersections and developed accordingly (Fig. 14). However, if the extended property lines meet at a point or produce an area of overlap within the intersection, the entire intersectional area must be considered a single multiple intersection (Fig. 15).

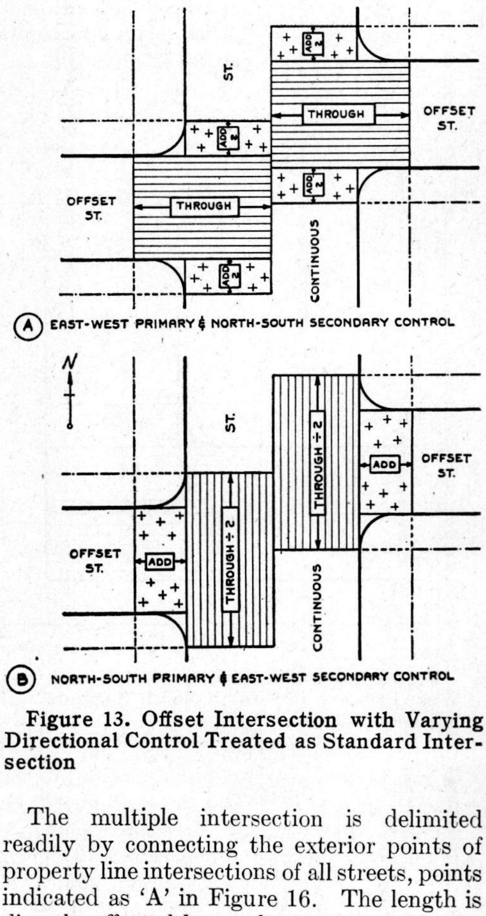


**Figure 13. Offset Intersection with Varying Directional Control Treated as Standard Intersection**

The multiple intersection is delimited readily by connecting the exterior points of property line intersections of all streets, points indicated as 'A' in Figure 16. The length is directly affected by, and may vary with, the choice of directional control. While any combination may be used, for the purpose of this explanation assume a primary directional control along the diagonal street, W. Lisbon Ave., secondary control along the east-west street, W. Garfield Ave., and tertiary control along the north-south street, N. 45th St. To obtain the total length of a multiple intersection, the entire pavement area is subdivided into sections having widths equivalent to that

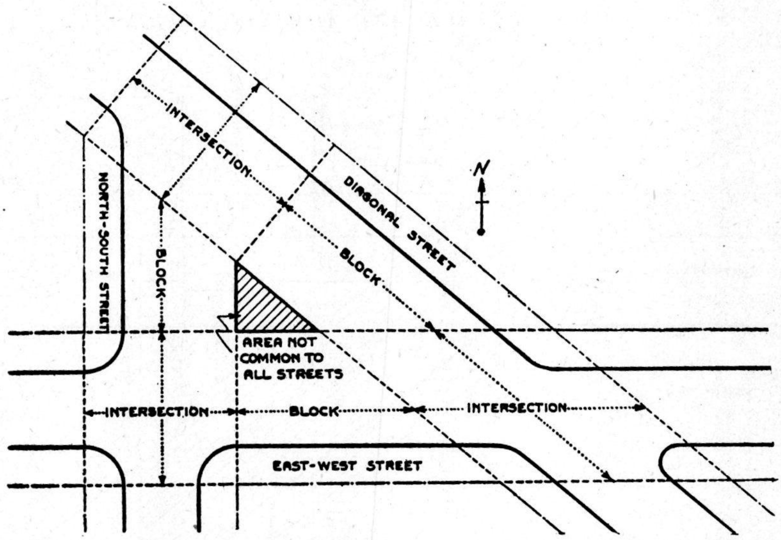


Figure 14. Apparent Multiple Intersection Divided into Component Blocks & Intersections

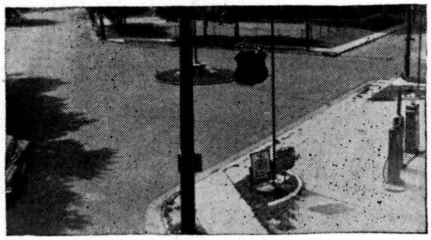

Figure 14a. Apparent Multiple Intersection—Note that grass plot within intersection occupies the "area not common to all streets."

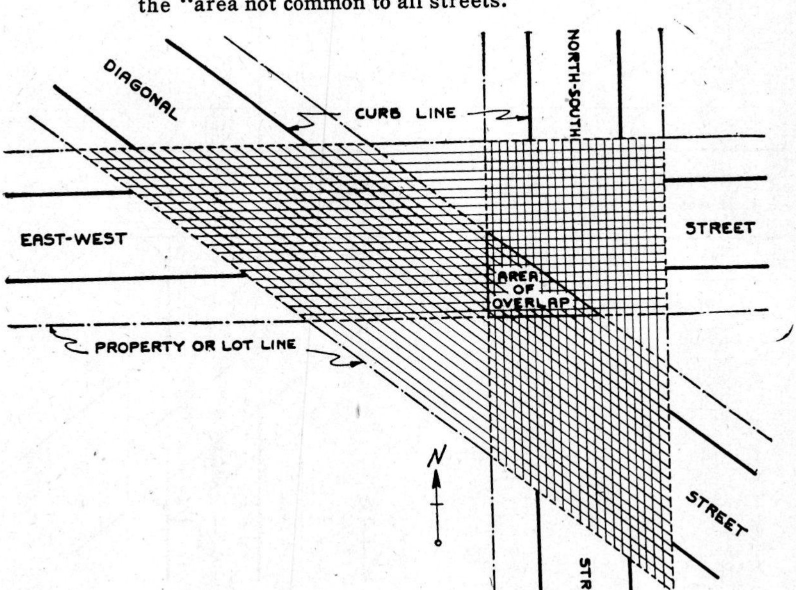


Figure 15. Multiple Intersection Showing Area of Street Overlap

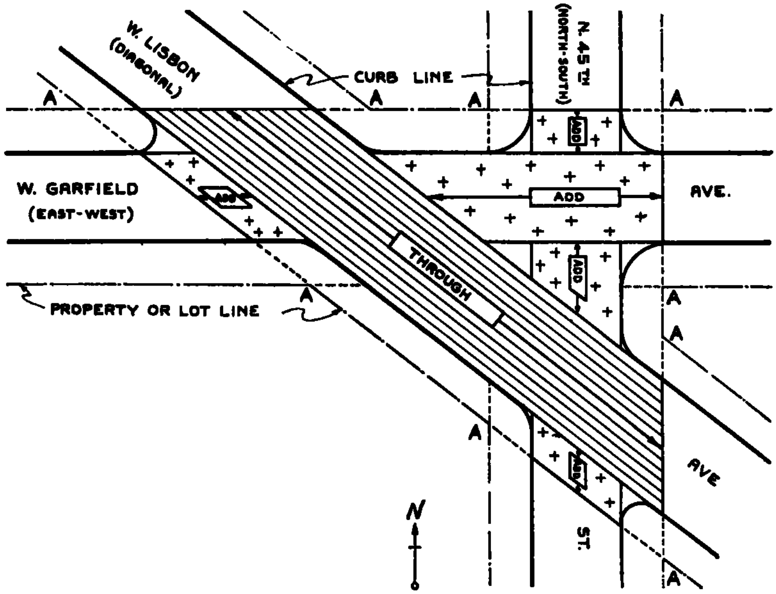


**Figure 16. Multiple Intersection with Diagonal Primary, East-West Secondary, and North-South Tertiary Directional Control**

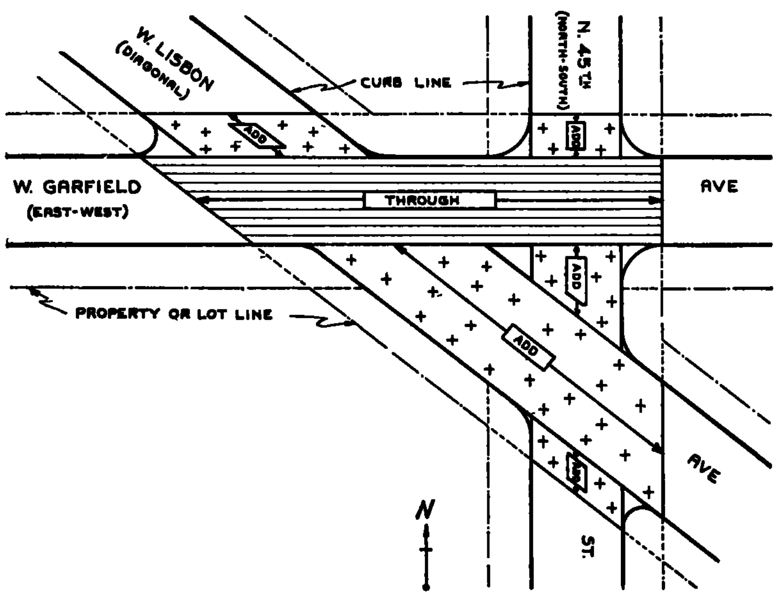


**Figure 17. Multiple Intersection with East-West Primary, Diagonal Secondary, and North-South Tertiary Directional Control**

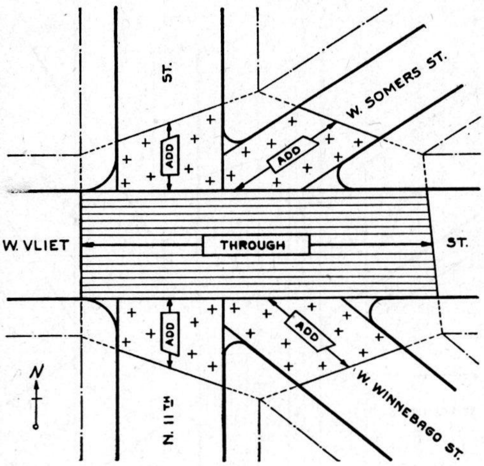


**Figure 18. Multiple Intersection with East-West Primary, North-South Secondary, and Digonal Tertiary Directional Control**

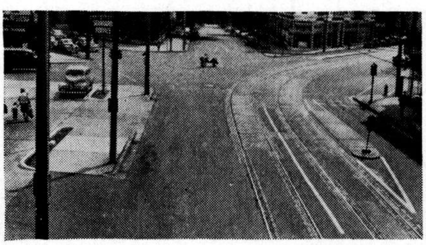

**Figure 18a. Multiple Intersection—Looking East Along W. Vliet St.**

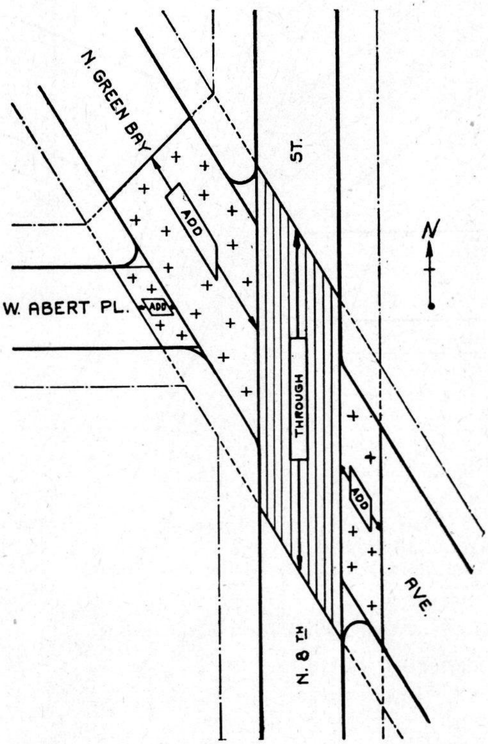


**Figure 19. Multiple Intersection with North-South Primary, Diagonal Secondary, and East-West Tertiary Directional Control**

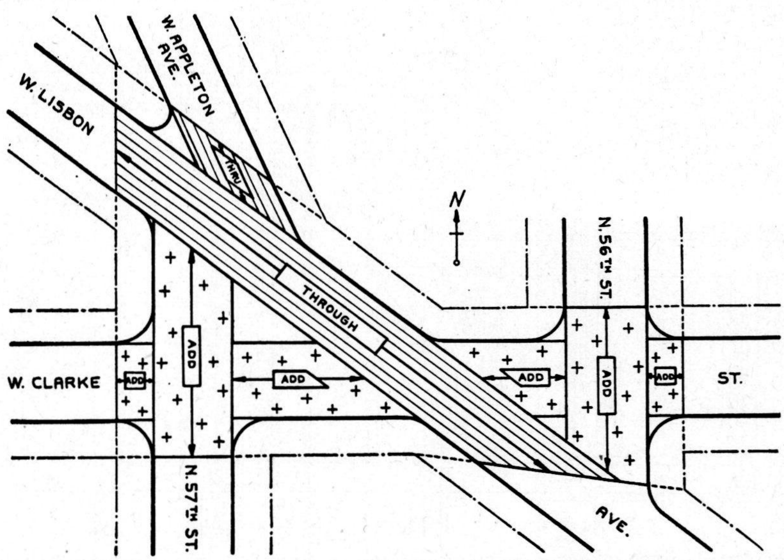


**Figure 20. Multiple Intersection with Diagonal Primary, North-South Secondary, and East-West Tertiary Directional Control**

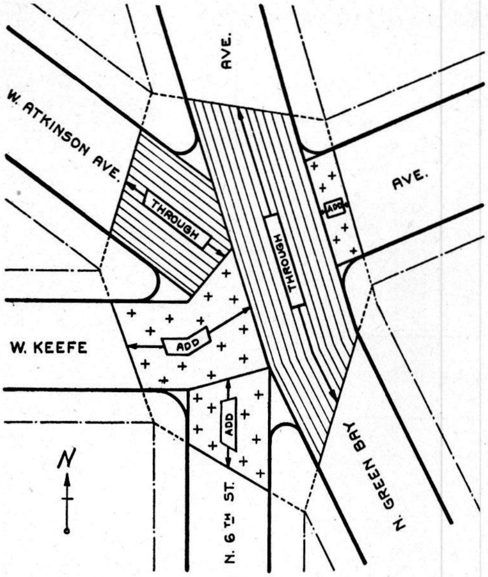


**Figure 21. Multiple Intersection with Diagonal Primary, East-West Secondary and North-South Tertiary Directional Control**

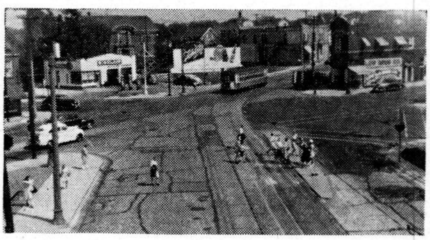

**Figure 21a. Multiple Intersection—Looking Southeast Along W. Atkinson Ave.**

of the adjoining streets. As in the case of a standard intersection extend the curb lines of the primary diagonal street through the entire intersection to produce the through

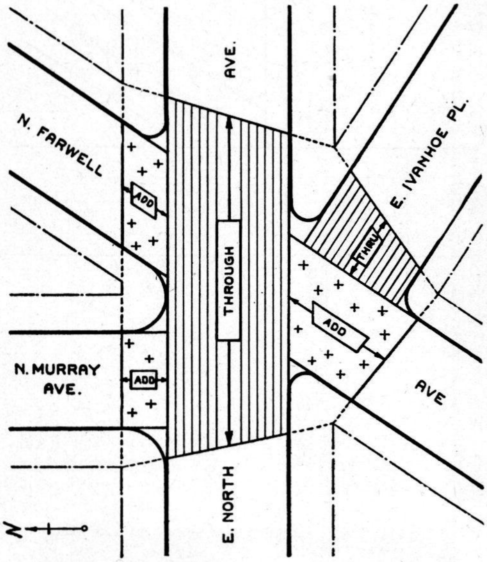


**Figure 22. Multiple Intersection with East-West Primary and North-South Secondary Directional Control**

length, a length of pavement with a width equivalent to that of the diagonal street. Similarly the curb lines of the secondary east-west street are extended through the intersection. That pavement area previously formed along the diagonal street is omitted. This produces the add length in an east-west

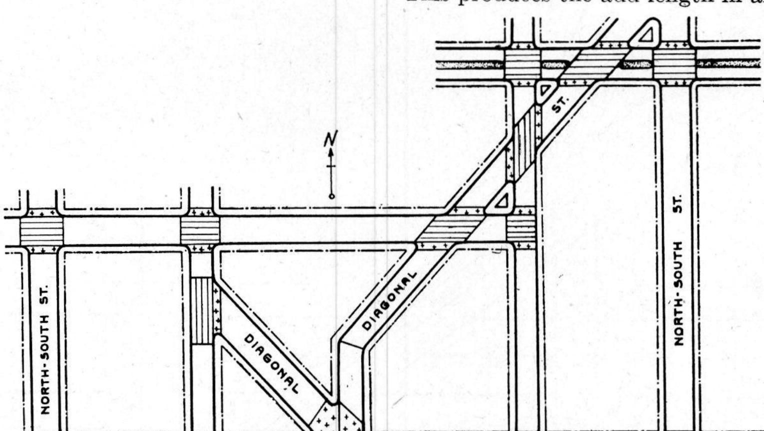


**Figure 23. Sample Street Layout Showing Various Types of Intersections with East-West Primary, North-South Secondary, and Diagonal Tertiary Directional Control**

direction. Finally the curb lines of the tertiary north-south street are extended through the intersection, again avoiding a duplication with previously formed areas, to produce the add length in a north-south direction. The sum of the diagonal through length, the east-west add length, and the north-south add length is the total length of pavement in the intersection.

Figure 17 illustrates the same intersection with different directional controls, east-west as primary, diagonal as secondary and north-south as tertiary. Other multiple intersections, with varying combinations of directional control, are shown in Figures 18, 19, 20, 21 and 22.

This discussion has been restricted to a description of the control procedures for individual intersections of various types. The application of these principles will solve the problem of lengths for any intersection, and will provide for positive length control in any desired direction without duplication when applied to all of the streets in a given area (Fig. 23).

# DEPARTMENT OF DESIGN

C. N. Conner, *Chairman*

## THE COOPERATIVE PROJECT ON STRUCTURAL DESIGN OF NONRIGID PAVEMENTS

By A. C. Benkelman, *Research Specialist*

and

F. R. Olmstead, *Senior Soil Specialist*

*Division of Physical Research,*
*Public Roads Administration*

### SYNOPSIS

This paper is a progress report of the Investigation of Nonrigid Pavement Design being undertaken as a cooperative project between the Highway Research Board, the Asphalt Institute and the Public Roads Administration. The investigation was planned and begun during the war period. Included is a statement of objectives, a discussion of the methods of approach, an account of the construction of the test pavement, and finally a discussion of test apparatus and testing techniques.

While some preliminary data of a highly significant character have already been secured, the present discussion is concerned primarily with a detailed description of the project. Considerable laboratory work is involved, but the main part of the investigation deals with the construction and testing, both under moving and plate load tests, of sections of pavement laid outdoors on natural subgrade soils.

Interest in the problems of structural design of the bituminous or nonrigid pavement grew enormously during the war period. To determine how thick such pavements should be to accommodate heavy airplanes, research work of a scope that would never have been considered feasible in peace time was undertaken. Most of the work was carried on under the supervision of engineers of the U. S. Army and Navy. In spite of the fact that much of the work had to be planned and executed in as short a period of time as possible, a great deal of useful and pertinent information was developed. It has served to bring about a much clearer perspective of the problem and has resulted in the development of several methods of thickness design that have considerable merit.

The scope of the cooperative investigation is sufficiently comprehensive to permit examination, study, and intercorrelation of all known theories and methods of design.

The principal objectives of the investigation include:

1. The development, by means of field bearing and moving wheel load tests on full-size pavement sections, of fundamental data on the load supporting value of nonrigid