MEDIAN DESIGN
EFFECT ON TRAFFIC BEHAVIOR
AND
SAFETY

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ABSTRACT

The grade separation structures of the Beirut - Tripoli Highway, Beirut - Maameltain section, a four lane divided facility, were used to study the effect of median design on traffic behavior, to determine the most appropriate actual existing condition and future needs for a most efficient, economic and safe operation of traffic.

The data on lateral clearances and speeds were obtained by the use of a motion picture technique using a 16mm motion picture camera and analyzed by projecting through a time and motion study projector. The data on volume counts were obtained by the use of automatic traffic counters. The spot speeds of the vehicles were measured using an electro-matic radar speed meter.

The locations chosen presented different conditions of cross-sectional design : on straight tangents with unrestricted sight distances and an alignment on a left curve.

The study revealed that there is a significant relationship between the arithmetic mean of the lateral placement of vehicles and the hourly volume, and that median types affect lateral placement of vehicles. Furthermore, vehicles behave diffrently, for the same type of median, on a straight tangent and on a curve.

The study showed that the average speeds of free moving vehicles are not affected by one type of median differently than by any other of the medians and for the traffic volumes studied. But it appeared that average speeds vary significantly at different lateral placements for the various types of median.

INTRODUCTION

The objective of modern freeways and expressways is to provide good service for high volumes of traffic. They are intended to provide a generally high level of service to their users and to the communities which they serve, offering rapid traffic movement without outside interference (8)*. Safe and efficient highway transportation requires increasing attention to enforcement and driver education as well as to engineering (1).

There is no one cause of traffic accidents. The influences acting at any instant are innumerable and probably are more or less important in certain combinations. Consequetly, the engineering role of any one engineering factor, such as median width, may never be susceptible to a simple description for the reason that its role changes according to the presence or absence of other factors (25). But if one element of a facility functions at a lower level than the selected level of service, it may limit the level of service over a substantial portion of the freeway section; therefore, every element must be in proper balance with all other elements.

Divided highways have demonstrated their ability to carry large volumes of traffic efficiently and safely. However, the most modern highway does not prevent all accidents. This results in a continuing demand to improve design and increase safety.

One of the major questions with respect to safety is the type and design of medians for the various conditions under which they must be constructed. Varying terrain in rural areas and high cost of right-of-way in urban areas have led to a variety of median designs.

A median is the portion of a divided highway separating traffic movement in opposite directions. This includes all type of continuous separation, ranging from a narrow painted line to an area of several hundred feet in width, located within the right-of-way, and not intended for use by through traffic as a path of continuous travel.

The degree of control of access on highways greatly affects the number and types of functions which medians are expected to perform. The functions will mainly depend upon the degree of access control the highway under study is to provide.

«Full control of access whereby entrance and exit movements to and from the through traffic lanes are limited to designated points where these maneuvers can be performed safely has been the most important single factor in accident reduction ever developed» (25).

** Numbers in parenthesis refer to listings in the bibliography.*

Accident and fatality rates on fully controlled access highways have been only one third to one half as great as those on highways with no control of access. This is not due wholly to the control of access feature, but to grade separation of intersections, provision of separate roadways for opposing directions of traffic, and other design refinements customerely employed in conjunction with access control (25).

The primary functions of a median for divided highways with complete control of access can be summarized as follows (in parenthesis are mentioned similar functions for highways with partial or no control of access):

1. - Delineate the left extremity of the authorized path of vehicle travel and the general alignment of the roadway so as to decrease the amount of inadvertant vehicle encroachment upon the median and roadside areas.

2. - Separate opposing traffic streams so as to favorably influence vehicle behavior, particularly under accident conditions; increase the capacity of the facility and increase driver comfort and convenience.

3. - Prevent U turns (prevent left of U turns except at designated locations and provide protection and control for these vehicles).

4. - Provide appropriate stopping or recovery conditions and space for vehicles running off the left edge of the pavement under various degrees of control.

5. - Provide storage or refuge space for disabled vehicles.

There are other secondary but still important functions such as:

1. - Provision of space for drainage

2. - Provision of space for future expansion of facility

3. - Reduction of headlight glare

4. - Provision of grade differential space for separate roadway profiles

5. - Provision of space for structural appurtenances

But there are many limitations within which the design of medians must be accomplished. The limitations of initial cost, maintenance and traffic operation, have a great effect upon the degree and manner of provision of the benefits potentially obtainable from medians.

1. - Initial Cost
   - Extra right of way is needed
   - Additional length of grade separation structures are required
   - Additional earthwork and drainage facilities may be needed.
   - The cost of effectively employing barriers, screens, plantings, delineators, curbs, special paints, or other such accessories to improve the performance of medians may exceed the cost of providing more liberal median dimensions.

2. - Maintenance
   - Trash and debris removal from median is necessary
   - Maintenance of median surfacing and appurtenances is required.

3. - Operational
   - Access from facility to abutting property is limited (this being the main public objection to medians)
   - Access for emergency vehicles, police cars, ambulances, maintenance units, is made more difficult.

Decisions must be made with regard to limitations that available space, money, and traffic demands impose on the design. A general order of relative importance of the various design details and functions of medians must be kept in mind throughout all phases of the planning, design, construction, operation, and maintenance of a facility.

Design of medians of divided highways have gone through an extended period of development involving the trial installation of many different median widths and cross sectons.

There are three basic median types, having decidedly different properties. These are:

1. - **The traversable type** : Includes those medians which have no obstructions and are easily crossed by traffic. The flush paved and the compacted flat earth-type medians are in this class.

2. - **The deterring type:** by means of a physical obstruction, discourages deliberate entrance or crossing of the median. The raised bar or low ditch, the mountable double curb, and most of the earth type medians with flat cross slopes are in this group.

3. - **The non-traversable type :** is physically designed to prevent crossing from one roadway to another. Separate roadways, barrier type medians including the non mountable curbs, and

earth **medians** with a continuous obstruction are included in this group. Also included are earth medians with a steep cross-slope. Additionally, all medians greater than 30 meters (100 feet) in width are classified as non-traversable.

Besides grouping by basic types, medians can be divided into classes by widths. Three width classes have been commonly used, though these are by no means fixed.

1. - **Narrow medians** : are difined as those which are less than 5 or 6 meters (15 or 20 feet) in width.

2. - **Intermediate width medians** : include those which are more than 6 meters (20 feet) but less than 15 or 18 meters (50 or 60 feet) in width.

3. - **Wide medians** : are those with widths more than 18 meters (60 feet).

Available information gathered during the last two decades are so various and numerous that designers are faced with a serious problem of interpretation and still this information may or may not apply to the specific median design problems at hand. Moreover, extremely important but intangible benefits such as safety, comfort, and convenience should be considered and yet the extent to which medians can be designed to provide them is a matter of opinion. This makes it difficult to justify any additional investment involved in providing median widths and cross-sections that are intended to yield those benefits unless more tangible benefits from such designs can also be demonstrated.

As a result to these different factors, the choice of a basic median width and cross section is often left to the administration responsible of the project but supported by qualitative analysis and individual engineering judgment.

PURPOSE

The purpose of this investigation was to determine the effect of median dividers on lateral positions of vehicles and on speeds at different hourly volumes of traffic. Due to the lack of accident records, the basis of all sound analyses and evaluations of the relative safety of any highway design feature, it was also hoped to reach a conclusion as to the safest and most efficient existing median treatment and recommend a design for use in Lebanon which would provide an efficient and safe operation of vehicular traffic.

SCOPE

The study was limited to the four lane Beirut-Tripoli divided highway, the section falling between the Nahr el Moat Rotary and Maameltain. This is the only rural facility on level terrain in Lebanon having separate roadways for opposing traffic streams.

The study locations were specifically selected to provide data on lateral placements and speeds of vehicles for the various types of median designs and for operations under different traffic volumes.

Three locations were chosen on level and nearly tangent terrain. A fourth location similar to the second one but along a horizontal curve was also chosen in order to evaluate the effects, if any, that such a condition has on traffic behavior.

Unfortunately, the studies could not be made at different locations with similar conditions of median design, in order to evaluate if the results would be repetitive or if other factors, such as shoulder width and condition, have a significant bearing on the results. The reason for this was the absence of proper observation points for similar conditions of median design and / or the material impossibility of erecting high towers where the movie camera could be installed.

The types of vehicles studied were only passanger cars. Buses and trucks were not included.

Information for the estimation of speeds and lateral placements of vehicles were recorded in this study.

Information for only free-moving vehicles were recorded for vehicular speed computations. For a vehicle to be considered free flowing, it must be able to overtake and pass other vehicles without any speed reduction. Consequently only these vehicles were used which were not affected by other vehicles in their path of movement. Vehicles following were not considered. This restriction did result in only the lead vehicle of a platoon being recorded.

For lateral placement, data of all vehicles leading or following were recorded.

Data collection took place when the pavement was dry and under optimum atmospheric conditions, i.e. absence of fog or dust. This was particularly essential as all the data was obtained photographically and a clear and sharp picture from a considerable distance was necessary. Data were collected during the daytime on weekends for most of the cases. It is felt that the day of observation has no significant effect upon the vehicular characteristics for the type of traffic that used this facility.

Reconnaissance studies and preliminary surveys for determining sample sizes were conducted in November and December 1967. The actual collection of lateral placement and speed data took place from January 1968 until May 1968 on days of good weather conditions. Approximately 4000 passenger cars were studied. Daily volume counts for each of the locations were obtained during the period the study was performed.

No accident records were available for this facility, as for all other facilities in Lebanon. This was a serious drawback as the relative safety of each of the locations under study could not be ascertained based on actual accident record data.

PREVIOUS INVESTIGATIONS

There is quite a difference of opinion among highway engineers regarding the relative merits and effectiveness of the different types and widths of median dividers. But during the last decade extensive research has been conducted in the United States to study the relative safety of various types of median design and their effect on traffic behavior.

A good number of these research projects were sponsored by the U.S. Bureau of Public Roads and conducted with the cooperation of State Highway Departments, Universities, Foundations, and Private Institutions.

All types of medians with a large variety of widths were thoroughly studied during these investigations. Efforts were made to evaluate the effects of medians

— on traffic behavior : speeds, lateral placement of vehicles, day or night driving,

— on safety : accident rates, types and severity, median barriers etc.

A large number of specialized engineers and technicians participated in those researches. Complicated equipment was used. Time was devoted and large sums were allocated by public and private institutions.

Detailed and properly filed accident records accumulated during many years by several Police Departments permitted engineers to prepare charts, to make statistical analyses and to reach conclusions as to the relative safety of median dividers under different design conditions.

The results, conclusions, and recommendations of the different research projects relating median design to traffic behavior and safety are summarized in the following paragraphs.

I. EFFECTS OF MEDIAN DESIGN ON TRAFFIC BEHAVIOR

1\. — The average speeds of vehicles are not affected by one type of median differently than by any other (4) (15).

2\. — There is a linear relation between the average lateral position of vehicles and the hourly volume of traffic. As the volume increases, vehicles in the right lane, on an average, travel closer to the shoulder and those in the left lane travel closer to the median (4) (17).

3. — There does not appear to be a very significant difference between day and night speeds and lateral placements of vehicles (4).

4. — The shift in placement away from narrow medians during heavy peak opposing traffic flow indicates an influence of density of opposing flow rather than individual opposing vehicles (27).

5. — Barrier fences constructed along the center of narrow medians (about 1.20 meters — 4 feet) have little influence on the placements of vehicles in the left lane. Moreover barriers provide a better reference point for driving in the left lane than a low curb (17) (19).

6. — Delineation of narrow medians is essential. Edge markings appear to have some influence on operating speeds, a factor which might permit a deduction that the added delineation of the pavement edge increases driver confidence with a resulting safer operation (27). The use of a painted strip adjacent to the median is an aid in delineation, as is planting, and aids further in defining the edge of the roadway and reduce headlight glare. Median plantings significally reduce the frequency of vehicle encroachment on the medians, especially on or near curved alignment where the hazard of headlight glare from opposing vehicles is most severe (13).

II. EFFECTS OF MEDIAN DESIGN ON SAFETY

Many variables other than median type and design influence the frequency of traffic accidents. Some of these factors are: the overall standards of design and features of a particular facility, traffic density, climatic conditions, differentials in vehicular speeds (10) (19).

The studies conducted by the different research groups were concentrated on various types and widths of median dividers. Sections of divided highways with different median treatments but similar design characteristics and degree of access control were considered. All accidents, pedestrian, intersection, or others due to factors not pertaining to the study proper were excluded from the accident data used in the analysis.

A. RESULTS

1. -- Total Accident Rates Vs. Median Width

There appears to be no correlation between the overall accident rates of facilities and the width of their median (7) (10) (19)..

This seems to contradict the hypothesis that, for the same general conditions, the greater the lateral separation, the safer the facility. One explanation for this contradiction is that the median width used in

studies and as generally defined, is the width between the edges of opposing roadways, not the width available for maneuvring or for emergency parking. When a vehicle leaves the roadway, there is a good good chance of avoiding an accident if maneuvering room is available. The width of the median between opposing lanes of traffic is not a direct function of this maneuvering room. If effective width instead of median width was used a somewhat different conclusion might have resulted.

Effective median width is assumed to be the lateral distance from a vehicle traveling in any lane in one roadway to the nearest possible vehicle traveling the opposing roadway of a divided highway having a traversable median, or obstruction preventing the crossing of the median of a divided highway having a non-traversable median (19).

The introduction of a physical barrier in a traversable or deterring median reduces the usable width of the median by one half. If this usable width of the median is a factor in the overall safety of a facility, it would be a logical explanation of the noted increase in the accident rates with the installation of a barrier (19). A driver's freedom to maneuver to avoid collision with other vehicles is reduced by a median barrier. There are undoubtedly vehicles which enter and in some cases cross the median and recover without a reportable accident when no barrier is present.

It is frequently taken for granted that if a car crosses a median of a heavily-travelled facility, it is bound to collide with a car proceeding in the opposite direction. This is not true. Even during daytime hours, there are many long spaces between vehicles, and during the hours from 9 P.M. to 5 A.M., when the fatal accident rate is greatest, most of the spaces between vehicles are several tens of meters long (25).

Total accident rates range mostly from 30 to 40 fatal and injury accidents per 100 million vehicle miles (10).

2. - Median Accident Rates Vs. Median Width

Earlier research studies showed no relationship between the median accident rates and width of median. This result was not logical as one would expect greater safety with wider medians. It was concluded that perhaps drivers are more alert when the median is narrow and that top speeds are higher on facilities with larger medians (7) (10) (19).

Accident rates range mostly from 10 to 20 injury and fatal accidents per 100 million vehicle miles or 1/3 of the total accidents on the facilities under study (10).

Further studies (10) (19) used a new approach to the analysis of median accidents. Median accidents were divided into two separate categories.

a. — When the vehicle struck, entered or encroached upon the median but did not cross it

b. — When the vehicle crossed the median and entered the opposing traffic lanes. These were called «cross-median» accidents.

A good correlation between crossed median accidents and median width could then be established :

— the cross-median accident rate went down as the median width went up (7)(10)(19).

Again, a definite relationship was found when the percent of head-on accidents were compared to median width:

— head on accidents as a percentage of total accidents decreased rapidly as the median width increased (10)(19).

It was found that widths of less than 50 feet (15 meters) will not prevent vehicles from crossing the median, although the probability is greatly reduced when that width is exceeded. Only medians much larger, 100 feet (30 meters) or more, or a vertical physical barrier would prevent nearly all vehicles from crossing the median.

Head-on accidents, very much critisized by the public in general as it affects «innocent» drivers, are a small percent of total accidents, but they are extremely severe. One of the studies (10) shows that 6 out of 10 head-on accidents are personal injury or fatal accidents. While they accounted for 1/25 of all injury accidents they were responsible for 1/5 of all fatal accidents (10) (19).

Fred W. Hurd in his study «Accident Experience with Traversable Medians of Different Widths, " (10) concludes :

«There is no reason why the width of traversable medians should influence the accident rate except in the case of head-on collisions with vehicles in the opposed flow. In other words, except for head-on collisions, a traversable median without trees, bridge piers, or other obstructions, offers no greater hazard than the right side road margin so long as physical obstructions are equal distances from the right and left edges of pavement. Therefore the objective of median design on limited access facilities is to prevent head-on accidents».

3. - Traffic volumes Vs. Median Accident Rates

Traffic volumes appear to be a factor in the relative safety of various types of medians. On highways with traffic volumes between 15,000 and 130,000 vehicles per day the non-barrier type medians were superior. Where traffic volumes exceeded 130,000 vehicles per day the advantage shifted to the non-traversable barrier type medians. Hence traffic volume appears to be the major criterion for the installation of median barriers. At volumes of 130,000 or more vehicles per day, it is indicated that median barriers add to the safety of a divided highway (19).

4. - Median Barriers Vs. Cross-Median Accident Rates

The primary objective of a design engineer would be to provide a roadside as safe and free of obstructions as possible. Only when this is absolutely impossible that rails should be used. The guardrail, at best something of a hazard, should not be used if the need for a protective rail can be eliminated in some other manner.

The cross-median collision of all accident types, probably holds the greatest promise of prevention. Initial highway design with inclusion of adequate median widths between opposing roadways can almost completely prevent the serious head-on motor vehicle accident. This, of course, is an impossibility on many existing highways where cross-sectional design cannot be improved, to a large extent, within existing right-of-way. The highway designer will, therefore, find other means of physically separating the opposing vehicular traffic. But the economic consideration of barrier erection may appear at the beginning prohibitive and many questions remain unanswered as to the best design for a barrier and where and under what conditions should a barrier be erected.

The California Median Study (19) showed that two-thirds of the fatal cross-median accidents occured on freeways carrying more than 60,000 vehicles per day although these accounted for only one-fifth of the total mileage of freeway traffic. But accident data analysis showed that at traffic volumes of 130,000 vehicles per day, or more, median barriers add to the safety of a divided highway. The study concludes :

«In order to make a significant attack on the cross-median fatal accident problem (1/5 of fatalities), it would be necessary to reach down to the 60,000 ADT level with the installation of median barriers. Past experience indicates that barriers may convert cross-median accidents to other types. However, newly developed barrier designs may reduce the severity of collisions with the barriers and result in fewer casualties even though the accident rate may rise.»

B. RECOMMENDATIONS

No one type of median will prove best in all cases. Right-of-way costs, topography, and other factors influence the selection of the median type on any particular road. The following are the recommendations of different research studies.

1. - Median Design

Consideration should be given to the design of flatter median cross-slopes as a means of :

— decreasing the maximum lateral extent of movement of encroaching vehicles, and

— decreasing the frequency of erratic vehicle reentry to the traffic stream.

Obstacles commonly built into the median, in the form of culvert headwalls, drainage inlet structures, and earthen ditch checks, place a serious limitation on the value of the median as a safe vehicle stopping or recovery space. The median appurtenances presented by these obstacles should be decreased to the smallest practical number and designed so as to present the least possible hazard to the passage of vehicles encroaching upon the median at normal highway operating speeds.

A 30 feet (9 meters) width of obstacle - free median with mild cross slopes (24: 1 for a 30 ft median width and steeper allowable slopes for greater median widths) appears to be the absolute minimum requirement for safe stopping or control of vehicles encroaching on medians at rural highway operating speeds. This provides no more than a minimum reasonable chance for escape from the median, under control, without crossing into the opposing traffic movement (1) (11).

This minimum width should always be exceeded in the design of new rural highway facilities, because the severity of vehicle encroachment increases with traffic volumes. A 40 ft (12 meters) width would be the minimum desirable. Where possible, médians wider than this minimum are now used because of the decrease in headlight glare by plantings and frequent economical improvement of roadway alignment. A desirable median width of 60 ft (18 meters) or more is therefore, not unreasonable (1).

When for measures of economy, the above absolute minimum width cannot be provided, the installation of suitable median barriers, on the basis of suggested traffic volume warrants, should be considered.

2. - Median Barriers

For a barrier to be effective in reducing the severity of accidents it must :

— Prevent vehicles from crossing the median

— Minimize the possible injury to occupants of the vehicle striking the barrier

— Prevent the vehicle from reflecting back into the traffic lanes.

Since much of the rail erected in the past has been designed and located in such a manner that it may be more of a hazard than a safety device, it became necessary to examine guardrails, to determine if they can be used in an effective manner, and what should be done to improve their characteristics. Considerable research has been conducted in this area during the past several years. The California Division of Highways (2) and the General Motors (5) have performed full scale crash tests.

The results of these tests are the following :

— From the stand point of over-all safety a flexible type barrier with chain link fence, light steel posts and three 3/4 in. cables is the most effective out of the 15 designs for a barrier that were subjected to full-scale tests. This cable-chain link barrier (Figure 1) should be used as a barrier in medians where the width available will allow for at least 8 ft (2.4 meters) deflection of the barrier. It could be used in a median of lesser width depending on the degree of risk involved in allowing a momentary encroachment into the opposing roadways. The minimum median width required for this barrier would be in the range of 12 to 16 ft (3.6 to 4.8 meters). This barrier was the only type tested in which the deceleration within the vehicle was tolerable to human occupants.

— For median widths 3 to 12 ft (0.9 to 3.6 meters), the blocked-out metal beam barrier (Figure 1) should be used as the space is insufficient for the cable-chain link barrier.

— For median widths less than 3 ft (0.90 meters), a concrete wall would be the most effective type of barrier in the space available (19).

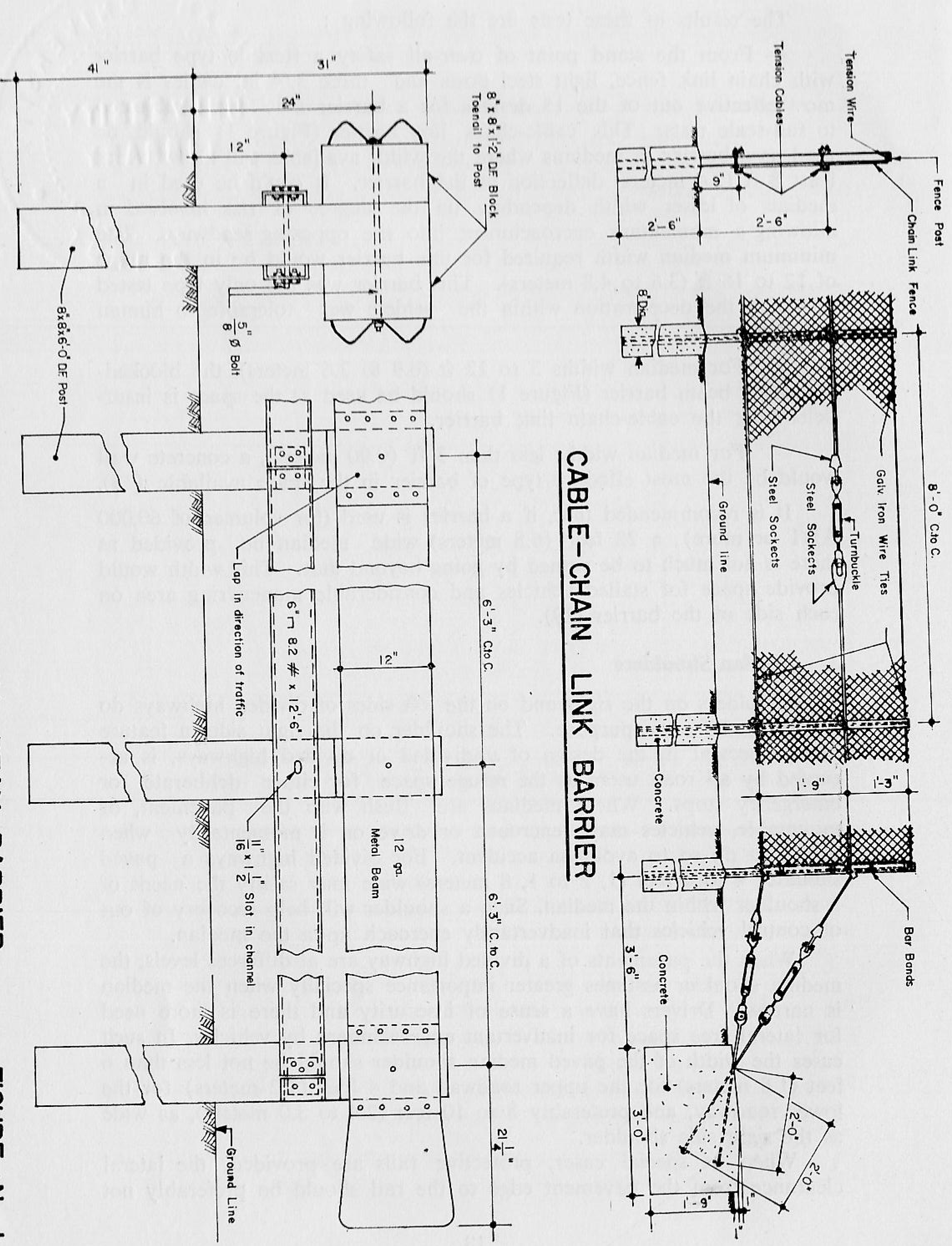
It is recommended that, if a barrier is used (for volumes of 60,000 ADT or more), a 22 feet (6.8 meters) wide median be provided as there is not much to be gained by going beyond that. This width would provide space for stalled vehicles and considerable maneuvring area on each side of the barrier (19).

3. - Median Shoulders

Shoulders on the right and on the left sides of divided highways do not serve the same purpose. The shoulder on the right side, a feature always present in the design of undivided or divided highways, is accepted by all road users as the refuge space for either deliberate or emergency stops. Where medians are flush with the pavement, or mountable, vehicles may encroach or drive on it momentarily when forced to do so to avoid an accident. For divided highways a paved shoulder 4 to 6 feet (1, 2 to 1, 8 meters) wide may satisfy the needs of a shoulder within the median. Such a shoulder will help recovery of out of control vehicles that inadvertantly encroach upon the median.

When the pavements of a divided highway are at different levels, the median shoulder assumes greater importance specially when the median is narrow. Drivers have a sense of insecurity and there is more need for lateral free space for inadvertant encroachment by vehicles. In such cases the width of the paved median shoulder should be not less than 6 feet (1.8 meters) for the upper roadway and 4 feet (1.2 meters) for the lower roadway, and preferably 8 to 10 feet (2.4 to 3.0 meters), as wide as the right side shoulder.

When in special cases, protective rails are provided, the lateral clearance from the pavement edge to the rail should be preferably not



BLOCKED OUT METAL BEAM BARRIER

FIGURE No. 1

less than 6 feet (1.8 meters). The bare minimum allowable will be 4.5 feet (1.4 meters) on the high road and 3.5 feet (1.1 meters) on the low road (1).

4. — Summary of Recommended Median Treatments

The Automotive Safety Foundation and the U.S. Bureau of Public Roads (25), as a summary to the different researches undertaken to relate median treatment to safety, make the following recommendation.

TABLE 1

SUMMARY OF RECOMMENDED MEDIAN TREATMENTS

Volume Class	Median Width		
	Narrow	Medium	Wide
	(o' - 2o') (0m. - 6m.)	(20' - 60') (6m. - 18m.)	(Over 60') (Over 18m.)
Low (less than 60.000 ADT)	None	None	None
High (over 60.000 ADT)	Rigid Barrier	Flexible Barrier	None

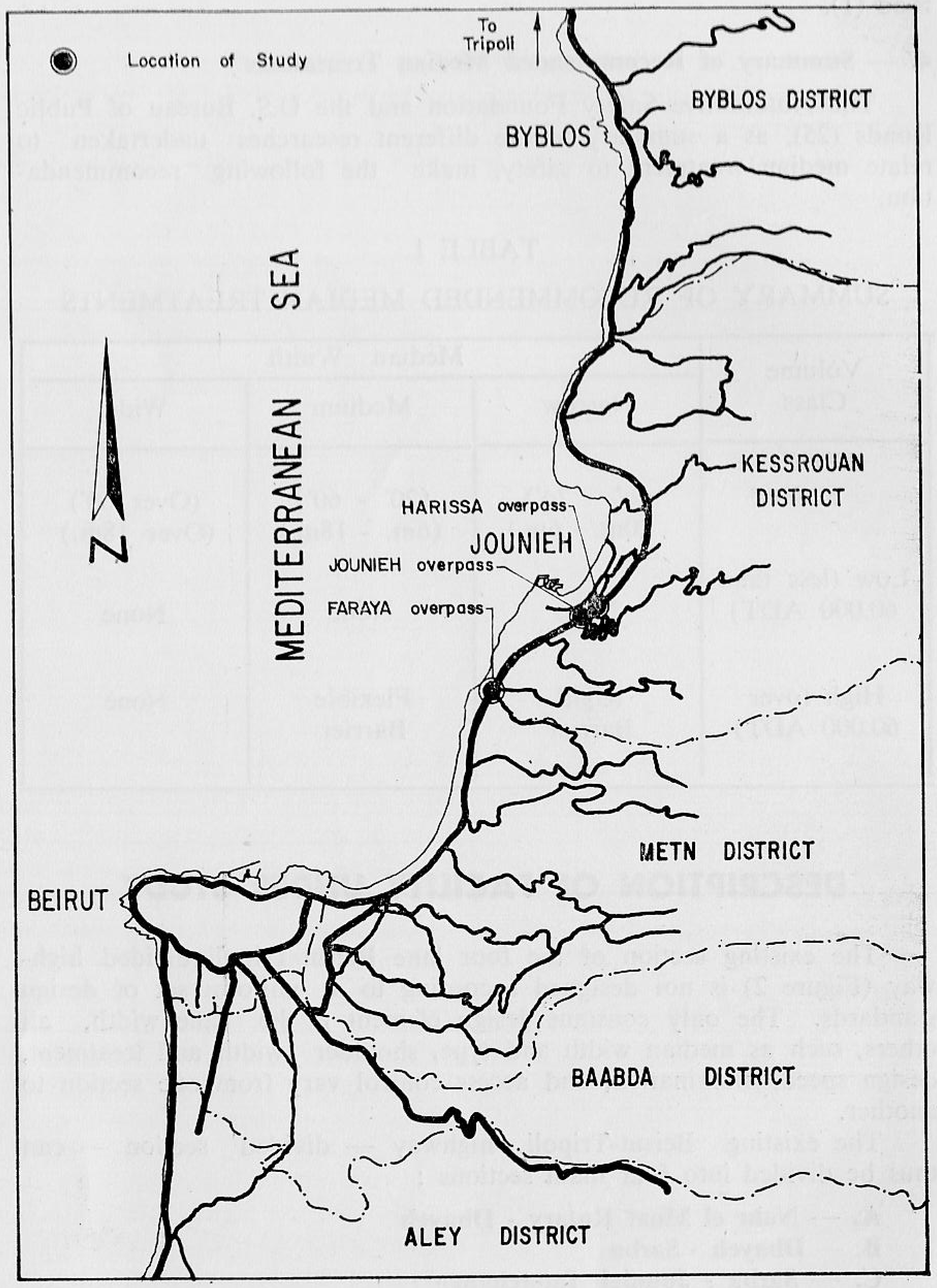
DESCRIPTION OF FACILITY UNDER STUDY

The existing section of the four lane Beirut-Tripoli divided highway (Figure 2) is not designed according to a uniform set of design standards. The only constant design element is the lane width, all others, such as median width and type, shoulder width and treatment, design speed, illumination, and access control vary from one section to another.

The existing Beirut-Tripoli highway — divided section — can thus be divided into four main sections :

A. — Nahr el Moat Rotary - Dbayeh
B. — Dbayeh - Sarba
C. — Sarba - Jounieh Interchange
D. — Jounieh Interchange - Maameltain

These sections were, moreover, designed and executed at different stages. The cross-sectional and longitudinal characteristics, access cont-



MEDIAN STUDY LOCATIONS

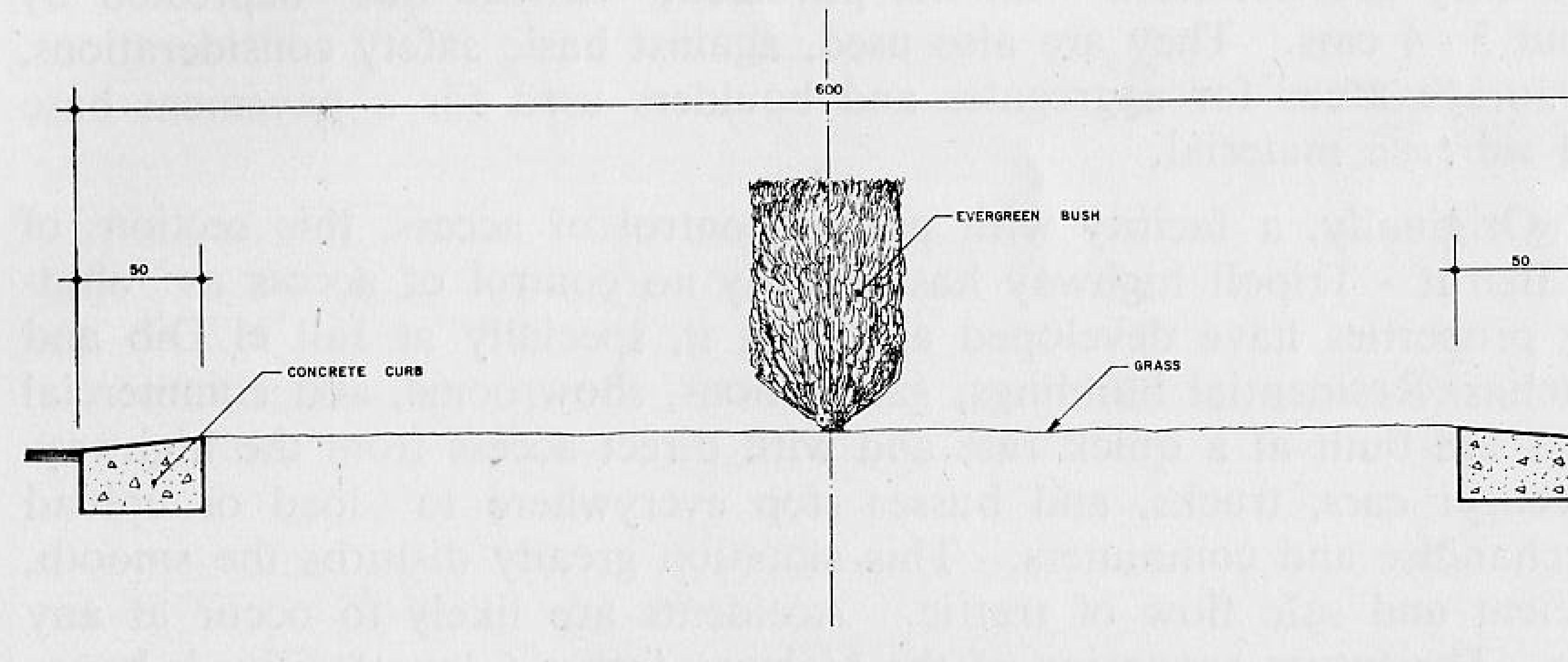
FIGURE No. 2

rol, and roadside development of each of the sections will be described hereafter. A movie ilm 200 ft long is available presenting the different sections and aspects of the highway.

A. — Nahr el Moat Rotary - Dbayeh

The two through traffic lanes are 3.6 meters (12 feet) wide each and the pavement slopes towards the shoulders for drainage purposes.

The median - Type A - is 6 meters (20 feet) wide (figure 3). It is of the flat earth type with flush mountable concrete curbs and can be



MEDIAN CROSS SECTION

TYPE A

FIGURE No. 3 Dimensions in Centimeters

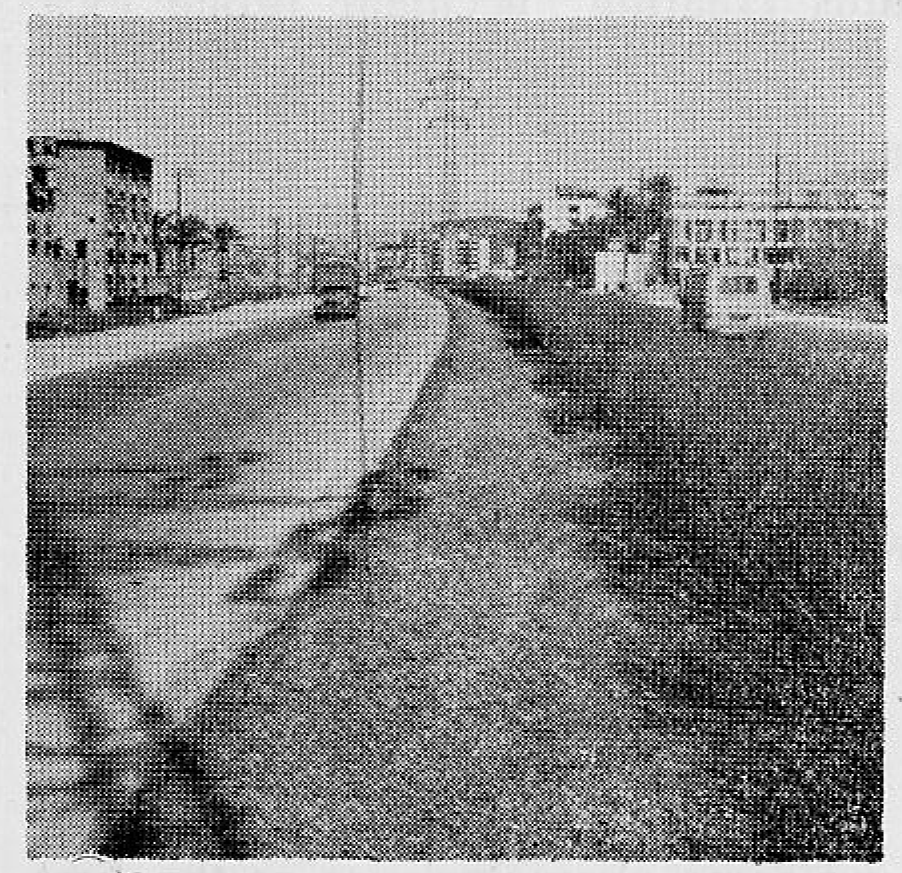


Figure No. 4
Median planted with evergreen bushes

classified as being narrow and traversable. The concrete curbs (singing shoulder) have transverse grooves to warn drivers who, inadvertantly encroach upon the median. All along this section, the median is planted with evergreen bushes (figure 4) which reduce headlight glare from opposing vehicles during night time, prevent deliberate crossing of the median, and provide additional traffic guidance both in day time and at night, thus reducing encroachment frequencies (13). In case of any encroachment or crossing, the flat median permits the driver to direct the vehicle without loss of control back into the traffic lane or if needed to stop without undue damages to the vehicle.

Unfortunately the erection, in the median strip, of huge concrete blocks as bases for electricity pylones, has reduced, to a large extent, the safety of the median strip and the chance of out of control vehicles to stop without hitting them. These large unprotected blocks of concrete can cause severe accidents if hit by vehicles.

Large shoulders 5 meters (16 feet) wide (actually partly paved to provide an additional lane for increased traffic volumes) are provided for both directions of traffic. But due to lack of maintenance, these shoulders have become uneven, rough, and covered with boulders. Moreover they are not flush with the pavement surface but depressed by about 3 - 4 cms. They are also used, against basic safety considerations, as storage areas for aggregates and boulders used for a pavement base and subbase material.

Originally, a facility with partial control of access, this section of the Beirut - Tripoli highway has actually no control of access as abutting properties have developed all along it, specially at Jall el Dib and Antelias. Residential buildings, gas stations, showrooms, and commercial shops are built at a quick rate and with direct access from the highway. Passenger cars, trucks, and busses stop everywhere to load or unload merchandise and commuters. This situation greatly disturbs the smooth, efficient and safe flow of traffic. Accidents are likely to occur at any time. The future expansion of the highway into a 6 lane facility is hence hindered due to the extensive roadside development and lack of extra right-of-way to be used as a shoulder area.

Intersections with facilities leading to the neighboring regions are at grade and unsignalized. No grade separation structures are provided for heavy left turning movements, thus creating accident prone locations.

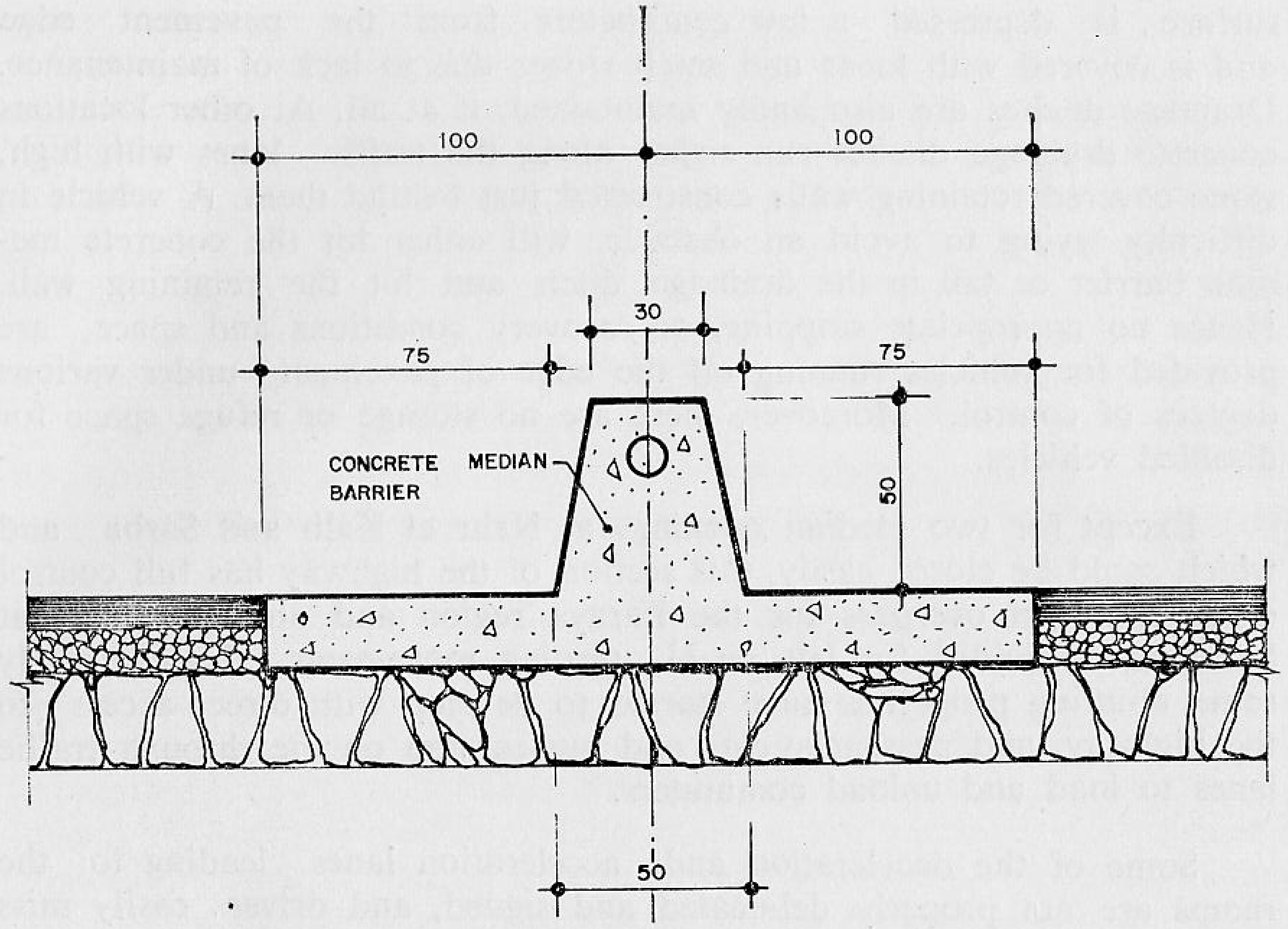
This section of the highway is not illuminated, neither are the different intersections. Moreover these intersections, or exits, are not easily detected, specially by unfamiliar and relatively fast moving drivers during night time or even during day time as traffic directional signs are very small, poor and unsatisfactory.

The longitudinal profile of the section is acceptable. Grades are low, horizontal curves large, which with a rather smooth pavement surface permit comfortable driving even for heavy trucks.

B. — Dbayeh - Sarba

This section of the highway has the same characteristics as the first one as far as the pavement width is concerned.

The median — Type B — is 20 meters (6.5 feet) wide. It has, at its middle, a raised concrete barrier 50 cms wide and 50 cms high (figure 5). It can be classified as being narrow and non-traversable. A



MEDIAN CROSS SECTION

TYPE B

Dimensions in Centimeters

FIGURE No. 5

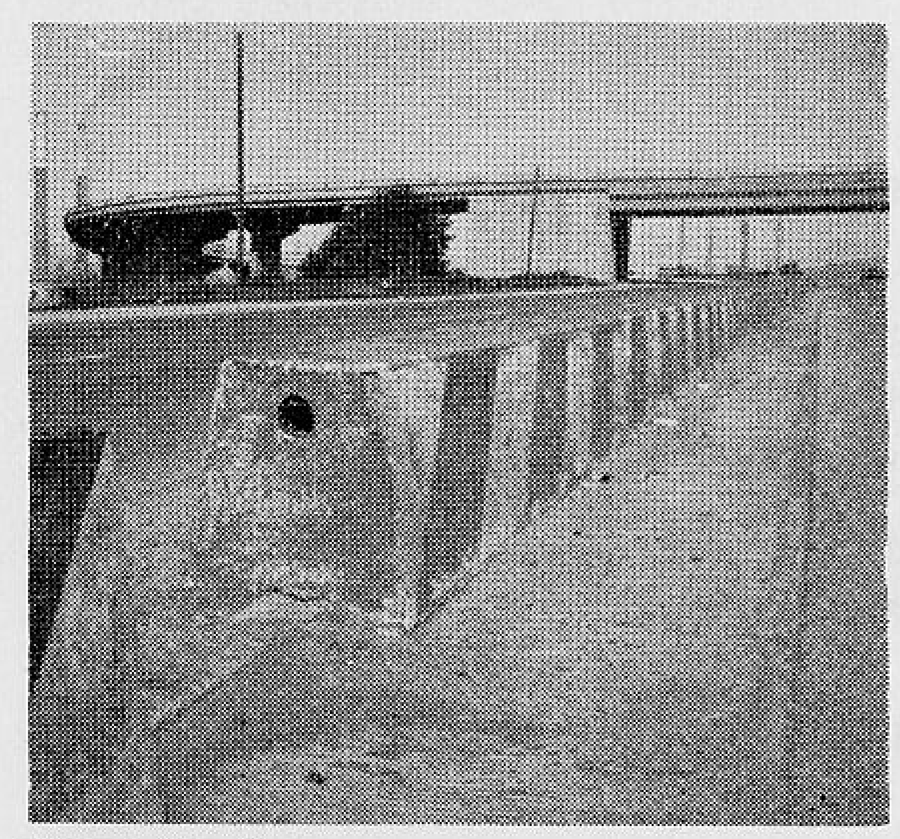


Figure No. 6
Concrete median barrier

big disadvantage of this type of median is that out of control vehicles have no available recovery space and will be severely damaged if they hit the concrete barrier (figure 6). The flush concrete flat curbs on both sides of the median barrier have transverse grooves which give an audible warning to drivers whenever their tires stray off the pavement.

The width of the shoulders vary all along this section of the highway. At certain locations the shoulders are not paved. Their surface is depressed a few centimeters from the pavement edge and is covered with loose and small stones due to lack of maintenance. Drainage ditches are also badly maintained, if at all. At other locations concrete drainage ditches run right along the traffic lanes with high, stone covered retaining walls constructed just behind them. A vehicle in difficulty trying to avoid an obstacle, will either hit the concrete median barrier or fall in the drainage ditch and hit the retaining wall. Hence no appropriate stopping, or recovery conditions and space, are provided for vehicles running off the edge of pavement under various degrees of control. Moreover, there are no storage or refuge space for disabled vehicles.

Except for two median openings at Nahr el Kalb and Sarba and which could be closed easily, this section of the highway has full control of access. An overpass for the Faraya region and an underpass at Sarba are provided for left or U turning movements. Unfortunately some abutting properties have started to develop with direct access to the highway, and passenger cars and busses stop on the through traffic lanes to load and unload commuters.

Some of the deceleration and acceleration lanes leading to the ramps are not properly delineated and signed, and drivers easily miss them.

This section of the highway and the intersections along it are not illuminated. Directional traffic signs are poor and unsatisfactory.

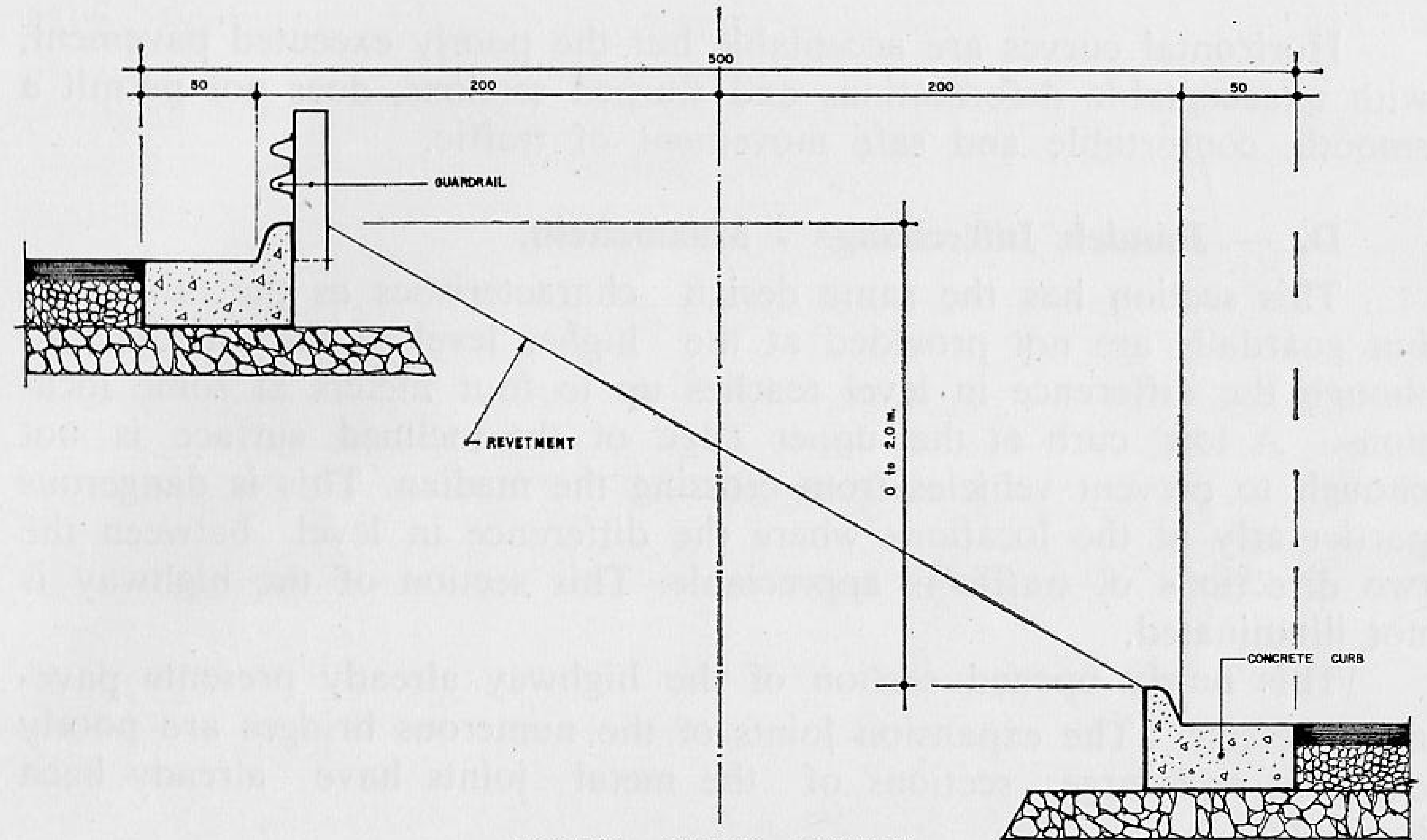
The longitudinal grades of this section are acceptable but horizontal curves at some locations are at substandard levels. These curves are unsafe and uncomfortable specially under wet pavement conditions for speeds higher than 70 to 80 kph (45 to 50 mph).

The pavement itself is quite smooth without excessive deformations.

C. — Sarba - Jounieh Interchange.

As for the first two sections described hereabove, the third section under consideration has the same pavement design characteristics: two through lanes 3.6 meters (12 feet) wide each, for both directions.

The median - Type C - is 5 meters (16 feet) wide. For most of its length, it has an inclined stone paved surface, the difference between the two levels varying between zero and two meters. (Figure 7). Guardrails at the higher level protect vehicles from crossing the median and



MEDIAN CROSS SECTION

TYPE C

Dimensions in Centimeters

FIGURE No. 7

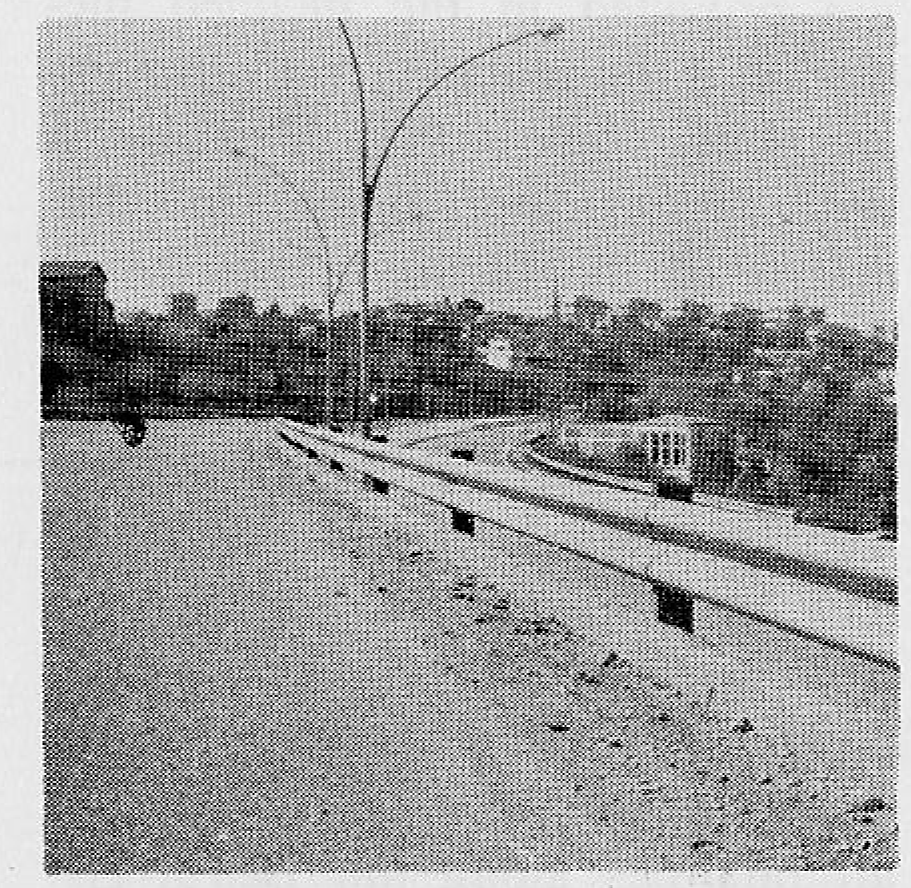


Figure No. 8
View of guardrail

falling down to the lower level, (figure 8). The median can hence be classified as : narrow and non-traversable.

The uniform shoulders are 2 meters (6.5 feet) wide, they are again of the earth type. But at one location near the Jounieh Interchange and in one direction only, no shoulders are provided. Guardrais prevent vehicles to run off the pavement edge and to fall down the retaining walls behind. Concrete blocks with transverse groves 50 cms (1.5 feet) wide and flush with the pavement are provided all along.

This section of the highway has full control of access. As it passes through dense residential agglomerations, many grade separation structures are provided to serve local traffic. Abutting properties have no direct access to the highway.

The highway is illuminated all along this section, lamp poles are located in the median. Traffic signs are unsatisfactory.

The longitudinal grades of this section are steep (6 to 7%). Heavily loaded trucks slow down while climbing the long steep grades.

Horizontal curves are acceptable but the poorly executed pavement, with unacceptable deformations and warped sections, does not permit a smooth, comfortable and safe movement of traffic.

D. — Jounieh Interchange - Maameltein.

This section has the same design characteristics as the third one, but guardails are not provided at the higher level of the median although the difference in level reaches up to four meters at some locations. A low curb at the upper edge of the inclined surface is not enough to prevent vehicles from crossing the median. This is dangerous particularly at the locations where the difference in level between the two directions of traffic is appreciable. This section of the highway is not illuminated.

This newly opened section of the highway already presents pavement defects. The expansion joints of the numerous bridges are poorly executed and large sections of the metal joints have already been torn out.

All along the Beirut-Tripoli divided highway no provisions are made for pedestrian traffic. Pedestrians cross the highway without any control.

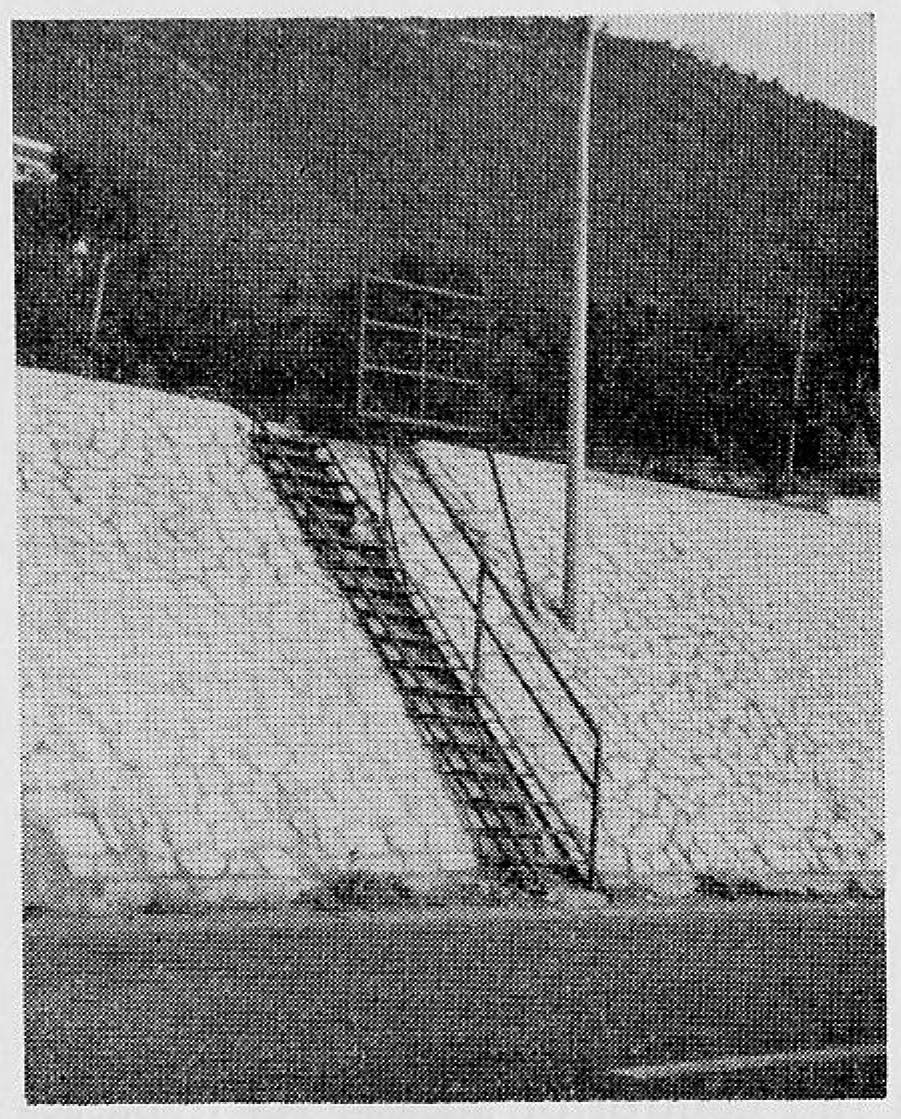


Figure No. 9
Pedestrian crossing in median

At some locations even steps are provided in the inclined median and the retaining walls for pedestrians (figure 9). This is a very serious shortcoming in the design of the facility. This defect should be remedied and all pedestrian movements banned altogether from the highway right-of-way. That will surely increase the safety of pedestrians and reduce to a large extent the pedestrian fatality rate along the facility and which accounts for about 52% of all fatalities along the Beirut-Tripoli highway.

The following tables 2 and 3 present accident record data during the 1960-1966 period.

This information was obtained from the report on Beirut-Tripoli road, published by B.C.E.O.M. (Bureau Central d'Etude d'Outre-Mer, France) and A.C.E.C. (Associated Consulting Engineers and Consolidated Engineering Company, Lebanon).

TABLE No. 2

Number of Accidents in Police Records

1960 - 1966

Year	All Lebanon	Beirut - Tripoli Road
1960	1947	348
1961	2142	443
1962	1992	438
1963	2141	516
1964	2099	446
1965	2146	460
1966	2423	622
Total	14894	3273

TABLE N° 3

Composition of Accidents Existing. In

Beirut - Tripoli Road 1960 - 1966

Accidents including	All accidents	Accidents including death	Accidents including Injuries
Car Alone	16,2%	16,9%	18,3%
Car with pedestrian	44,2%	52,2%	40,3%
Car with 2 wheeler	5,6%	3,3%	4,2%
Car with car	33,1%	23,1%	35,6%
Car with train	0,9%	4,5%	1,6%

LOCATIONS OF STUDY

The divided section of the Beirut-Tripoli highway, is a unique site where a study on this subject could materially be performed. The grade separation structures presented perfect locations where a motion-picture camera could be installed without interference from the through traffic stream.

Figure 2 indicates the location of the different grade separation structures where the motion-picture camera was installed, and which are referenced as follows:

A - Faraya Overpass. - Case I

B - Harissa Overpass. - Case II

C - Jounieh Overpass - Case III

Figure No. 10
Concrete median barrier - type B -
Location under study

A - Faraya Overpass

The Faraya Overpass was used to study the concrete median barrier - Type B - (Figure 5). It is located on a straight section of the highway and far from any horizontal curves which might affect traffic behaviour (Figure 10). The low longitudinal grade does not materially affect the speed of passenger vehicles.

The traffic volume characteristics of this section of the highway is shown in Figure 11.

The behavior was studied for hourly volumes varying in between 500 vph and 1100 vph. the increments being 100 vph. Each hourly volume, V, represents in reality a range from V- 50 vph to V + 50 vph.

Being the first location under study, vehicle behavior was considered for two cases.

1. - When vehicles were moving in the left lane alone,
2. - When vehicles were moving in both lanes.

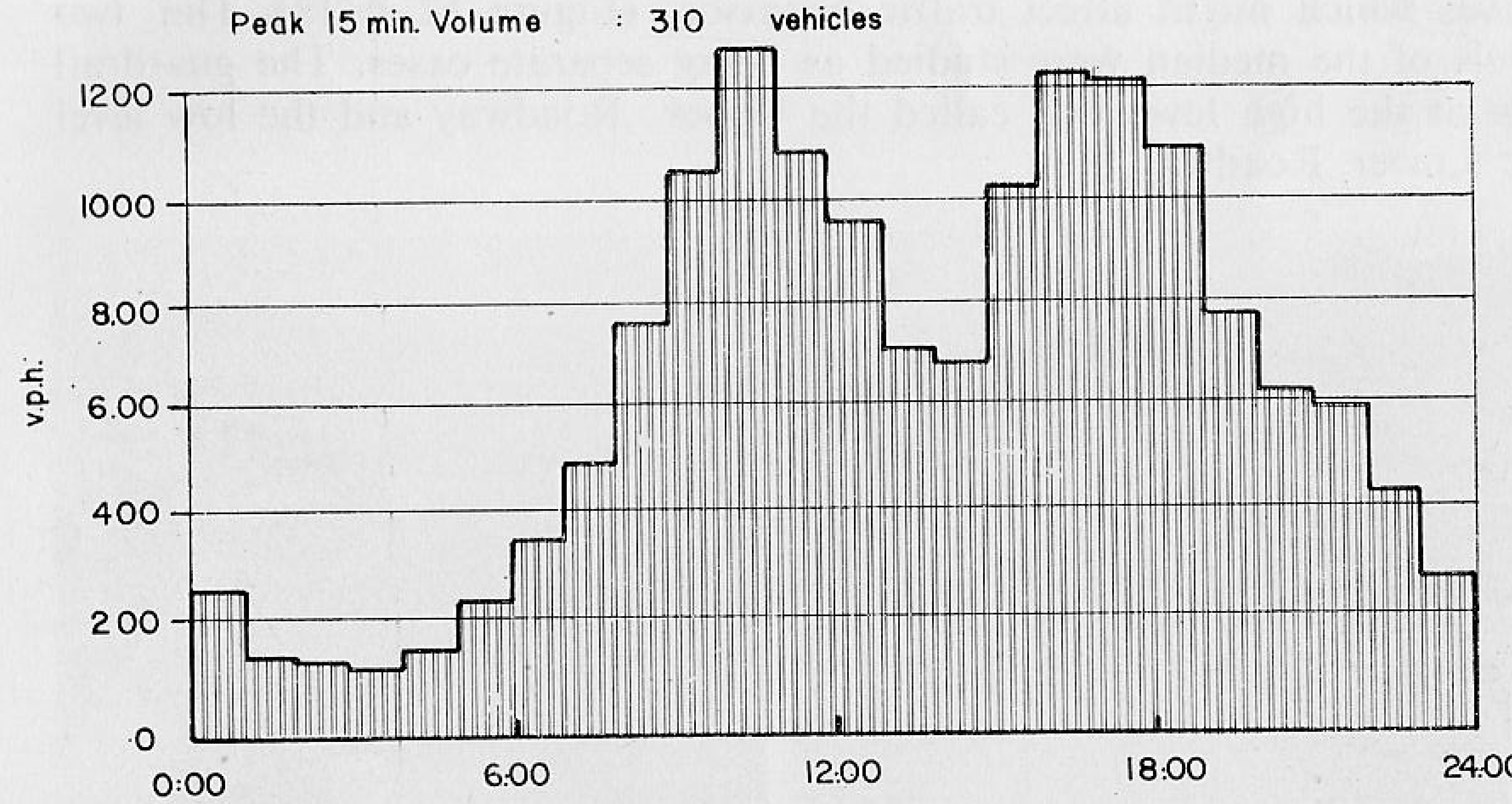
The results showed, for a certain traffic volume, that vehicles travel further from the median in the first case. This is quite natural, as vehicles, with an obstruction only on their left side, tend to travel far from it.

FARAYA OVERPASS

Direction S-N

SUNDAY

Daily Volume	:	15887	v.p.d.
Peak hour Volume	:	1283	v.p.h.
Average hourly Volume	:	662	v.p.h.
Peak 15 min. Volume	:	310	vehicles



TYPICAL WEEKDAY

Daily Volume	:	11931	v.p.d.
Peak hour Volume	:	871	v.p.h.
Average hourly Volume	:	497	v.p.h.

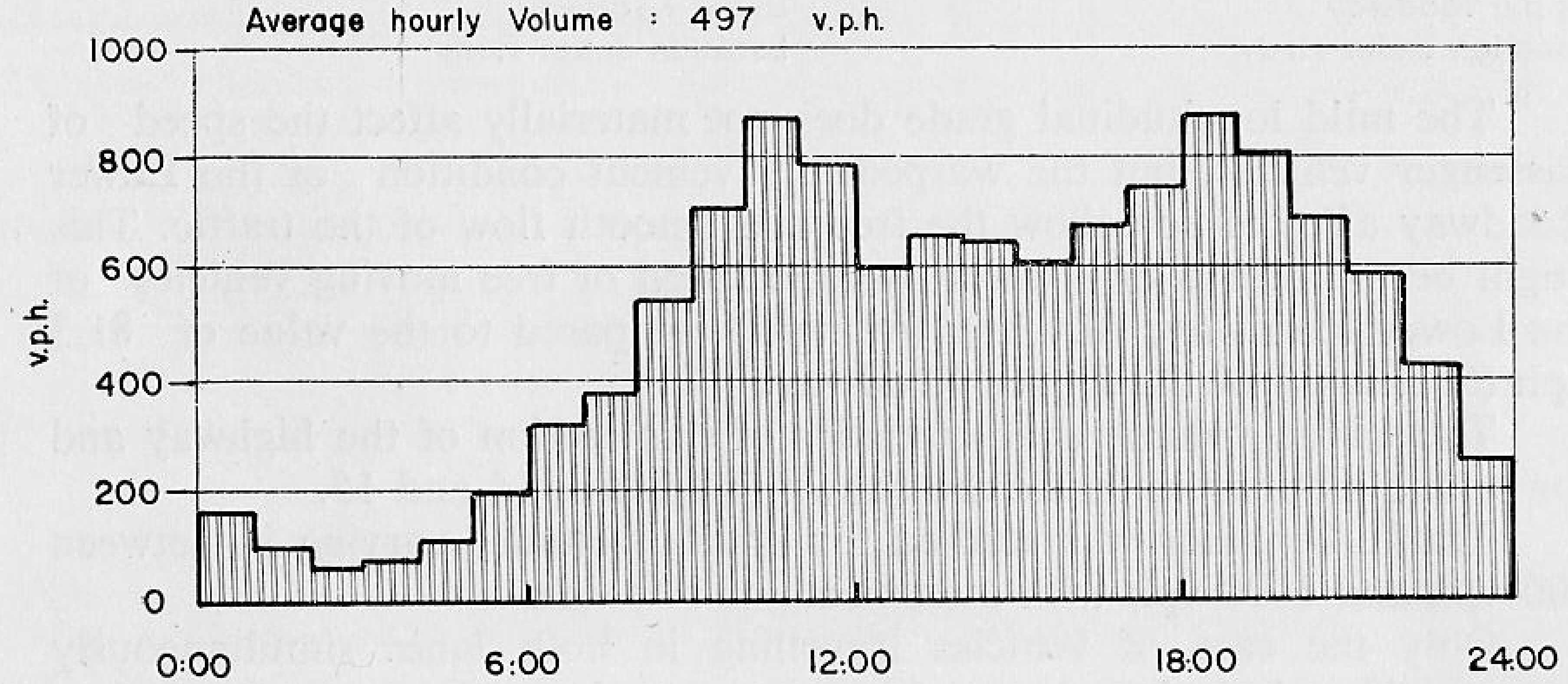


FIGURE No. 11

Daily Traffic Flow Diagrams

The study was continued from thence only for the second case, i.e., when vehicles travelled in both lanes simultaneously.

The average speed of free flowing vehicles was found to be 82 kph (51 mph).

B - Harissa Overpass

The Harissa Overpass was used to study the Split Level Median with Guardrail - Type C - (Figure 7). This grade separation structure is located on a straight section of the highway and far from horizontal curves which might affect traffic behavior. (Figure 12 & 13). The two levels of the median were studied as being separate cases. The guardrail side at the high level was called the Upper Roadway and the low level the Lower Roadway.

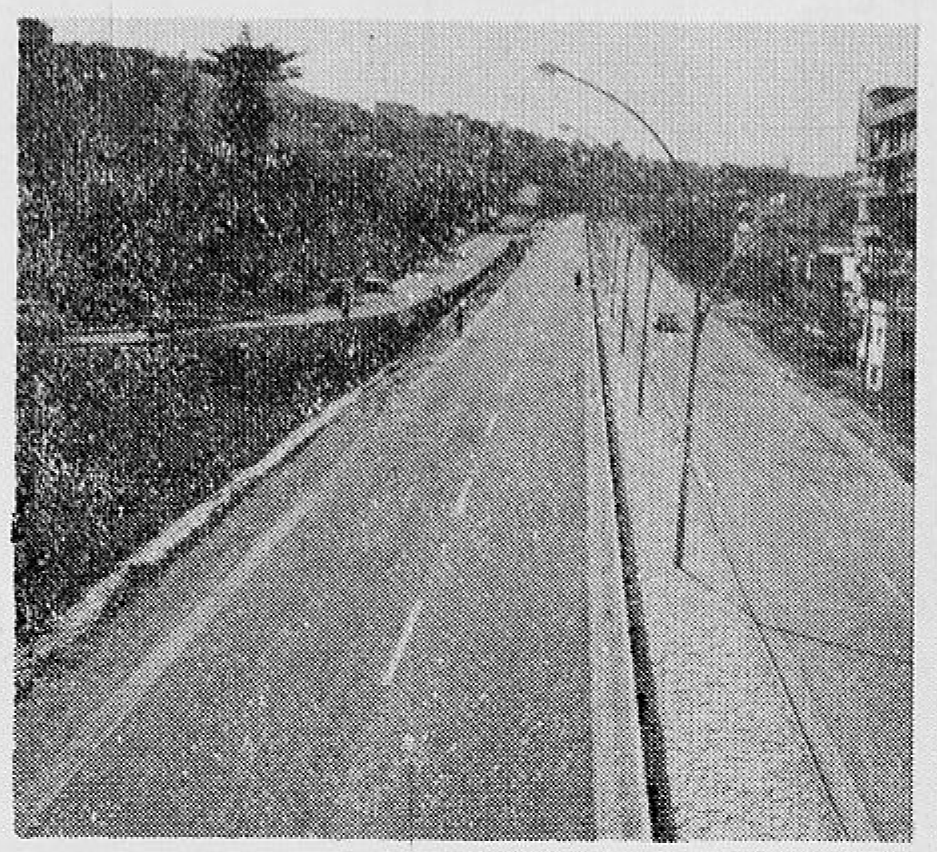


Figure No 12
Split level median with guardrail - type C -
Upper roadway
Location under study

Figure No. 13
Split level Median with guardrail - typé C -
Lower roadway
Location under study

The mild longitudinal grade does not materially affect the speed of passenger vehicles, but the warped pavement condition of the Lower Roadway affected somehow the free and smooth flow of the traffic. This might be the reason of a lower average speed of free moving vehicles of the Lower Roadway, 78.4 kph (49 mph) compared to the value of 81.3 kph (50.5 mph) of the Upper Roadway.

The traffic volume characteristics of this section of the highway and for both directions of traffic are shown in Figures 14 and 15.

Traffic behavior was studied for hourly volumes varying in between 400 vph and 1000 vph with increments of 100 vph.

Only the case of vehicles travelling in both lanes simultaneously was considered during the study.

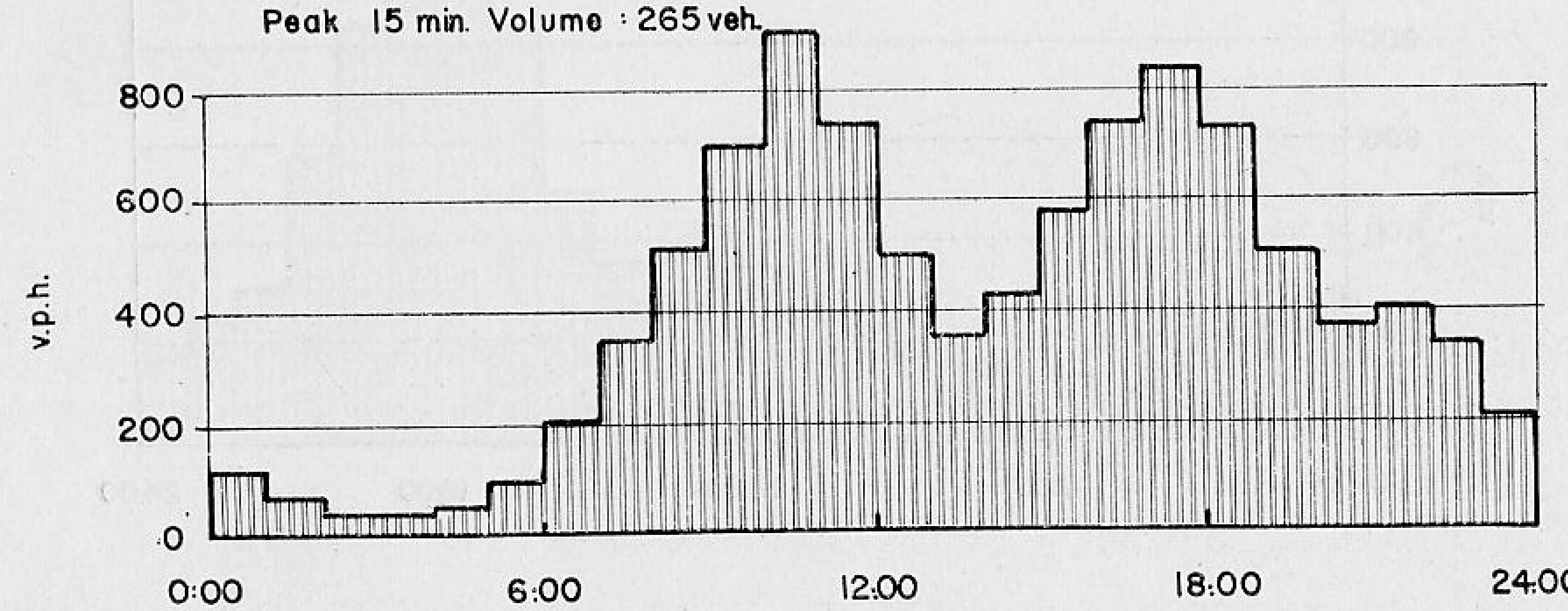
The two levels are referenced as follows :

Upper Roadway - Case IIa
Lower Roadway - Case IIb

HARISSA OVERPASS
Upper Roadway
Direction S – N

SUNDAY

Daily Volume : 9728 v.p.d.
Peak hour Volume : 903 v.p.h.
Average hourly Volume : 405 v.p.h.
Peak 15 min. Volume : 265 veh.



TYPICAL WEEKDAY

Daily Volume : 7261 v.p.d.
Peak hour Volume : 511 v.p.h.
Average hourly Volume : 302 v.p.h.

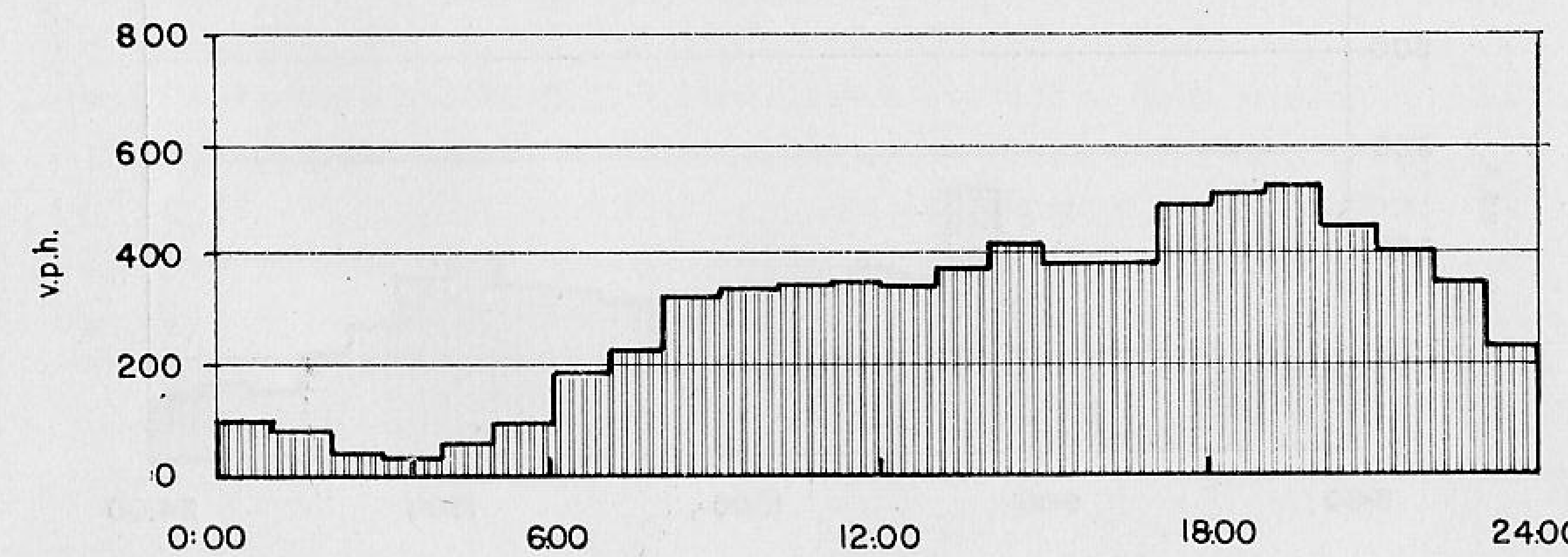
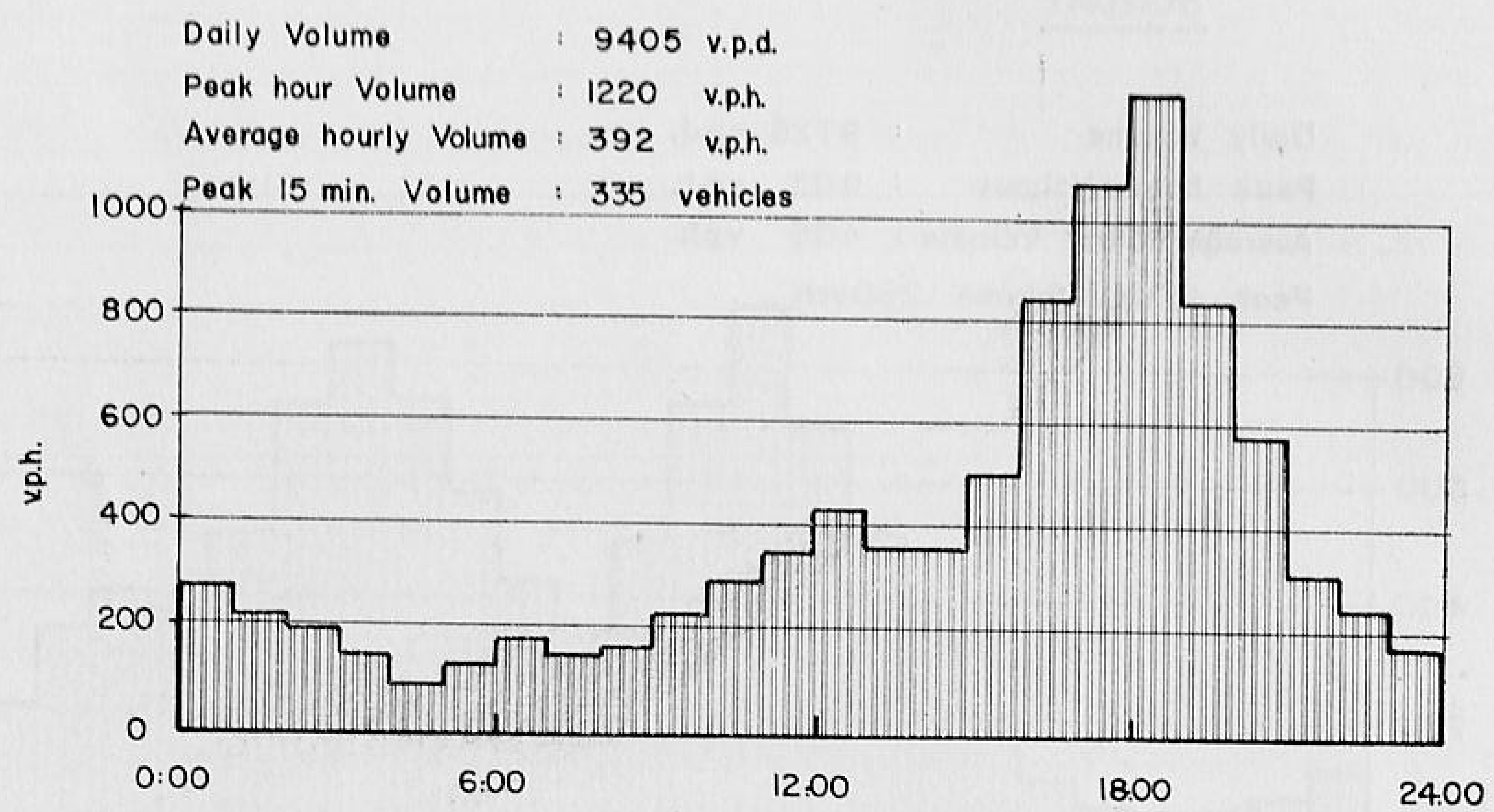


FIGURE No. 14
Daily Traffic Flow Diagrams

HARISSA OVERPASS
Lower Roadway
Direction N - S

SUNDAY



TYPICAL WEEKDAY

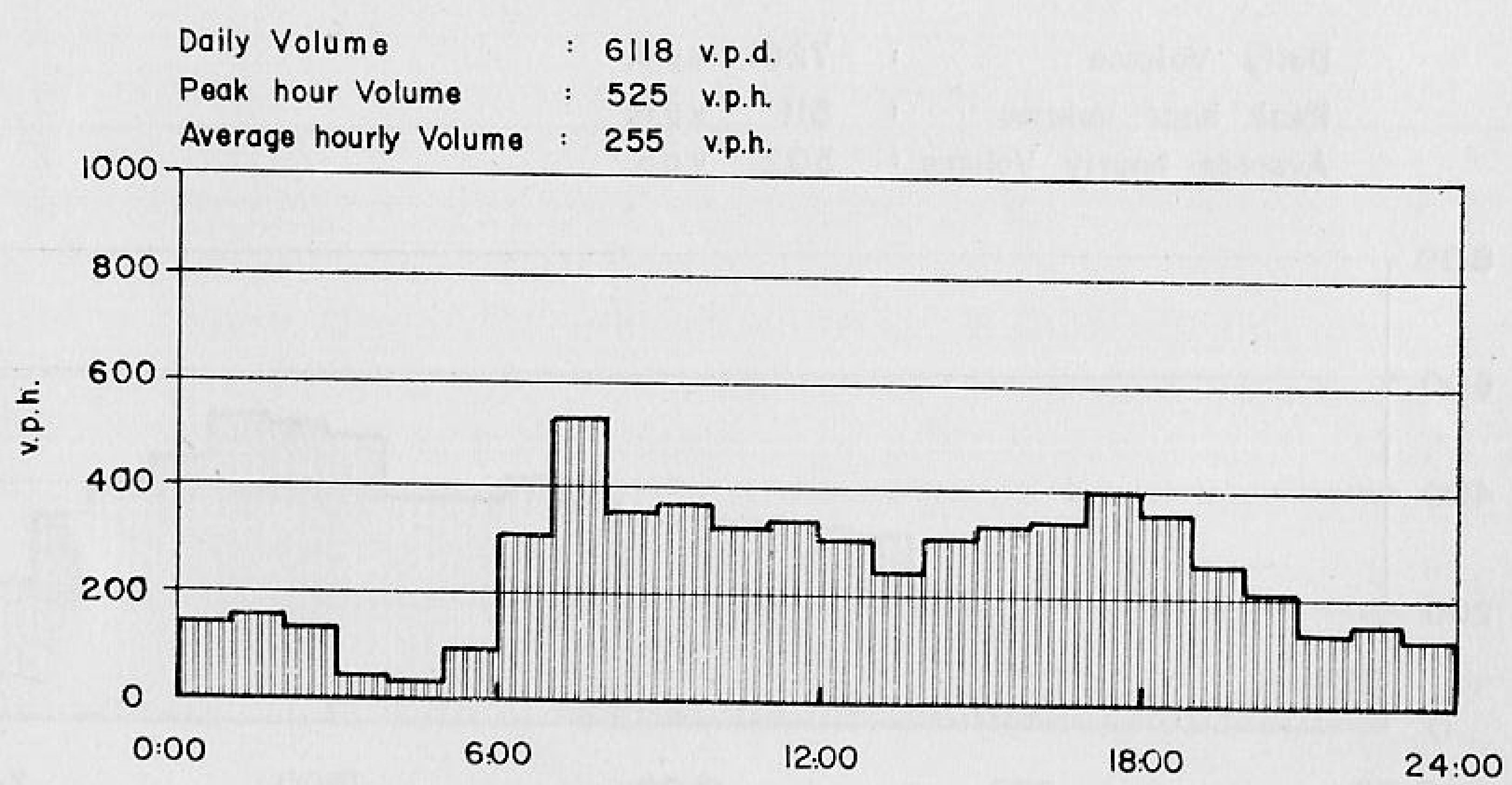


FIGURE No. 15

Daily Traffic Flow Diagrams

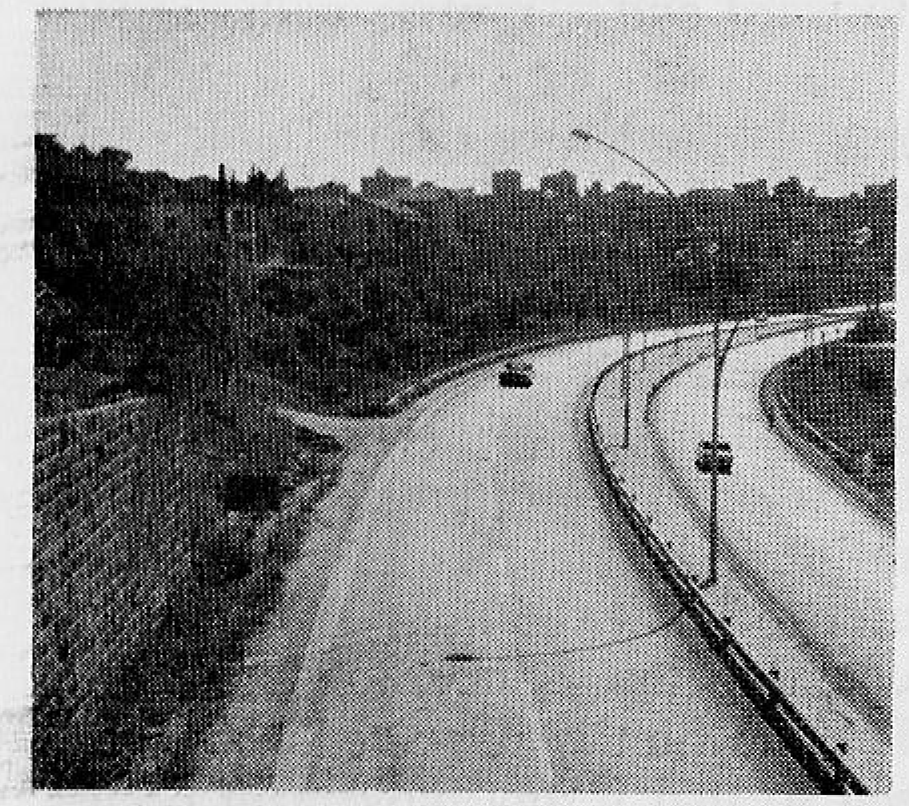


Figure No. 16
Split level median with guardrail - type C -
Upper roadway on horizontal curve
Location under study

C - Jounieh Overpass

The Jounieh Overpass was used to study the Split Level Median with Guardrail - Type C - (Figure 7) but located on a horizontal left curve (Figure 16). The Upper Roadway on the guardrail side was only considered to see if the traffic behavior is affected by a horizontal curve by comparing the results to the ones of the straight line section : Case IIa.

The longitudinal grade at this location is quite high (about 6%) and hence only data for lateral placements at hourly volumes ranging from 400 vph to 1000 vph, were considered.

Again only the case of vehicles travelling in both lanes simultaneously, was considered during the study.

The traffic volume characteristics are the same as for Case IIa, as the two locations under study were near other (figure 14).

EQUIPMENT

A MOTION PICTURE CAMERA

The camera used to record the vihicular movement of the through lanes was a standard 16mm Bell and Howell - the OTMR - camera (9) with improved geared turrets which automatically bring into position the matching viewfinder for the lens in use. For this study the 3 inch telescopic lense and the 3 inch viewfounder objective were used.

The camera uses a 100 foot magazine of 16mm film. Kodak Plus-X black and white film was used with filming done at a speed of 15 frames per second. The camera was mounted on a tripod by means of a standard socket found at the bottom of the camera.

B. PROJECTOR

The projector used to analyse the film for speed and lateral placement was a 16mm Model 173, Bell & Howell, Time and Motion Study Projector. The projector can be operated at movie speed (15 frames per second or 900 frames per minute) forward and reverse with instant change of direction.

This type of projector is specially well adapted to single frame movie picture analysis. If one desires to study a particular frame of the film, the frame in question can be placed in the proper position by simply moving the film with a hand crank which is attached to the motor of the projector. The single frame can be projected as a still picture for an indefinite period without loss of illumination or damage to the film. The projector has a frame counter which adds when the projector is operating forward and substracts when it is operating in reverse and can be reset to zero. This last feature allows the operator to know the time that has elapsed between any two exposures (by counting the number of frames).

A rigid set-up is also required when the film is projected. A reference mark is also located on the screen so that if any movement occurs in the projector or the screen, this movement can be detected and the error corrected. Usually a reference mark such as a rigid light pole or the edge of the pavement was used for this purpose.

C. TRAFICOUNTERS

The volumes of traffic used in this study were obtained by using standard Model RC Traficounters manufactured by the Streeter Amet Division of Goodman Manufacturing Company, Illinois, U.S.A.

The counter operated on a 6 volt battery and recorded traffic volumes every quarter of an hour.

D. ELECTRO-MAJIC RADAR SPEED METER

As with all such meters, a transmitter-receiver unit beams a microwave radio frequency at an advancing vehicle in the operating zone and receives this same frequency back plus or minus a doppler shift. The doppler shift is measured and converted to the speed of the vehicle and is read directly in kilometers per hour on the linear scale of the indicator. The meter operates on a 12 volt battery. The battery was regularly checked by means of a voltmeter to insure against speed readings being affected due to fluctuation or change in voltage. The instrument operates within a range from 0 to 120 Kph. The radar meter is linearly calibrated in scale divisions of one kilometer per hour. When using the meter, vehicle detection is effective within a core of approximately twenty degrees throughout a range of 50 meters. The above range holds true when the unit is placed approximately three feet off the ground. Increasing the height of the unit increases the range slightly. and conversely decreasing the height decreases the range slightly. Thus the unit was placed approximately three feet off the ground throughout the study. The radar meter was also placed so that its beam was at an angle of ten degrees or less with respect to the direction of traffic. By making this angle small, any error in the speed readings due to directional factors are negligible.

The radar meter provides an indicated speed by the needle swinging sharply to a definite reading when a vehicle comes into its operating beam, which is shaped somewhat like a spot light beam and has very much the same characteristics, remaining there for an instant, and then returning to zero when the car passes out of the beam. It is essential that the reading be maintained for an instant to insure a true reading. At the beginning and throughout the speed study, a tuning fork was used for calibration and for checking of the meter. This tuning fork vibrated at a frequency equivalent to that which would register 60 kilometers per hour on the indicator.

PROCEDURE

A. FIELD WORK

The data on lateral placement and speeds of traffic using the through traffic lanes at the different locations under study, were obtained by use of motion picture photography using a 16mm. motion picture camera. The motion picture type of study was selected, after consideration of other methods, as being the best available method to study and analyse. The «Traffic Analyzer», developed by the Bureau of Public Roads, U.S., is the best suited and most precise digital speed - placement equipment for such studies but it is not available in Lebanon and is a very expensive piece of equipment. This complicated and automatic recording unit is described in Appendix A.

Time lapse movie photography has been used by industrial engineers for several years to make time and motion studies. Their experience has indicated that time lapse photography could be used for traffic analysis with great success (6).

Time lapse movie photography is used because this method has many advantages over other means of taking and analyzing traffic data. Only one person, the camera operator, is required for obtaining data.

The motion picture type of survey provides an accurate method of obtaining all necessary data for studying traffic operational characteristics. A permanent record of all collected data is also recorded on film which then may be rerun many times so that a given traffic situation can be studied over and over again.

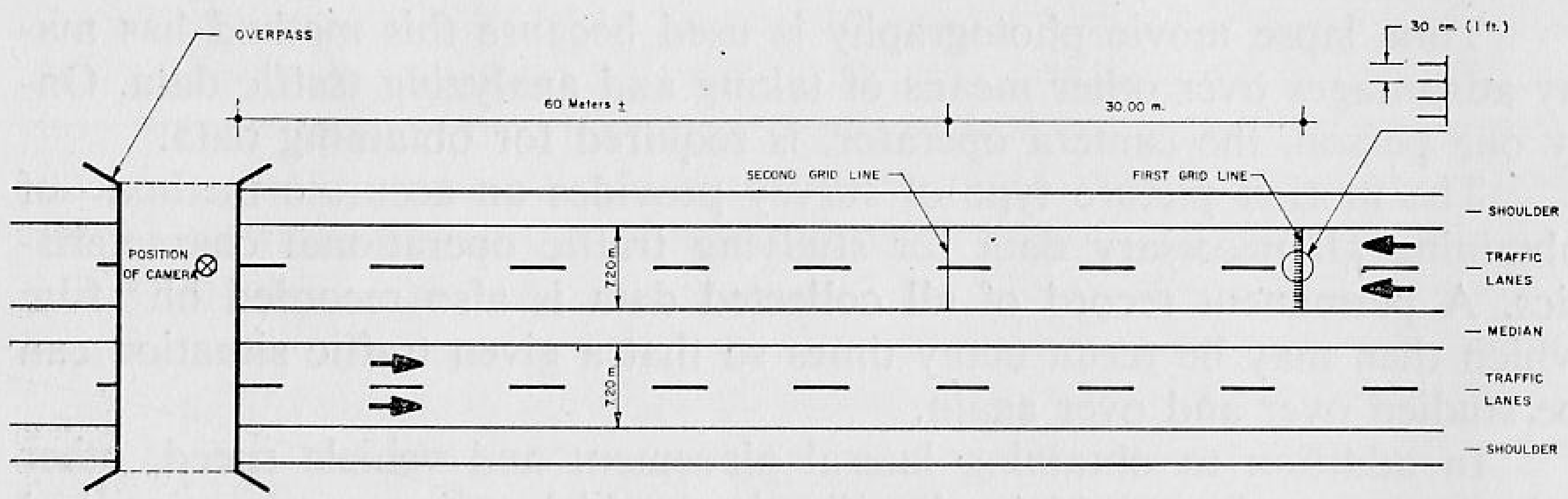
In addition to obtaining lateral placement and vehicle speed, other information such as vehicle classification, vehicle using acceleration and deceleration lanes, and vehicle weaving can be also obtained by motion picture type of surveys. Furthermore, a lane by lane analysis of traffic flow can also be made.

A movie camera capable of taking pictures at a rate of 15 frames per second, or 900 frames per minute, was used to study traffic operations. This particular camera had a film capacity of 100 feet and therefore could be used to collect data for about a four minute period of time. The time interval between consecutive frames of the movie film was one fifteenth of a second. This is not the lowest number of frames possible on this type of camera but it was found to be adequate for this type of study. Moreover this is the minimum speed of the projector used in the study.

Reconnaissance studies and preliminary surveys were conducted before the study proper was undertaken. The different locations, along the divided section of th Beirut-Tripoli highway, (Nahr el Moat Rotary-Maameltain) suitable for this investigation were first chosen. To determine the best location for the movie camera, pictures from different angles were next taken, inspected, analyzed and the best location selected. The most appropriate procedure to follow during the photography was also determined and tested. The minimum sample size was determined statistically to be one hundred vehicles for each location.

Traffic counters were installed at each location before any photography was undertaken. As expected the maximum traffic volumes were obtained during the weekends or holidays, when traffic generated by pleasure trips reached to a maximum. This was true for all the locations. These counts were used as a guidance during the study proper as the behavior of drivers at different traffic volumes was under consideration.

Before any photography was taken at a particular location a grid line was installed on the pavement by placing 3 inch white medical adhesive tapes on the asphalt surface. The adhesive tape was placed perpendicular to the center line of the highway, at two different points 30 meters (98.4 feet) apart to measure vehicular speeds. The reason for using adhesive tape was to avoid placing permanent markings on the pavement. Furthermore small pieces of adhesive tape were placed at 30 cms (or nearly I foot) center to center, at one of the grid lines and parallel to the center line of the highway to measure the lateral placement of vehicles (Figure 17).



PLAN VIEW OF GRID LINE SYSTEM
& POSITION OF MOVIE CAMERA

FIGURE No 17

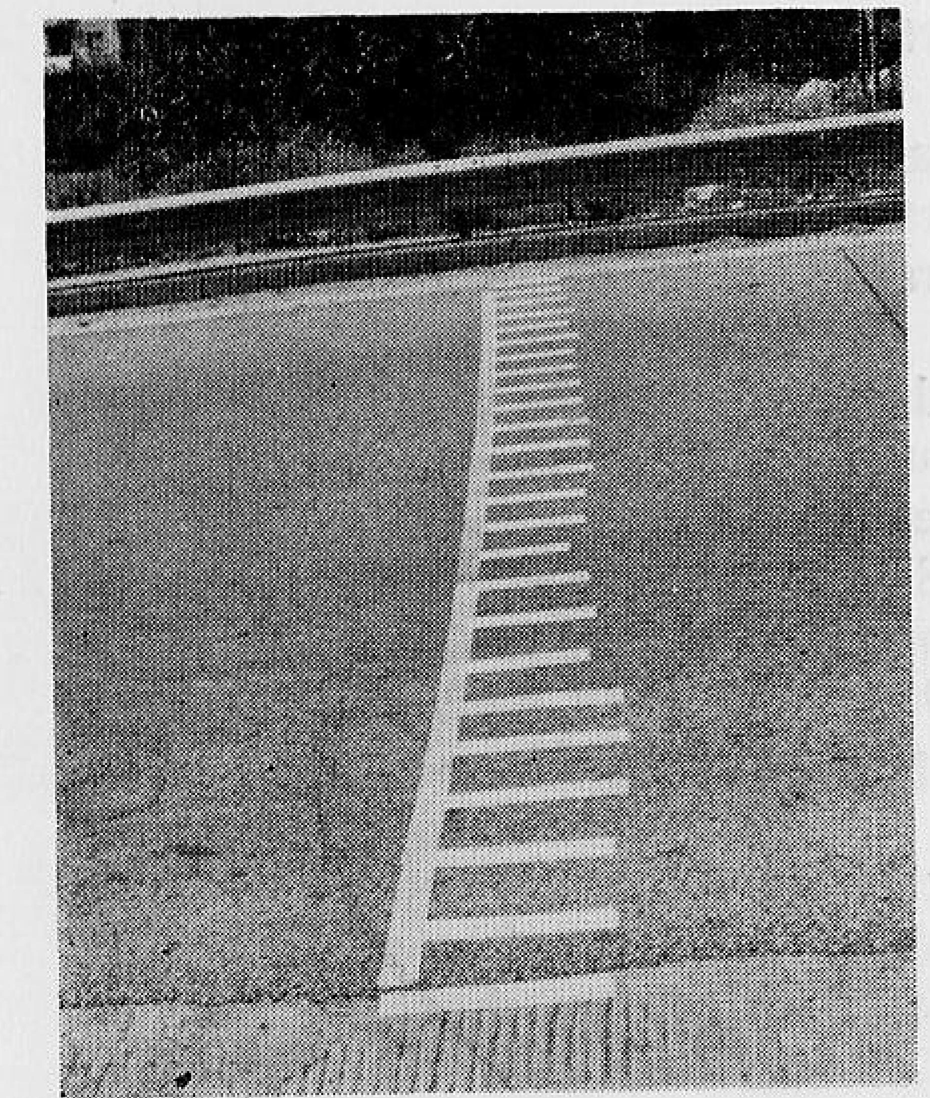


Figure No. 18
First grid line on bavement

Figure 18 shows a typical grid system layout that was used at one of the locations under study.

To estimate the exact speed of the movie camera, a certain object was filmed during exactly 10 seconds and the number of frames counted during the projection of the film. This procedure was repeated once for every three or four cartridges of film, as a check, to be sure that no variations occured. These tests showed that the speed of the movie camera was exactly 15 frames per second, or 900 frames per minute, and this value was used during the computation of vehicular speeds. Once this value vas set the speed regulator of the movie camera was not touched any more.

The average speed of vehicles along the highway under study was about 80 kph (50 mph). This required 20 frames for a vehicle running at a speed of 80 kph to cross the two grid lines installed on the pavement 30 meters apart (Table 4). The number of frames lost per vehicle was estimated to be about 15 frames. The number of frames per cartridge 100 feet long being 3800 approximately, the number of vehicles that could be filmed per cartridge was about eighty to one hundred vehicles depending upon the traffic volume.

The filming was done from a vantage point to have as accurate a picture as possible of the traffic flow. The grade separation structures along the Beirut-Tripoli highway provided excellent locations to install the 16mm. motion picture camera. These locations overlooking the highway lanes from a vertical position were especially advantageous for exact estimations of lateral placements.

The camera was located at approximately 60 meters from the location under study. Adequate photography for analysis could be taken from such a distance. The median, the two traffic lanes, and the shoulder between the two grid lines, 30 meters apart, could be photographed together. The camera was placed on a rigid tripod and was not moved during the time of photography. The 3 inch telescopic lense and viewfinder were used during all the study.

Movies were taken of each vehicle just before it reached the first grid line and until it crossed the second one. This procedure allowed the measurement of lateral placement and speed of each vehicle travelling in between the two grid lines. The two front wheels of the vehicles were used as reference points, as the pictures were taken facing the traffic stream.

A traffic counter located near each grid line system recorded traffic volumes during the period of photography. The exact time and date each film was shot were also recorded. Traffic volumes and the results were obtained during the office work.

The relatively slow camera speed used during the study did result in some loss of accuracy for high vehicular speeds (table 4). A vehicle travelling a distance of 30 meters between two grid lines during 36 frames would be travelling at a speed of 43.8 kph (27.2 mph). The variation per frame is only 1.2 kph (0.8 mph). On the other hand if only 18 frames were required the speed would be 90.0 kph (55.9 mph), while for 19 frames it would be 85.3 kph (53.0 mph). The variation per frame at this speed is 4.7 kph (2.9 mph).

Spot speeds of vehicles travelling at the different locations of study were measured using an automatic radar speed meter. The meter was fixed on the window of a car which was parked on the shoulder. The cover of the engine was raised as if the car was disabled. This concealed the meter and avoided suspicion and curiosity from drivers who otherwise might have reduced their travel speed. The speed was measured after the vehicle had passed the transmitter which consequently was directed to transmit the beam in the direction of traffic flow.

B. OFFICE WORK

The films were analyzed by projecting them through the time-motion study projector. The screen was installed at a fixed distance from the projector and a grid was traced on the screen from the movies to the same relative scale as that which was placed on the pavement. The longitudinal lines of the grid, parallel to the center line and at 30 centimeters (one feet) intervals, were numbered to facilitate the work of the recorder.

The lateral placement of the vehicles was determined by using the first transverse grid line placed on the pavement. The vehicular speeds were computed by obtaining the number of frames a certain vehicle required to travel the constant distance of 30 meters (98.4 feet) in between the two transverse grid lines.

To record the lateral placement and speed of each vehicle the procedure discribed herebelow was used:

The frame showing a particular vehicle at the first grid line was stopped, its lateral placement range and the frame number read on the projector's counter recorded. The frame number was recorded in numbered columns relative to that particular lateral placement range. Then the film was advanced using the projector's hand crank until the vehicle reached the second grid line and the frame number recorded near the

first one. The difference between the two frame numbers gave the number of frames, n, that the vehicle, with the recorded lateral placement, needed to travel between the fixed distance of 30 meters between two grid lines.

The vehicle speeds were computed by the following procedure:

as $v = D/t$ where

v = velocity of vehicle in meters per second between two grid lines
D = distance in meters between two grid lines (30 meters or 98.4 feet)
t = time in seconds between two grid lines

As the movie camera was set to take 15 frames per second, the time, in seconds, to travel D meters will be

$t = n/15$ seconds

hence $v = \dfrac{30}{n/15} = \dfrac{450}{n}$ meters per second

The value of v can now be converted to the speed of the vehicle in kph, and is expressed by the following formula:

$$V = \frac{450}{n} \times \frac{3600}{1000} \quad \text{or} \quad \boxed{V = \frac{1620}{n} \text{ in kph}}$$

Table 4 gives the number of frames and their corresponding speeds in kph. and mph., for two grid lines 30 meters (98.4 feet) apart and a movie camera operating speed of 15 frames per second.

For vehicular speed computations only free moving vehicles or vehicles leading a platoon were considered. For lateral placement vehicles following other vehicles were also considered.

As part of the pictures were taken at a camera speed of 14 frames per second, vehicular speeds corresponding to number of frames at that camera speed are also included in table 4. In this case

$$V = \frac{1512}{n} \text{ in kph}$$

TABLE 4

NUMBER OF FRAMES — VEHICLE SPEED RELATIONSHIP

Number of Frames*	Camera Speed: 15 frames per second — Vehicle speed Kph	mph	Camera Speed: 14 frames per second — Vehicle speed Kph	mph
13	124·6	77·4	116·3	72·3
14	115·7	71·9	108·0	67·1
15	108·0	67·1	100·8	62·6
16	101·3	62·9	94·5	58·7
17	95·3	59·2	88·8	55·2
18	90·0	55·9	84·0	52·2
19	85·3	53·0	79·5	49·4
20	81·0	50·3	75·6	47·0
21	77·1	47·9	72·0	45·5
22	73·6	45·7	68·7	42·7
23	70·4	43·7	65·7	40·8
24	67·5	41·9	63·0	39·2
25	64·8	40·3	60·5	37·6
26	62·3	38·7	58·2	36·2
27	60·0	37·3	56·0	34·8
28	57·8	35·9	54·0	33·6
29	55·9	34·7	52·2	32·4
30	54·0	33·6	50·4	31·3

* *Distance between two grid lines : 30 meters*

STATISTICAL ANALYSIS PROCEDURES

A. LATERAL PLACEMENTS

Statistical procedures were used in the analysis of the lateral placement data for the following two cases :

1. to determine whether the relationship between the hourly volumes and the corresponding arithmetic mean of lateral placements for each different case is significant, and
2. to determine whether the differences between the arithmetic means of lateral placements for the different cases at different hourly volumes is significant.

The first situation was a case of testing the significance of the «best fitting line» or «regression line» obtained by the «method of least squares» for the different cases. The lateral placements were assumed to be normally distributed.

The t test for small samples (Students t Distribution) was used to determine the significance of the relationship

$$t = \frac{m}{s} \sqrt{\sum x_i^2 - n\bar{x}_i^2} \qquad (1)$$

Where

$$s = \sqrt{\frac{\sum (y_i - y)^2}{n - 2}} \qquad (2)$$

where
m is taken from the «regression line» equation

$$y = m x + b$$

x_i and y_i = observed values
$\bar{x}_i$ = mean observed values x_i
y = value on regression line for values of x_i
n = Sample size
n — 2 = degree of freedom

The second situation was a case of testing the significance of the differences between the arithmetic means of lateral placements for different cases at different hourly volumes.

The F - ratio test was used in this case.

We can call the different cases under study $C_1, C_2, \cdots C_n$ and the different hourly volumes $V_1, V_2, \cdots V_n$. We can prepare the following table

v.p.h. / Case	V_1	V_2 ...	V_i ...	V_n	
C_1	X_{11}	X_{12} ...	X_{1i} ...	X_{1n}	a_1
C_2	X_{21}	X_{22} ...	X_{2i} ...	X_{2n}	a_2
C_k	X_{k1}	X_{k2} ...	X_{ki} ...	X_{kn}	a_k
C_n	X_{m1}	X_{m2} ...	X_{mi} ...	X_{mn}	a_m
	b_1	b_2	b_i	b_n	T

where X_{ki} represents the outcome (mean lateral placement) of case C_k under the volume V_i, a_k is the sum of the terms of the row k, b_i is the sum of the terms of the column i, and T is the sum of all values

If n is the number of all values
c is the number of cases
and v is the number of volumes, than

$$\text{Correction factor} = C.F. = \frac{T^2}{n}$$

$$S = \text{Total SS} = \sum_{i=1}^{n} X_i^2 - C.F.$$

$$C = \text{Cass SS} = \frac{a_1^2 + a_2^2 + \cdots a_m^2}{v} - C.F.$$

$$V = \text{Volume SS} = \frac{b_1^2 + b_2^2 + \cdots b_n^2}{c} - C.F.$$

$$E = \text{Error SS} = S - C - V$$

the following table can be established

Variation due to	S.S.	Degree of Freedom	M.M.S.	F-Ratio
Case	C	$c_1 = c - 1$	$C' = \frac{C}{c_1}$	C'/E'
Volume	V	$v_1 = v - 1$	$V' = \frac{V}{v_1}$	V'/E'
Error	E	$n_1 - v_1 - c_1$	$E' = \frac{E}{n_1 - v_1 - c_1}$	
Total	S	$n_1 = n - 1$		

From tables the critical values F at 5% significant level are found for degrees of freedom

a. $c - 1$ and $n_1 - v_1 - c_1$

and b. $v - 1$ and $n_1 - v_1 - c_1$

if the F - ratio is larger than the corresponding Fo value, at 5% level, the result is significant, if smaller, the result is not significant.

To compare the cases two by two, the Least Significant Difference for «case-mean» (for 5% significance level), is calculated.

$$LSD = t(0.05)\sqrt{\frac{2 \times E'}{v}} \qquad (3)$$

Where t (0.05) is the 5% point of t distribution with $(n_1 - v_1 - c_1)$ degree of freedom.

If the value $\frac{a_1 - a_2}{v}$ is greater than LSD, than the two cases are significantly different at 5% level, if smaller, they are not significantly different at 5% level of significance.

B. SPEEDS

1. — to determine whether the relationship between the arithmetic mean of speeds of all observed volumes combined and the corresponding lateral placement ranges for each different case is significant, and

2. — to determine whether the differences between the arithmetic mean of speeds of all volumes combined for the different cases at different lateral placement ranges is significant.

The same tests were used to determine the significance of the results obtained.

An illustrative example for both situations is given in Appendix B.

FIELD RESULTS

Tables 5, 6, 7 and 8 present the lateral placement distributions (or frequencies) of vehicles at different hourly volumes for the four cases under study.

A summery of the results obtained for the lateral placements at different hourly volumes at each location studied are given in Tables 9 and 9a. Figures 19, 20 and 21 represent the different Regression Lines or Best Fitting Lines for average lateral placement Vs. volume per hour at the different locations studied. A similar table for speeds at the different locations studied is Table 10 and 10a. Figures 22, 23 and 24 represent the different Regression Lines or Best Fitting Lines for lateral placement range Vs. average speed at the different locations studied.

These tables and figures are included to provide a comparison of the various designs and to permit a quicker evaluation by the reader of the findings which are given in the next section of the report.

The average speed values obtained by the radar speed-meter differed by only 2 to 3% from those obtained from the movie films.

TABLE N° 7
Harissa Overpass — Case N° IIb
Lateral placement distribution at different hourly volumes

LPR*	Mid- Point xi	VEHICLE PER HOUR 400	500	600	700	800	900	1000
0 – 1	0·5	1	4	4	3	5	6	6
1 – 2	1·5	23	21	23	27	25	28	27
2 – 3	2·5	27	25	36	25	27	25	29
3 – 4	3·5	20	22	17	24	18	19	24
4 – 5	4·5	18	21	10	11	13	16	11
5 – 6	5·5	8	4	7	8	10	5	3
6 – 7	6·5	3	3	3	2	2	1	—
Total :		100	100	100	100	100	100	100

TABLE N° 8
Jounieh Overpass — Case N° III
Lateral placement distribution at different hourly volumes

LPR*	Mid- Point xi	VEHICLE PER HOUR 500	600	700	800	900	1000
0 – 1	0·5	—	—	—	—	2	2
1 – 2	1·5	3	6	10	12	3	11
2 – 3	2·5	24	32	43	38	34	37
3 – 4	3·5	33	26	21	26	36	28
4 – 5	4·5	24	22	13	15	18	14
5 – 6	5·5	13	10	61	7	7	8
6 – 7	6·5	3	4	2	2	—	—
Total :		100	100	100	100	100	100

*** Lateral placement range in feet (zero point is at the edge of median)**

TABLE N° 5
Faraya Overpass — Case N° 1
Lateral placement distribution at different hourly volumes

LPR*	Mid- Point xi	VEHICLE PER HOUR 500	600	700	800	900	1000	1100
0 – 1	0·5	1	1	—	7	4	3	9
1 – 2	1·5	15	8	19	18	28	18	27
2 – 3	2·5	23	26	32	27	27	37	25
3 – 4	3·5	34	31	24	22	23	26	21
4 – 5	4·5	19	23	17	16	12	9	12
5 – 6	5·5	8	10	7	8	4	5	6
6 – 7	6·5	—	1	1	2	2	2	—
Total :		100	100	100	100	100	100	100

TABLE N° 6
Harissa Overpass — Case N° IIa
Lateral placement distribution at different hourly volumes

LPR*	Mid- Point xi	VEHICLE PER HOUR 400	500	600	700	800	900	1000
0 – 1	0·5	—	—	—	2	1	3	1
1 – 2	1·5	7	12	14	18	25	28	23
2 – 3	2·5	31	29	32	28	26	30	32
3 – 4	3·5	23	35	30	24	23	18	24
4 – 5	4·5	21	14	15	17	18	15	15
5 – 6	5·5	14	10	9	11	6	6	5
6 – 7	6·5	4	—	—	—	1	—	—
Total :		100	100	100	100	100	100	100

* Lateral placement range in feet (zero point is at the edge of median)

TABLE N° 9
Summery of Results — Lateral Placements
Metric System

Case	Volume 400[1]	500	600	700	800	900	1000	1100	t - test S or NS[4]	Overall mean of lateral placements
I[2]	—	1·00	1·07	0·96	0·93	0·89	9·89	0·82	S	0·95
IIa	1·11[3]	1·01	0·98	0·97	0·93	0·86	0·90	—	S	0·94
IIb	0·97	0·94	0·88	0·90	0·91	0·85	0·81	—	S	0·88
III	—	1·16	1·10	1·00	0·98	1·02	0·96	—	S	1·04

TABLE N° 9a
Summery of Results — Lateral Placements
Foot System

Case	Volume 400[1]	500	600	700	800	900	1000	1100	t - test S or NS[4]	Overall mean of lateral placements
I[2]	—	3·29	3·51	3·14	3·04	2·81	2·93	2·68	S	3·12
IIa	3·66[3]	3·31	3·23	3·19	3·04	2·82	2·94	—	S	3·09
IIb	3·17	3·09	2·89	2·95	2·97	2·80	2·66	—	S	2·89
III	—	3·79	3·60	3·28	3·23	3·36	3·15	—	S	3·40

1. Hourly Volumes
2. Denomination of Median Divider Type
3. Arithmetic Mean of Lateral Placement — meters (Table No. 9)/Feet (Table No. 9a)
4. S : Significant NS : Not Significant (at 5% Significance Level)

F — Ratio Test

Both Cases and Volumes Significantly affect (at 5% level) the values of mean lateral placements

Comparison of Cases two by two — (Differences at 5% Level)

I and IIa	NS	IIa and IIb	S
I and IIb	S	IIa and III	S
I and III	S	IIb and III	S

TABLE N° 5

Faraya Overpass — Case N° 1

Lateral placement distribution at different hourly volumes

LPR*	Mid- Point xi	VEHICLE PER HOUR 500	600	700	800	900	1000	1100
0 – 1	0·5	1	1	—	7	4	3	9
1 – 2	1·5	15	8	19	18	28	18	27
2 – 3	2·5	23	26	32	27	27	37	25
3 – 4	3·5	34	31	24	22	23	26	21
4 – 5	4·5	19	23	17	16	12	9	12
5 – 6	5·5	8	10	7	8	4	5	6
6 – 7	6·5	—	1	1	2	2	2	—
Total :		100	100	100	100	100	100	100

TABLE N° 6

Harissa Overpass — Case N° IIa

Lateral placement distribution at different hourly volumes

LPR*	Mid- Point xi	VEHICLE PER HOUR 400	500	600	700	800	900	1000
0 – 1	0·5	—	—	—	2	1	3	1
1 – 2	1·5	7	12	14	18	25	28	23
2 – 3	2·5	31	29	32	28	26	30	32
3 – 4	3·5	23	35	30	24	23	18	24
4 – 5	4·5	21	14	15	17	18	15	15
5 – 6	5·5	14	10	9	11	6	6	5
6 – 7	6·5	4	—	—	—	1	—	—
Total :		100	100	100	100	100	100	100

* Lateral placement range in feet (zero point is at the edge of median)

TABLE N° 9

Summery of Results — Lateral Placements

Metric System

Case	Volume 400[1]	500	600	700	800	900	1000	1100	t - test S or NS[4]	Overall mean of lateral placements
I[2]	—	1·00	1·07	0·96	0·93	0·89	9·89	0·82	S	0·95
IIa	1·11[3]	1·01	0·98	0·97	0·93	0·86	0·90	—	S	0·94
IIb	0·97	0·94	0·88	0·90	0·91	0·85	0·81	—	S	0·88
III	—	1·16	1·10	1·00	0·98	1·02	0·96	—	S	1·04

TABLE N° 9a

Summery of Results — Lateral Placements

Foot System

Case	Volume 400[1]	500	600	700	800	900	1000	1100	t - test S or NS[4]	Overall mean of lateral placements
I[2]	—	3·29	3·51	3·14	3·04	2·81	2·93	2·68	S	3·12
IIa	3·66[3]	3·31	3·23	3·19	3·04	2·82	2·94	—	S	3·09
IIb	3·17	3·09	2·89	2·95	2·97	2·80	2·66	—	S	2·89
III	—	3·79	3·60	3·28	3·23	3·36	3·15	—	S	3·40

1. **Hourly Volumes**
2. **Denomination of Median Divider Type**
3. **Arithmetic Mean of Lateral Placement — meters (Table No. 9)/Feet (Table No. 9a)**
4. **S : Significant NS : Not Significant (at 5% Significance Level)**

F — Ratio Test

Both Cases and Volumes Significantly affect (at 5% level) the values of mean lateral placements

Comparison of Cases two by two — (Differences at 5% Level)

I and IIa	NS	IIa and IIb	S
I and IIb	S	IIa and III	S
I and III	S	IIb and III	S

TABLE N° 10

Summcry of Results — Speeds of Free Moving Vehicales
Metric System

Case	Lateral placement ranges 0·0·30	0·30–0·60	0·60–0·90	0·90–1·20	1·20–1·50	1·50–1·80	1·80–2·10	t - test S4 or NS	Overall mean of speeds
I2	84·9	84·5	82·6	81·7	80·9	80·0	79·6	S	82·0
IIa	—	85·9	83·5	81·7	80·0	79·2	77·5	S	81·3
IIb	79·23	78·8	78·3	78·8	77·9	77·1	—	S	78·4

TABLE N° 10a

Summery of Results — Speeds of Free Moving Vehicales
Foot System

Case	Lateral placement ranges 0—1	1—2	2—3	3—4	4—5	5—6	6—7	t - test S4 or NS	Overall mean of speeds
I2	52·8	52·5	51·3	50·7	50·6	49·7	49·5	S	51·0
IIa	—	53·4	51·8	50·8	49·7	49·3	48·2	S	50·5
IIb	49·3	49·0	48·7	48·9	48·5	47·9	—	S	48·8

1. Range of Lateral Placement — meters (table No. 10) / feet (table No. 10a)
2. Denomination of Median Divider Type
3. Arithmetic Mean of Speeds — kph (table No. 10) /mph (table No. 10a) — Free Moving Vehicles.
4. S: Signifiant NS : Not Significant (at 5% Significance Level)

F — Ratio Test

Both Cases and lateral placements significantly affect (at 5% level) values of mean speeds of free moving vehicles

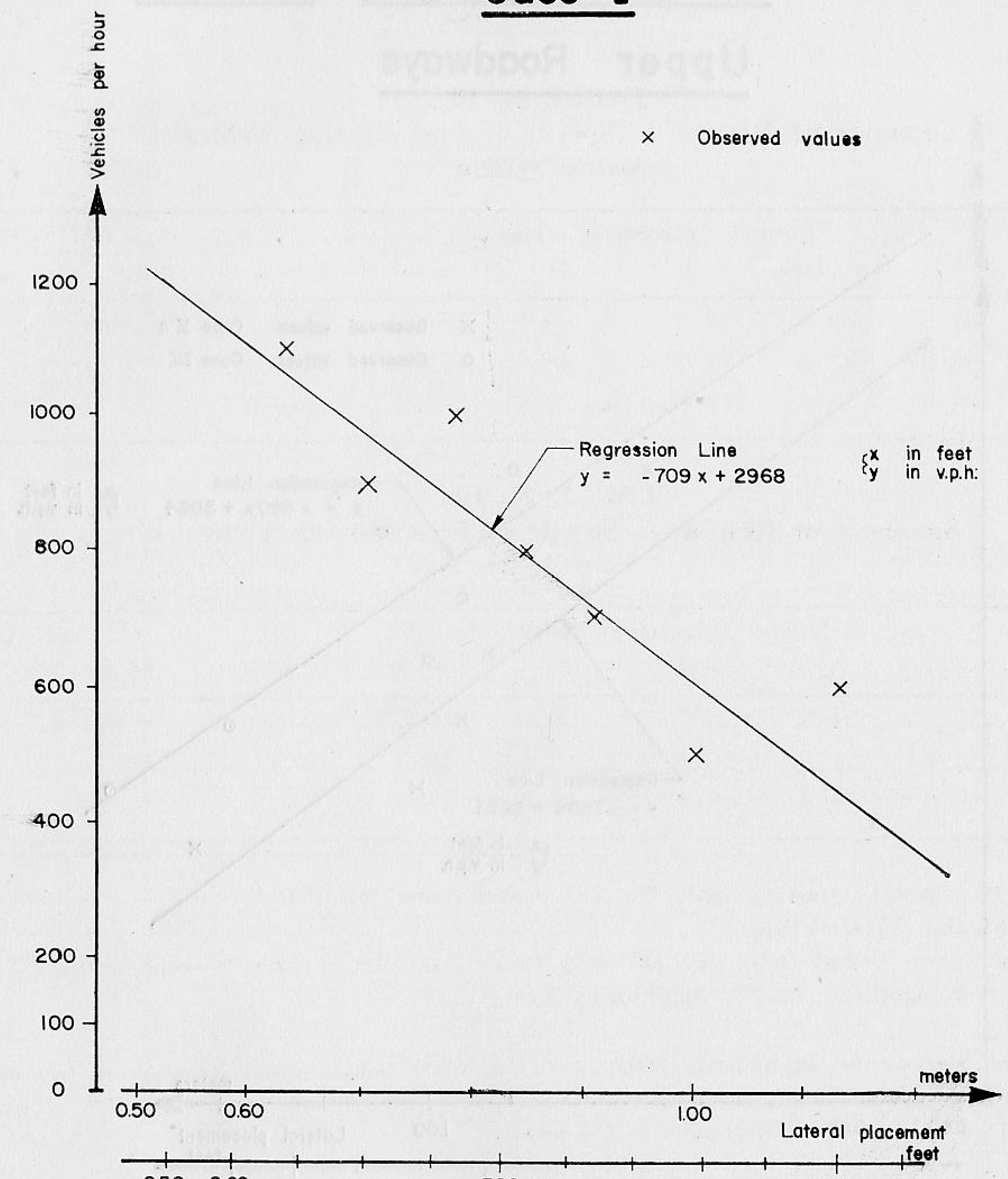
Volumes do not significantly affect (at 5% level) the values of mean speeds of free moving vehicles

Comparison of Cases Two by Two — (Differences at 5% level)

I	and IIa	NS
I	and IIb	S
IIa	and IIb	S

FARAYA OVERPASS

Case I



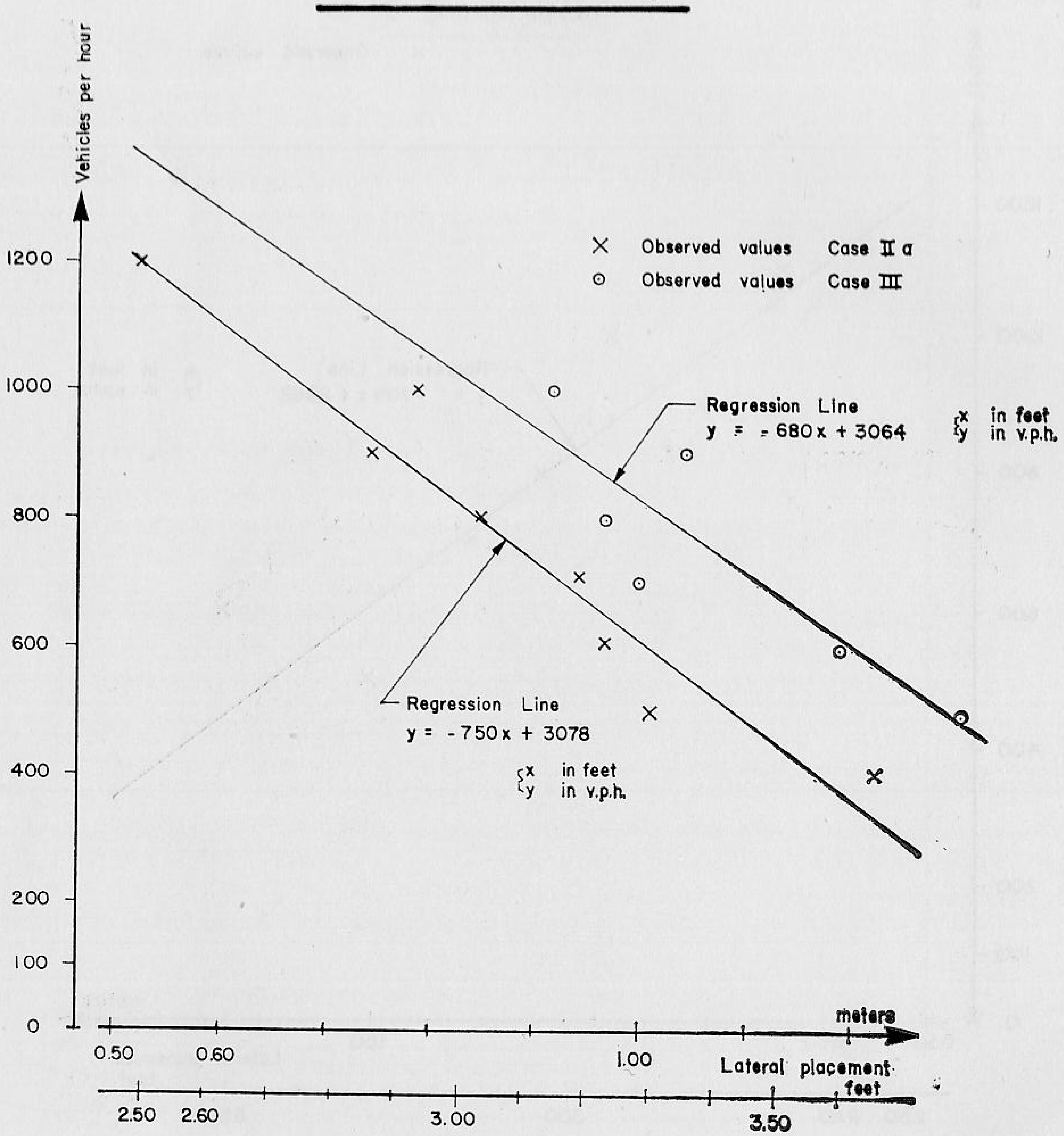
AVERAGE LATERAL PLACEMENT
Vs.
HOURLY VOLUME

FIGURE No. 19

HARISSA OVERPASS Case II a

JOUNIEH OVERPASS Case III

Upper Roadways



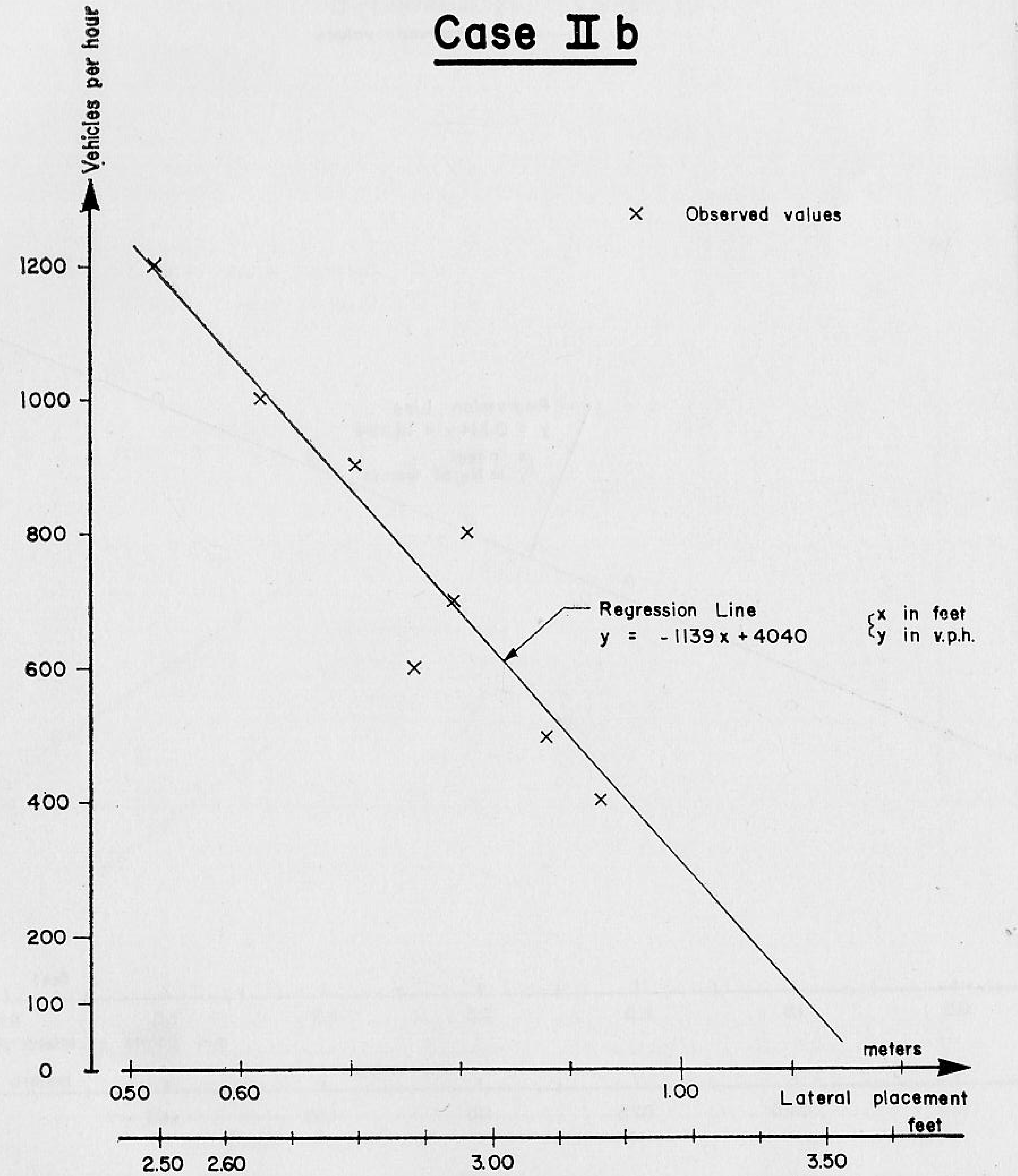
AVERAGE LATERAL PLACEMENT
Vs.
HOURLY VOLUME

FIGURE No. 20

HARISSA OVERPASS

Lower Roadway

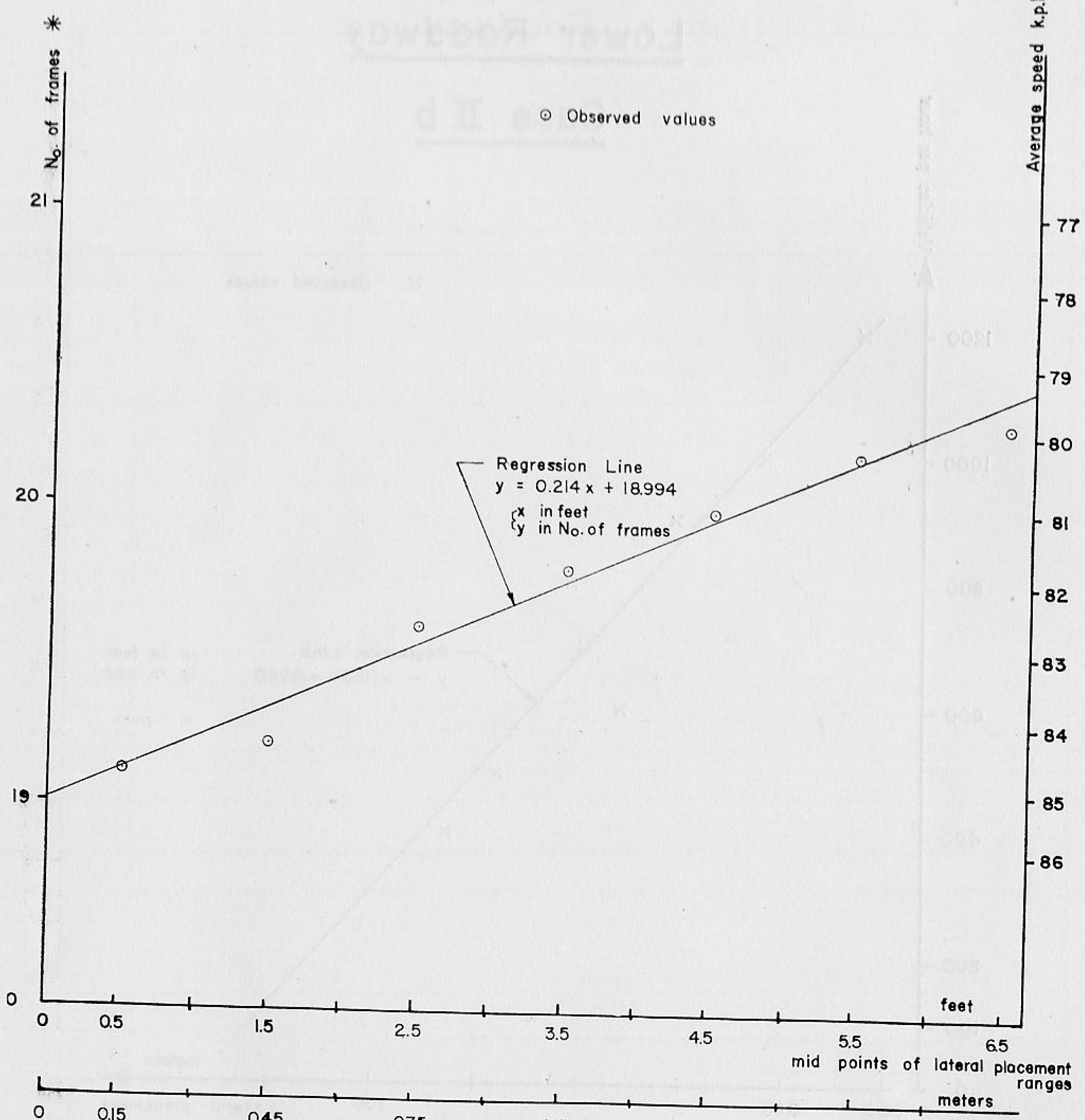
Case II b



AVERAGE LATERAL PLACEMENT
Vs.
HOURLY VOLUME

FIGURE No. 21

FARAYA OVERPASS

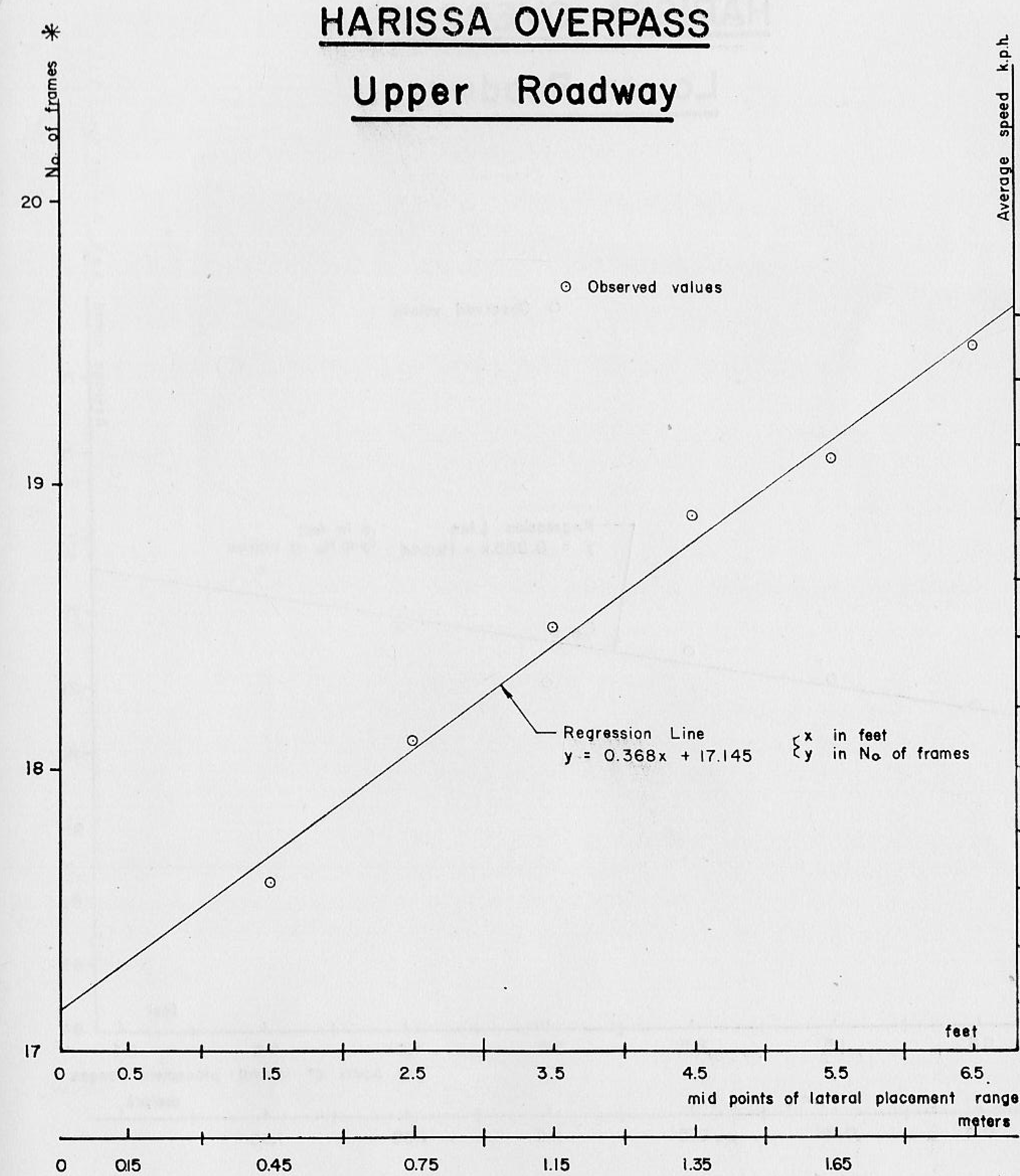


* No. of frames required to travel a distance of 30 meters – Camera speed 15 frames/sec.

LATERAL PLACEMENT
Vs.
AVERAGE SPEED

FIGURE No. 22

HARISSA OVERPASS
Upper Roadway



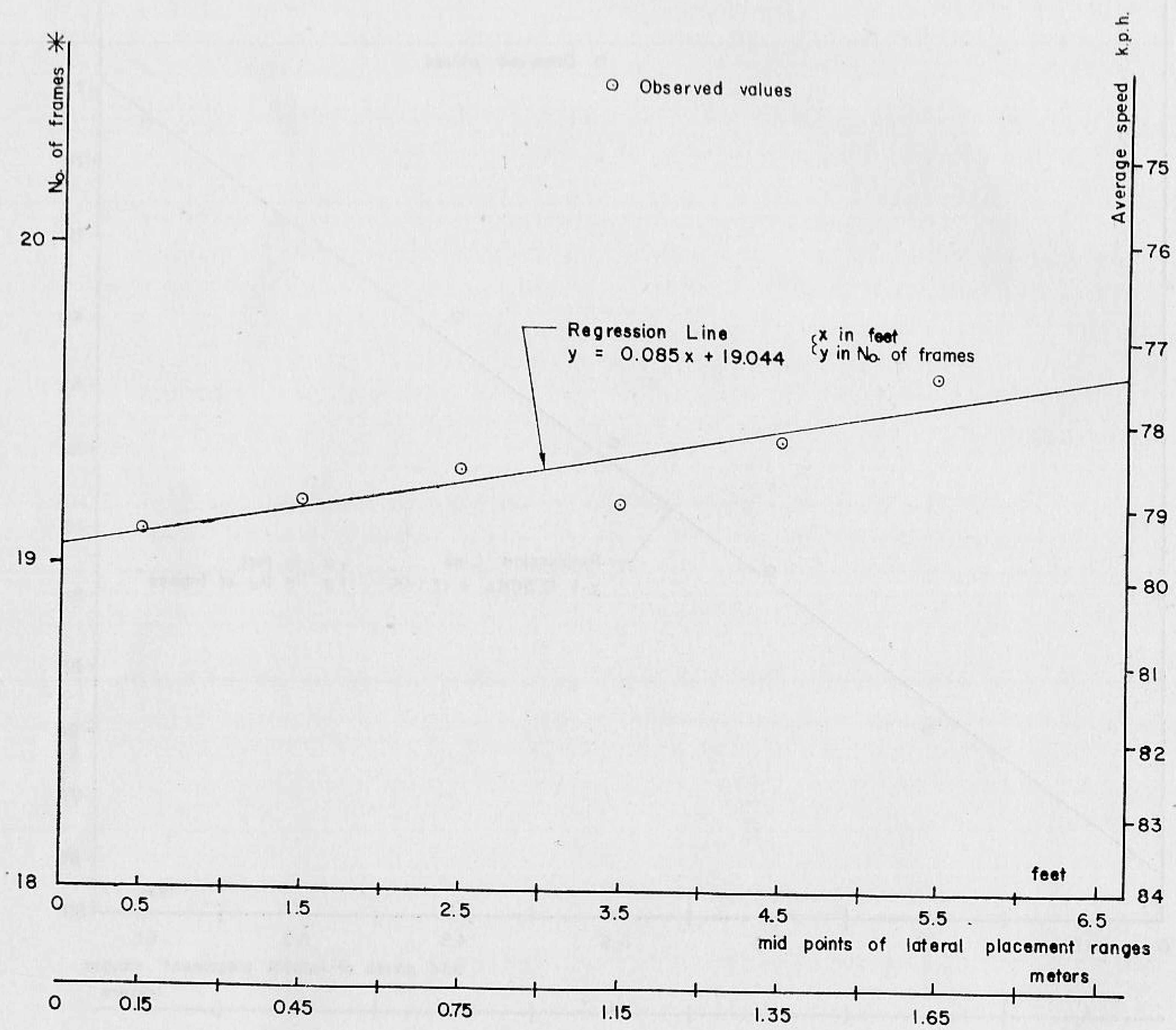
* No. of frames required to travel a distance of 30 meters – Camera speed 14 frames/sec.

LATERAL PLACEMENT
Vs.
AVERAGE SPEED

FIGURE No. 23

HARISSA OVERPASS

Lower Roadway



* Number of frames required to travel a distance of 30 meters — Camera speed 14 frames/sec.

LATERAL PLACEMENT
Vs.
AVERAGE SPEED

FIGURE No. 24

FINDINGS

The behavior of vehicles travelling in the left lane at the different locations under study shows that:

1. — In general there is a linear relation between the average lateral placements of vehicles and the hourly volume. As volume increases, vehicles in the left lane travel closer to the median divider.

2. — At all volumes vehicles travel closer to the lower level of the split level median than to the other types of median studied.

3. — The difference in lateral placements of vehicles travelling along the concrete barrier type of median and the guardrail or upper level of the split level median, is not significant.

4. — Vehicles travel farther from the guardrail (upper level of the split level median), on horizontal left curves rather than on straight line alignments.

5. — The average speeds of vehicles are not affected by one type of median differently than by any other of the medians studied. The slightly lower value for the lower level of the split level median is believed to be due to the warped condition of the pavement.

6. — In general there is a linear relation between the average speeds (ordinary operational vehicular speeds on rural divided highways) and the lateral placements of vehicles. Overpassing vehicles travel closer to the median at higher speeds and farther from the median at lower speeds.

7. — The rate of increase in speed with the decrease of lateral placement, is sharper for the concrete barrier type of median and for the upper level of the split level median, than the lower level of the split level median.

8. — The difference in average speeds of vehicles travelling at varying lateral placements for the concrete barrier type of median and the upper level of the split level median is not significant.

9. — In general the difference in average speeds of free moving vehicles at the different hourly volumes studied (400 to 1100 vph) is not significant.

DISCUSSION

Out of the median types under study the lower level of the split level median induces a better feeling of safety to drivers. The low and mountable curb at this level of the median induces drivers to travel closer to it than to the upper level, with a guardrail, or the concrete barrier type of median. The concrete barrier and the guardrail, non-traversable fixed obstructions, affect the behavior of drivers who tend to travel far from them. A median shoulder of about 1.20 meters (4 feet) wide will give a safer feeling to drivers and moreover provide a minimum space for emergency maneuvering.

Beyond the Jounieh Interchange, towards Maameltain, the split level median having even a larger difference in level, has no guardrails. Out of control vehicles hitting the low, mountable, median shoulder curb, will easily mount it and fall to the lower level. This will surely cause serious injury or even fatal accidents. A rigid guardrail, itself an accident producing element near the through traffic lanes, may still be preferable.

The California Median Study (19) shows that a non-traversable median is not warranted when daily volumes are as low as 15000 vpd. At such low volumes the traversable type median is superior to the non-traversable type for injury, death and overall - accident rates.

Although the non-traversable median has the lowest rate for the approach-type (head-on) accidents, this advantage is more than offset by the higher rate of overtaking and single-vehicle-type accidents at low daily traffic volumes.

The public in general is for the erection of unbreakable barriers. But the fact that when a car hits a barrier there is an accident, possibly fatal; the fact that this same car has a good chance of not becoming involved in any accident at all if there were no barrier to throw it out of control; and the fact that the cost of this unbreakable barrier must be deducted from the money available to correct other deficiencies, are all overlooked.

Of all the existing types of median along the divided section of the Beirut-Tripoli highway, the flat traversable median planted with ever green bushes is the best one available due to the following:

— It provides appropriate stopping or recovery conditions and space for vehicles running off the edge of pavement.

— It is safer as far as median accident rates are concerned as daily volumes at that section are less than the 60,000 ADT recommended limit set to erect median barriers, (19).

— The evergreen bushes prevent deliberate crossing of the median (U turns or left turns), reduce headlight glare and provide additional traffic guidance both in day time and at night. For maximum daily volumes in that section of about 30,000 vehicles, the percentage of cross median accidents which would involve opposing vehicles is very low (25 to 30%) (19). If a fixed barrier were erected, the accident severity and rate at actual daily volumes would be higher.

Still another advantage of this median is that in the future at higher ADT volumes (more than 60,000), a cable-chain link type of barrier, recommended by the crash tests (2) (5) (Figure 1), can be advantageously erected, as the minimum requirement of 8 ft (2.4 meters) for the deflection of the barrier will be met.

A serious disadvantage of this median, but not a defect due to design, is the existance of huge concrete blocks for electricity pylones. These blocks largely decrease the advantages of this, in other respects acceptable, median type.

Unfortunately, due to the absence of classifed accident records and the material impossibility of gathering the available accident reports dispersed in a multitude of police headquarters, it is impossible technically to analyze the relative safety of the different medians under study and present sound and statistically reliable conclusions.

RECOMMENDATIONS

1. — The 50 feet (15 meters) wide median, recommended by the different median studies performed in the U.S.A., is difficult to apply everywhere in Lebanon. A rough, mountenous country where land acquisition and the construction of flat and wide traversable medians is expensive, a certain sacrifice may be accepted without forgetting the basic and minimum safety requirements. Still, whenever possible it is always better to buy land for future expansion and wider medians from the beginning as land values increase after its opening to traffic. This simple but important fact should always be in the mind of highway planners.

2. — The use of inventories of median designs, would decrease any tendency toward unnecessary repetition of the process of evolution of these designs at different times in other countries as a result of the subsequent development of the same design conditions. The work should be directed toward the improvement of currently accepted median designs and their adaptation to local needs and possibilities.

3. — To remedy the situation of complete absence of classified and reliable accident data a reorganization of local police departments responsible for circulation should be undertaken.

A special engineering department part of the Highway Department of the Ministry of Public Works with the cooperation of the police department should:

— prepare a reliable method of recording accident data : condition and collision diagrams, traffic information,

— prepare a filing system for accident locations and occurence.

— prepare an accident analysis; monthly and annual trends, estimation of losses,

— analyze accident problems : signing, markings,

— prepare an improvement program in order of priorities,

— prepare a preventive program : education of people at home and at school, enforcement of laws and better engineering.

4. — For further studies, the following recommendations are made:

— As it was not physically possible to study similar median types along tangent alignments at different locations, it is recommended that, after the opening of the new section of the Beirut-Tripoli divided highway, studies of similar types of medians, be undertaken to compare the results to the ones already studied. This would ascertain to a higher degree the significance of the results obtained. The impossibility of studying similar medians was the absence of grade separation structures where a camera could be advantageously installed.

— Hourly volumes up to 1100 vph did not significantly affect the average speed of free moving vehicles. In the future results for higher volumes should be obtained to determine the hourly volume which would significantly affect average speeds.

— The relative safety advantages of one type of the existing medians or another should be reevaluated in the light of reliable accident records which would be classified by an organized engineering department of the Highway Department with the cooperation of a trained police force.

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APPENDIX

APPENDIX A

THE TRAFFIC ANALYZER

In the past twenty years significant advances in the development of improved standards for geometric highway design have stemmed primarily from the increasing knowledge of traffic performance, driver behavior, and highway capacity. A better understanding of the many problems has been made possible by the detailed study of the speed and placement of each vehicle in the traffic stream and its relation to the lateral placements, and the longitudinal positions of vehicles ahead, behind, and adjacent (24).

For this special purpose the Bureau of Public Roads has developed automatic recording equipment, the latest and most precise being the digital speed-placement equipment ; the traffic analyzer.

The recording adding machines and electronic equipment are installed in a custom body on a commercial delivery-truck chassis.

Special vehicle detectors are placed at any position where vehicular traffic data are desired. The usual detectors consist of either two pneumatic tubes or two positive contact strips, in used lengths of 3.6 to 14.4 meters (12 to 48 feet) to detect speeds and segmented detectors (1 foot units) to detect vehicle placement.

The data which are automatically recorded for each vehicle are speed, lateral placement referenced to a designated traffic lane, and precise time of day each vehicle passes from the point of observation. Vehicle speed is recorded as travel time in hundredths of a second over the known distance between the speed detectors ; lateral placement is recorded as a direct measurement of both the right and left wheel positions with respect to the right edge of the traffic lane, by the segmented detector, and time of the day is continuously measured in intervals of one ten-thousandth of an hour. All of the data are recorded the instant that the front axle of each vehicle passes over the second speed detector.

These recorded data are subsequently taken into the office and interpreted through the use of an electronic digital computer. Vehicle speed is calculated from the travel time and the distance between detector tubes ; the position of the center of vehicle is computed from the wheel placement, and the time spacings between vehicles are determined and reduced to headway distances measured in feet.

The high speed computer is also used to determine the speed and the lateral and longitudinal positions of each vehicle relative to all other vehicles which are ahead, behind, or adjacent to it.

Vehicle classification or any other desired information is usually set up by an observer in manually controlled columns in the recorder.

The traffic analyzer has been successfully utilized for different special purpose studies.

— to prepare tabulations showing averages and distributions of speeds, placements, and headways of vehicles, under different conditions of delineation and illumination

— to obtain valuable highway capacity data

— to evaluate the effectiveness of roadside delineation, pavement markings, and a combination of delineation and markings under various conditions of highway illumination

— to evaluate the effect on traffic operation of various shoulder widths and types, and of edge markings

— to evaluate the effect of median dividers on driver behavior and highway capacity, etc.

The traffic analyzer has become a reliable and accurate equipment for traffic researchers throughout the U.S. for gathering field data on traffic behavior.

APPENDIX B

DEFINITION OF STATISTICAL TERMS

Arithmetic Mean : is the sum of all values of the variable in the sample, occuring with different frequencies, divided by the number of observations

$$\bar{x} = \frac{\sum fx}{n}$$

x is the variable, f is the number of frequency, and n is the Sample Size.

Best Fitting Line or Regression Line : of all lines approximating a given set of data points, the curve having the property that

$D_1^2 + D_2^2 + \cdots D_n^2$ is a minimum is called a

Best Fitting Curve, where $D_1 = y_1 - y$

y_i = observed value for X_i

y = value on Best Fitting Line for X_i

Significance level : The probability of the test statistic lying in the rejection region when the hypothesis is in fact, true.

Confidence level : The probability of the test statistic lying in the acception region when the hypothesis is true.

Population : The collection or aggregate of elements about which an inference is to be made.

Sample : a number of elements selected from the population.

Normal distribution : A certain theoritical relation between the values of the measured variable and the relative frequency of the value.

Degree of freedom : is the number of independent observations in the sample (i.e. the sample size) minus the number of population parameters which must be estimated from sample observations.

Illustrative Example

The purpose of this calculation was to determine whether the relationship between the hourly volumes and the corresponding arithmetic mean of lateral placements for the different cases is significant or not.

The example chosen is for Case I where

y = — 709x + 2968, Regression Line

m = 709 $\sum x_i^2 = 65.90$

n = 7 $\bar{x}^2 = 9.35$

n — 2 = 5 $\sum (y_i - y)^2 = 53499.89$

From equation (2)

$$S = \sqrt{\frac{53499.89}{5}} = 103.43$$

From equation (1)

$$t = \frac{709}{103.43} \sqrt{65.90 - 7 \times 9.35} = 4.60$$

This value of t is more than 2.57 and hence is significant

The purpose of this second calculation was to determine whether the differences between the arithmetic means of lateral placements for the different cases at different hourly volumes is significant or not.

Following the F - ratio test*.

$C.F. = 234.50 \qquad c_1 = 5$

$S = 1.68 \qquad v_1 = 3$

$V = 0.68 \qquad n_1 = 23$

$C = 0.79 \qquad n_1 - v_1 - c_1 = 15$

$E = 0.21$

$V' = 0.136 \qquad C' = 0.263 \qquad E' = 0.014$

The F ratios are

$V'/E' = 9.71 \qquad C'/E' = 18.80$

These values are both larger than the critical values Fo 2.90 and 3.29, hence the differences for both Cases and volumes is significant.

From equation (3)

$$LSD = 2.13 \sqrt{\frac{2 \times 0.014}{6}} = 0.145 \text{ (at 5 \% level)}$$

Taking Cases I and IIa

$$\frac{a_1 - a_2}{v} = \frac{18.72 - 18.53}{6} = 0.032$$

as 0.032 is less than LSD = 0.145 the two cases are not significantly different from each other at 5% significance level.

* *For this test only the hourly volumes from 5oo to 1ooo vph were taken into consideration as all four cases had values of lateral placements at that specific volumes.*

APPENDIX C

Table No. II

MEDIAN CHARACTERISTICS OF MOTORWAYS IN SOME EUROPEAN COUNTRIES & THE U.S.A.

COUNTRY	MEDIAN			
	Total Width [m]	Safety Strips (each) [m]	Surface and Slope	Safety Barrier
ITALY	3.00 – 4.00	0.80 – 1.20	green depressed	yes
FRANCE	5.00	0.20	green depressed	yes
GERMANY	5.50	0.75	green depressed	yes
GREAT BRITAIN	4.00 (13')	—	green depressed	for protection of obstacles only
SPAIN	2.00 – 5.00	—	green	exceptionally
SWEDEN	9.00 – 12.00	2.00	green depressed	exceptionally
FINLAND	4.00 – 9.00	0.50 – 1.25	green depressed	yes when total width smaller than 6.00
SWITZERLAND	5.00	0.50	green depressed	yes
BELGIUM	14.00	1.00	green depressed	exceptionally
AUSTRIA	5.50	0.75	green depressed	exceptionally
HOLLAND	4.50	—	green depressed	yes
CALIFORNIA	14 to 60 (46' to 200')	1.50 – 2.40 (5' to 8')	natural undisturbed	depends upon width of median and traffic volume
U.S.A.	120 to 18.00 (4' to 60')	1.10 – 2.40 (3.5' to 8')	green depressed for medium & large medians	

Values obtained from bibliography 1 & 20