

# ***Shoulders and Accident Experience on Two-Lane Rural Highways: A Summary***

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Several studies have been made attempting to determine the relationship between the frequency of accidents and the width of shoulders on 2-lane rural highway sections. This report brings together the information available from these past studies and correlates them with Oregon's concluding research on this phase.

The studies of gravel shoulders on 2-lane rural highways have indicated a tendency for total accidents and property-damage accidents to decrease as the shoulder width increased for the intermediate traffic volume ranges. No relationship was indicated for the low and high traffic volume ranges, nor was any relationship found for personal-injury accidents.

In contrast to the gravel shoulder studies, the studies of paved shoulders on 2-lane rural highways have indicated a tendency for total accidents and property-damage accidents to increase as the paved shoulder width increased. For personal-injury accidents the same relationship has been indicated in one study, but was not found in another study.

In summary, it appears rather certain that higher average accident frequency occurs on sections having wide paved shoulders. The findings of the studies could be stated to the effect that "it cannot be shown that increasing the width of paved shoulders is actually helpful in reducing accident frequency on 2-lane rural highways." Although there appears to be an adverse relationship between shoulder width and accidents, it must be kept in mind that this is only one element of many governing the selection of proper shoulder width.

● THE STEADY INCREASE in the weight and size of trucks and the growth of traffic volumes has resulted in considerable damage to highways in the area of the shoulder immediately adjacent to the traveled portion of the roadway. During recent years, it has become standard practice on highways with heavy volumes and/or heavily loaded vehicles to pave an additional distance of the shoulder beyond the normal travel lane. This additional paving has been added to reduce maintenance costs by increasing the strength of the pavement. Among the by-products received from this pav-

ing of the shoulder was believed to be increased safety by the provision of an emergency area which would allow disabled vehicles to pull off the roadway. It was also felt that the increased width of pavement would change the lateral placement of the vehicles. Several studies have now been conducted to study the relationship between paved shoulders and changes in the safety features as a result of shoulder improvement.

In 1953 one of the first comprehensive analysis of accidents and relationship to various roadway elements was reported by Morton S. Raff (1). This study, however, did not deal with paved shoulders, rather it is believed that most of the data analyzed were for graveled shoulders. The New York Studies in 1956 and 1957 (3, 4) also reported on the relationship between accidents and graveled shoulders. In 1956 one of the authors (J. A. Head) reported on the relationship between accident data and the width of graveled shoulders in Oregon (2). The Oregon study was an actuality prompted by two earlier studies by Belmont (5, 6), studies on paved shoulders in California. A study in Oregon on the relationship between the frequency of traffic accidents and the width of paved shoulders was reported in 1959 by the authors (7), and subsequent to that time research has been continued in Oregon which is contained in an unpublished report in the files of the Oregon State Highway Department.

Considerable research has been completed, and as is often the case, some contradictory results have been presented. In the main, however, the various studies have tended to compensate each other, and much valuable information is available for actual application. It is the intent of this report to pull together all data, so that it will be readily available in summary form for use by those parties desiring information on the relationship between paved shoulders and accident experience.

#### GRAVEL SHOULDERS

In Raff's report (1) it was the intent to determine, if possible, how accident rates on main rural highways are affected by design features and use characteristics. To supply the necessary data, 15 states supplied information covering a year's accident experience on about 5,000 mi of highway. The basic technique involved divided the study routes into a large number of short homogeneous sections which could then be combined so as to group these sections according to any factor whose effects were of interest. An accident rate was computed for each group. Regression coefficients were computed where it appeared that there was a steady trend or relation between accident rate and the roadway characteristic. The study indicated that on 2-lane tangent highways there was no significant relationship between shoulder width and accident experience. However, on 2-lane curves there was a definite tendency for a reduction in the accident rate with increased shoulder width.

The Oregon report of gravel shoulders (2) was confined to a study of shoulders on tangent and level sections of rural highway. This provided for a physical control of terrain, curvature, sight distance, accesses, etc. Those sections which had 30 percent or more sight distance restrictions were excluded from this study. In Raff's report (1), considerable difficulty was experienced in comparing the data obtained from the different states, because of the difference in accident reporting from one state to the next. In the analysis of the data in his study three analyses were made so that accident data could be grouped based on different assumptions. In the Oregon study, however, it was felt that accident reporting

was very good and generally represented 80 to 90 percent of all accidents. It was, therefore, possible to compute the relationship not only for total accidents, but for property damage and personal-injury accidents. In the Oregon study no significant relationship was found between shoulder width and accident experience for those sections with an ADT less than 3,600 vehicles per day. In the higher ADT ranges (in excess of 3,600 vehicles per day) the frequency of all types of accidents appeared to decrease as shoulder widths increased. Statistically, the only reliable trends were that total accidents and property damage accidents decreased as shoulder widths increased in the 3,600 to 5,500 ADT range. No statistical or significant relationship was found between accidents and shoulder widths for those sections with an ADT of 5,600 to 7,500 vehicles per day. No significant relationships were found between shoulder width and personal-injury accidents.

The New York Report (4) was fairly evenly divided between earth and/or grass, and graveled and/or macadam shoulders. The study was confined to accidents reported on Highway Form HA-48, and covered a period from October 1947 through July 1955. The accidents included in this report were fatal and serious-injury accidents, and those accidents occurring on the highway system which involved state-owned motor equipment. For the study, only sections on 2-lane rural highways were studied.

The New York Study indicated that medium wide shoulders had lower accident indices than narrow shoulders under all conditions of horizontal and vertical alignment. Wide shoulders had lower accident indices than narrow and medium wide shoulders on poor alignment.

#### PAVED SHOULDERS

The initial study of paved shoulders was conducted by Belmont (5) based on personal-injury accidents reported for 2-lane rural highways of the California Interstate Highway System for the year 1948. The sample was further limited to rural areas with a 55 mph speed limit, no extensive roadside culture and predominately straight and level. All sections included in the study had paved or treated shoulders with some being concrete, but the large majority bituminous. Regression equations were computed using the square root of the number of accidents as a dependent variable. The erratic nature of data required that the analysis be based on three shoulder widths; that is, less than 6 ft, 6 ft, and more than 6 ft. The study indicated that shoulders 6 ft wide were safer than the narrow shoulders, and further they were also safer than the wider shoulders for those sections with a traffic volume in excess of 5,000 vehicles per day.

Because of limitations of the original data, Belmont followed with a study (6) based on California data for the years 1951 and 1952. The sample in the study included only the sections with paved shoulders bordered by not more than 1 ft of untreated or soft shoulders. Roads were excluded if they adjoined long stretches of firm ground which could readily be used as shoulders by a motorist. The roads were all in rural areas with a 55 mph speed limit and no extensive roadside developments. They were generally straight and level and no curves to restrict speed or visibility.

Because of the method of accident reporting, it was desirable to confine the study to an analysis of personal-injury accidents only. Regression equations were computed using the square root of the number of accidents as the dependent variable for ungrouped data and the number of accidents as the dependent variable for grouped data.

The general results of the study indicated a tendency for injury accidents to increase with increases in shoulder width, except for sections with traffic volumes less than 2,000 vehicles per day for which no relationship was found. This report contradicts to some extent the earlier investigation; however, they do agree that 6-ft shoulders appear to be safer than the wider shoulders at high traffic volumes.

This pioneer effort on paved shoulders raised many an eyebrow, inasmuch as the results were quite contrary to what most students in the field would expect. Therefore, additional studies were undertaken in Oregon to determine if the relationships were chance relationships with respect to personal-injury accidents only, or whether the same relationships might be found for all accidents.

The accident reporting in Oregon as contrasted to California requires a report for any accident occurring on a public way, regardless of the extent of property damage. Although it is a known fact that not all accidents are reported, it is generally assumed that 80 to 90 percent of the total accidents are reported, and that those not reported normally involve only minor property damage.

The authors reported in 1959 on the Oregon Study (7) on the relationship between paved shoulders on level and tangent rural 2-lane highways and accident frequency. Because of the limited number of sections with paved shoulders, it was necessary to use sample elements in the analysis. The sample elements were obtained by multiplying each 1-mi section of highway meeting the minimum criteria for the study by the number of years for which accident data were available after the paved shoulders were constructed. This then provided a sufficient sample for the analysis.

Two methods were utilized in Oregon's procedures--the partial correlation technique and the analysis of co-variance. The partial correlation technique was utilized to determine if there were any relationship between accident frequency and paved shoulder width. With the exception of the 2,000-2,999 ADT range where property damage and total accidents showed a significant tendency to increase as the width of the paved shoulders increased, no relationship between accident frequency and paved shoulder width was found. The analysis of co-variance, on the other hand, indicated that the wide paved shoulders had a significantly higher mean number of property damage and total accidents than did the narrow paved shoulders. In the analysis of co-variance, shoulder widths were grouped; those over 8 ft and those under 4 ft. There were insufficient samples of paved shoulders in the widths from 4 to 8 ft, therefore they were not included in this analysis. No significant relationships were found for personal-injury accidents by either method of analysis.

The final study in Oregon, an unpublished report, varies from the original in that it considered all sections which had horizontal and vertical alignment restrictions. It was again confined to rural 2-lane highways. It was felt that this additional study, along with the original, would encompass all possible rural 2-lane sections without regard to alignment characteristics.

Although there were large differences in alignment for the sections included in the two studies, the relationships as found in the first study were identical to the relationships found in the second study. This would indicate then that in Oregon there is a tendency for the accident frequency to increase on sections with wide paved shoulders as contrasted to sec-

tions with narrow paved shoulders, further that there is a real causal relationship between accidents and paved shoulder width for highways in the traffic volume group of 2,000-2,999 vehicles per day.

#### DISCUSSION OF FINDINGS

Although definite relationships have been found between shoulder widths and accident experience, there is still some question as to exactly how these two are related. Figure 1 shows graphically the relationship as generally found in the studies. This figure is a symbolic presentation only, and indicates that in general gravel shoulders tend to have a decreasing accident experience with an increase in shoulder width. On the other hand, paved shoulders tend to have an increase in accident experience with increasing shoulder width. These general tendencies have been found in all studies reported to date. It must be remembered, however, that in some of these studies the relationships were found only for property-damage accidents, and in others only for personal-injury accidents, and in most instances the relationships were statistically significant only for certain traffic volume ranges. It is quite possible that a negative result is indicated from the studies; namely, "that it cannot be shown that increasing the width of paved shoulders is actually helpful in reducing accident frequency on rural 2-lane highways."

The analysis of data does not tell us why wide gravel shoulders should be safer than narrow gravel shoulders and on the other hand why wide paved shoulders are more hazardous than narrow paved shoulders. It is possible that items such as the greater off-the-road parking space, or the greater emergency maneuverability provided by this off-the-road parking space received different type of use for highways with different types of shoulders; that is, graveled or paved. In the gravel shoulder study an attempt was made to relate the speed to ADT and accident experience. It was found in intermediate volume ranges from 3,600 to 5,500 vehicles per day that there was no significant relationship between shoulder width and speed, whereas, in the volume range of 5,600 to 7,500 vehicles per day vehicles were found to move faster on those sections with the wider shoulders. It appears that the detracting influence of increased speed on the benefits of the wider shoulders may have been partially responsible for the insignificant tendency for a reduction in accident frequency on wider shoulders in the higher ADT ranges. It is entirely conceivable that this relationship between ADT and speed becomes much stronger for sections with paved shoulders and may even reach the point where the reduced accidents resulting from increased shoulder width are offset and the trend is reversed by the increase in accidents due to increased speeds. To date, however, no factual study has been made to check this theory.

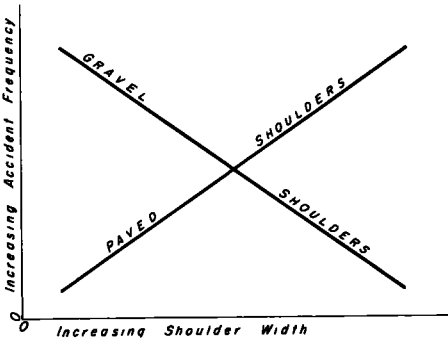


Figure 1. Accident frequency and shoulder width.

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An analysis was made to help explain why accidents increased with the increase in the paved shoulder width. For this analysis the total shoulder width, paved plus gravel, was considered. It was thought that possibly those sections with a high number of accidents on wide paved shoulders had narrower over-all shoulder width. A preliminary analysis, however, indicated that those sections with high accidents and wide paved shoulders normally had the widest over-all shoulder width. It appears that one of the original conclusions made by Belmont (6)—"As shoulder width increases, drivers may gain an unjustified feeling of security. Speed may increase, with an attendant rise in accident rate"—has as much meaning today as it did when it was first made.

It must be remembered that the paving of shoulders was initially a design function to help increase the structural strength of the pavement and was not done primarily to increase the safety to the motoring public. It does appear from the data available that no additional safety can be gained by adding extra width to the paved shoulders, and that, therefore, the width of the paved shoulders should probably be controlled by the width required to obtain the structural strength necessary to avoid raveling and deterioration of the pavement by heavy traffic volumes or heavily loaded vehicles coupled with emergency stops.

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