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CORRELATION ROAD GEOMETRIC ON ROAD DAMAGE

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ABSTRACT

The implementation of safe road infrastructure can be defined by the minimum number of traffic accidents that occur on these roads. Traffic accidents can caused by several factors, encompassing the geometric attributes of the road, characteristics of vehicles, human elements, and environmental conditions. Previous studies have identified specific geometric features, including superelevation, degree of curvature, road slope, and shoulder type, as influential factors in traffic accidents. Simultaneously, the state of the pavement, characterized by issues such as rutting, potholes, IRI value, and skid resistance, also plays a crucial role in traffic accident. The interplay between road geometric and pavement conditions underscores the importance of effective road management for ensuring safety. Existing research highlights a correlation between road geometric and road damage, with the Pavement Condition Index (PCI) directly correlating with road and shoulder width, and inversely correlating with transverse and longitudinal road slope. This phenomenon is, in part, attributed to heightened shear strain on narrow road shoulders and a reduction in the resilience modulus value of the subgrade on sloped roads.

Keyword: Road Geometric, Road Damage, Pavement Condition Index

1. INTRODUCTION

Roads primarily serve the essential function of facilitating the advancement of production and service sector activities, as well as fostering regional development[1]. In order to function optimally, roads must be designed according to both geometric and pavement requirements [2][3]. Geometric planning is road planning which focuses on planning the physical form which does not include planning for pavement thickness and road drainage[4]. Meanwhile, pavement design includes the thickness of the pavement [5]. Typically, road pavement design tends to overlook road geometric factors, instead emphasizing material properties and traffic loads[6]. Meanwhile, road geometric significantly influences driver behavior [7][8]. For example, on roads with a significant slope, drivers typically reduce their vehicle speed which increase the bearing load on the road surface, making these areas more susceptible to damage[9]. Road damage can result from various factors, including vehicle load, inadequate road maintenance, temperature fluctuations, material quality, insufficient drainage, and road geometric[10][11][12][13][14][15][16]. However, the impact of road geometric factors on road damage has not been extensively explored by researchers[17].

The implementation of safe road infrastructure can be defined by the minimum number of traffic accidents that occur on these roads Traffic accidents can caused by several factors, encompassing the geometric attributes of the road, characteristics of vehicles, human elements, and environmental conditions[18][19][20]. Previous studies have identified specific geometric features, including superelevation, degree of curvature, road slope, and shoulder type, as influential factors in traffic accidents[21][22]. Simultaneously, the state of the pavement, characterized by issues such as rutting, potholes, IRI value, and skid resistance, also plays a crucial role in traffic accident[23][24][25]. Hence, given the considerable influence of road geometric and road damage on the safety of road performance,

it is important to investigate the correlation between road geometric and road damage. Such analysis is crucial to inform forthcoming repair and maintenance strategies. Additionally, it serves to mitigate the risk of traffic accidents and minimize associated repair and maintenance costs. This research delves into the potential correlation between road geometrics and road damage, drawing upon literature studies from prior research.

2. RESEARCH METHODOLOGY

This research was conducted through a literature study review, drawing upon existing studies in the field.

3. ANALYSIS AND RESULT

Determining the correlation between road damage and geometric factors can be achieved through various approaches. Previous studies have employed diverse methods, including direct examination of damage behaviors across different geometric shapes and an analysis of forces involved in variations of geometric shapes and pavement thickness. The subsequent section presents the analysis and findings of prior research, focusing on the correlation between road geometric and road damage.

3.1. Correlation of Geometric Aspects to Road Damage

Conducted research aimed at establishing the correlation between geometric aspects of roads and road damage. This study focused on Two-Way Two-Lane Rural Roads in Iran, considering various geometric factors, including degree of curvature, transverse slope, longitudinal slope, road width, and road shoulder width. The assessment of road damage utilized the Pavement Condition Index (PCI) method. Notably, the study consider a constant traffic factor, as it was conducted on a single road section, which uniform traffic load values across all sample points. Figure 1 serves as a representative sample unit in this research.
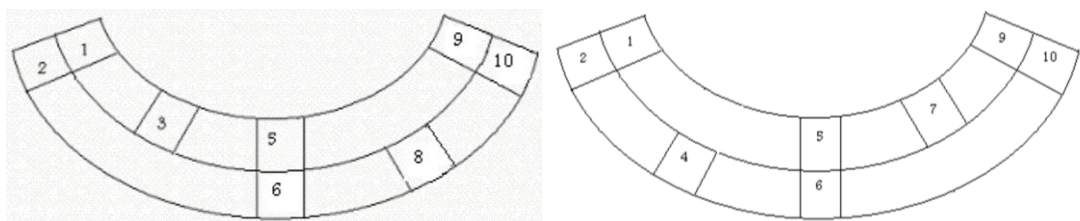

Figure 1. Sample Unit

Source: [17]

Table 1. Result of T test in regions

No.	Difference of average	Confidence level	T test	Topography of region
1	-3.16	0.139	-1.53	Plain region
2	-3.81	0.028	-2.53	Rolling region
3	-5.32	0.004	-5.04	Mountain region

Source: [17]

The findings from the examination presented in Table 1 reveal that, in flat terrain, the t-test, which assesses the independence of PCI populations inside and outside of curves, is not rejectable at a 95% confidence level. However, the test underscores a noteworthy distinction between PCIs observed in rolling and mountainous regions.

There is a linear regression between the geometric characteristics and PCI. For the rolling region, it described with Equation 1 and Equation 2 for the mountain region.

$$PCI = 1.93\,W - 4.38\,C + 0.00002\,R - 2.27\,G + 79.86 \qquad (1)$$
$$R^2 = 0.409$$

$$PCI = 1.81\,W - 5.6\,C + 0.0002\,R - 0.09\,G + 86.9 \qquad (2)$$
$$R^2 = 0.409$$

Where:
PCI = Pavement Condition Index
W = Sum of shoulder and lane width (m)
C = Cross slope (%)
R = Curve radius (m)
G = Longitudinal slope (%)
(Source: Solatiyan, 2012)

Equation 1 reveals that when each independent variable is treated as an operating variable while holding other independent variables constant, a one-unit increase in road width results in a 1.93 increase in PCI. Similarly, a one-unit increase in slope width leads to a PCI decrease of 4.38, a one-unit increase in radius corresponds to a PCI increase of 2.15E-0.005 units, and a one-unit increase in longitudinal slope results in a PCI decrease of 2.27. Turning to Equation 2, it indicates that when each independent variable is considered as an operating variable with other independent variables held constant, a one-unit increase in lane and shoulder width results in a PCI increase of 1.81. Additionally, a one-unit increase in cross slope leads to a PCI decrease of 5.63, a one-unit increase in radius corresponds to a PCI increase of 0.0002 units, and a one-unit increase in longitudinal slope results in a PCI decrease of 0.92 units. In summation, it can be inferred that the PCI value exhibits a direct correlation with the augmentation of road width and the curve radius. Notably, the impact of the longitudinal slope is more pronounced in the rolling region, whereas the influence of cross slope and curve radius is more significant in the mountainous region.

It is important to highlight that the applicability of the two linear regression models developed in this research is contingent upon their use on roads with traffic conditions resembling those during the research. This prerequisite is essential to ensure that the Pavement Condition Index (PCI) values obtained from the models accurately depict or closely approximate the prevailing actual conditions.

3.2. Effect of Road Geometric and Pavement Thickness on Pavement Behavior

In 2020, Forghani et al. conducted an analysis of the behavior of flexible pavement on urban collector roads in Hamilton, Ontario, with variations in geometric shape and pavement thickness. The study employed the PSIPave 3D™ methodology. The selection of the PSIPave 3D™ method stems from its capacity to incorporate road geometric aspects, and the results it yields offer comprehensive insights into pavement performance and behavior that are not attainable through another methods. The road geometric variations utilized in this research are detailed in Table 2.

Table 2. Variation of Road Geometric

| Case	Details
1	Narrow shoulder (0.7 m) with a steep cross slope (1:1.7)
2	Narrow shoulder (0.7 m) with a gradual cross slope (1:6.4)
3	Wide shoulder (3.95) with a steep cross slope (1:1.7)
4	Wide shoulder (3.95) with a gradual cross slope (1:6.4)

Source: [6]

The additional geometric data employed in this research encompasses the following parameters:
a. number of lanes: 2,
b. lane width: 3.5 meters, and

c. presence of drainage.

The pavement thickness variation is through three distinct methods, namely:
a. AASHTO 93,
b. Shell, and
c. MEPDG.
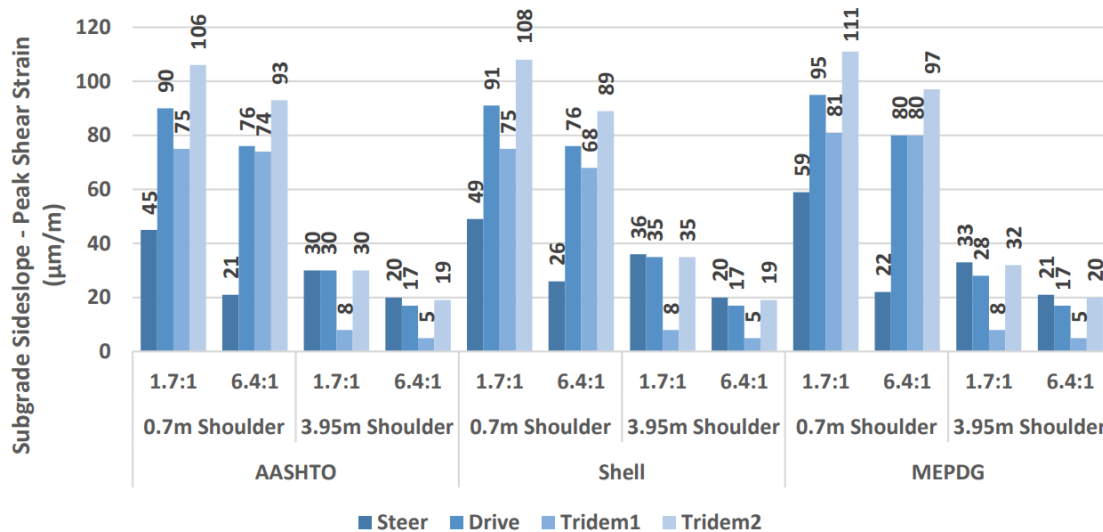


Figure 2. Peak Shear Strain in Subgrade Side Slope

Source: [6]

The present research focused on quantifying normal strains and shear strains. Consequently, it was observed that geometric factors exert a modest influence on normal and shear strains under load, with the most significant impact being on peak shear strains in the subgrade side slope, as depicted in Figure 2. The illustration in Figure 2 reveals a dependency of shear strain in the subgrade side slope on shoulder width and side slope. The variation in shear strain between the most constrained scenarios (narrow shoulder, steep cross slope) and the most expansive scenarios (wide shoulder and gradual cross slope) experienced increments of 520%, 530%, and 550% for the AASHTO 93, Shell, and MEPDG thickness cases, respectively. Therefore, road geometric emerges as a pivotal factor affecting the subgrade side slope, and these strains have the potential to induce failures, compromising the overall integrity of the pavement structure. Additionally, issues such as erosion and moisture ingress may arise, contributing to a decline in pavement performance. Consequently, it is crucial to construct wider shoulders as an effective measure to decrease shear strains.

For subsequent research endeavors, the inclusion of road geometric variations, such as longitudinal slopes and curve radius, would enhance the comprehensiveness of comparisons and findings.

3.3. Effect of Road Geometric on Pavement Thickness

In 2021, Anggreana conducted an analysis of the geometric impact on pavement thickness employing the AASHTO 1993 method. The AASHTO 1993 method, along with other comparable methodologies, does not distinguish in the design of roads based on varying vertical alignments. Illustrated in Figure 3 is the resilience modulus in operation on flat road versus uphill road. The findings indicated a decrease of approximately 35% in the resilience modulus on uphill roads when compared to the resilience modulus on flat roads.
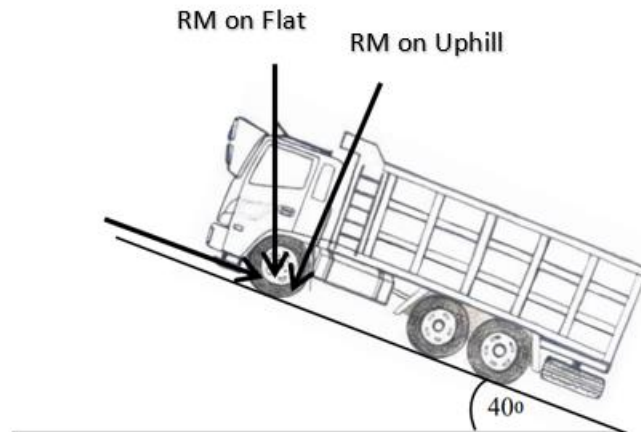
Figure 3. Comparison of Resilience Modulus Value on Flat VS Uphill Roads

Source: [9]

In this study, the average daily traffic data (LHR) on each road was collected at different times, resulting in varying vehicle load values when calculating different structural number values. Table 3 presents detailed CESA values for both roads. On the flat road, the existing vehicle load is smaller compared to the load on the uphill road. This leads to a greater need for pavement thickness on the uphill road (in this case), not only due to the geometric shape of the uphill road but also influenced by the role of the vehicle load.

Table 3. Comparison of CESA on Flat VS Uphill Roads

Comulative Equivalent Standard Axle (CESA)	
Flat Roads	2.690.337,73
Uphill Roads	12.173.369,65
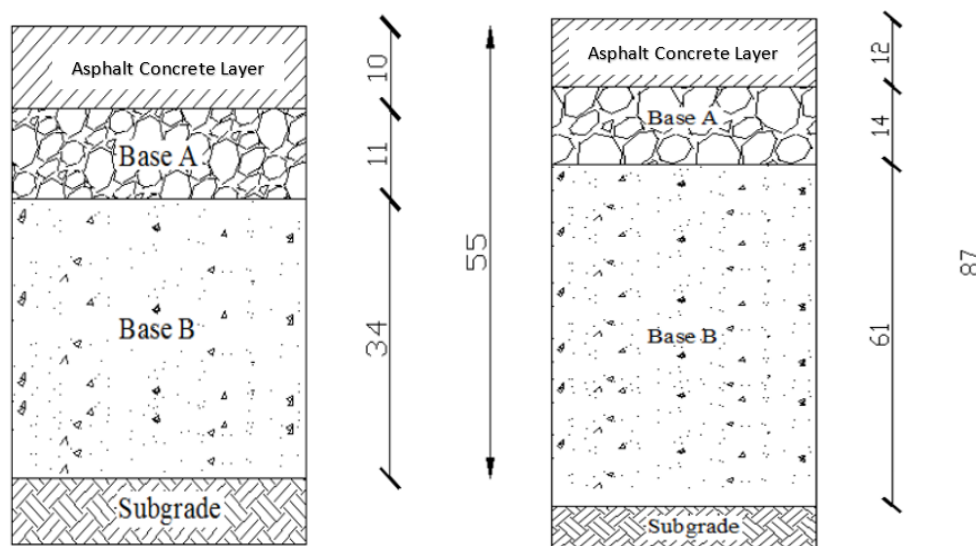
Figure 4. Comparison of Pavement Thickness on Flat VS Uphill Roads

Source: [9]

As illustrated in Figure 4, the prescribed thickness of the pavement layer for a level road is 55 cm (depicted on the left), while for an ascending road, it is 87 cm. Disparities in the resilience modulus of the subgrade result in variations in the thickness of Subbase course under identical vehicle loads. Thus, the inference can be drawn that a lower subgrade resilience modulus makes uphill road pavements more susceptible to damage in comparison to flat roads, even with the same load. If the implementation persists in using the same SN value, it is imperative to enhance the quality of the materials employed on

uphill roads, ensuring that the road can effectively accommodate traffic in accordance with its intended design life.

In subsequent research, additional methodologies can be incorporated to compare pavement thickness result. Moreover, case studies may be conducted under the assumption of a constant or uniform vehicle load, enabling a more detailed elucidation of variations in pavement thickness arising from the road geometric.

4. CONCLUSION

Based on the analysis and results, it can be concluded that a correlation exists between geometric factors and road damage. Assuming constant traffic values, the Pavement Condition Index (PCI) is found to be directly proportional to the width of the road and shoulders, and inversely proportional to the transverse and longitudinal slope values. Additionally, the width of the road shoulder influences the shear strain value, contributing to potential erosion. The inverse correlation of PCI with transverse and longitudinal slopes is attributed to the smaller resilience modulus of the subgrade on uphill roads. This discrepancy leads to variations in the required thickness of road pavement, potentially causing road damage on roads with high vertical alignments.

Further research is essential to explore the influence of road geometric on road damage under different variables, considering factors such as various study locations, average daily traffic, and a comparative analysis between rigid and flexible pavement. This comprehensive approach aims to augment and refine the insights derived from prior research.

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