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Analysing the Influence of Encroachment Angle and Median Parameters on Safety of Rural Highways Using Vehicle Dynamics Performance

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Abstract. Cross median crashes are among the most dangerous types of highway crashes, especially for trucks, which should be more considered by highway engineers. Skidding and roll-over are the important factors which affect trucks' cross median crashes. In this research, the median safety is evaluated through TruckSim dynamic simulation and violations of running off from the median; also, statistical analyses are carried out. The results of this research show that encroachment angle is the most effective parameter for skidding and roll-over. The side friction factor increases as the speed increases, which means that more side friction demand is produced for trucks at high speeds. From the viewpoint of rolling, the most critical situation is found at 25° of encroachment and 0.8 m shoulder width. It can be seen that the unpaved shoulder is more critical than paved shoulder and two-way slope cross-sections are more important than the one-way slope. The result of this paper could be used for designing safer roadways.

1. Introduction

Vehicle crashes, because of dangers for human life and health, are a major challenge in most countries today. Every year, many people are killed in car crashes and, in addition to heavy costs on the society platform, particularly it can be much more important in countries where the human resources are in the great value. Usually, if any solution cannot be found for mortality and effects of crashes, always it will be increased as other national problems of each country, and caused to waste of human and financial resources of the country and serious disruption in the country's development programs. Increasing the number of vehicles in the country and developing new ways, will help to increase the number of crashes and casualties.

At the end of 2004, about 6.18 million vehicle accidents were reported in the United States of America [1]. Nearly half of these accident led to personal injury and totally 42,636 deaths were recorded. These numbers of deaths have remained relatively unchanged for more than one decade and it is equivalent to one death every 12 minutes on the road [2]. In 2008, more than 37000 passengers were killed and 2.3 million injuries were recorded in the road networks of USA [3]. These crashes resulted in considerable socio-economic damage. Neuman et al., cited to Central management statistics of roads that show cross median crashes (CMC) occurred every per 200 miles of highways and almost 250 deaths, are related to



CMC in one year. It can be concluded that crashes due to CMC are three times more severe than other types of crashes on highways. Even though highways are generally designed using the most uniform and integrated geometric design criteria, crashes related to CMC are important safety issues on the highways [4]. In order to reduce the cross median crashes and rolling in the middle of divided roads, it is important to first understand the relationship between these types of crashes with road, median design specifications, traffic, as well as driver and vehicle characteristics [5].

In this study, the relative impact of encroachment angle, speed, type, and width of median, as well as cross slope on the road safety is discussed by multi-dimensional dynamic performance modelling of TruckSim.

2. Literature review

The roadside design guide [6] has provided the regulations of barriers for divided highways. A negative consequence of these barriers in the middle of roads is that the installation of these barriers in medians will increase the number of crashes [7].

Graham et al. found that, due to little variation among the state transportation organizations in the design of median cross-section on rural divided highways, vehicle dynamics simulation in the new design is economical [8]. Stine et al. (2010) examined the impact of the median cross-section design on road safety using the vehicle dynamics simulations. Several thousand simulations have been done to create a set of real data that best represent the range of encroachment results on actual highways. The following algorithms and methods are frequently used for the simulation:

Step 1: Define the median cross-section.

Step 2: Choose the vehicle.

Step 3: Apply the initial conditions.

Step 4: Determine the responses and actions.

Step 5: Run the simulations.

Step 6: Repeat the output of the summary and simulation [2].

To better express the probability of any specific encroachment which occurs in real life highway median encroachments, the post-processing weighting method is implemented, in which the weights are implemented at the relative probability of each crash occurring on the highway. A national household travel survey is used to obtain the probability of each vehicle class on the road. Therefore, each vehicle class is assigned by a coefficient, equal to the numbers of vehicle traveling [8].

Total weighting factor = Weight coefficient results from the combination of speed and encroachment \times Vehicle weighting factor

Bligh et al. (2006) and Miaou et al. (2005) have estimated severity consequences for CMC on divided highways without any median barrier and other crashes related to sections with no median barrier. They have analyzed the crashes related to medians on interstate highways, urban freeways, and rural arterial roads in 52 counties of Texas during 1998-9. Five consequences of severity of crash are taken into account: fatal, incapacitating (A), nonincapacitating (B), probability of injury (C), and only damage (PDO). They have considered median width, number of lanes, and speed limit as variables and found that these variables do not have any great effects on CMC severity model [9], [10]. Hu et al. studied the severity models of median crossing and roll-over crashes on rural divided highways in Pennsylvania. The aim of the research was to find the outcomes of the severity of crashes passing through medians and roll-overing by applying binary and multinomial logit models. 76 crashes of median crossover and 231 roll-over during five-year analysis period were reviewed. Data demonstrated that crashes of median crossover had more portions (23%) in fatalities and intensive injuries than median roll-over (10%) [5].

Lu et al. analyzed three crash severity; PDO, injury and fatal using 631 reports during three-year period between 2001 to 2003. They found that driver disorders, wet and snowy road conditions, medians with low width, high traffic volume, and young drivers were related to the severity of median crossover crashes [11]. Also, Obeng (2007) and Gabauer et al. (2010) have used binary logit model by combining fatalities and severe injuries in one single series and compared severe outcomes with lower level

consequences [12], [13]. Mehrara et al. (2015) studied the effect of the confluence of horizontal curves and longitudinal grades on skid of different vehicles. They concluded that the most critical part of horizontal curves on a road was at the beginning part of the curve due to the fluctuations of steering angle and lateral acceleration, which was 5-10% more than other points of the curve. Braking had too much effect on the side friction factor, especially in passenger cars, and was considered a serious threat for passengers (in spite of skidding). Based on the results, a truck faces more lateral acceleration in downgrades and less lateral accelerations in upgrades [14].

Abdi et al. (2015) analyzed the effect of fore slope design on errant vehicle safety using dynamic stimulation. They concluded that trucks had the least side friction factor compared with passenger vehicles. Therefore, the skid probability of trucks was less than other types of vehicles, which was in fact due to the higher level of truck mass than other vehicles and more vertical forces on its wheels. In steep fore slopes, the probability of skidding increased, since there was more lateral acceleration and centrifugal force. In addition, more steering angle in vehicle led to higher possibility of skidding of trucks. In fact, speed of 100 and 120 km/h was the critical speed for the trucks with the encroachment angle of more than 10 degrees. Such a condition happened at 120 km/h speed for sedans [15]. Abdi et al. (2015) in another paper analyzed the influence of coinciding horizontal curves and vertical sag curves on side friction factor and lateral acceleration by simulation modelling. They concluded that the coincidence of horizontal and vertical curves increased the slip probability of moving vehicles. According to the results, maximum side friction factor only happened when the deepest point in the vertical curve occurred in the middle of the horizontal curve. Also, they realized that side friction factor of trucks was much less than that of passenger cars, on the other hand, lateral acceleration of the trucks was much more than that of other vehicles. As indicated by the assessment of lateral acceleration in the simulation, the movement of horizontal curve points due to vertical curves had slight influences on skidding and lateral acceleration, since lateral acceleration was influenced by changing the steering angle [16].

3. Research method

It is possible that considering several scenarios are included in design of various states of the three-dimensional highway and manoeuvring the vehicle dynamics to assess the instability and threshold of skidding or rollover in some cases rather than some old physical formula that are considered a vehicle as a point mass and are not compatible with the real world and also rather than field test that it will be much expensive and in some cases impossible. Therefore, researchers, in this study, believe that based on development of the vehicle dynamics modelling, it is required the highway geometric design be analyzed to ensure the safety of highway elements on the design or predominant condition; As a consequence, crashes are may likely happen as a result of driver behaviours and traffic conditions.

3.1. TruckSim simulation test

TruckSim is a vehicle dynamics simulation software package developed by the Transportation Research Institute at University of Michigan, which has engaged in vehicle dynamics simulation research for more than 20 years. Due to use of the parametric modelling method and the characteristic of module parameter accurate setting, this software can be used to analyze the response of roads, environment, driving behaviour, and the vehicle itself parameter input [17].

3.2. Three-dimensional road model

The presented three-dimensional road model is derived from MQ interpolation which is one of the best approximation methods in road modelling [18], [19]. The road modelling approach with MQ incorporation can be derived as follow:

$$F(X) = (x + a)^n = \sum_{j=1}^n a_j [(x - x_j)^2 + R^2]^{0.5} \quad (1)$$

$$F(X,Y) = \sum_{j=1}^n a_j [(x - x_j)^2 + (y - y_j)^2 + R^2]^{0.5} \quad (2)$$

$F(x)$ = one-variable MQ interpolation function

a_j = undetermined coefficient.

x_j = The j th centreline coordinate scattered on horizontal curve

R = smooth factor

x = interpolation point between x_j and x_{j+1}

$F(X,Y)$ = bivariate interpolation function, which is applied to handle 3D road smoothness and elevation.

3.3. Vehicle

The truck used in this work had the specific characteristics which are shown in Table 1.

Table 1. Truck characteristics

Design Vehicle Type	Symbol	Dimensions (m)					WB ₁
	SU	Overall			Overhang		
		Height	Width	Length	Front	Rear	
Single Unit Truck		3.4-4.1	2.4	9.2	1.2	1.8	6.1

3.4. Driver behaviour

Driver behaviour included input steering angle, speed, and encroachment angle. Speed input was 60, 80, 100, and 120 km/h and encroachment angle was for the three states of 7.5, 15, and 25 degrees.

3.5. Highway features

The shoulder type included unpaved (0.9) and paved shoulders (1). Shoulder width of 0.8, 1.2, 1.6, and 2 m were considered for this study. Also, 2% cross-slope was used for one- and two-way slope conditions and 8 states were defined in the software in terms of width, shoulder materials, and cross slope, as shown in Table 2. As a result, 576 simulation tests were conducted for this study.

Table 2. Cross section used in research and classification of shoulder material (type) and width

Shoulder width (m)	Type of cross slope	Shoulder Material
0.8	One Way Slope	unpaved
1.2	One Way Slope	unpaved
1.6	One Way Slope	unpaved
2	One Way Slope	unpaved
.8	Two Way Slope	paved
1.2	Two Way Slope	paved
1.6	Two Way Slope	paved
2	Two Way Slope	paved

4. Outcomes of simulation modelling

The outputs in this part of the study were side friction factor, roll and roll rate, yaw, yaw rate, and lateral acceleration. Figure. 1 shows the summary of software outputs.

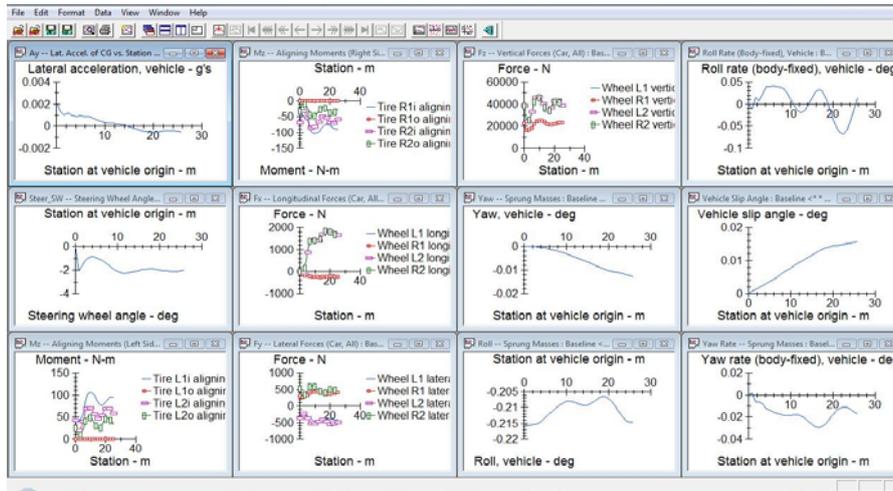


Figure 1. Summary of the simulation outputs

4.1. Side friction factor

Friction is a criterion which provides safety for vehicles against skidding. The difference between friction supply and friction demand is called margin of safety [20]. If side friction demand is more than side friction supply, then vehicles will face skidding. The friction which is established due to the contact of tire and pavement surface is divided into two directions perpendicular to each other.

Longitude friction: It provides friction towards the movement of vehicle and reduces/increases speed.

Transverse friction: It estimates slide and side frictions required during movement. Direction of this force is perpendicular to the movement of vehicles and provides the chance of changing direction for vehicles. Figure. 2 shows the forces of friction applying to the tires' contact area and pavement. Considering all forces applied on each tire, the friction factor could be calculated using equations (3).

$$f_y = |F_y / F_z| = |F / F_l| \tag{3}$$

where: f_y = Side friction factor;
 F_y = Side friction forces; and
 F_z = Longitudinal friction forces.

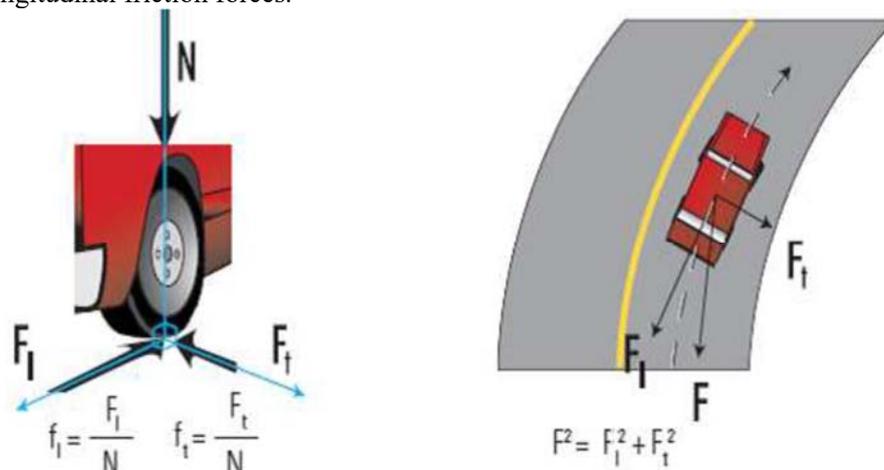


Figure 2. Forces of friction applying to the tires' contact area and pavement [21]

Since mass center of vehicles is not in the middle of axles, weight distribution is not equal on wheels and axles. Conventionally, 55-60 percent of weight is on the front axis and 40-45 percent is on the rear axle [22]. Weight distribution on wheels' changes during rotation in horizontal curves due to imposing centrifugal force. Consequently, side friction factor in each wheel will be different from other wheels and each axle will be different from the other axle.

Figure. 3 indicates the side friction of trucks versus various speeds. Based on the simulations and output data, graphs, and analyses done by SPSS, encroachment angle (81.8%), speed (15.7%), are the most effective factors for side friction factor. Effect of speed is significant at low encroachment angles. Trucks departing at the 25° encroachment angle experience a larger value of side friction factor. With the rise of speed, side friction factor increases, thus the maximum value of side friction factor occurs at the speed of 120km/h and encroachment angle of 25°. At the high value of encroachment angle, two-way slopes are more critical than one-way slopes.

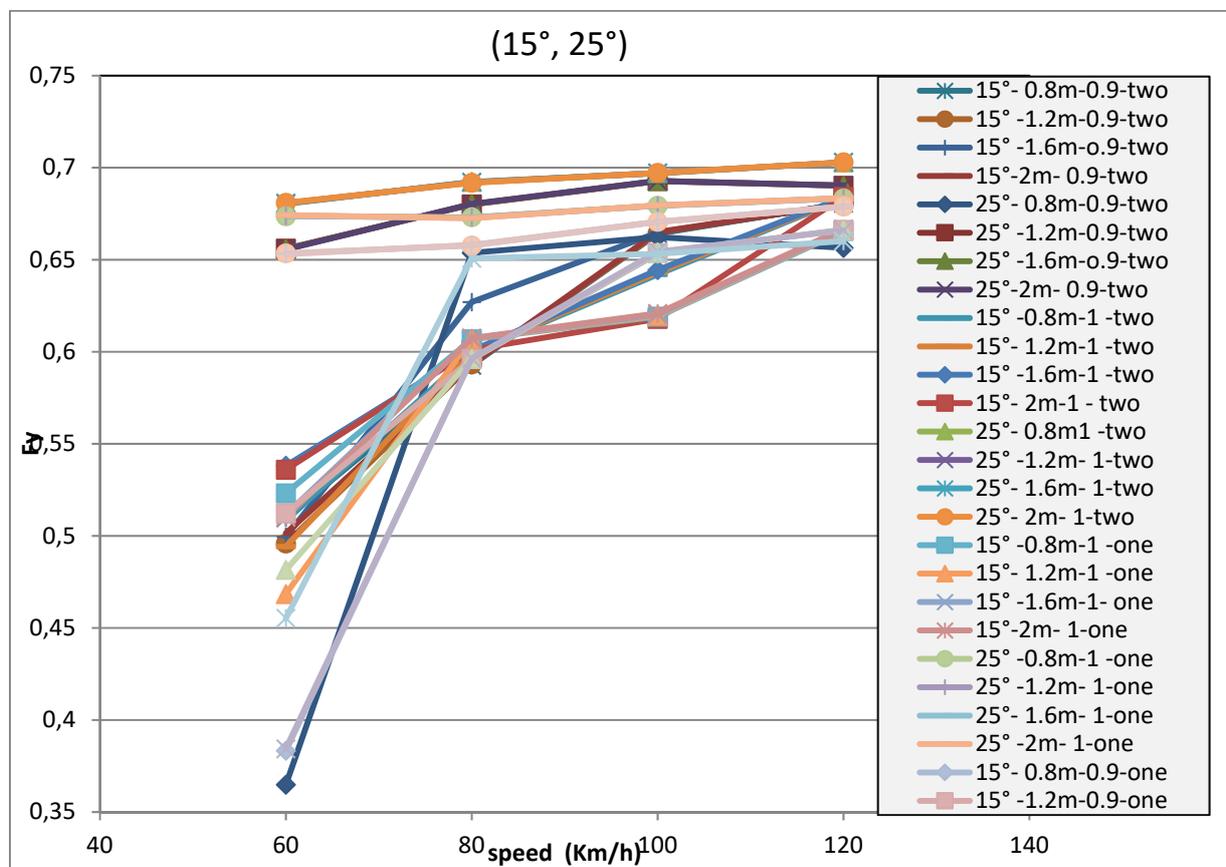


Figure 3 a) Side friction of trucks versus various speeds for 15°, and 25° encroachment angle.

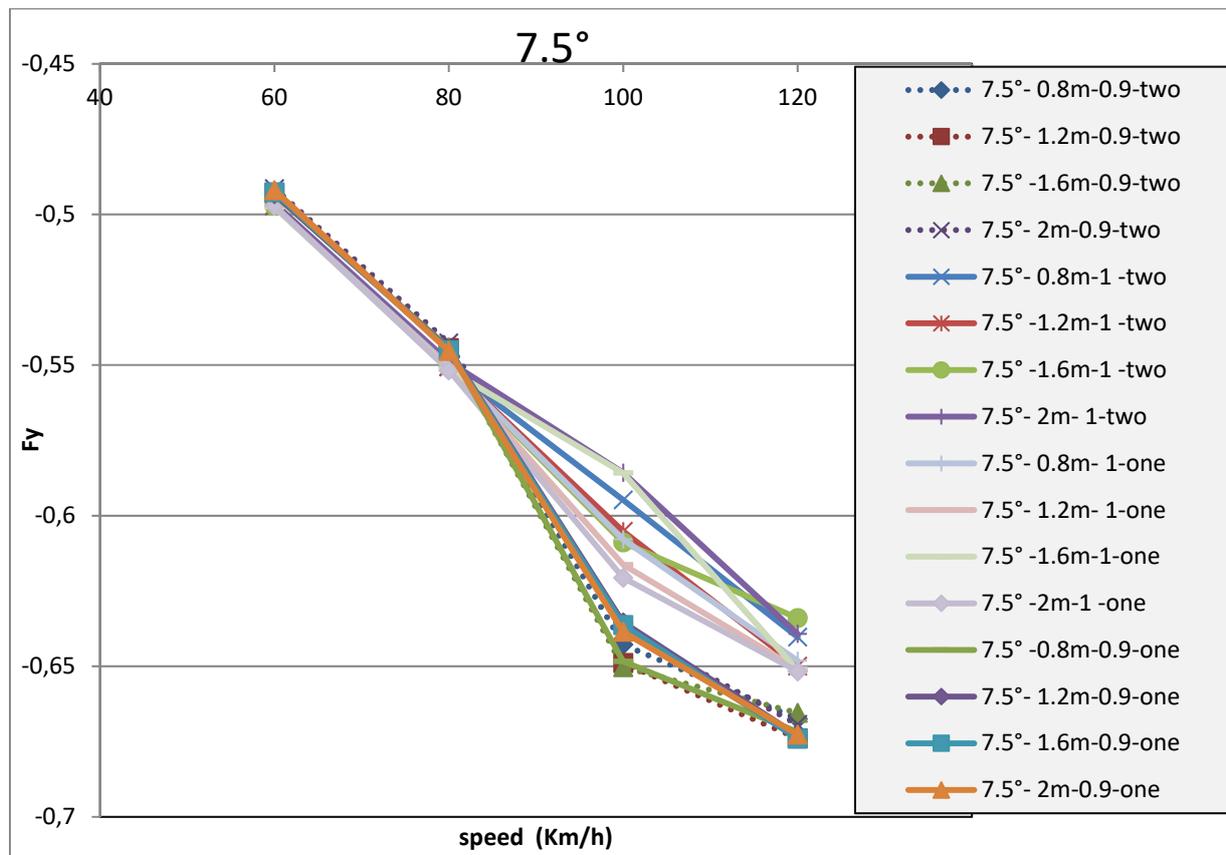


Figure 3b) Side friction of trucks versus various speeds for 7.5° encroachment angle

4.2. Roll and roll rate

Roll includes a certain part of casualties of road crashes which is divided into two forms of tripped and untripped. In the tripped situation, roll happens due to external forces like collision with guardrail. In the untripped status, the created side forces lead to the roll of vehicle due to the quick rotation of steering and passing from the curve at high speed or quickly changing the lanes. Main reasons behind most of the rolling are driving mistakes, too much loadings, adverse weather conditions, and inappropriate design; design and wrong implementation of super elevation are the most important parameters in the design part. Roll risk of vehicle depends on two criteria of width and height of gravity center. Due to too much loading, vehicles lead to the roll with the rise of height of mass center and, as a result, reduction of consistency [14]. The roll-over threshold for passenger cars is significantly higher than that for trucks [23].

Crashes due to rolling are the main concern for the safety of vehicles. These crashes are more intense and lead to more damage. With the reduced level of deviation and speed of vehicles, inclination toward rolling is reduced. Roll angle (ϕ_v) refers to the angle between the surface vertical axle and vehicle vertical axle when vehicle body moves through its longitudinal vector. Figure. 4 shows vehicle roll-over model, in which h is the height of center of gravity, (ϕ_v) and (ϕ_r) are the vehicle roll angle and road bank angle, respectively [24].

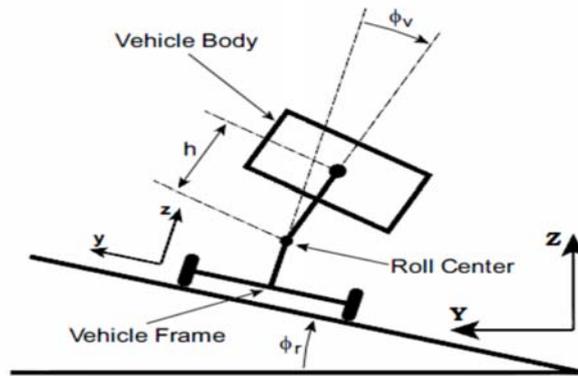


Figure 4. Vehicle roll model [24].

Figure. 5 shows the amount of roll versus speed for all the conditions. According to the results, encroachment angle (74.6%), width of shoulder (15.8%), and shoulder type (10.5 %), respectively, influence the rolling of trucks. Effect of speed is substantial mostly at the low value of encroachment angle. 25° encroachment angle and 0.8 m unpaved shoulder are the most critical conditions.

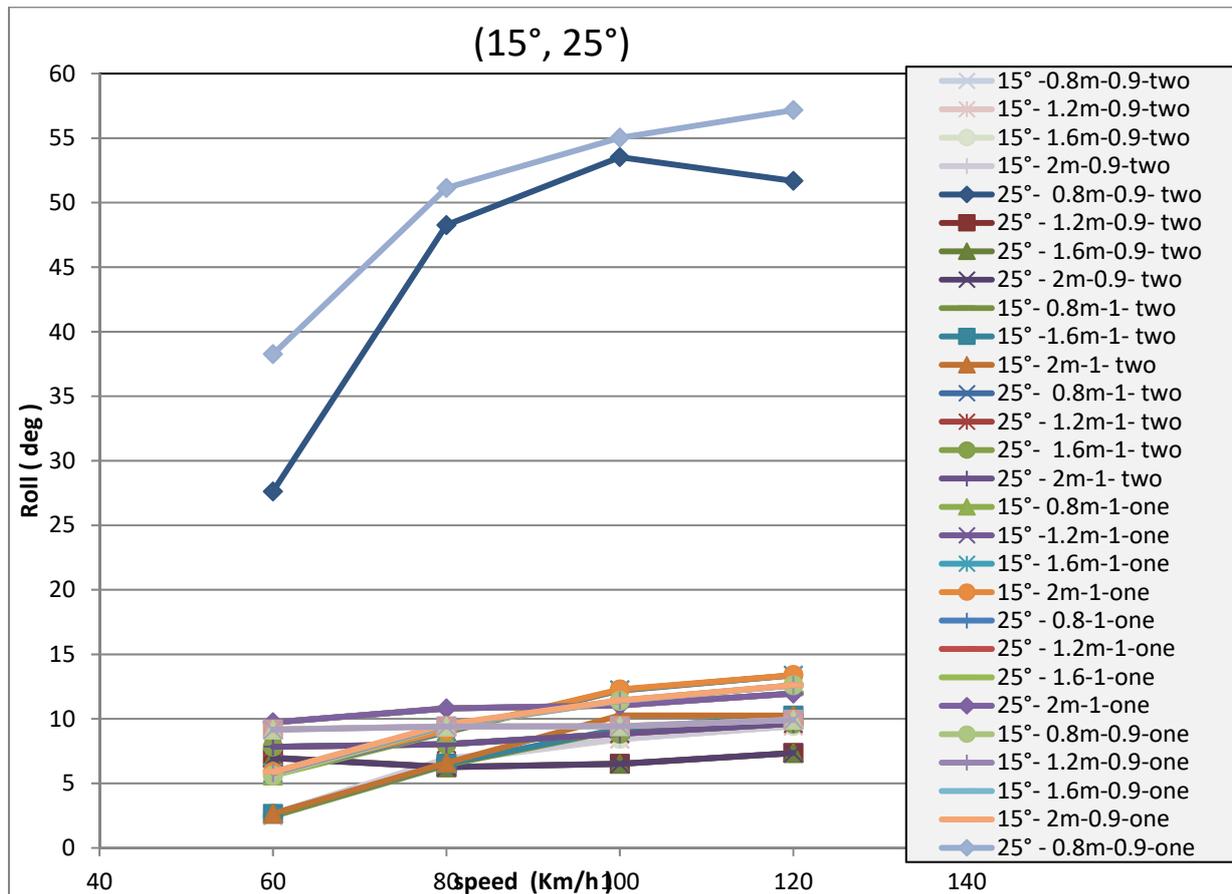


Figure 5 a) Roll graphs versus speed for 15° and 25° encroachment angle.

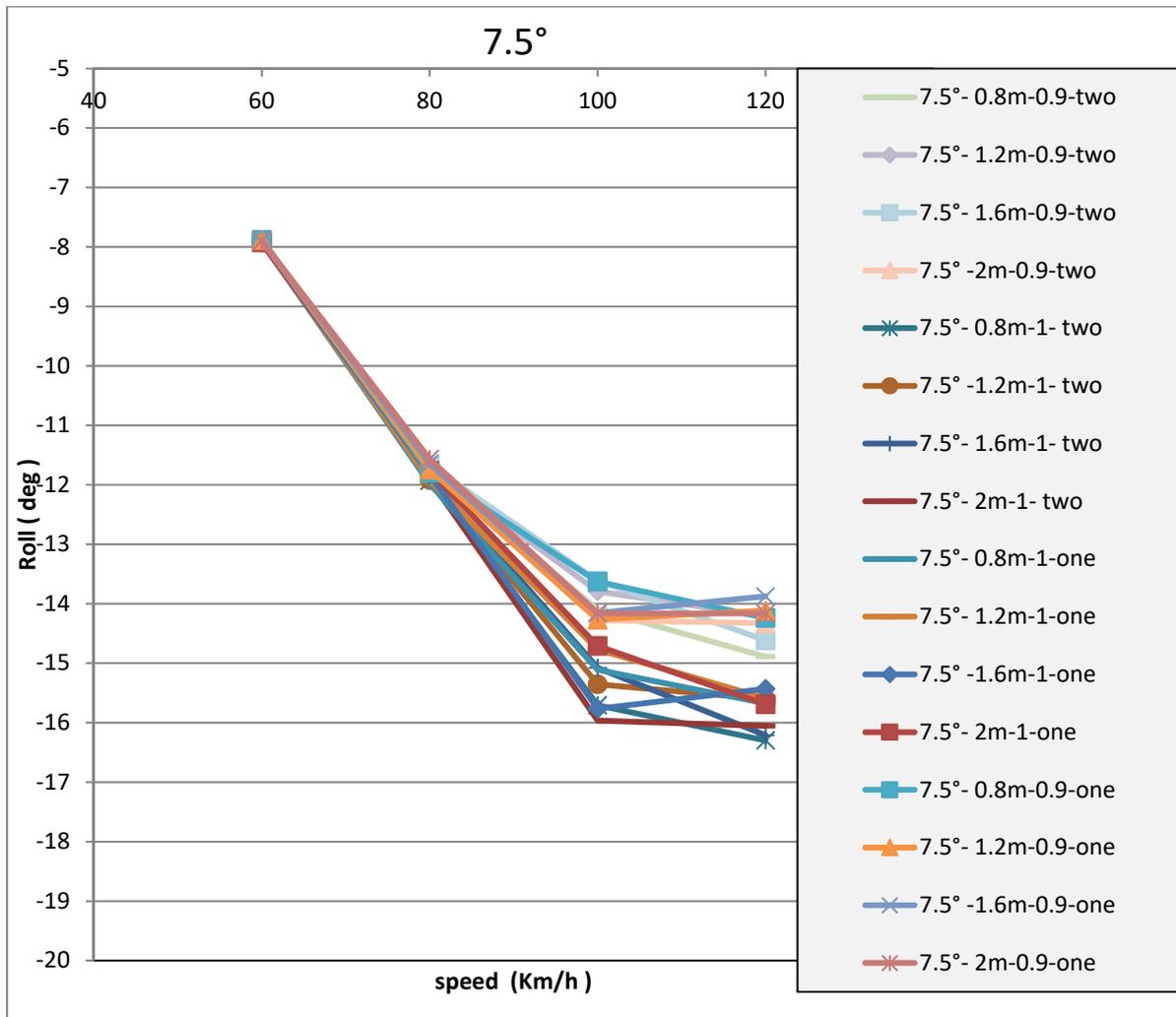


Figure 5 b) Roll graphs versus speed for 7.5° encroachment angle.

Regarding the roll rate, such as rolling, two factors of encroachment angle (65.2%) and shoulder width (17.4%) are the effective parameters. Also on the highways with unpaved shoulder, there is more probability of rolling than the paved shoulder ones. The most probability of rolling is at 25° encroachment angle and 0.8 m unpaved shoulder. Figure. 6 indicates roll rate versus speed for 7.5°, 15°, and 25° encroachment angle.

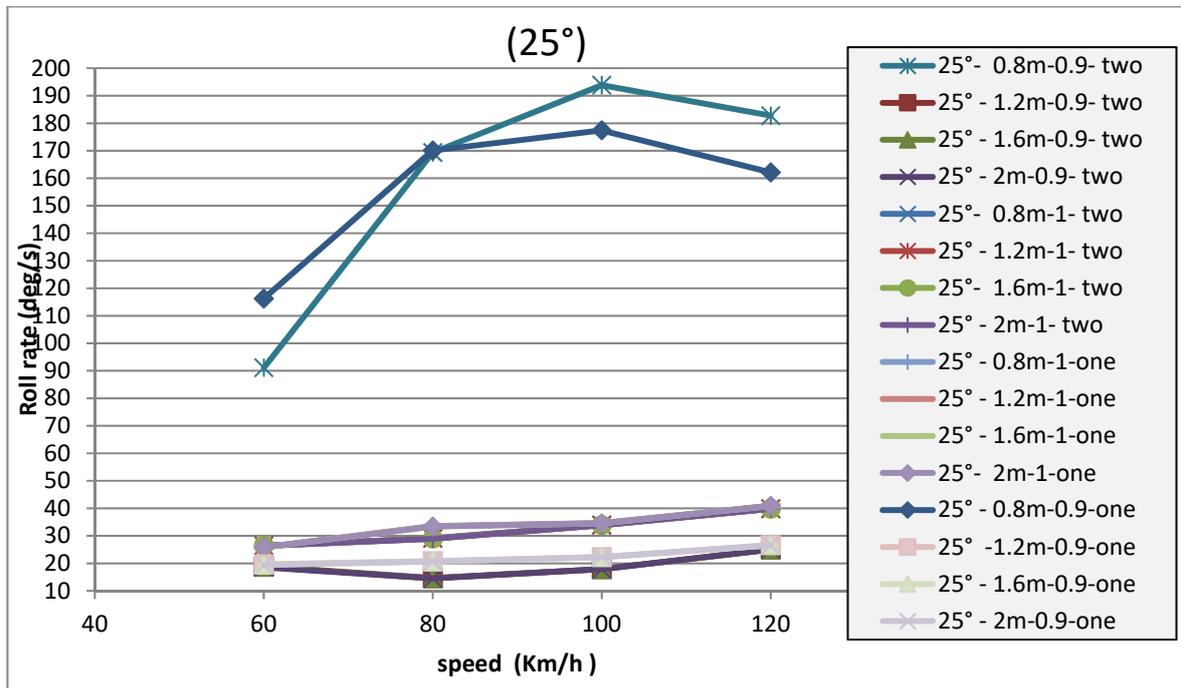


Figure 6 a) Roll rate versus speed for 25° encroachment angle

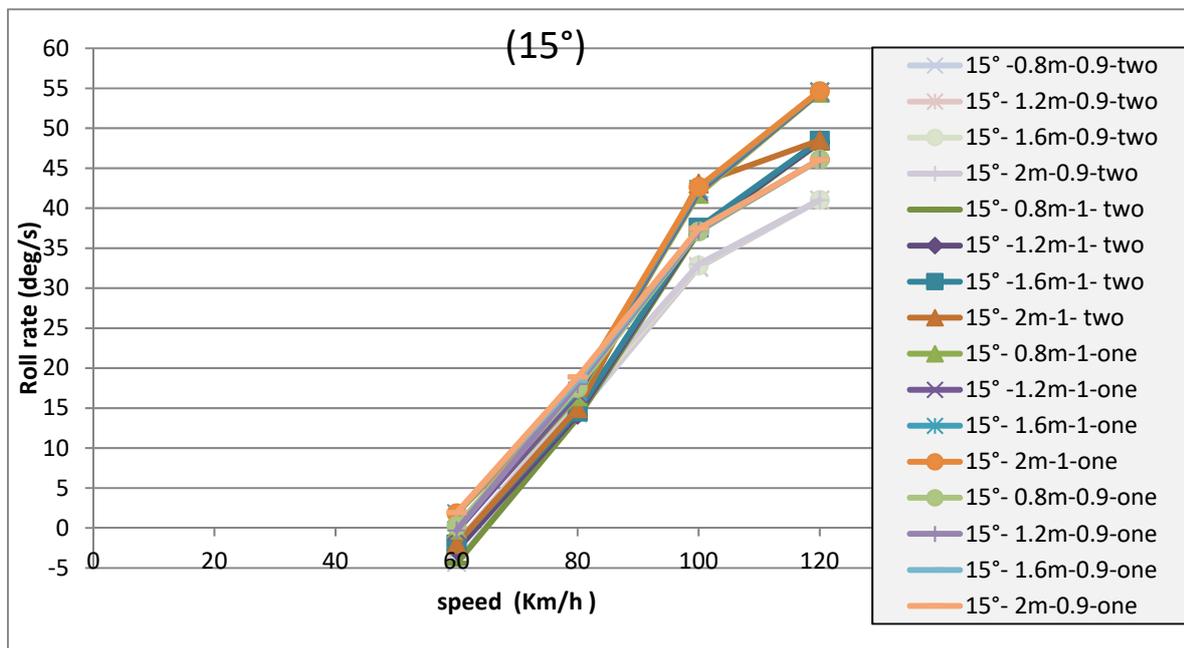


Figure 6 b) Roll rate versus speed for 15° encroachment angle

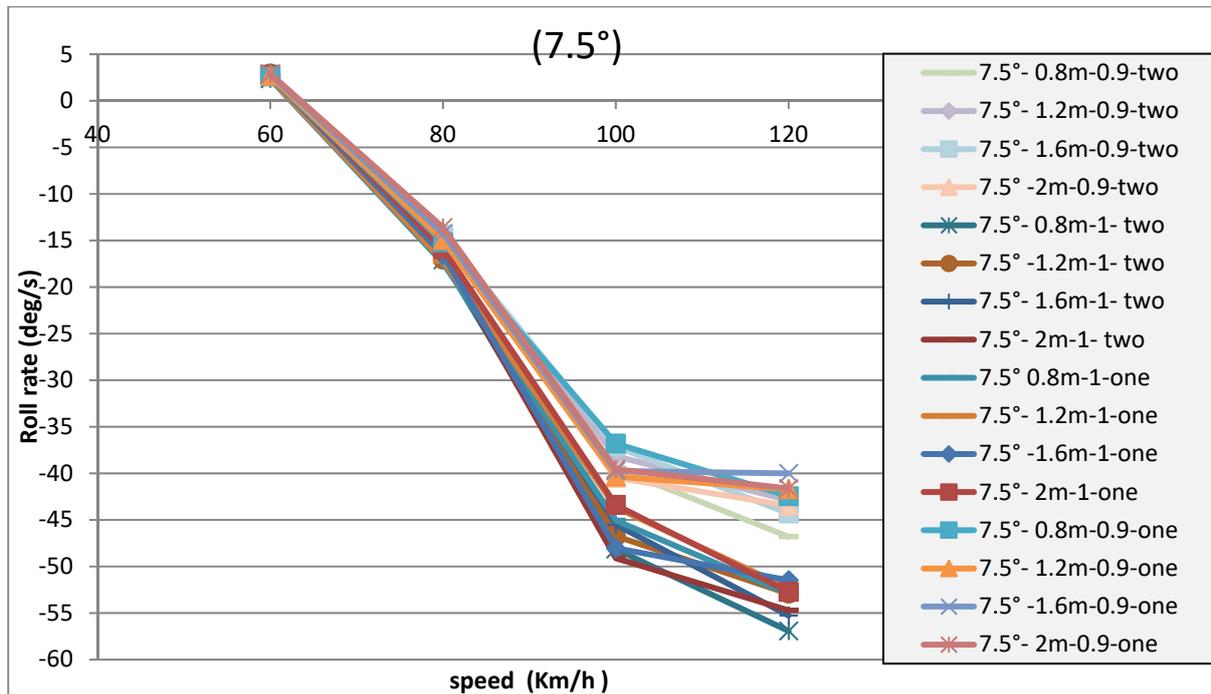


Figure. 6(c). Roll rate versus speed for 7.5° encroachment angle.

4.3. Yaw and yaw rate

Analysing and reviewing forces which apply to trucks show that, in addition to side, vertical, and longitude forces, a moment imposes on truck around axis of vertical forces (Fz) because of weight and high height of vehicle. This effect has a key role in the skidding of back wheels around front axle, especially at high speed. Figure. 7 shows all the forces applied to moving vehicles.

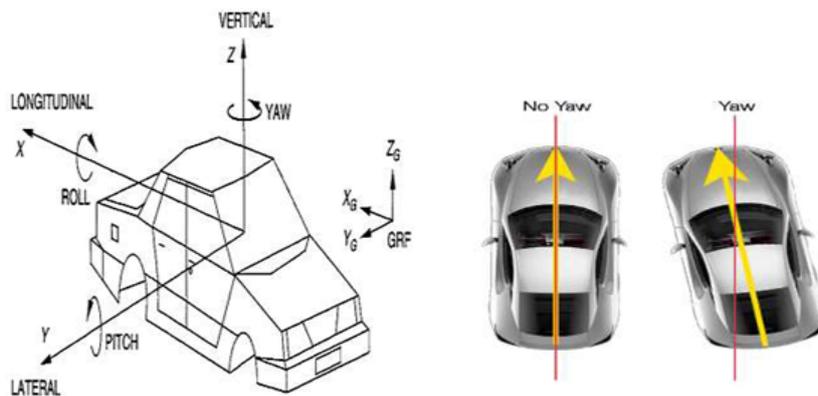


Figure. 7. Forces and moments applied to moving vehicles [25].

According to Figure. 8, encroachment angle has the most effect on Yaw (83.4%). Also, 25° encroachment angle and 0.8 m unpaved shoulder are the most critical conditions. Investigations have indicated that, with the rise of encroachment angle, yaw level is increased.

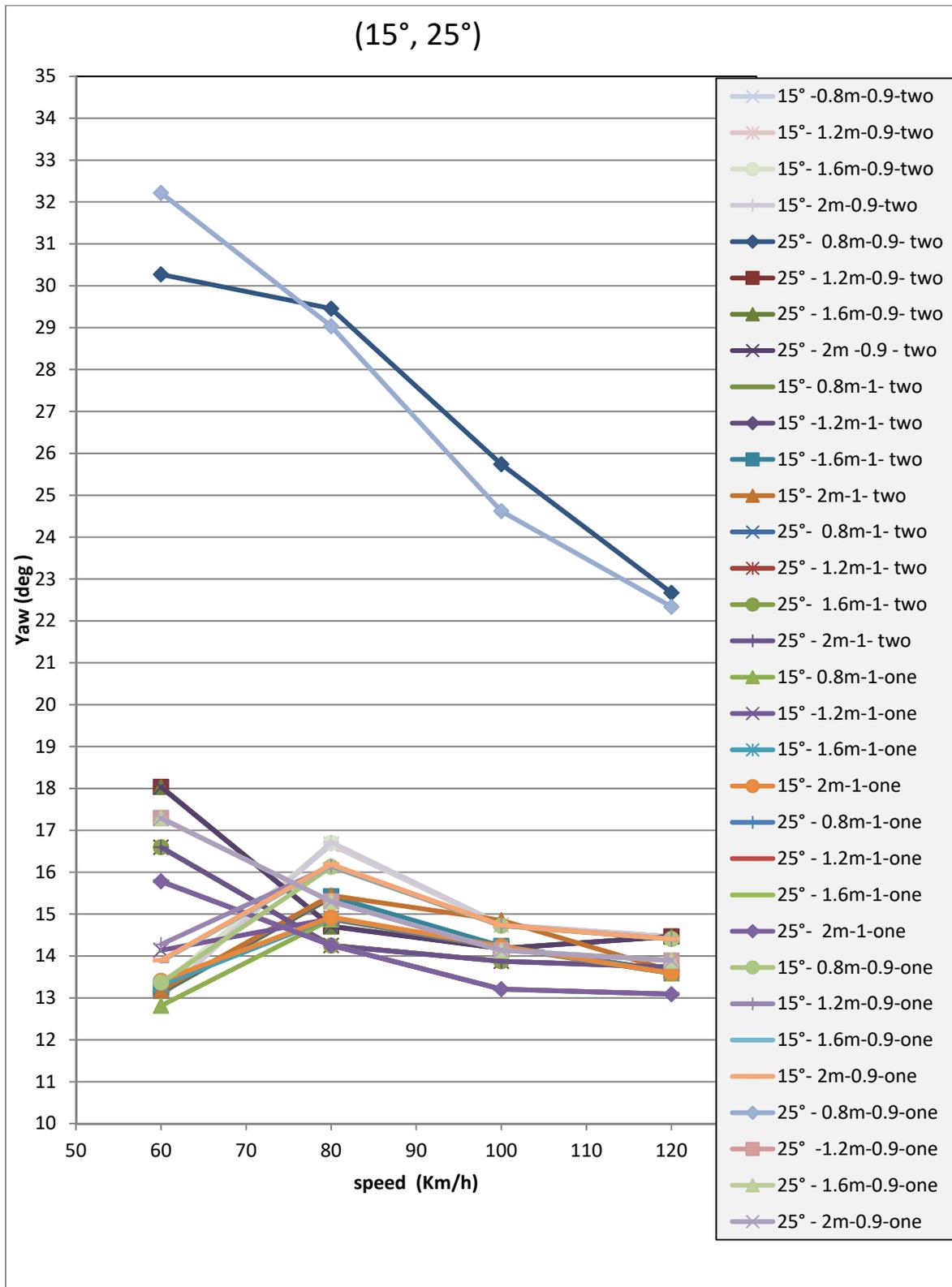


Figure 8 a) Amount of yaw versus speed for 15° and 25° encroachment angle.

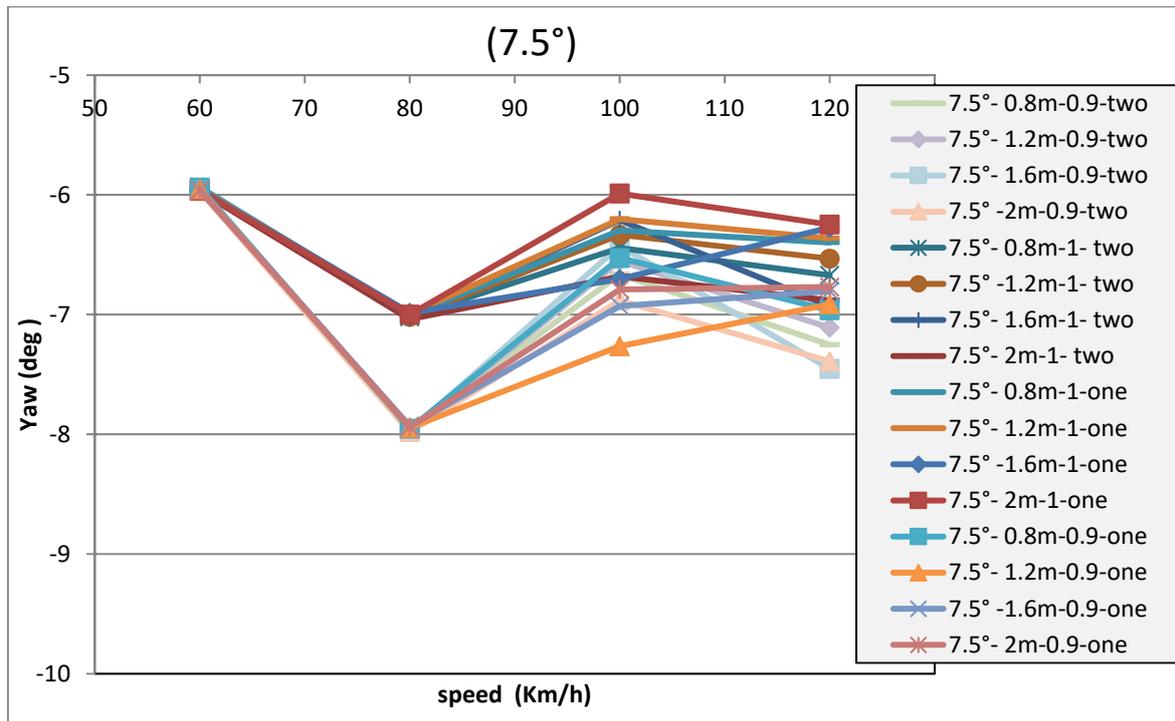


Figure 8 b) Amount of yaw versus speed for 7.5° encroachment angle.

Figure. 9 shows yaw rates for various speeds and encroachment angles. The values of yaw rate on highways with two-way slope are more than the values in one-way slopes. The maximum amount of yaw rate occurs on the road with two-way cross slope and unpaved shoulder. In this situation, the encroachment angle is 25° which happens at the shoulder width of 2 m and speed of 60km/h. The amount of yaw rate in this state is 32.46 degree per second and the growth rate is 39.97 %.

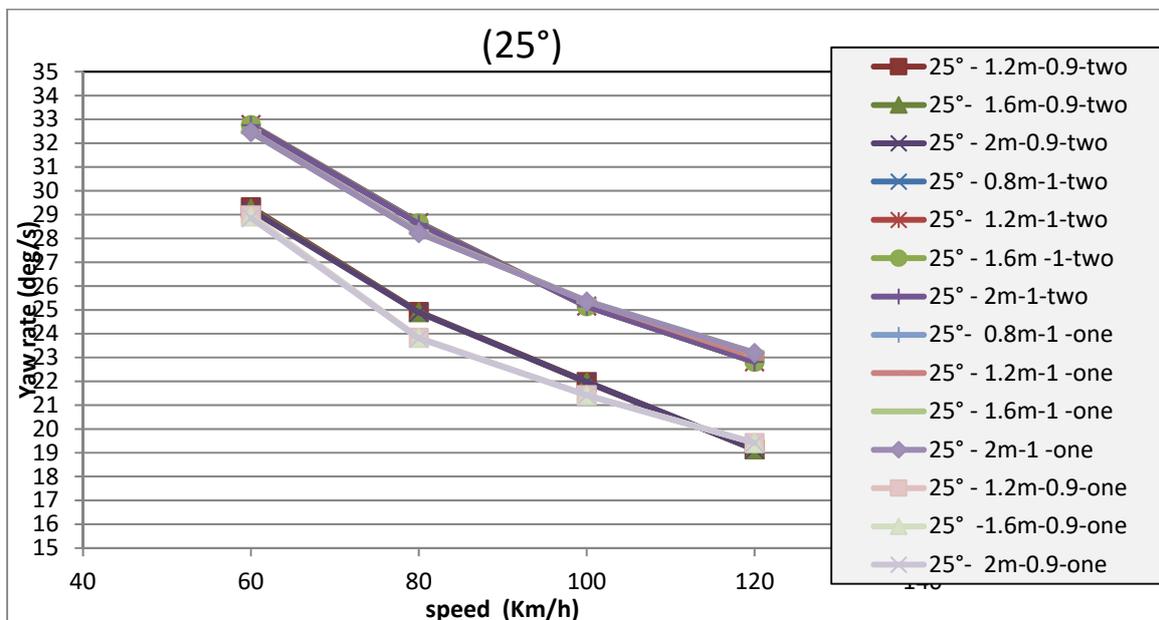


Figure 9 a) Yaw rate for 25° encroachment angle.

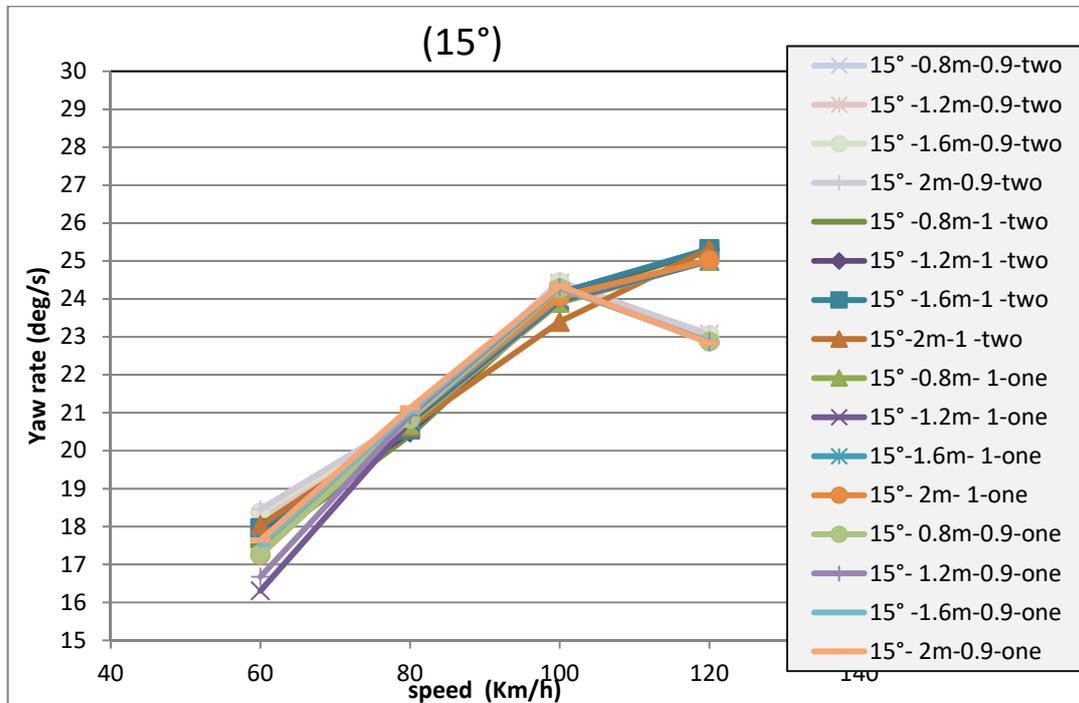


Figure 9 b) Yaw rate for 15° encroachment angle.

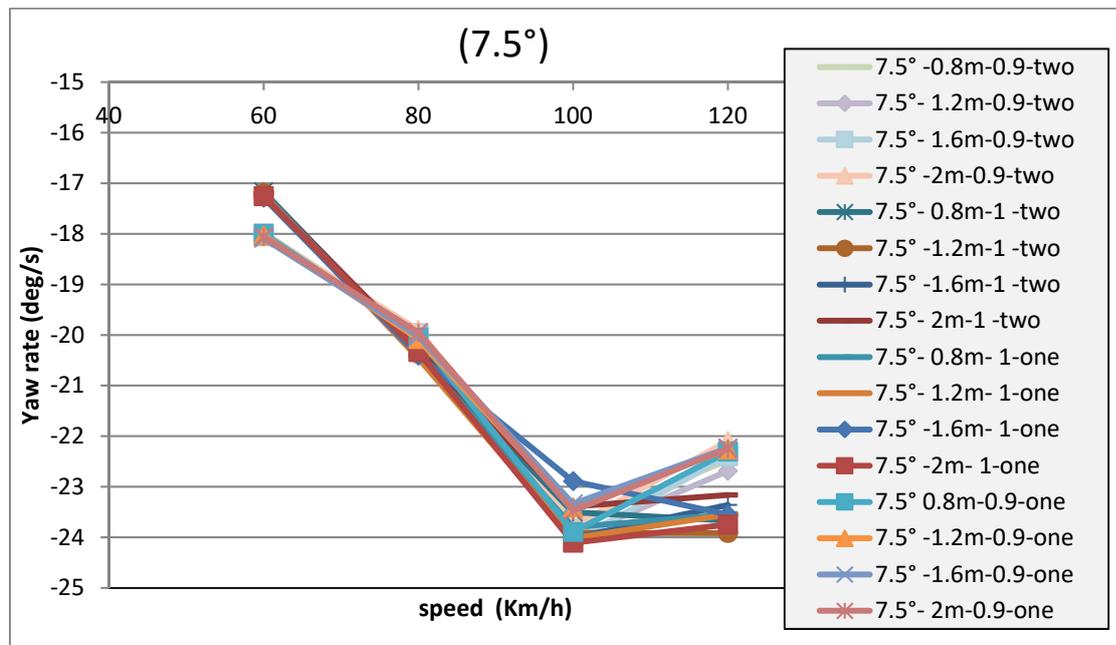


Figure 9 c) Yaw rate for 7.5° encroachment angle.

4.4. Lateral acceleration

Lateral acceleration during passing horizontal curve is another parameter regarding the safety of vehicles, especially their consistency against rolling. Totally, there are two terms on lateral acceleration: centrifugal acceleration and centripetal acceleration. The first one is virtual acceleration which is formed in the case of moving in a circular manner and is against the direction of centripetal acceleration. Also, acceleration resulting from surface friction and super elevation is called centripetal acceleration.

Based on Figure. 10, the encroachment angle has the maximum effect on lateral acceleration (A_y) which is observed as 84.3 %. Encroachment angle of 15° is the most critical situation which in speed of 120 km/h and two-way slope mode with unpaved shoulder, lateral acceleration is .99, in this status growth rate is 49.9%. The values of lateral acceleration on the highways with two-way slope are more than the values on the one-way slopes. With the rise of speed, lateral acceleration (A_y) increases and graphs go upside. Table 3 shows the samples of output and input data. Table 4 indicates the samples of animation for various states.

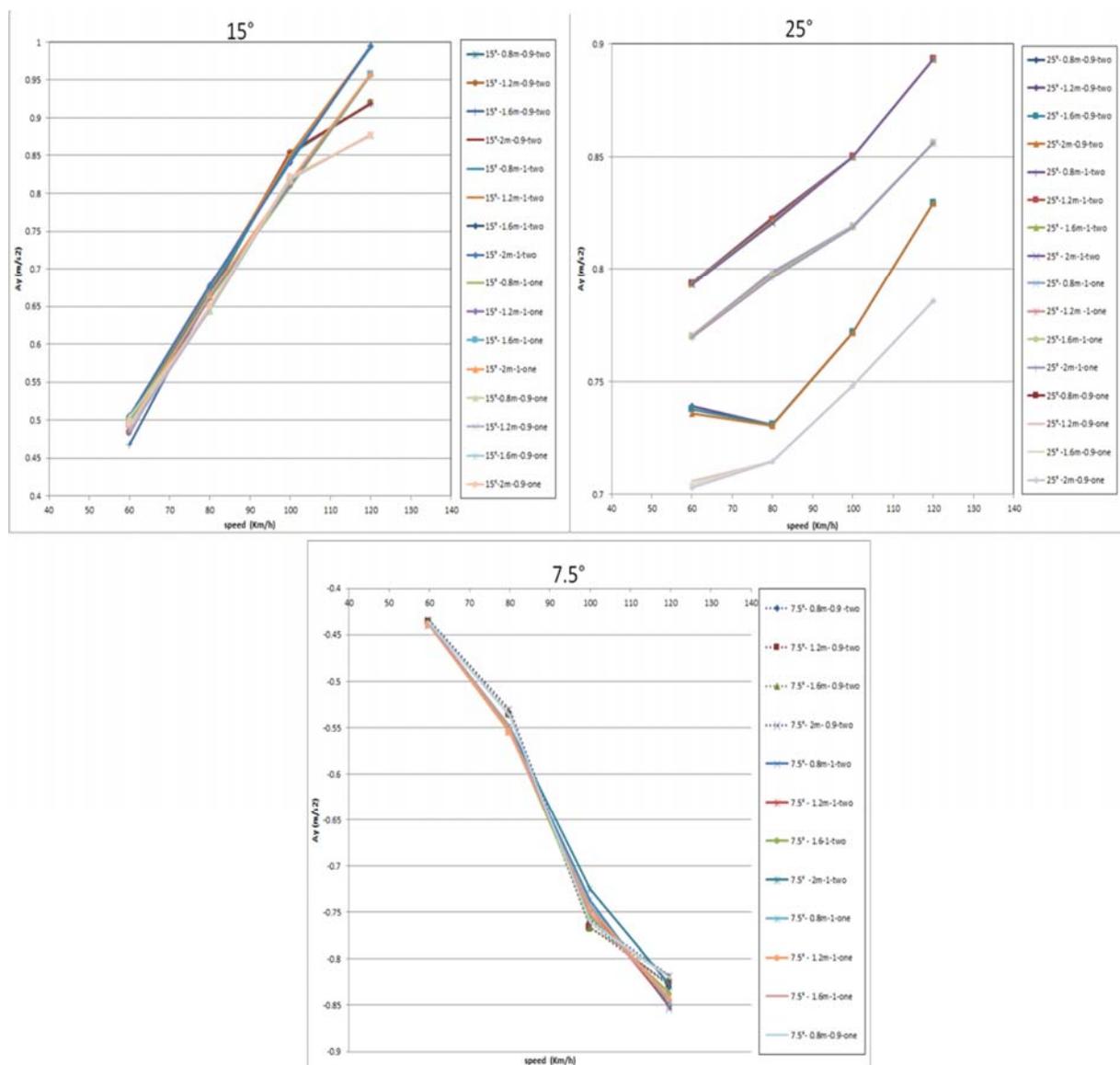


Figure 10. Lateral acceleration versus speed for 7.5° , 15° , and 25° encroachment angle.

Table 3. Samples of input and output data

Test No.	Speed (km/h)	Encroachment angle (deg)	Cross slope	Shoulder width (m)	Frict. Factor	Yaw (deg)	Roll (deg)	Yaw Rate (deg/s)	Roll Rate (deg/s)	Side Friction Factor
1	60	7.5	Two way slope	0.8	0.9	-5.9513	-7.8771	-17.972	2.62	- 0.49331178
2	60	15	Two way slope	0.8	0.9	13.246	2.4565	17.938	-4.3072	0.50985691
3	60	25	Two way slope	0.8	0.9	30.271	27.621	27.58	91.126	0.36485040
4	60	7.5	One way slope	0.8	0.9	-5.9392	-7.8796	-17.995	2.6098	- 0.49354975
5	60	15	One way slope	0.8	0.9	13.368	5.6066	17.277	0.2556	0.38327161
6	60	25	One way slope	0.8	0.9	32.217	38.259	21.768	116.27	0.45527877
7	60	15	One way slope	0.8	1	12.814	5.6084	17.427	-0.19586	0.52313817
8	60	25	One way slope	0.8	1	15.779	9.7222	32.488	25.858	0.67367080
9	60	7.5	Two way slope	0.8	1	-5.949	-7.9026	-17.166	2.3603	- 0.49728440
10	60	15	Two way slope	0.8	1	13.116	2.4388	17.493	-4.445	0.50833142

5. A model for side friction factor

The input-independent variables for the software are shown in Table 5 to model the results related to the truck. Friction, shoulder width, encroachment angle, cross slope, and speed are the dependent variables and the result is the side friction.

The common correlation coefficient between the independent and dependent variables is 0.838 and the coefficient of determination is 0.703.

According to the determination of the final model, the results derived from the fitting model are separately represented in the forms of tables which are goodness of fit, ANOVA, and the main results of the estimation of the selected coefficients, respectively. Table 7 suggests the significance of the regression and the linear relation between the variables; the obtained level of significance ($\text{sig}=0.000$) confirms its significance at the confidence level of 95% and, given the fact that the level of significance of the test error for the confidence level of 95% is less than 5%, it can be said that using the linear regression model is allowed. In other words, at least one of the independent variables can predict the dependent variable. Table 8 indicates the output coefficients for the side friction factor.

Table 4. Results of simulation which can be observed in animation form.

Cross slope	Friction Factor	Shoulder width (m)	Encroachment Angle (degree)	Speed (km/h)	Vehicle Condition
One Way Slope	0.9	0.8	7.5	60	Running off the subject roadway takes place; after crossing median and oppose roadway returns back to the subject roadway.
One Way Slope	0.9	0.8	7.5	80	Running off the subject roadway takes place; after crossing median and oppose roadway skids to the subject roadway.
One Way Slope	0.9	0.8	7.5	100	Running off the subject roadway takes place; after crossing median and oppose roadway rollovers
One Way Slope	0.9	0.8	7.5	120	Running off the subject roadway takes place; after crossing median and oppose roadway rollovers with high severity
One Way Slope	0.9	0.8	15	60	Running off the subject roadway and median jumping takes place; after crossing oppose roadway, Rollovers after skidding at long distance
One Way Slope	0.9	0.8	15	80	Running off the subject roadway and median jumping takes place; after crossing oppose roadway, Rollovers after skidding at long distance
One Way Slope	0.9	0.8	15	100	Roll overs at median
One Way Slope	0.9	0.8	15	120	Roll overs at median
One Way Slope	0.9	0.8	25	60	Roll overs at median
One Way Slope	0.9	0.8	25	80	Roll overs at median
One Way Slope	0.9	0.8	25	100	Roll overs at median
On Way Slope	0.9	0.8	25	120	Roll overs at median

Table 5. The input and deleted variables for side friction factor

Model	Input variables	Deleted variables	Depended variable	Pattern
1	Shoulder material, shoulder width, encroachment angle, cross slope, speed.	.	F _Y	input

The results and output obtained from the software can be interpreted in Table 6.

Table 6. summary of the model for side friction factor

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.838	0.703	0.695	0.33100

Table 7. ANOVA for side friction factor

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	48.189	5	9.638	87.970	0.000
	Residual	20.378	186	0.110		
	Total	68.567	191			

Table 8. The output coefficients for side friction factor

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant Number	-0.926	0.479		-1.935	.055
Speed	0.004	0.001	0.157	3.935	.000
Encroachment angle	0.068	0.003	0.818	20.472	.000
Cross slope	-0.035	0.048	-0.030	-.740	.460
Shoulder width	0.181	0.053	0.128	1.893	.046
Shoulder Type (material)	-0.511	0.478	-0.043	-1.069	.286

And finally, the proposed function for the truck model is shown below:

$$f_y = 0.157 V + 0.818 EA - 0.030 (CS) + 0.128 (SW) - 0.043 (TS) \tag{4}$$

f_y = Side friction factor

V= Speed

EA= Encroachment angle

CS= Cross slope

SW= Shoulder width

TS= Shoulder type (material)

According to the statistical analysis, there is a strong relationship between side friction factor and encroachment angle.

The Pp-plot of residuals is drawn in Figure. 11. The points derived from the data of residuals are around a straight line, indicating that they follow a normal distribution that is an important assumption for the accuracy of the model.

Normal P-P Plot of Regression Standardized Residual

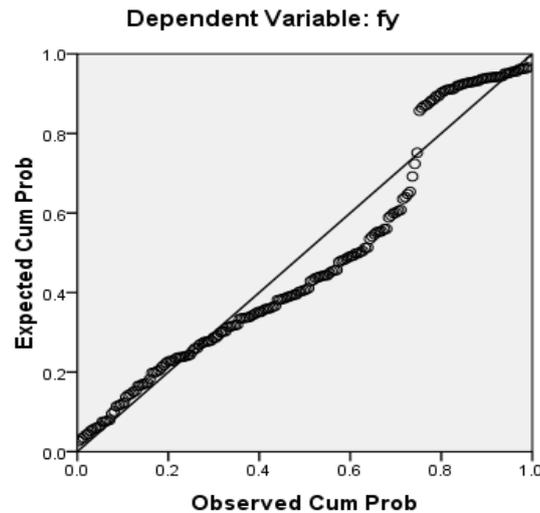


Figure 11. The normal p-p plot of regression standardized residual

5.1. Test of normality of errors

Another assumption in the regression is that the errors have a normal distribution with zero mean. Obviously, regression cannot be used if this default is not achieved. For this purpose, we should calculate the standard value of errors and, then, draw the graph of data distribution and the normal graph; next, a comparison is made between these two graphs. Based on the test results shown in Figure. 12, by comparing the graphs of frequency distribution of errors and normal distribution, it is seen that error distribution is almost normal, so regression can be used. The provided average amount on the right side of the graph is very small and close to zero and a standard deviation is close to one. Consequently, the regression equation is correct.

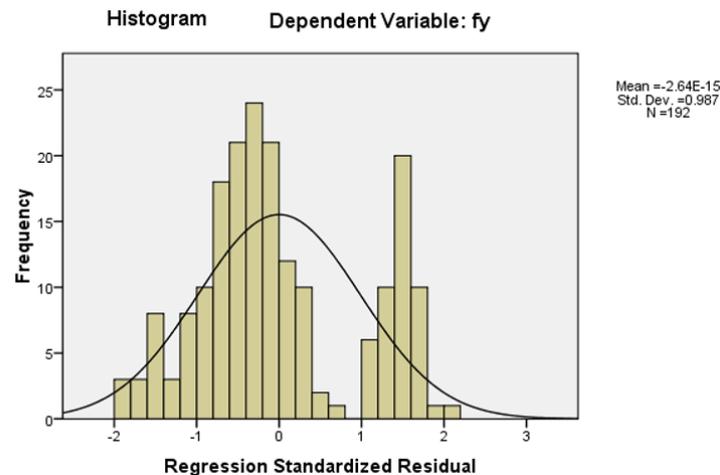


Figure 12. Graph of errors' normality test for the truck

6. Conclusion

In the conducted simulation and the data derived from the software and graphs, the most effective factors for the side friction of the truck were encroachment angle (81.8%) and speed (15.7%), respectively. The side friction factor increased as the speed increased. Generally, from the perspective of skidding, two-way cross slopes were more critical than one-way cross slopes. Also, 25° encroachment angle was the most critical parameter.

Generally, the yaw level increased as the encroachment angle increased. Also, 25° encroachment angle and .8 m unpaved shoulder were the critical state.

From the viewpoint of rolling, the most critical situation was found at 25° of encroachment and .8 m shoulder width. The probability of rolling in the unpaved shoulders was more than that of the paved shoulders. The lateral acceleration increased as the speed increased. Also, the truck experienced more lateral acceleration in two-way slopes than the one-way slopes.

According to the results, road designers should consider the width, type of shoulders and cross-section as parameters of design. One way cross slopes, paved shoulders and more than .8m shoulder width are appropriate factors for Trucks departing in rural highways.

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