SINERGI Vol. 24, No. 3, October 2020: 213-222
http://publikasi.mercubuana.ac.id/index.php/sinergi
http://doi.org/10.22441/sinergi.2020.3.006 .

DESIGN OF ANTI-SLIP SHOES FOR 12 TON PALM OIL TRUCK WHEELS

Dani Tri Wahyudi[1,2]*, Deni Shidqi Khaerudini[2]
[1,2]Mechanical Engineering Department, Universitas Mercu Buana
Jl. Raya Meruya Selatan, Jakarta 11650, Indonesia
[2]Research Center for Physics, Indonesian Institute of Sciences (LIPI)
Puspiptek Serpong, South Tangerang, Banten, Indonesia
*Corresponding Author E-mail: danitriw@gmail.com

Abstract -- *The rainy season will have a severe problem to the transportation sector (including heavy-duty trucks) in the off-road area in Indonesia, especially in areas that do not have permanent access roads (asphalt or concrete roads). For heavy vehicles, especially oil palm transport trucks will experience such obstacles, including slippage when crossing muddy dirt roads, and it will have an impact on the logistics delivery process. Therefore, it is necessary to design a support system, especially on the wheels, to reduce the risk of skidding or rolling on truck-type vehicles. In this work, the design of the anti-slip shoe wheels of the colt diesel double type truck (CDD) is used on the rear-wheel-drive as a tool for handling the slippage. In this design, the maximum traction factor of the wheels based on the calculation on the rolling resistance should be higher than 594 kg. The next step is to determine the value of soil cohesion and soil internal friction angle obtained from the previous studies. In this study, a calculation simulation was carried out to accomplish the design of the main components of the anti-slip of a truck wheel in the form of a traction rod fin. The design is namely U channel profile steel based on SNI 07-0052-2006 type U50, U65, and U80 with dimensions of the fin depth (z) are 3.8 cm, 4.2 cm, and 4.5 cm and length of 30 cm. The results show that the three types of U channel iron used for the anti-slip shoes are useful for freeing trucks from slippage with a total load of 12 tons. Thus, the truck will be safe when crossing the muddy roads with clay, muddy clay, and sandy loam under the following conditions: minimum cohesion number of 0.008 kg/cm^2, minimum internal friction angle in the soil of 4.631°, and the maximum water content of 59.6%.*

Keywords: *Anti-Slip Shoes; Colt Diesel Truck; Palm Oil Truck; Traction Simulation; Wheel Slip*

Received: December 15, 2019 *Revised: April 14, 2020* *Accepted: April 21, 2020* *Published: July 15, 2020*

INTRODUCTION

Palm oil is one of the mainstay commodity products to support the national economy [1, 2, 3]. But in terms of transportation, oil palm plantations have not been fully endorsed by the equitable distribution of permanent (asphalt) road infrastructure. The problem of the road in oil palm plantations can cause enormous losses [4].

This condition will be a severe problem for the transportation of this valuable commodity, especially in the rainy season. The surface of the dirt road will become soft, or the hardness of the land decreases due to mixing with water and even becomes a mud puddle. Oil palm transport trucks are often trapped and skid on the road conditions.

The case of skid tracks in the rainy season is a routine problem for the transport of oil palm fresh fruit bunches (FFB) at oil palm plantation centers in Indonesia [4]. Such conditions are certainly very detrimental. Oil palm FFB transport trucks were even forced to be stuck for days in the plantation area. It can also be found that the vehicles are overturned due to slipping mud due to slippage.

In general, oil palm transport trucks in Indonesia are not specifically designed to cross muddy roads. The trucks use standard wheels for permanent (paved) roads. Thus, those have the potential to slip during the rainy season when crossing muddy oil palm roads.

Although slippage often occurs, practical solutions have not been found in the field. The efforts made are still conventional and require a long time between others: pushing back and forth, closing mud puddles with wooden sticks, pulling trucks with other trucks, and pulling or pushing using heavy equipment, as shown in Figure 1.

Figure 1. Palm oil carrier truck being pulled by heavy equipment to free slippage on muddy roads [5]

In four seasons countries, a similar problem is found in winter. At the turn of the 20th century, snow chain products were developed, that is, a device mounted on a vehicle's wheels to provide maximum traction or friction when driving through snow and ice. The slippage occurs because the wheels lack grip on the snowy road surface.

The snow wheel chain was discovered in 1904 by Weed in Canastota, New York, by obtaining US patent number 768495 for" Grip-Tread for Pneumatic Tires "in 1904 [6]. Until now, snow chains have become a product that continues to grow by sharing variations and derivatives like automated traction devices (ATDs) as Figure 2.

In Indonesia, devices such as snow wheel chains are urgently needed by vehicles in the countryside area, including oil palm hauling trucks. However, the wheel traction-enhancing products, especially for trucks, are challenging to find in the Indonesian market. Until now, the related research is complicated to find, or there are no specific studies on it. Therefore, it is required such specific accessories tools to be developed to overcome such conditions of the muddy road as well as to help the local palm oil industry in terms of transportation of oil palm FFB. In this research, a tool with the concept of anti-slip shoes will be designed as a support for truck drive wheels with a 12 ton of maximum capacity.

Figure 2. Automated traction devices (ATDs) [7]

This research is a continuation of our previous study entitled Design of Anti-Slip Shoes for Colt Diesel Truck Wheels on Muddy Roads [8], which aimed for the maximum truckloads of 8 tons that follow the maximum load of CDD type trucks. In this current work, the design of anti-slip shoes is advanced for the 12-ton truckloads purposes. The design is due to the practical, and the CDD type trucks are used to with the load of 12 tons (overload capacity condition). In the previous study, the design of traction fin trunks only used U-channel U80 type steel with a length of 20 cm, fin depth of 4.8 cm. In this current work, one of the traction rods will still be used the U80 steel by adjusting the length and also will be used of several types of U channel steels that have smaller dimensions than the U80 type. The use of more modest sizes expects to make such lighter and more practical of the design. So that in the present research will verify whether the design is still sufficient for freeing slippage on the truck wheels with the heavier loads condition.

METHOD

The Calculation of Traction Enhancer Bars

The anti-slip shoes of the truck wheels are mounted on the rear-wheel-drive of the truck. For the practical purposes of the anti-slip shoes for truck wheels, some requirements need to be considered, such as: installable, removable, and storable in a vehicle.

The purpose of this current design is to simplify and practical in its installation as the similar products in the snow tire chains. The situation is considered due to that, and not everyone can install to wheels easily. It requires preparation and skills. Therefore, this design is expected to facilitate the installation in emergency conditions or when the truck's wheels are stuck in the mud. Outside the area of the mud trap, this tool must be removed because the use of traction enhancers on the paved road will damage the road surface, hamper the vehicle's speed, wasteful of fuel, and damage the device itself.

The design of the anti-slip shoes of the wheels truck can be fitted into the standard size of the Colt diesel-type truck, as shown in Figure 3 (a). The wheel type is 7.50-16-14PR double rear wheels, tubed type with an outer tire, rim 16x6.00GS, and six studs [9]. Tire diameter is 816 mm (81.6 cm) with cross-section width of 211 mm (21.1 cm) and maximum truckload (empty + load) 12 tons.

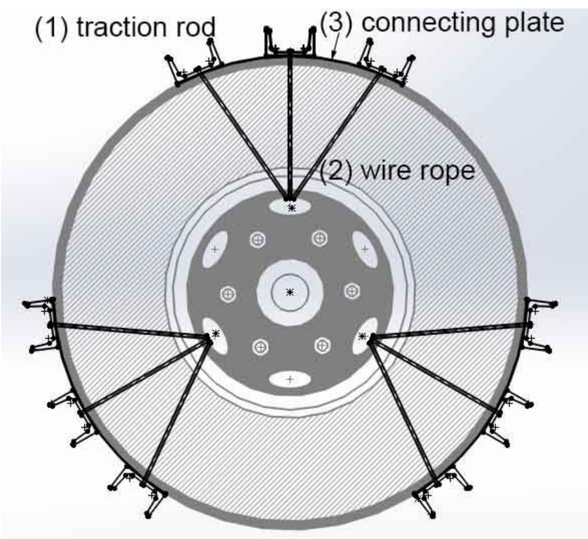
The applied anti-slip shoe material is based on the standard of SNI 07-0052-2006 of

U channel steel. The calculations of this design are focused on determining the dimensions of the traction rod fins as the main component of the truck wheel anti-slip shoes. The traction rod is mounted on the surface of the rear truck drive wheel, as depicted in Figure 3 (a) of the CDD type. So, it is expected to be having a similar function as in the tractor wheel, as shown in Figure 3(a). The condition is aimed to provide a wheel grip on the muddy ground. The length and depth dimensions of the traction fin will be determining the parameters for the slip less rolling for a wheel.

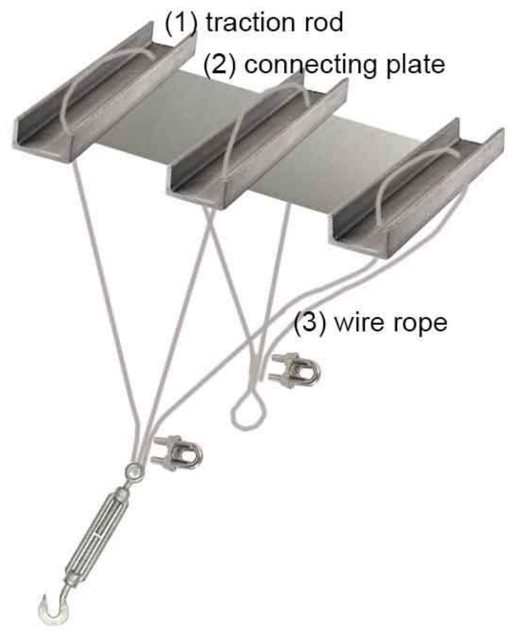
The two dimensions of the traction rod applied as the parameters to get the maximum traction value, which used for the next step of design simulation. Other parameters that required to calculate the maximum traction value of anti-slip shoes are soil cohesion and soil internal friction angle. Data on soil cohesion, soil internal friction angle, and secondary data on the physical properties of soil are taken from several references from the relevant studies. At the same time, the calculation of material strength and selection of supporting components are not discussed further as a limitation of this study.

The Sketch Design of Anti-Slip Wheel Wheels Colt Diesel Trucks

The design of CDD type anti-skid truck wheel shoes from several necessary components, namely: (1) traction rods/wheel fins (as the focus of this study), (2) traction rod connecting and (3) fastening components, plates (2 and 3 are not discussed), as shown in Figure 3.



(a)



(b)

Figure 3. The design of CDD
(a) Sketch of an anti-slip shoe mounted on the rear wheel of a CDD type truck (front view position). (b) Sketch of 3-dimensional anti-slip shoes on CDD type truck wheels

RESULTS AND DISCUSSION

To design the anti-slip shoes on a palm oil hauling truck, the assumption of traction calculation on the tractor wheels relates to the forces acting under the wheels and the ground, as shown in Figure 4.

The study uses a tractor wheel design as a guideline because of the availability references with scientific discussion, especially in the agricultural technology journals. The vehicle tire traction enhancer products are already widely available in world markets, but there is not in the scientific journal yet that discusses them. There are only patent documents that can be found for such similar products [10][11].

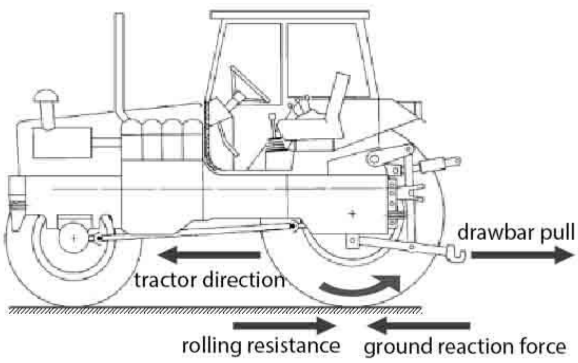


Figure 4. Horizontal forces for tractor wheels [11]

Traction is the force produced by the torque of the wheel into an overall straight motion. Conversely, if the torque of the wheel does not produce an overall straight motion, then the slippage occurs [12]. A tractor can move if the horizontal ground reaction force (F_h) must be greater than the sum of half drawbar pull (*DBP*) and rolling resistance, as shown in Figure 4, or $\Sigma F_h \geq 0.5\ (DBP + R)$ [11]. Thus, the DBP formula can be expressed as:

$$DBP = F_h - R \quad (1)$$

DBP = draw bar pull (kg), F_h = traction or thrust (kg), R = rolling resistance(kg). Because the truck is not pulling the load then $DBP = 0$, so $F_h - R = 0$, or

$$F_h = R \quad (2)$$

Thus the truck can move forward if:

$$\Sigma F_h \geq R \quad (3)$$

The weight of the tractor used will directly affect the amount of rolling resistance which is estimated to be proportional to the dynamic weight on the cogs, so that:

$$R = C_R . W \quad (4)$$

Where C_R = coefficient of rolling resistance, with the values as shown in Figure 5, W = dynamic weight on the wheel drive (kg).

In an effort to increase traction on a tractor, the maximum shear force under the wheels ($F_{h\ max}$) (kg) equals maximum wheel traction (H_{max}) (kg)

$$F_{h\ max} = H_{max} = 0.78.b.l.C + W \tan \varphi \quad (5)$$

Where C is the soil cohesion (kg/cm^2), b is the width of the track (cm), l is the length of the track in contact with the soil (cm) as in Figure 6, and φ is the internal friction angle.

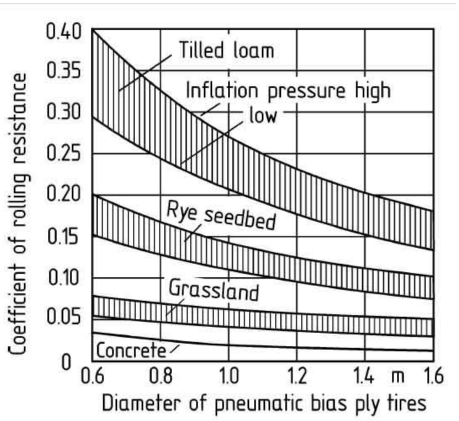


Figure 5.The value of the rolling resistance coefficient and its relationship to the type of soil and wheel diameter [12]

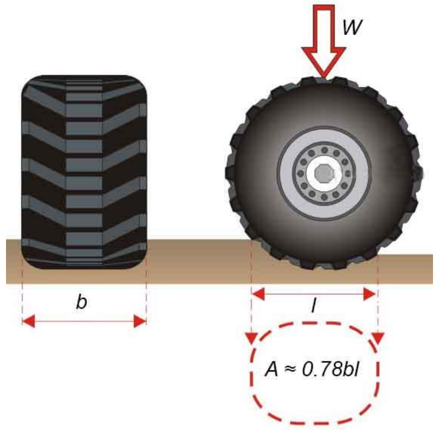


Figure 6. Effect of dynamic weight on tractor wheel pedestal area [13]

The designed tools had to increase the tractor wheels in wet soil condition, especially clay, were carried out by increasing the area of the tangents of the wheels to the ground. As the value of *b* and *l* increases, the value of traction automatically increases. The situation is done by using a steel wheel or a cage wheel [14], as shown in Figure 6. For CDD type trucks or 1.2 L (medium) trucks has load distribution on the front wheels (34%) and rear wheels (66%), as shown in Figure 7.

Figure 7. Axis load configuration for truck vehicle types (S=single, D=double) [15][16]

Soil cohesion value (*C*) and soil internal friction angle (*φ*)

Oil palm transport trucks experience such skidding because they have to cross over the wet ground. The slippage occurs due to the soil undergoes such deformation or changes in shape due to the internal tensile forces between particles or soil cohesion that were not strong enough to withstand the shear loads when the movement of truck wheels. On clay soil surfaces and wet clay, soils tend to be slippery and cause the wheel to slip. It is because the soil cohesion value decreases due to the influence of the water mixture.

Soil cohesion and internal friction angle are needed to find the maximum wheel traction (H_{max}) according to Equation (5). Table 1 and Table 2 contain data of soil cohesion, internal friction angle, soil water content, soil sample location, and soil compaction, which are the results of soil experiments collected from various references.

Soil cohesion and soil internal friction angle are obtained from direct shear tests that refer to Mohr-Coulomb failure law such as Equation (6).

$$\tau = c + \sigma \tan \varphi \quad (6)$$

Where T is shear strength (kg/cm^2), C is cohesive strength or cohesion soil (kg/cm^2), σ is normal stress (kg/cm^2), and φ is internal friction angle (degree). The relationship between these parameters in direct shear strength is shown in Figure 8. While the internal friction angle is a, describe the ability of the ground unit to withstand shear stress. One of the internal friction angle values is obtained from the results of the direct shear test of the soil [17].

Table1. The results of the direct shear test of wet soil samples from various locations to get the value of soil cohesion (*C*) and internal friction angle (φ) without soil compaction [18] [19]

Item	Location	Soil Type	Dept (cm)	*w* (%)	*C* (kg/cm^2)	φ (˚)	Compaction (collision times)
1	A1.1	silty clay loam	0-15	58.69	0.016	3.833	-
2	A1.2	silty clay loam	15-30	42.59	0.080	3.776	-
3	A2.1	silty clay loam	0-15	52.49	0.045	1.318	-
4	A2.2	silty clay loam	15-30	39.21	0.104	0.401	-
5	A3.1	silty clay loam	0-15	75.42	0.011	2.233	-
6	A3.2	silty clay loam	15-30	47.62	0.029	1.776	-
7	A4.1	silty clay loam	0-15	32.25	0.108	5.313	-
8	A4.2	silty clay loam	15-30	27.63	0.214	10.924	-
9	B1	clay	0-15	58.88	0.282	8.363	-
10	B2	clay	15-30	48.62	0.397	4.631	-
11	C1	silt clay	-	50	0.19	8.7	-
12	C2	silt clay	-	57.5	0.22	26	-
13	C3	silt clay	-	59.6	0.11	30	-

Table2. The results of the direct shear test of wet soil samples from various locations to get the value of soil cohesion (*C*) and internal friction angle (φ) with soil compaction [20] [21]

Item	Location	Soil Type	Dept (cm)	*w* (%)	*C* (kg/cm^2)	φ (˚)	Compaction (collision times)
1	D1	clay	-	34.54	0.375	23.5	10
2	E1	clay	-	27.79	0.475	22	10
3	F1	clay	-	25.5	0.41	20.5	10
4	G1	clay	-	33.52	0.445	23	10
5	H1	clay	-	32.25	0.54	23	10
6	D2	clay	-	34.54	0.85	22.5	25
7	E2	clay	-	27.79	0.85	26.25	25
8	F2	clay	-	25.5	0.93	28.5	25
9	G2	clay	-	33.52	0.925	29	25
10	H2	clay	-	32.25	0.72	27	25
11	D3	clay	-	34.54	1.325	31.5	55
12	E3	clay	-	27.79	1.25	32	55
13	F3	clay	-	25.5	1.72	33	55
14	G3	clay	-	33.52	1.9	35	55
15	H3	clay	-	32.25	1.075	26	55
16	I1	sand : loam (100:0)	-	32	0.23	38.9	25
17	I2	sand : loam (90:10)	-	27	0.18	46.2	25
18	I3	Sand : loam(80:20)	-	24	0.16	54.2	25
19	I4	Sand : loam(70:30)	-	22	0.15	59.2	25
20	I5	Sand : loam(60:40)	-	20	0.008	62.3	25

w = soil water content (%)
C = soil cohesion (kgf/cm^2)
φ = internal friction angle (°)
A1.1-A4.2 Locations: PT Sang Hyang Seri Sukamandi rice field, Subang, West Java [18]
B1 and B2 Locations: Siswadhi Soepardjo Field Lab, Bogor, West Java [18]
C1 Location: slope on Unand Polytechnic campus, Padang, West Sumatra [19]
C2 and C2 Locations: slope on Unand campus, Padang, West Sumatra [19]
D1-D3 Locations: Godong Subdistrict, Purwodadi District, Central Java [20]
E1-E3 Locations: Gubung Subdistrict, PurwodadiDistrict, Central Java [20]
F1-F3 Locations: GenukSubdistrict, Semarang City, Central Java [20]
G1-G3 Locations: Pucang Gading Village, Semarang City, Central Java [20]
H1-H3 Locations: Karangawen Subdistrict, Demak District, Central Java [20]
I1-I5 Locations: Rawa Sragi Area, Belimbing Sari Village, East Lampung Regency [21]

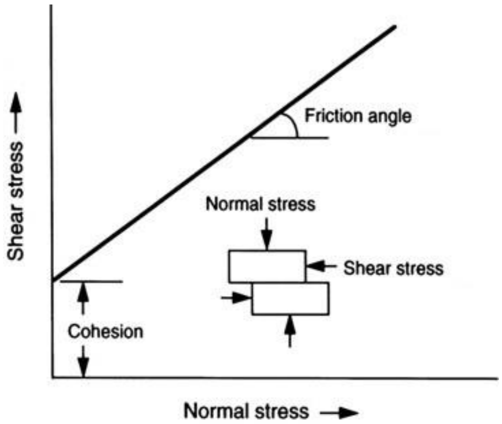


Figure 8. The graph of normal and shear stresses during the direct shear test [17]

The direct shear test is the easiest and most simple test for shear strength parameters [21]. A normal force is placed on the top of the box. A horizontal force is placed on the horizontal plane. Due to vertical and horizontal loads working on tools will cause stress to the ground. The stress is in the form of major main stress (major principal stress) and small main stress (minor principal stress), which can cause the soil to experience shear stresses that form an angle to the shear plane, as shown in Figure 8. The angle of internal friction for a given soil is the angle on the graph of the shear stress and normal effective stresses at which shear failure occurs. While the intermediate principal stress continues to work evenly on all sides, but it does not calculate because it does not cause deformation.

The shear test can be controlled by stress or strain. In vertical experiments, the tension is adjusted according to the needs and experimental plan, while the shear force is applied to collapse on the ground gradually. The collapse occurred on the entire surface of the sliding plane. Direct shear tests are usually carried out several times on a soil sample with normal stress values that vary with the beating of the soil sample. The apparatus used for the direct shear test is shown in Figure 9 (a).

Groundwater content is secondary data that is not used as a parameter to get the value of anti-slip shoe traction. But this data is essential for the purpose of analyzing results. Measurement of water content is done by weighing wet soil samples and dried soil samples. They are drying using an electric oven at a temperature of 105 ° C for 24 hours in the laboratory. Then the wet sample and the dry sample are weighed respectively by digital scales as in Figure 9 (b).

(a)

(b)

Figure 9. (a) Direct shear stress apparatus (b) Digital scale [18]

The water content in the soil sample is calculated using Equation (7).

$$w_0 = \frac{m_w}{m_s} x\ 100\% \quad (7)$$

Where w_0 is the gravimetric water content (%), m_s is the mass of the dry soil particles (kg); and m_w is the mass of the water (kg) [20]. Table 1 shows the direct shear test of soil samples from 13 different points in three location areas (A-C) obtained from various references. Data in Table 1 is for the soil samples that not receive any compaction treatment. Table 2 shows the results of the soil shear test from 20 location points in 9 area locations (D-I). The soil sample is treated with compaction with collisions. This soil compaction treatment data is needed to get closer to the condition of the land road in the actual oil palm plantation. Soil roads in oil palm plantations generally experience compaction both when first opened with compaction by heavy equipment and compaction every day when crossed by oil palm transport trucks in the dry season.

Rolling Resistance Value (R)

It was simulated a colt diesel truck carrying palm oil with a total load or maximum load of 12 tons or 12000 kg, the truck wheels diameter of 81.6 cm with radius r (0.5 *d*) of 39.5 cm. Referring to Figure 7, the maximum load on the rear truck wheels to one side or W = 0.66 x 0.5 x 12000 is 3960 kg.

The value of rolling resistance coefficient (C_R) is shown in Table 1, with a truck wheel diameter of 81.6 cm and running on wet clay mud obtained C_R values in the range of 0.15. From Equation (4), rolling resistance $R = C_R. W$ = 0.15 x 3960 = 594 kg. So that the truck does not slip by the provisions of Equation (3), the soil reaction force $F_h \geq R$ means that the ground reaction force must be higher than 594 kg.

Determination of the size of the traction enhancer rod (wheel fins)

In this section, it is assumed that the wheels of oil palm trucks are already 100% skid on muddy roads. So, the rear wheel truck needs to be engineered so that it is as similar as possible to the tractor wheels by installing the fins as a slip-free tool in the form of U channel steel.

Fins are mounted transversely on the surface of the wheel. Here the length and width of the fins largely determine the release from wheel slip. The depth of the fin is mentioned as the value of soil submergence (z) and stated in the value of b (mm) (Table 3).

While the value of b, as shown in Figure 10, is the length of the traction rod determined 30 cm, which is made to exceed the value of the standard truck wheel width of 7.50-16-14PR, which is 21.1 cm. In the previous research, the traction rod length was used 20 cm for an 8-ton truckload. The addition of the length of the traction rod in this study because it considers the use of a planning load of 12 tons, which is greater than the previous planning load of 8 tons. Adding the value of the length of the traction rod will affect the increase in maximum traction value.

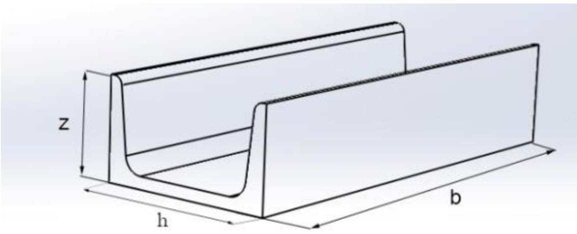


Figure 10. U channel steel SNI 07-0052-2006 [21] for the anti-slip fin on the truck wheels

Tabel 3. Dimension of U channel steel SNI 07-0052-2006 in (mm) [21]

Code	*h* (cm)	*z* (cm)
U50	5	3.8
U65	6.5	4.2
U75	7.5	4
U80	8	4.5
U100	10	5
U120	12	5.5
U125	12.5	6.5
U140	14	6
U150	15	7.5

Refers to the Equation (5), the value of *z* is determined based on the dimensions of the two sides of the U channel steel in Table 3 and three sizes are selected at once namely U50, U65, and U80 with each side dimension or fin depth (*z*) 3.8, 4.2 and 4.5 cm.

The truck wheel diameter (*d*) of 81.6 cm is used as a reference to scatter the projections of the fulcrum with the ground (*l*) (Figure 6). The numerical results by using Solidworks software from all fins (*z*) 3.8 cm on U50 steel obtained the length of the track in contact with the soil (*l*), which 36.03 cm based on the design sketch as in Figure 3 (a) is then shown in Figure 11.

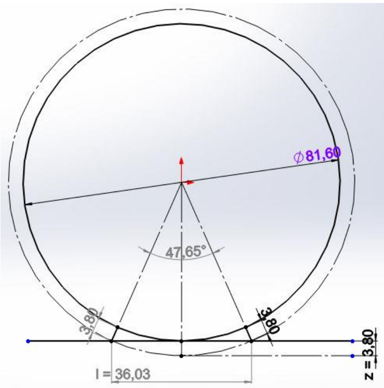


Figure 11. Finding the projection length value of the length of the track in contact with the soil. (*l*) based on the value of the drowning depth of the fins (*z*), wheel diameter (*d* = 81.6 cm), using Solidworks software

With the same step fin depth calculation, the length of the track in contact with the soil (*l*) is then obtained for the sketch design of the U65 and U80 dimensions. The results are shown in Table 4.

Table 4. The results of the length of the track in contact with the soil

U Channel Steel	*z* (cm)	*l* (cm)
U50	3.8	36.03
U65	4.2	37.97
U80	4.5	39.7

Determining the maximum traction values (H_{max})

By using the reference data as in Table 1, in this study, the length of the traction rod (*b*) is determined at 30 cm with the dynamic weight factor (*W*) on the wheel is 3960 kg. Meanwhile, the length of the track in contact with the soil (*l*) is taken from Table 4. The dynamic weight factor on the wheel W is 3960 kg. Then the maximum traction value (H_{max}) is calculated by using Equation (5). The obtained variety of maximum traction values (H_{max}) indicated by blue bars as in Figure 12 and Figure 13 with input values of values, *b* (30 cm), *l* (Table 4), and *C* and *φ* (Table 1 and Table 2). Whereas the parameter *R* or rolling resistance marked with red bars in Figure 12 and Figure 13 is used as a skid boundary and whether or not the design of the traction fin of U channel steel is chosen to be simulated in each soil sample. The slippage occurs when the supply of $H_{max,}$ as shown in Figure 12, shown as the blue bars, is smaller than the rolling resistance value (*R*) 594 kg (the red bars). The slip occurs on soil samples A1.1-A4.1. The H_{max} values above the red bars mean that the traction fin design is free of slippage. In Figure 12 and Figure 13, the following is the result of H_{max} from the simulation of the use of U channel U 50 steel.

The next step is to calculate the maximum traction of the fins of steel U65 and U80. The input value is *b* (30 cm), *l* (Table 4), *C,* and *φ* (Table 1 and Table 2).. The H_{max} plot for the U65 and U80 traction fin is precisely the same as the H_{max} plot for the use of the U50 traction rod U50, as in Figure 12 and Figure 13. The condition means that slippage occurs in soil samples of A1.1-A4.1. For the rest of the soil samples are free from slippage. Thus, Figure 12 and Figure 13 represent the H_{max} of the use of U channel U50, U65, and U80 steel traction rod fins.

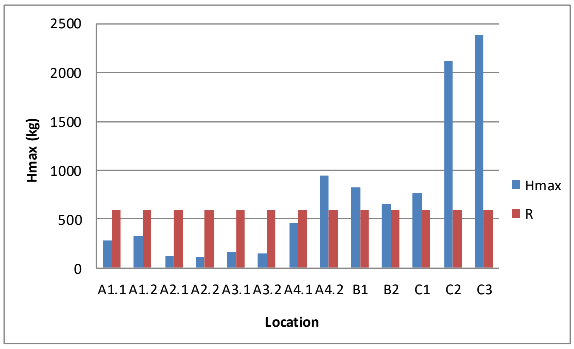


Figure 12. The maximum traction values (H_{max}) of each soil sample without compaction from Table 1 with the use of U channel U50 steel traction rods

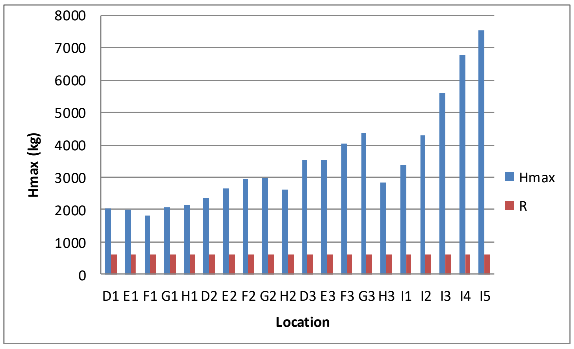


Figure 13. The maximum traction values (H_{max}) of each soil sample by compaction from Table 2 with the use of U channel U50 steel traction rods

After scrutinizing using Table 1, slippage occurs in soils with the cohesion of 0.11-0.108 kg/cm^2 with a sliding angle value in the soil of 0.401-5.313° with a relatively high-water content of 32.25-75.42%, from soil samples of paddy fields (A1.1-A4.1) from rice fields of PT Sang Hyang Seri Sukamandi, Subang West Java [16]. The low cohesion value of paddy soils is due to lose soil conditions after plowing and soaking water for planting purposes. Tractor wheels can only cross these soil conditions with the use of wider and longer fin. Whereas H_{max} on A4.2-C3 soil samples in Figure 12 and all soil samples in Figure 13 shows that the wheels with the use of traction fins from steel U Channel of U50, U65, and U80 can be free from slippage.

From Table 1 and Table 2, the non-skid soil samples have a range of soil cohesion values of 0.008-1.9 kg/cm^2, shear angles in 4.631-62.3°, and water content of 20-59.6%. The average slippage-free soil sample is not from the paddy field area. Except for the A4.2 soil sample from PT Sang Hyang Seri Sukamandi rice field, Subang, West Java with a soil cohesion value of 0.214 kg/cm^2, shear angle in the soil of 10,924°, and 27.63% water content which is also able to free slippage.

Likewise, all soil samples made compaction in Table 2 used to obtain the H_{max} value in Figure 13 approached by the actual condition of the oil palm plantation road. Land roads in oil palm plantations are compacted. Compaction takes place from the moment it was opened, namely by heavy equipment, and compaction occurs daily by palm transport trucks that pass in the dry season. Soil compaction is one of the important factors to add maximum traction value. Other factors that have to be calculated are soil type, moisture content, soil cohesion, and internal friction angle. As shown in Figure 13, the last soil sample I5, despite having a relatively low soil cohesion value of 0.008 kg/cm^2, produced the highest H_{max} value. Sample I5 of Table 2 is supported by other factors so that it shows the best performance of the mechanical properties of soil among different soil samples. Supporting factors include clay composition: sand ratio of 60:40 with compaction of the soil sample 25 times, making this soil sample have a moisture content of 20%, and increasing the internal friction angle of 62.3°. So that the treatment of soil samples in item I5 is quite good and recommended to be applied to roads in oil palm plantations.

During the rainy season, the hardened road surface also experiences a decrease in soil density on the surface due to rainwater. The results in slippery roads and can cause standard truck wheels to slip when crossing them. Traction rod fins mounted on standard truck wheels are expected to reach and grip the slippery soil so that it reaches deeper parts of the soil with conditions of cohesion value, and soil density higher than the surface soil. So, the traction fins function to increase the traction of standard wheels on muddy dirt roads or wet ground.

To overcome the slippage on truck wheels on muddy roads, it can be applying the finned like iron wheels of the tractors. Based on Equation (5), maximum traction or traction with a large value can be obtained by enlarging the dimensions of the traction shaft fin. Likewise, the results of the study of soil sample measurements in Table 1 items number 1-10 in the 4th column show soil sampling at 0-15 cm and 15-30 cm depths at the same location. As a result, soil cohesion and internal friction angle are greater at deeper soil sample positions. Logically, determining the design of fins with higher depth dimensions increases traction. That's because fins can reach depths of soil that have greater cohesion and internal friction angle than those on the surface.

The dimensions of the truck wheel fins are certainly not the same as in the tractor wheel fins, which has the large fins type. The large one has the potential causing the truck unable to move. The situation is due to the effect of high traction force on the soil. It disrupts engine power efficiency, wasteful of fuel, thus accelerating damage to the truck engine. When the dimensions too large, it also caused greater damage to the road. In addition, there is also the risk of traction shaft friction in the tailgate or the brow of the truck due to the dynamic motion of the wheel suspension, which causes damage to the truck tires. Similarly, with aesthetic considerations, the dimensions of the traction fin on truck wheels are limited to certain dimensions.

Thus, the components of the traction rod fins on the anti-skid shoes of the colt diesel truck wheels in this study were based on SNI 07-0052-2006 with U channel U50, U65, and U80 steel codes as simulated in this study.

CONCLUSION

The use of SNI 07-0052-2006 U channel steel with steel dimensions of U50, U65, U80 is carried out using the method of calculating the maximum shear force of the soil under the wheel or maximum sufficient traction to overcome the wheel slip of a 12-ton capacity CDD palm transport truck. The selection of larger dimensions is not effective because it is inefficient. Likewise, the selection of smaller dimensions of the fin is avoided because it has not been tested. The design of the 12-ton anti-skid truck wheels is useful for freeing wheel slips on the wet dirt road of oil palm plantations that are commonly crossed every day. Especially on roads with clay, clay, and sandy loam with minimum cohesion of 0.008 kg/cm^2, minimum internal friction angle in soil 4.631°, maximum moisture content of 59.6%. The purposes of this design are not used for the off-road, including crossing the planting areas. The simulation shows that this design is slippage on the cultivated soil samples as in the muddy of rice fields. Thus, our anti-slip shoe design recommended only for the soils with minimum physical characteristics as described, including the planting area of palm oil.

ACKNOWLEDGMENT

The author would like to thanks the Mechanical Engineering Department, Universitas Mercu Buana, for supporting facilities related to this research assignment.

REFERENCES

[1] R. B. Edwards, "Export agriculture and rural poverty: evidence from Indonesian palm oil," *Working Paper*, Dartmouth College, USA, 2019, pp. 1-25.

[2] Z. B. Mat Sharif, N. B. Mohd Taib, M. S. Bin Yusof, M. Z. Bin Rahim, A. L. Bin Mohd Tobi, and M. S. Bin Othman, "Study on Handing Process and Quality Degradation of Oil Palm Fresh Fruit Bunches (FFB)," *IOP Conference Series: Material Science and Engineering*, vol. 203, no. 1, 2017. DOI: 10.1088/1757-899X/203/1/012027.

[3] A. Firdaus and M. S. Ma'arif, "Creating the Standard for Specific Energy Consumption at Palm Oil Industry," *SINERGI,* vol. 20, no.

1, pp. 9-13, February 2016. DOI: 10.22441/ sinergi.2016.1

[4] I. Jelsma, L. S. Woittiez, J. Ollivier, and A. H. Dharmawan, "Do wealthy farmers implement better agricultural practices? An assessment of implementation of Good Agricultural Practices among different types of independent oil palm smallholders in Riau, Indonesia," *Agriculturan System*, vol. 170, pp. 63–76, March 2019. DOI: 10.1016/ j.agsy.2018.11.004.

[5] Youtube, “Truk Mitsubishi Canter Ragasa Hino Dutro dan Toyota Dyna Muatan Sawit,” Youtube. https://www.youtube.com/watch? v=UAlrTK98O10.

[6] H. D. Weed, "Grip Tread for Pneumatic Tires," *US Patent*, No 768,495, 1904.

[7] G. W. Burkett and S. A. Velinsky, "Evaluation of Devices for Improving Traction Control in Winter Conditions," *Advanced Highway Maintenance Construction Technology Research Center*, vol. 0003, 2018.

[8] D. T. Wahyudi, “Design of Anti-Slip Shoes for Colt Diesel Truck Wheels on Muddy Roads,” *Jurnal Teknik Mesin*, 2019.

[9] M. Getan, "Review Mitsubishi Colt Diesel FE 74 HD 2017," hargamobil.com, 2018. https://hargamobil.com/review-mobil-terbaru/review-mitsubishi-colt-diesel-fe-74-hd-2017-aid689.

[10] D. Martin, "Tire Traction Device," *US Patent,* No. 9,981,511 B2, 2018.

[11] J. Tyszkiewicz, "Vehicle Tire Traction Device," *US Patent*, No. 9,469,170 B1, 2016.

[12] K. T. Renius, *Fundamentals of Tractor Design*, 1st Ed. Cham: Springer, 2019.

[13] T. Porinsky, T. Pentek, A. Bosner, and I. Stanki, "Ecoefficient Timber Forwarding on Lowland Soft Soils," *Global Perspective on Sustainable Forest Management*, pp. 275-288, April 2012. DOI: 10.5772/34687.

[14] A. V. Piyush Pradhan and Department, "Cage Wheel for Traction Improvement In Power Tiller," *Journal of Plant Development Sciences*, vol. 9, no. 7, pp. 631-636, 2017.

[15] T. Megiso, "Optimization of Bus Body Building Methods by Investigation of the Existing Problems and Rectification in Addis Ababa, Ethiopia.," *International Journal of Advanced Research*, vol. 5, no. 2, pp. 1923–1938, February 2017. DOI: 10.21474/ ijar01/3362.

[16] H. Pranoto, “Efisiensi Power Engine Truck Pergerakan Dinamis dengan Mengubah Ration Final Gear pada Trcuk Kapasita 30 Ton, “ *SINERGI,* vol. 19, no. 1, pp. 45-50, February 2015. DOI: 10.22441/sinergi. 2015.1.008.002

[17] S. K. Chaulya and G. M. Prasad, “Slope Failure Mechanism and Monitoring Techniques,” In *Sensing and Monitoring Technologies for Mines and Hazardous, Springer*, 2016. DOI: 10.1016/B978-0-12-803194-0.00001-5

[18] A. Rouf, “Prediksi Kedalaman Ketenggelaman Roda Traktor Roda-4 pada Tanah Sawah Berdasarkan Hasil Uji Geser Langsung,” *Scientifec Repository*, Institut Pertanian Bogor, 2013.

[19] S. Liliwarti, Silvianengsih, “Karakteristik Sifat Mekanis Tanah Lempung Terhadap Kadar Air (Kampus Unand Limau Manis Padang),” *Rekayasa Sipil*, vol. 4, no. 1, pp. 21–26, 2015.

[20] M. Purnomo, “Korelasi Antara CBR, PI dan Kuat Geser Tanah Lempung,” *Jurnal Teknik Sipil dan Perencanaan*, vol. 13, no. 1, pp. 81-90, 2011, DOI: 10.15294/jtsp.v13i1.1336.

[21] S. Syahreza Nurdian and L. Afriani, “Korelasi Parameter Kekuatan Geser Tanah dengan Tanah Lempung Substitusi Pasir,” *Jurnal Rekayasa Sipil dan Desain*, vol. 3, no. 1, pp. 13-26, 2015.

[22] Y. Ma, L. Qu, W. Wang, X. Yang, and T. Lei, "Measuring soil water content through volume/mass replacement using a constant volume container," *Geoderma*, vol. 271, pp. 42-49, June 2016, DOI: 10.1016/ j.geoderma.2016.02.003.

[23] Badan Standardisasi Nasional, “Baja Profil Kanal U Proses Canai Panas,” *Badan Standardisasi Nasional*, 2006. http:// sispk.bsn.go.id/SNI/DetailSNI/ 7065.