Friction Values for Sliding Commercial Motor Vehicles

Introduction:

Numerous papers have been written about frictional values of commercial vehicles sliding on various surfaces. One paper that is often referenced was from WREX2000 authored by Stopper et al and published in 2010 NWU-CPS Crash Reconstruction Manual[1].

This paper was work done to expand on the data compiled from that and other sources. During August 2019 a multi-organization venture took place in an attempt to pull a commercial city bus across gravel, grass and asphalt surfaces in order to determine the frictional relationship.

Commercial City Bus:

The bus was a 2009 Daimler local city bus equipped with two axles and was classified as a kneeling style bus. A kneeling bus is defined as a bus which can lower its body or entrance door to facilitate accessible boarding.

The bus was outfitted with a combination of forward facing, side facing and flip and folding seats. The bus still had the Cummins ISX engine but was missing the transmission, driveshaft, batteries and related hybrid electric components. The bus had a gross vehicle weight rating of 42,540 lbs (19,296 kg). The actual weight of the bus was measured with Haenni portable wheel load scales and found to weigh 30,313 lbs (13,750 kg).

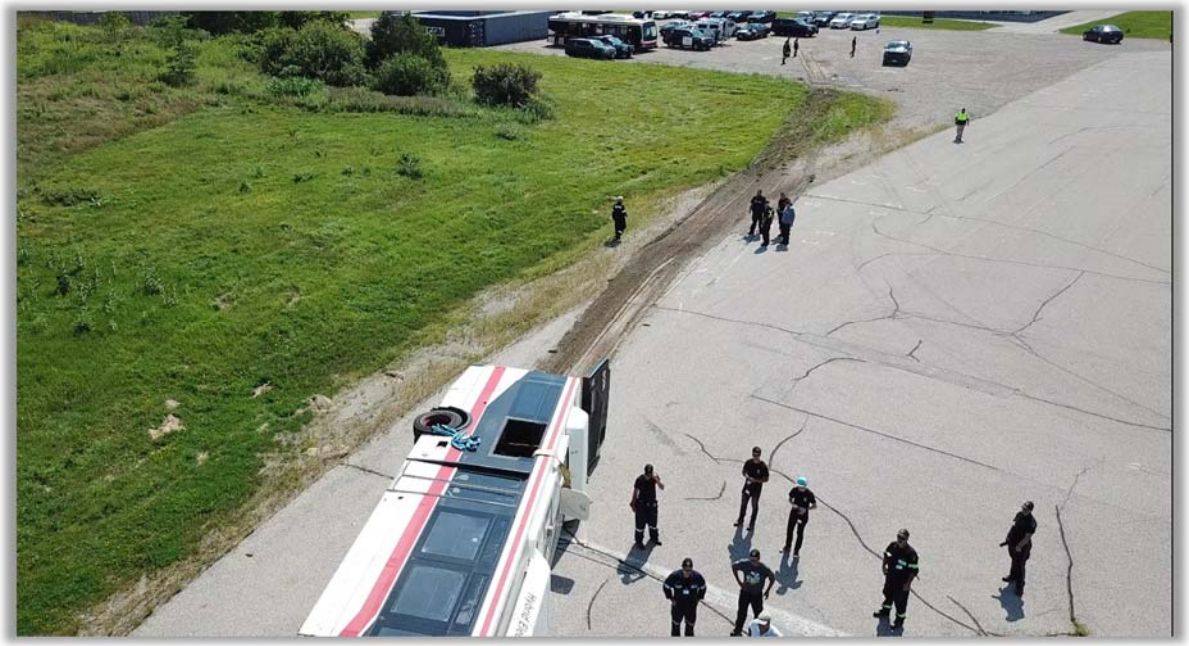
Testing Equipment:

The force required to drag the bus was recorded through the use of a Dillion-ED 2000 plus 50,000 lbs (22,680 kg) rated load cell which was monitored with a radio remote readout. The remote does not have a recording capability, so the remote screen was videotaped. The values reported were in the raw data format, representing the drag factor as calculated by the force divided by the weight of the bus for the relative percentage in relation to gravity for the μ value.

The bus was pulled by a five axle heavy wrecker as close to parallel as possible.

Testing Location:

The bus was pulled across well packed gravel, well vegetative grass and worn asphalt at the Ontario Police College in Aylmer, Ontario. All of the surfaces were dry.



Testing – Gravel

The bus was pulled on the left side along the gravel surface and the Dillion ED-2000 remote was monitored by video. The bus was pulled on a slight incline of +0.1^{o} grade. When the recording commenced the starting display on the Dillion was 10 lbs (4.54 kg). The author believes that this value was the tension on the weight cell with static load versus dynamic movement where the load is actually sliding. A reduction of 10 lbs (4.54 kg) was taken from all the recorded/measured values. There were fourteen values displayed on the remote which were tabulated in excel with the calculated low, average and high values.

Gravel			
1	16040.00 lb	7271.09 kg	0.5288
2	18280.00 lb	8287.14 kg	0.6027
3	18540.00 lb	8405.08 kg	0.6113
4	17760.00 lb	8051.27 kg	0.5855
5	18650.00 lb	8454.97 kg	0.6149
6	17750.00 lb	8046.74 kg	0.5852
7	18060.00 lb	8187.35 kg	0.5954
8	18460.00 lb	8368.79 kg	0.6086
9	19210.00 lb	8708.98 kg	0.6334
10	17760.00 lb	8051.27 kg	0.5855
11	16870.00 lb	7647.58 kg	0.5562
12	16830.00 lb	7629.43 kg	0.5549
13	17220.00 lb	7806.33 kg	0.5677
14	16500.00 lb	7479.75 kg	0.5440

Gravel	
Low	0.5288
Average	0.5839
High	0.6334

Testing – Grass

The bus was pulled on the left side along the grass surface and the Dillion ED-2000 remote was monitored by video. The bus was pulled on a slight incline of +0.6^{o} grade. When the recording commenced the starting display on the Dillion was 260 lbs (117.93 kg). A reduction of 260 lbs (117.93 kg) was taken from all the recorded/measured values. There were fourty-four values displayed on the remote which were tabulated in excel with the calculated low, average and high values.

Grass							
1	18300.00 lb	8182.82 kg	0.5951	23	19060.00 lb	8527.55 kg	0.6202
2	18640.00 lb	8337.04 kg	0.6063	24	19140.00 lb	8563.83 kg	0.6228
3	18560.00 lb	8300.75 kg	0.6037	25	19130.00 lb	8559.30 kg	0.6225
4	18830.00 lb	8423.22 kg	0.6126	26	19080.00 lb	8536.62 kg	0.6208
5	18910.00 lb	8459.51 kg	0.6152	27	18800.00 lb	8409.61 kg	0.6116
6	19070.00 lb	8532.08 kg	0.6205	28	18970.00 lb	8486.72 kg	0.6172
7	19150.00 lb	8568.37 kg	0.6232	29	18680.00 lb	8355.18 kg	0.6076
8	19530.00 lb	8740.74 kg	0.6357	30	18930.00 lb	8468.58 kg	0.6159
9	19550.00 lb	8749.81 kg	0.6363	31	18880.00 lb	8445.90 kg	0.6142
10	19820.00 lb	8872.28 kg	0.6453	32	19080.00 lb	8536.62 kg	0.6208
11	19580.00 lb	8763.42 kg	0.6373	33	19110.00 lb	8550.23 kg	0.6218
12	19440.00 lb	8699.91 kg	0.6327	34	19070.00 lb	8532.08 kg	0.6205
13	19660.00 lb	8799.70 kg	0.6400	35	19140.00 lb	8563.83 kg	0.6228
14	19080.00 lb	8536.62 kg	0.6208	36	19180.00 lb	8581.98 kg	0.6241
15	19700.00 lb	8817.85 kg	0.6413	37	19010.00 lb	8504.87 kg	0.6185
16	19420.00 lb	8690.84 kg	0.6321	38	19510.00 lb	8731.66 kg	0.6350
17	19710.00 lb	8822.38 kg	0.6416	39	19290.00 lb	8631.87 kg	0.6278
18	19480.00 lb	8718.06 kg	0.6340	40	19240.00 lb	8609.19 kg	0.6261
19	19190.00 lb	8586.51 kg	0.6245	41	19280.00 lb	8627.34 kg	0.6274
20	19410.00 lb	8686.30 kg	0.6317	42	19180.00 lb	8581.98 kg	0.6241
21	19220.00 lb	8600.12 kg	0.6255	43	19570.00 lb	8758.88 kg	0.6370
22	19500.00 lb	8727.13 kg	0.6347	44	19690.00 lb	8813.31 kg	0.6410

Grass	
Low	0.5951
Average	0.6249
High	0.6453

Testing – Asphalt

The bus was pulled on the left side along the asphalt surface and the Dillion ED-2000 remote was monitored by video. The bus was pulled on a slight incline of +1.5^{o} grade. When the recording commenced the starting display on the Dillion was 120 lbs (54.43 kg). A reduction of 120 lbs (54.43 kg) was taken from all the recorded/measured values. There were twenty-nine values displayed on the remote and the low, high and average values were calculated below.

Asphalt							
1	14510.00 lb	6527.20 kg	0.4747	16	15680.00 lb	7057.91 kg	0.5133
2	17090.00 lb	7697.47 kg	0.5598	17	15290.00 lb	6881.00 kg	0.5004
3	17810.00 lb	8024.06 kg	0.5836	18	15000.00 lb	6749.46 kg	0.4909
4	18080.00 lb	8146.53 kg	0.5925	19	14840.00 lb	6676.89 kg	0.4856
5	18260.00 lb	8228.18 kg	0.5984	20	14530.00 lb	6536.27 kg	0.4754
6	17140.00 lb	7720.15 kg	0.5615	21	14360.00 lb	6459.16 kg	0.4698
7	16100.00 lb	7248.41 kg	0.5272	22	14960.00 lb	6731.32 kg	0.4896
8	15480.00 lb	6967.19 kg	0.5067	23	14650.00 lb	6590.70 kg	0.4793
9	15190.00 lb	6835.65 kg	0.4971	24	15140.00 lb	6812.97 kg	0.4955
10	15600.00 lb	7021.62 kg	0.5107	25	14850.00 lb	6681.42 kg	0.4859
11	15020.00 lb	6758.53 kg	0.4915	26	15030.00 lb	6763.07 kg	0.4919
12	15860.00 lb	7139.55 kg	0.5192	27	15620.00 lb	7030.69 kg	0.5113
13	15820.00 lb	7121.41 kg	0.5179	28	15720.00 lb	7076.05 kg	0.5146
14	15470.00 lb	6962.65 kg	0.5064	29	15160.00 lb	6822.04 kg	0.4961
15	15600.00 lb	7021.62 kg	0.5107				

Asphalt	
Low	0.4698
Average	0.5123
High	0.5984

Discussion/Summary:

During the WREX2000 testing, a tanker, semi-trailer and a school bus were dragged on a concrete surface. The average value for those three test vehicles was 0.556. Breaking down the values to the school bus only, the average was 0.545, which is in close proximity of the average values we found with our bus on the asphalt surface.

Traffic Crash Reconstruction Clip

Vehicle	Average Pulling Speed (mi/h)	$f(\mu)$ Avg
Automobile	12.8	0.54
Tanker	Static	0.73
Tanker	7.8	0.58
Semitrailer	7.7	0.54
School Bus	8.6	0.55

***Exhibit 150**. Test pulls conducted to determine the friction coefficient are summarized for several vehicle types sliding on their sides.*

Summary from this Testing

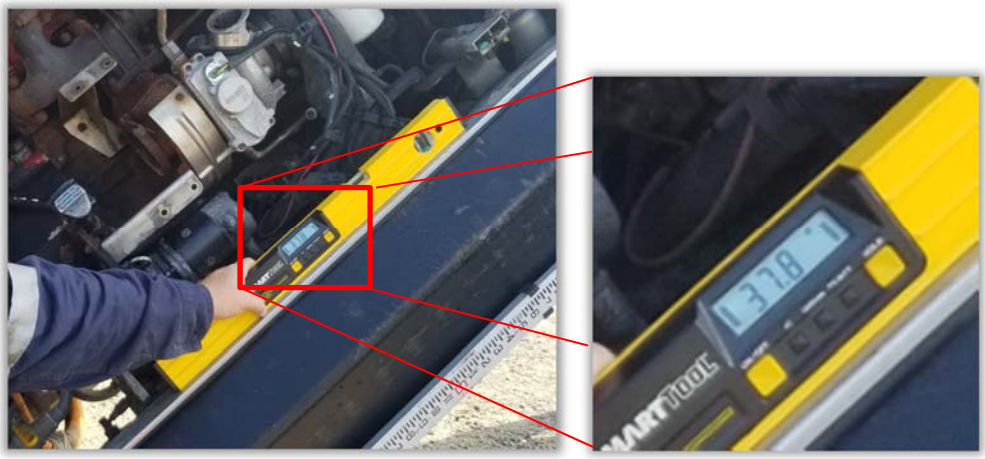
Summary	
Gravel	0.5839
Grass	0.6249
Asphalt	0.5123

More testing is planned, but this paper expands on the WREX2000 paper and will give an investigator usable values when reconstructing a collision with a commercial vehicle sliding on the side over various surfaces.

Rollover – Static Threshold

In preparation for the sliding tests, the static rollover angle was established by use of a Heavy Rotator Tow Truck wrecker to lift the bus to the balance point on the left tires and allowing the suspension to compress to the rollover threshold.

The TTC bus was slowly and carefully lifted with tow straps by the Heavy Rotator Tow Truck to the rollover threshold on the left side wheels. The TTC bus was titled and found to remain balanced at a 37.8 degree static angle. The angle was measured as lift straps were flexing without tension in either direction.



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- The Ontario Police College (OPC) https://www.mcscs.jus.gov.on.ca/english/police_serv/OPC/OPC_about.html
- Stopper and Associates http://stoppertrucks.com/
- 30FE https://www.30fe.com/
- Powell Contracting http://www.powell.ca/
- Ross' Towing http://www.rossservices.com/
- Crash Data Solutions LLC https://www.cdr-trainers.com/index.php
- The Toronto Police Service (TPS) http://www.torontopolice.on.ca/
- DNO Towing http://www.dnotowing.ca/
- The Ontario Provincial Police (OPP) https://www.opp.ca/
- The Forensic Training Group (FTG) https://forensictraininggroup.com/
- Toronto Transit Commission (TTC) http://www.ttc.ca/

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[1] Stopper, Dave, Voeglie, Chris, Heusser, Ron, and McKinzie, Steve; Friction Values of Sliding Commercial Vehicles vs. Autos; WREX2000, September 24-29, 2000, College Station, Texas

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