



Tractor-Trailer Combination Braking and Safety

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Date: 12 April 2007



Introduction

When you think about tractor-trailer combinations used on declines at our Mines;

What are the most common accidents which happen?

- n Run-away vehicles
- n Jack-knifing
- n Collisions with side walls etc



Introduction

- n Most of the trailers at the Coal Mines are not fitted with brakes.
- n I was part of an investigation team on the safety aspects regarding the use of tractor-trailer combinations on declines and inclines.
- n We did a series of practical brake tests to verify the advantages, if any, of fitting brakes to trailers.



Contents

1. HIRAC.
2. Testing the effect of fitting brakes to trailers.
3. Recommendations.



HIRAC

- n Hazardous Event Description
 - Driver loses control of vehicle on decline or incline
- n Consequence:
 - Running over personnel
 - Collision with other vehicles or equipment
 - Collision with side walls
 - Jack-knifing
- n Next level Consequences:
 - Injury or death of personnel
 - Damage to equipment or property
 - Production loss



Cause Analysis

Driver loses control of vehicle on decline or incline

- n Driver does not stop at the start of the decline
- n Vehicle runs too fast down decline
- n Skidding of tractor wheels when braking (jack-knifing)



Cause Analysis (cont)

n Next level causes

- *Inadequate rules or sign boards*
- *Inadequate training or discipline of drivers*
- *Ergonomics of gear selection difficult*
- *Brake failure*
- *Gearbox fault*
- *Insufficient braking capability*
- *Instability of vehicle when braking*
- *Trailer mass too high for tractor for safe stopping*
- *Allowable mass for trailer not marked on trailer*
- *Driver has no means to determine mass of load*
- *Poor road surface (wet and slippery)*



Remedial Actions/Recommendations

- n Mandatory stop far enough in front of decline to validate functionality of brakes and correct gear selection before start of decline
- n Trailer and load mass must be controlled
- n Allowable tractor-trailer combinations must be specified
- n Fit service brakes to heavier trailers to improve stability and to reduce the risk of jack-knifing
- n Prevent driving on declines when slippery (wet)
- n Regular testing and maintenance of brakes
- n Improve rules and signs to include recommendations
- n Re-train drivers (including practicing emergency stopping on declines)
- n Enforce discipline

Tractor – Bottom Dumper Trailer Combination





Ford Genesis Tractor Details

- n Engine: 6 cylinder, 80.9 kW@2100rpm
- n Brake system: Inboard wet brakes on rear wheels; front wheel braking is optional.
- n Model: 4X4
- n Gearbox: 12x12 speed
- n Tractor mass: 5 400kg



Bottom Dumper Trailer Details

- n Brakes: NCS U-300 3-Disc wet brakes
- n Load: Ash
- n Trailer gross mass: 10 300kg

NCS 3-Disc Wet Brakes on Trailer

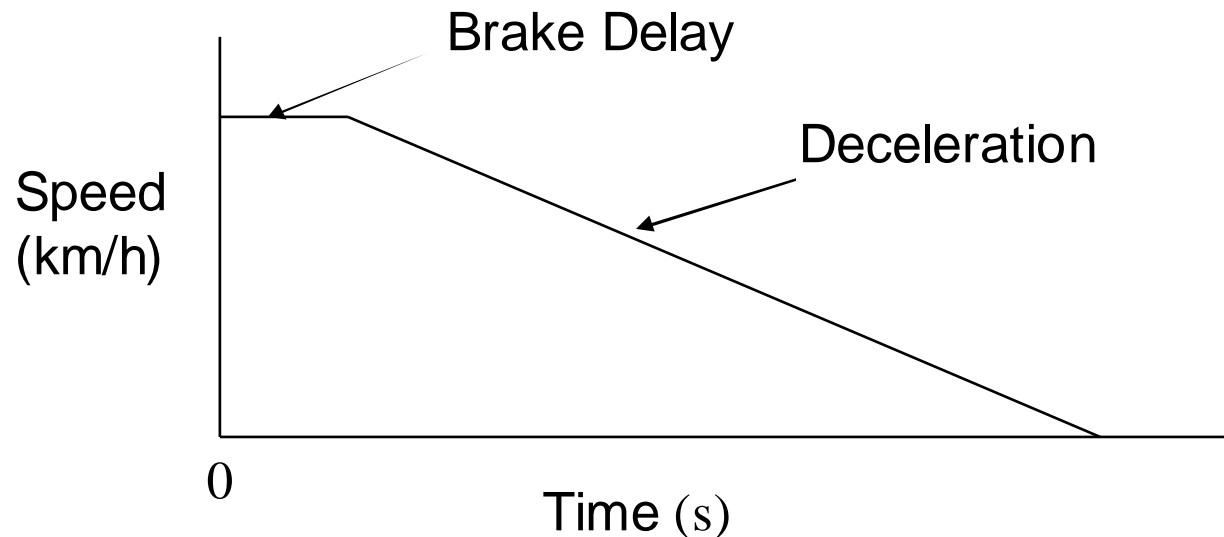


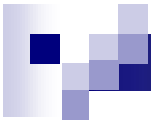
Simret Tester



Brake Efficiency

- n Brake efficiency is the mean deceleration from the start of deceleration to standstill expressed as a percentage of g (gravity)
- n $2,4\text{m/s}^2$ deceleration = $(2,4/9.81)\times 100 = 24,5\%$ g efficiency





Tractor with 4-wheel trailer



NCS 3-Disc Wet Brake on Rear Wheel





4-Wheel Trailer Details

- n Brakes: NCS U-300 3-Disc wet brakes
- n Load: Cement bags
- n Trailer gross mass: 8 940kg



Test Procedure

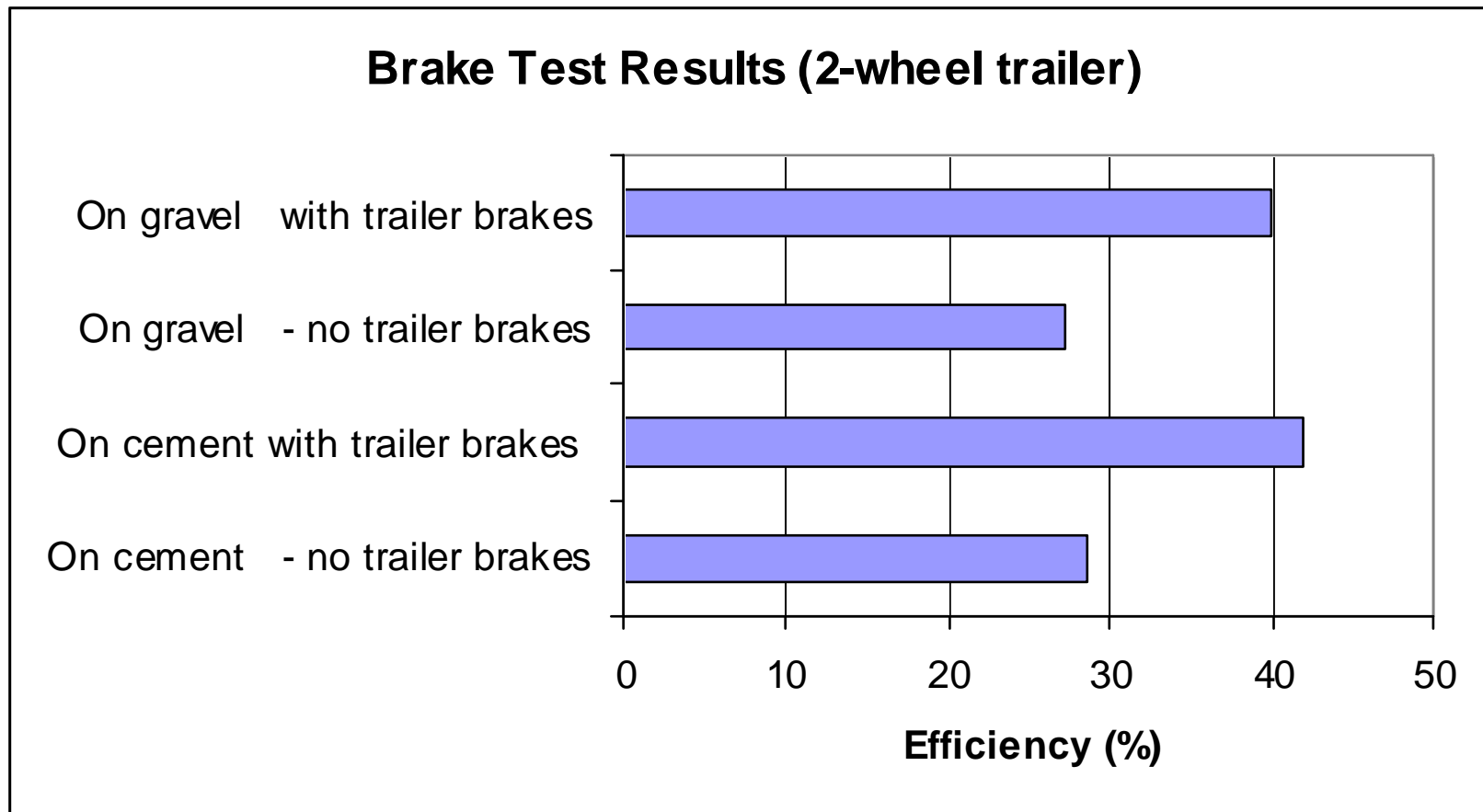
- n The tests were first done with the brakes on the trailer operational. The service brake pipe to the trailer was then disconnected and the tests were repeated.
- n The tests were done on cement / tar and on gravel road surfaces.

Skid marks

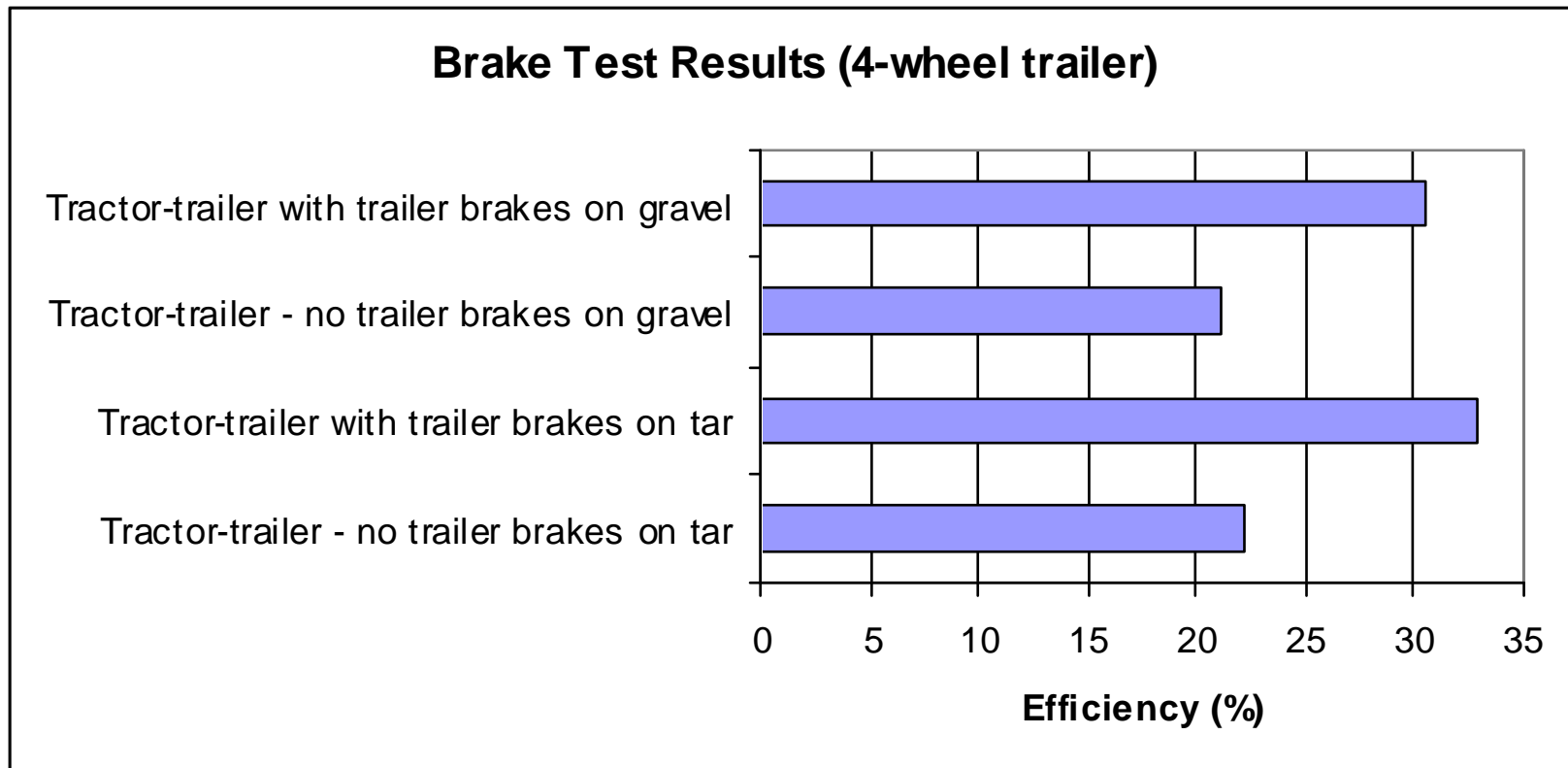


Front wheels on the tractor were also braking although no brakes were fitted (via 4x4 drive train).

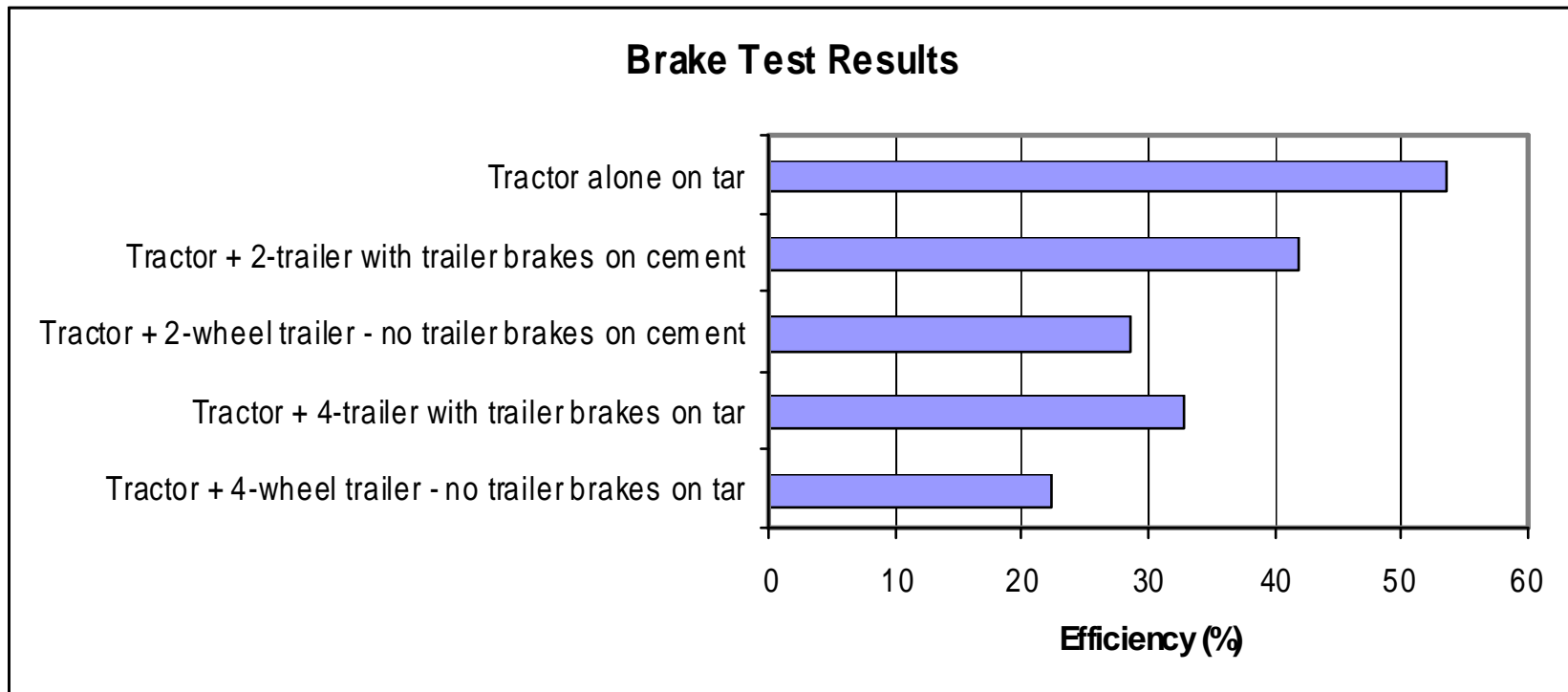
Test Results: Tractor with Bottom Dumper Trailer



Test Results: Tractor with 4-wheel Trailer



Comparison of Test Results





Discussion of Results

- n The brake efficiency of the tractor-trailer combination with trailer brakes is 43% - 48% higher than without trailer brakes.
- n It was observed during the tests that the ***stability of vehicle with trailer brakes is significantly better than without it.*** The tendency to jack-knife is much less.

Literature study

Title	Source
Compatibility of ABS Disc/ Drum brakes on class VIII vehicles with multiple trailers and their effects on jackknife stability	A Thesis for the Degree of Master of Science in the Graduate school of The Ohio State University By Scott Bradley Zagorski, B.S.M.E.
Mandatory Code of Practice for the Operation of Trackless Mobile Machines - Tractor	Sasol Mining Sap No: MGCMMG000019
United States of America House Bill 551	http://www.loadrite.com
National Road Traffic Act, 1996	South African Law
Braking (motor and towed vehicles, designed for low speed or for use off public roads) part 1 and part 2	SANS 1447-1 and SANS 1447-2
What Does Simret 3000 Measure?	Turnkey Instruments Ltd
The braking performance of trackless underground mining vehicles – Load haul dumpers and dump trucks	SANS 1589
Information to be supplied on safe operating grades for mobile equipment	Mine Safety Report No: SA 06-14
Six Cylinder Flameproof Tractor Specification	Diesel Flameproof Equipment (Pty) Ltd
Report on determining the SWL of a tractor-trailer combination at Brandspruit mine with specific focus on safe braking distance	Gideon Poolman
Earth moving machinery – Braking systems of rubber-tyred machines- Systems and performance requirements and test procedure	SANS 3450:2003 edition 1, ISO 3450: 1996 edition 3
Motor Vehicle Safety Standard Specification for Braking	SANS 1207



SA Road Ordinance

- n No brakes required on trailers up to 750kg GVM (gross vehicle mass) if trailer mass is less than half of towing vehicle Tare
- n Overrun brakes required on trailer with GVM 750kg – 3500kg on condition that trailer GVM is less than towing vehicle Tare
- n Service brakes and parking brake required for trailers over 3500kg GVM (to SABS 1207) or if trailer GVM is more than tare of towing vehicle



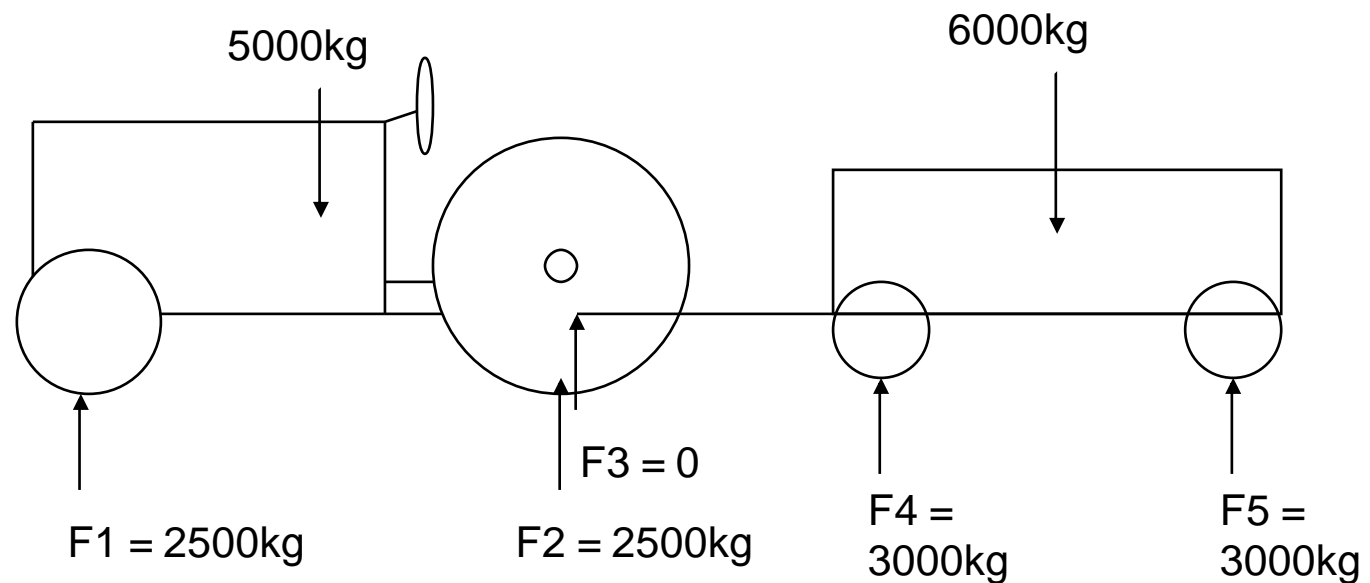
Recommendation

- n The Road Ordinance apply to vehicles travelling at up to 120km/h and more.
- n The maximum speed of the Mine's tractors is much lower (typically 25km/h).
- n Based on a risk assessment and past experience I propose that the guideline for mining tractor-trailer vehicles should be that service brakes shall be fitted to a trailer if the total mass on the un-braked axles of the vehicle exceeds the mass on the braked axles of the vehicle. (overrun brakes are not reliable in the mining environment and are not recommended)
- n The above risk assessment assumes declines of not more than 7 degrees and well maintained gravel roads. Each mine shall do a risk assessment and review this guideline for the specific conditions at that mine and the specific characteristics of the vehicles.

4-wheel trailers

Mass on un-braked wheels = 6000kg : Mass on braked wheels = 5000kg

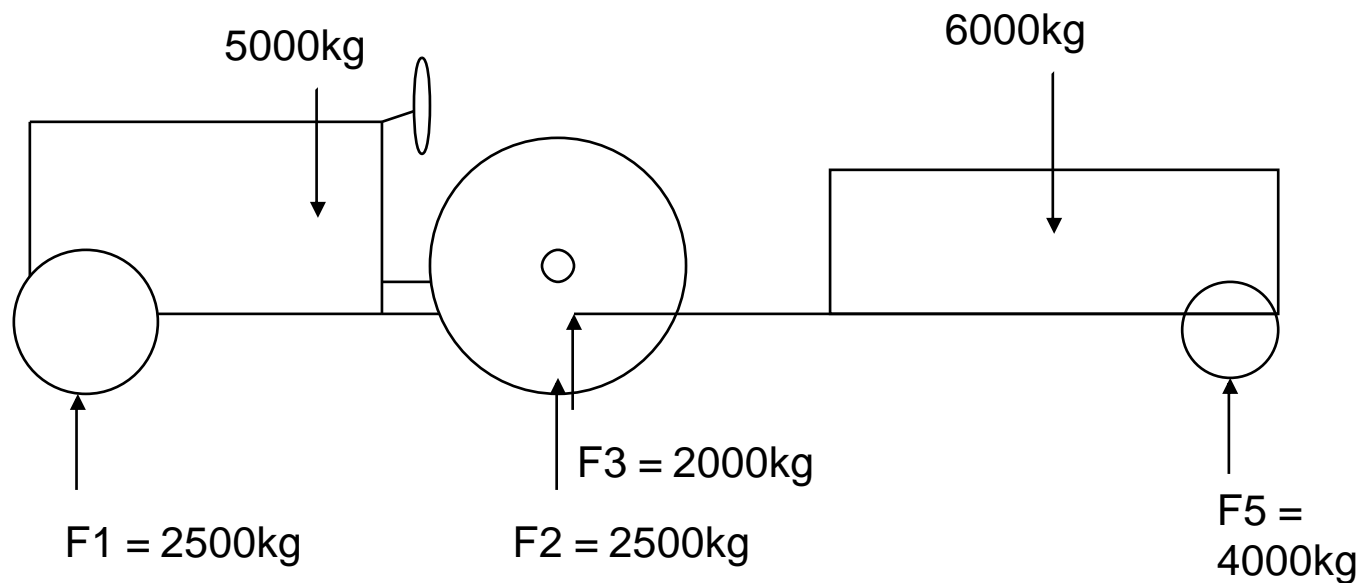
Ratio = 1,2 : 1



2-wheel trailers

Mass on un-braked wheels = 4000kg / Mass on braked wheels = 7000kg

Ratio = 0.57





Bottom Dumper Trailer Details

- n Brakes: NCS U-300 3-Disc wet brakes
- n Load: Ash
- n Trailer gross mass: 10 300kg
- n Load distribution: 7700kg on trailer axle
2600kg on tow bar

- n Ratios:
 - n Trailer mass/Tractor mass = $10300/5400 = 1,9$

 - n Mass on trailer axle/Mass on tractor axles
= $7700/(2600+5400) = 0,96$



4-Wheel Trailer Details

- n Brakes: NCS U-300 3-Disc wet brakes
- n Load: Cement bags
- n Trailer gross mass: 8 940kg
- n Load distribution: 5 500kg on rear trailer axle
3 440kg on front axle

- n Ratios:
 - n Trailer mass/Tractor mass = $8940/5400 = 1,66$

 - n Mass on un-braked axles/Mass on braked axles
= $3440/(5500+5400) = 0,32$



Braking Efficiency Recommendation

	Unladen $\leq 35\text{km/h}$	Laden $\leq 35\text{km/h}$	Laden $\geq 35\text{km/h}$
Road Ordinance		20	45
SANS 3450 @ 20km/h	28		
SANS 1589		40	
SANS 1447		24	
Proposal for Mining Tractor-trailer Vehicles (minimum)	28	20	45



Recommendations

- n Do a HIRAC for the specific conditions at your mine (Taking in account the slopes of declines, road conditions, specific tractor and trailer characteristics etc.)
- n Fit service brakes on at least one axle of heavier trailers (guideline: Mass on the un-braked axles should not be more than the mass on the braked axles.)
- n Regular testing of brakes.
- n Drivers to be re-trained (including emergency stopping).



Recommendations (cont)

- n Controlling of loads:
 - .. Load cells to be installed in cages, or weigh bridges at inclines, to determine the weight of loaded trailers.
 - .. Trailer empty weight, max load and max gross weight to be indicted on a plate on the trailer.
 - .. Each tractor *shall* be fitted with a plate indicating the max gross weight of trailer which may be hooked onto the tractor in case of a two-wheel trailer and a four-wheel trailer.
 - .. Suppliers shall indicate the weight of subassemblies and bundled material on the item. A safe operating procedure for loading of trailers shall be generated which shall indicate the weight of the items which is generally transported.



Recommendations (cont)

- o Drivers and store men shall be retrained in the correct procedures for loading and transportation by means of tractor-trailer vehicles.
- n Implement the other remedial actions identified in the HIRAC process.
- n Limit traveling through inclines and declines with fully loaded trailers by placing loading facilities as close as possible to the sections i.e. batching plants for ash and stone, stone dust silos, water, diesel and road treat supply facilities.



Questions ?

