

Vehicle Weights and Dimensions Study

Volume 9

**Pavement Response to
Heavy Vehicle Test Program:
Part 2 -- Load Equivalency Factors**

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The Technical Steering Committee will be considering the findings of these research investigations in preparing its "Final Technical Report" (Volume 1 & 2), scheduled for completion in December 1986.

PREFACE

The report which follows constitutes one volume in a series of sixteen which have been produced by contract researchers involved in the Vehicle Weights and Dimensions Study. The research procedures and findings contained herein address one or more specific technical objectives in the context of the development of a consistent knowledge base necessary to achieve the overall goal of the Study; improved uniformity in interprovincial weight and dimension regulations.

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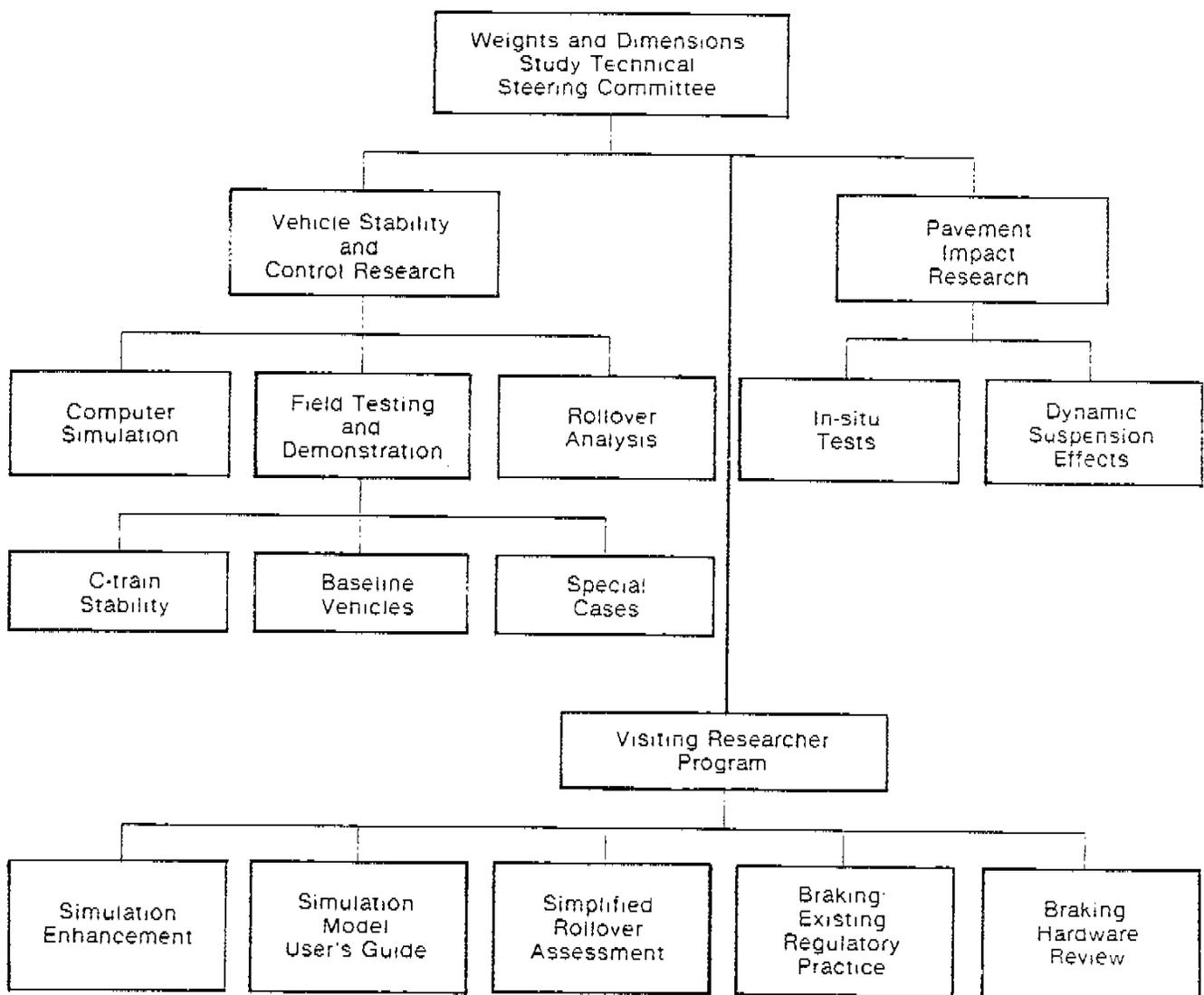
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HEAVY VEHICLE WEIGHTS AND DIMENSIONS STUDY

TECHNICAL WORK ELEMENTS OVERVIEW



Volume 9

**Pavements Response to Heavy Vehicle Test Program:
Part 2 -- Load Equivalency Factors**

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1.0 INTRODUCTION

During the summer of 1985, pavement surface deflections and interfacial tensile strains were recorded under a range of truck axle loads and configurations at fourteen instrumented pavement test sites located across Canada. The loading conditions included single, tandem and triaxle-dual tire configurations with gross weights ranging from approximately 9000 kg to 11 000 kg on single, 5500 kg to 22 000 kg on tandem, and from approximately 20 000 kg to 32 000 kg on triaxle configurations. Details of this extensive field testing program and summaries of the recorded pavement response variables are presented in the Pavement Impacts Investigation-Data Summary Report for this study. Using these field measurements and established pavement distress criteria, load equivalency factors for assessing the relative potential damaging effect of the traffic load variables on pavements have been developed.

This report describes the concepts used to develop the load equivalencies from the measured surface deflections and asphalt surface-base layer interfacial tensile strains. Data analysis procedures are described and predicted load equivalency factors for each test configuration are summarized by test site. From comparisons between the predicted factors, average loadings on different configurations equivalent in terms of potential damaging effect have been calculated and are presented with each test site summary. Analyses carried out to assess the influence of pavement structure on the magnitude of predicted load equivalency factors are described and results of the analyses are presented.

2.0 PAVEMENT RESPONSE - EQUIVALENCY FACTOR RELATIONSHIPS

Analysis of the destructive effects of traffic loadings on pavements is facilitated through use of load equivalency factors (F). These factors are defined as the number of applications (N_D) of a standard or base load which are equivalent in destructive effect to one application (N) of a given load; or $F = N_D/N$. Procedures used to predict load equivalency factors from in situ pavement surface deflections and interfacial tensile strain measurements are presented in Ref. 1. The following reviews the procedures as applied to the present study.

2.1 Deflection Response - Equivalency Relationships

The approach used to calculate equivalency factors from the pavement surface deflection measurements involved the use of limiting surface deflection - anticipated traffic loading relationships as shown in figure 2.1.

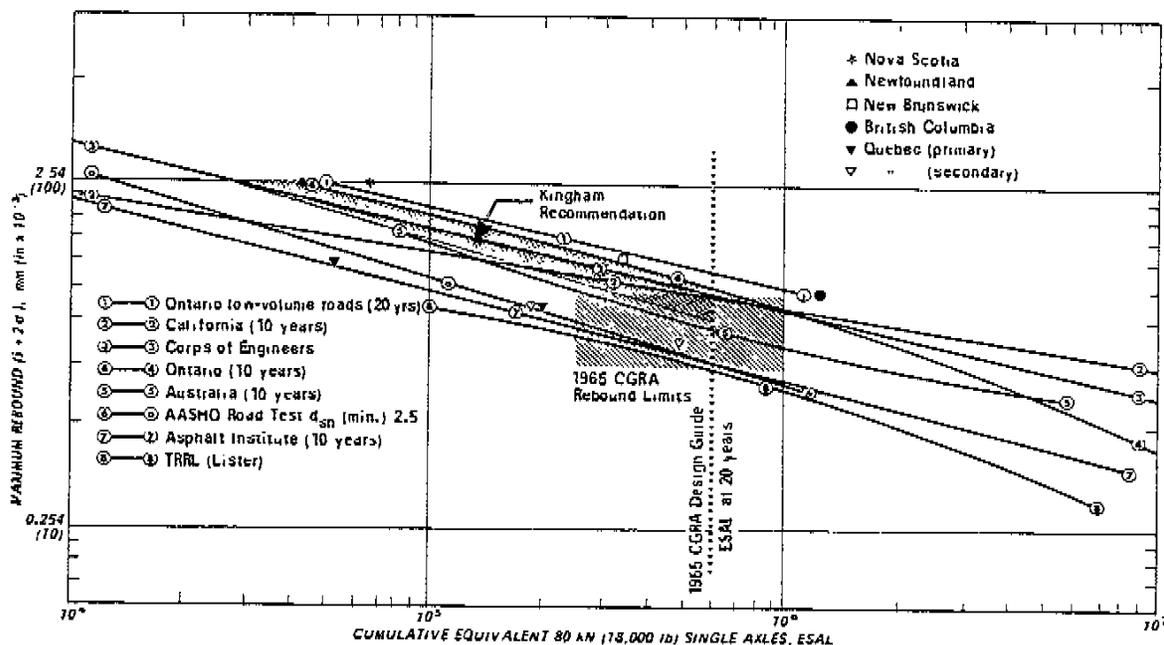


Figure 2.1 Maximum Benkelman Beam Rebound versus Cumulative Equivalent Single Axle Loads. (From Ref. 2)

These relationships indicate that pavement life, expressed in terms of equivalent standard load axle applications, N_D , can be approximated by the expression $N = K(1/D_D)^C$, where D_D equals the magnitude of the pavement surface deflection under the standard single axle-dual tire load. Combining this expression with the definition of a load equivalency factor, equivalency factors for single axle loads were predicted using the expression:

$$F = (D/D_D)^C$$

where:

D/D_D = the ratio of pavement surface deflections caused by a single axle load to those recorded under the standard 8160 kg single axle-dual tire load of the Benkelman Beam vehicle, and

C = the slope of the deflection - anticipated traffic loading relationship.

A typical longitudinal surface deflection profile recorded under a triaxle configuration is shown in figure 2.2.

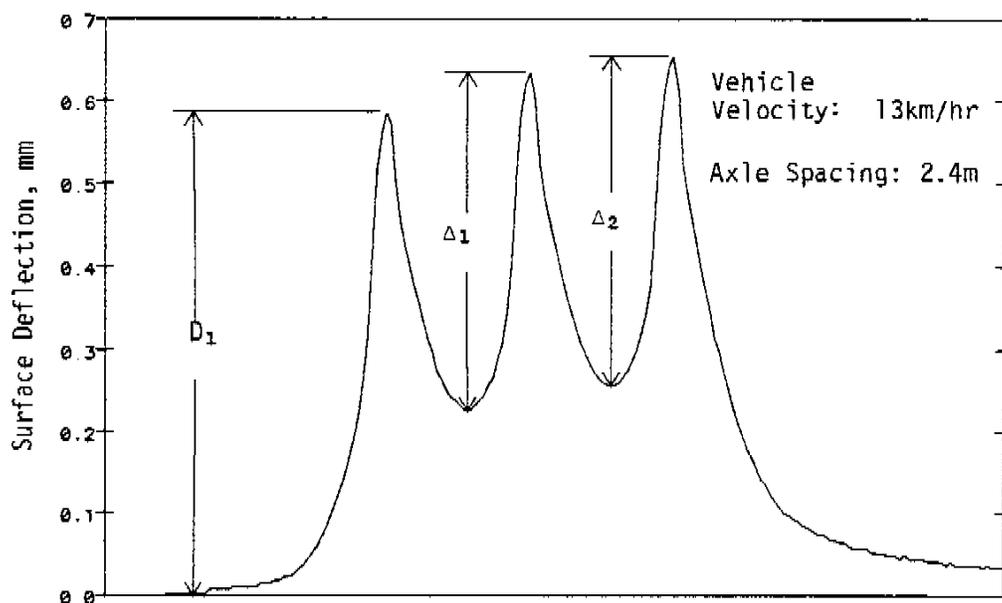


Figure 2.2 Surface Deflection Profile - Triaxle Configuration.

The general form of these profiles closely approximate longitudinal stress intensity profiles obtained from theoretical fracture mechanics concepts (Ref.3) and shown in figure 2.3. Suggested procedures for calculating equivalency factors from these profiles, shown on figure 2.3, were applied to the tandem and triaxle surface deflection records. Equivalency factors for these axle configurations were predicted using the expression:

$$F = (D_1/D_b)^C + \sum_{i=1}^{n-1} (\Delta_i/D_b)^C$$

where:

D_1/D_b = the ratio of maximum surface deflections under the leading axle of the axle group to those caused by the standard 8160 kg load,

Δ_1/D_b = the ratio of the difference in magnitude between the maximum deflection recorded under each succeeding axle and the minimum residual deflection preceding the axle (Δ , refer to figure 2.2) to deflections caused by the standard load, and

n = the number of axles in the axle group.

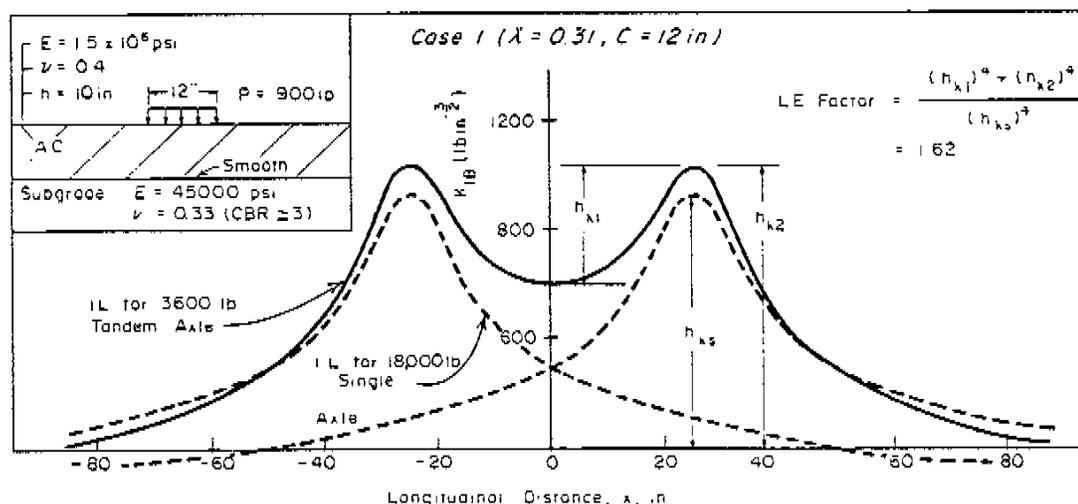


Figure 2.3 Load Equivalency Factor for Tandem Axle. (From Ref. 3)

2.2 Strain Response - Equivalency Relationship

A strain response profile at the asphalt concrete/base interface recorded under a triaxle load is shown in figure 2.4. Equivalency factor predictions from the tensile strain measurements involved the use of asphaltic concrete-fatigue life relationships as shown in figure 2.5. These relationships indicate that fatigue life, expressed in terms of the number of applications to failure, N , under a given load imposing a maximum tensile strain, S , can be approximated by the expression $N = K(1/S)^C$. Combining this expression with the definition of a load factor, equivalencies were predicted using the expression:

$$F = \sum_{i=1}^n (S_i/S_D)^C$$

where:

S_i/S_D = the ratio of longitudinal interfacial tensile strains recorded under each axle to those recorded under the standard load,

n = the number of axles in the axle group, and

C = the slope of the fatigue life-tensile strain relationship

Following the recommendations of the Pavements Advisory Committee to the study, average maximum deflection and strain values for each loading condition, tabulated in the Data Summary Report, were used for all load equivalency calculations. In addition, the exponents C were set equal to the recommended value of 3.8. This value is typical of results of laboratory fatigue tests on asphalt concrete mixes (figure 2.5) and approximates values ranging from 3.0 to 3.6 obtained from statistical correlations of deflection measurements with pavement serviceability levels (Ref.5) and obtained from pavement service life deflection studies (Ref.6).

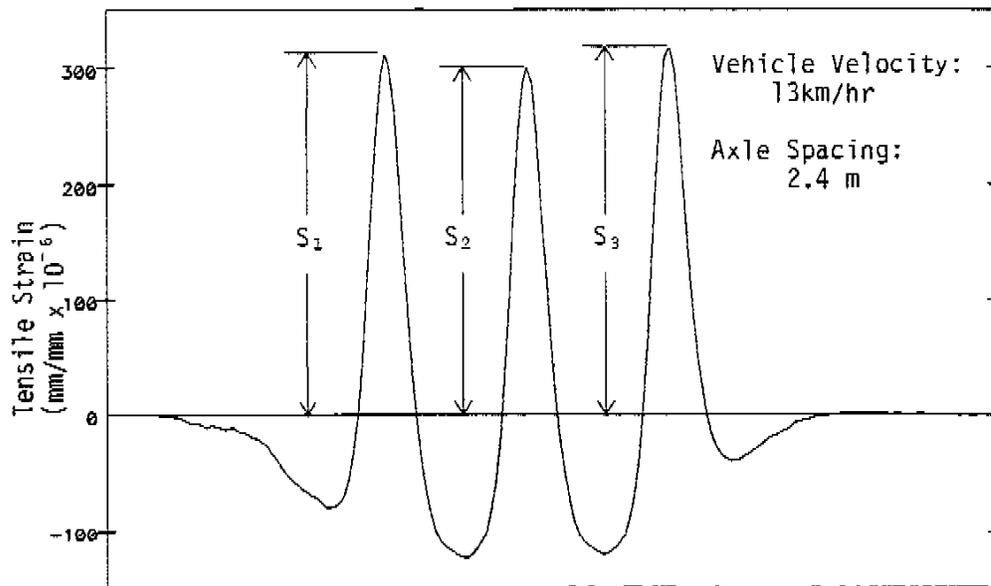


Figure 2.4 Longitudinal Interfacial Tensile Strain Profile-Triaxle Configuration.

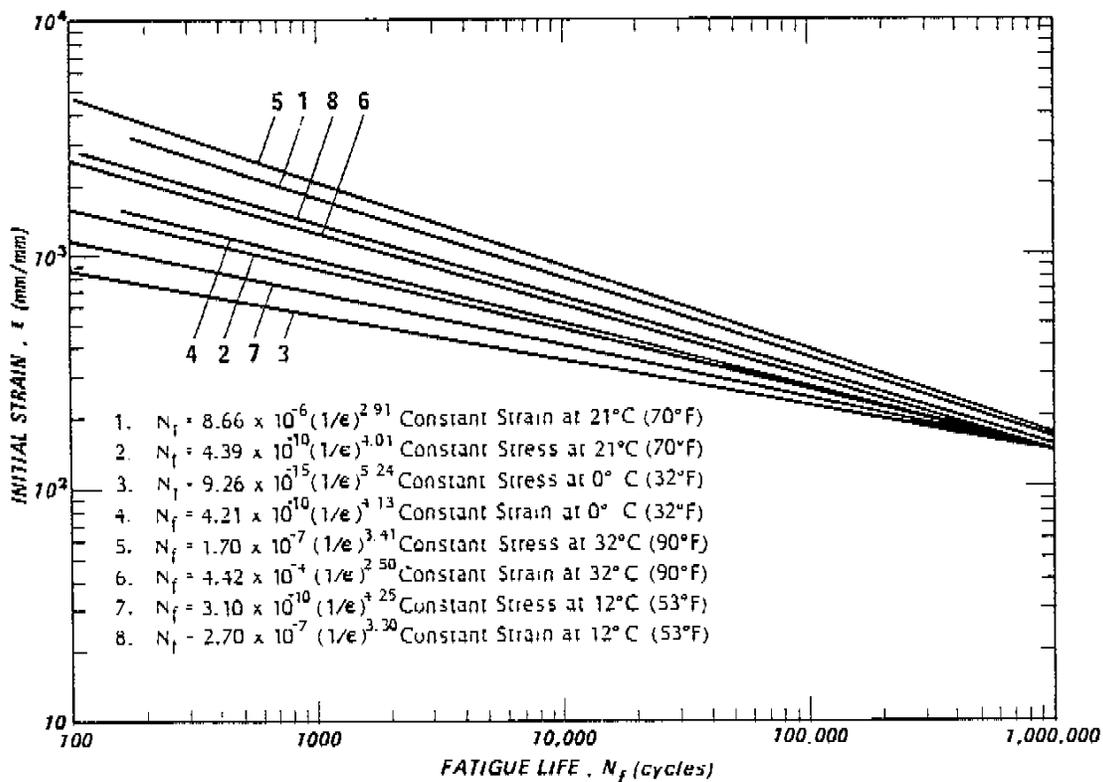


Figure 2.5 Fatigue Curves for Asphalt Concrete. (From Ref. 4)

3.0 DATA ANALYSIS

Average maximum pavement surface deflections and interfacial tensile strains for each loading condition were compared to those obtained from concurrent tests with the Benkelman Beam vehicle. These comparisons were in the form of deflection and strain ratios defined in Section 2. All loading conditions were tested at three vehicle velocities; approximately 6, 13 and 50 km/hr. The magnitude of the response ratios did not exhibit a consistent trend with velocity, remaining relatively constant over the three velocities for any given loading condition. (Maximum response ratios for a given load seldom exceeded minimum values by more than 10 percent). Therefore, the average of the three response ratios was used for the load equivalency predictions. An exception to this three point averaging was applied to strain measurements at site 12 - British Columbia. Strain ratios for the 50 km/hr test series at this site showed a wide variation in magnitude with little correlation with load. Reasons for this response are unknown. Load equivalencies based on strains at site 12 were predicted using the average response ratios for the two lower velocities.

Plots of axle weight versus deflection and strain ratios and summaries of regression analyses for tandem and triaxle configurations are presented in the Appendix. The figures reveal some data irregularities and show the influence of axle spacing on the magnitude of the pavement response ratios. These observations are discussed below.

3.1 Deflection Response

With the exception of site 2 - Nova Scotia and site 12 - British Columbia, deflections were highly correlated with axle load. At site 2, relatively large residual deflections were recorded between the tandem drive axles and the carrying axles of the pavement test vehicle. These residual deflections ranged from approximately 0.05 mm to 0.20 mm, with maximum values generally associated with tests conducted at high pavement temperatures (35C). Equivalency factors for carrying axle loads tested at site 2 were calculated using deflections equal to the

difference in magnitude between maximum deflections recorded under the axles and the residual deflections. Relative deflection values for site 12 - British Columbia, shown in figure A24, exhibited unusually wide variations in magnitude with changes in axle load. A detailed re-examination of the deflection measurements verified this behaviour.

The axle weight versus deflection ratio plots reveal that, at comparable loads, a variation in centre to centre spacing between adjacent axles from 1.5 m to 1.8 m had little, if any, influence on maximum surface deflections. Maximum deflections under adjacent axles at 1.2 m spacings were generally slightly larger in magnitude than those under axles with 1.5 m and 1.8 m spacings.

3.2 Strain Response

The axle weight versus strain ratio plots indicate that, at a number of sites, longitudinal interfacial tensile strains were relatively insensitive to changes in axle weight. At some sites, strain ratios for a given test configuration decreased with increasing load. Sites where one or more carrying axle test configurations revealed a decrease in relative strain values with increasing load were sites 4 and 5 in Quebec, site 6 - Ontario and site 12 - British Columbia. The relatively thin asphalt surfaces (ranging from 56 mm to 110 mm) of these pavement structures, high pavement temperatures (35C to 40C) during testing, and any small lateral misalignment of buried strain transducers relative to surface-set deflection transducer locations under these test conditions, may be contributing factors to these inconsistent measurements. In addition, plywood shipping stiffeners for the strain transducers were left in place during paving operations at sites 3A and 3B in Quebec. Therefore, strain recorded at these two sites should not be representative of the pavement response to load.

Equivalency factors based on strains were predicted for all loading conditions tested at each site. In view of the above noted irregularities, strain-related equivalencies for some configurations tested at the previously mentioned sites should be viewed with caution. Due to a

computer hardware malfunction, strains were not recorded at site 11 - British Columbia. The axle weight versus strain ratio plots reveal that a variation in spacing between adjacent axles from 1.2 m to 1.8 m had no measurable influence on the magnitude of interfacial tensile strains recorded under the lead axle of tandem and triaxle configurations.

3.3 Equivalent Loadings

Detail assessments of the relative destructive effects of traffic load variables on pavements involve identifying loads on different configurations which are equivalent in potential damaging effect. Such assessments can readily be carried out if gross weight versus load equivalency factor relationships are established for each axle configuration and the relationships encompass a common range of equivalency factor values. In the present study, a maximum of three loads/carrying axle configuration of the test vehicle were tested at each site. This did not provide sufficient data to develop reliable carrying axle gross weight-equivalency factor relationships.

In view of the above data limitations, deflections and strains recorded under the tandem (1.5 m) drive axles of the test vehicle were included in the analysis. At comparable load magnitudes, deflection and strain ratios, and therefore load equivalency factors, for the tandem drive axles were found to be in close agreement with those for the tandem (1.8 m) carrying axle configuration. Combining the data populations of these two axle groupings, gross weight versus load equivalency factor relationships for tandem (1.5 m to 1.8 m) axle-dual tire loads ranging from 5445 to 22 100 kg have been developed for each site. Using these relationships, tandem axle gross weights yielding equivalency factors equal in magnitude to those predicted for all other carrying axle loads and configurations have been identified.

4.0 LOAD EQUIVALENCY FACTORS

The following presents the predicted load equivalency factors, and, using these factors, summarizes results of analyses carried out to identify average loadings on different configurations which are equivalent in potential damaging effect. The predicted factors and analysis summaries are presented by test site in a common format as follows:

1. a table containing the average pavement surface deflection ratios, the average interfacial tensile strain ratios, and load equivalency factors derived from these ratios for each loading condition tested at the site, (The pavement response ratios are defined in Sections 2.1 and 2.2 of this report. The average values equal the mean of response ratios determined from test series carried out at three vehicle velocity levels; approximately 6, 13 and 50 km/hr.)
2. gross weight versus load equivalency factor plots for each test configuration,
3. results of least-squares regression analyses carried out to develop gross weight versus equivalency factor relationships for tandem (1.5 m to 1.8 m) axle-dual tire configurations, and
4. average gross weights on each configuration equivalent in potential damaging effect to tandem (1.5 m to 1.8 m) axle loads. The average equivalent gross weights are expressed as a percent of the tandem axle loads.

Utilizing the results obtained from all test sites, average tandem (1.5 m to 1.8 m) axle loads equivalent in damaging effect to all other carrying axle loading conditions included in the study, and the relative destructive effects of each configuration at comparable load magnitudes, are summarized in Section 4.15.

4.1 LOAD EQUIVALENCY FACTORS

SITE 1

NEW BRUNSWICK

Table 4.1
Average Pavement Response Ratios and
Load Equivalency Factors,
Site 1, New Brunswick

Loading Condition	Average Pavement Response Ratios						Load Equivalency Factors	
	Pavement Surface Deflections			Interfacial Tensile Strains			Based on	
	D_1/D_b	Δ_1/D_b	Δ_2/D_b	S_1/S_b	S_2/S_b	S_3/S_b	Deflections	Strains
Steering Axle								
3790 kg	0.589			0.664			0.134	0.211
5110 kg	0.762			0.826			0.356	0.484
Single Axle								
9182 kg	1.201			1.153			2.006	1.718
9570 kg	1.255			1.183			2.371	1.894
11127 kg	1.315			1.237			2.831	2.244
Tandem Axle (1.2m)								
13582 kg	1.003	0.681		0.813	0.784		1.244	0.852
18100 kg	1.233	0.703		1.077	0.969		2.479	2.213
22327 kg	1.394	0.811		1.191	1.145		3.889	3.398
Tandem axle (1.5m)								
5445 kg	0.577	0.477		0.342	0.330		0.184	0.032
6682 kg	0.678	0.501		0.450	0.424		0.301	0.086
8209 kg	0.738	0.583		0.536	0.537		0.444	0.188
9109 kg	0.824	0.681		0.647	0.731		0.711	0.495
9555 kg	0.786	0.678		0.644	0.642		0.629	0.373
10345 kg	0.803	0.693		0.718	0.708		0.683	0.553
10645 kg	0.793	0.624		0.740	0.727		0.581	0.616
11718 kg	0.944	0.726		0.753	0.740		1.100	0.659
11827 kg	0.938	0.715		0.727	0.729		1.064	0.599
12500 kg	0.942	0.764		0.828	0.850		1.156	1.027
13136 kg	0.975	0.793		0.868	0.844		1.323	1.084
13236 kg	1.000	0.675		0.829	0.807		1.225	0.933
14582 kg	1.002	0.848		0.902	0.903		1.542	1.364
14936 kg	1.039	0.791		0.946	0.934		1.567	1.581
15336 kg	0.982	0.780		0.906	0.891		1.322	1.332
15582 kg	1.074	0.883		0.957	0.963		1.935	1.747
19280 kg	1.346	0.874		1.171	1.150		3.692	3.523
Tandem axle (1.8m)								
14064 kg	0.900	0.825		0.849	0.917		1.151	1.256
18382 kg	1.141	0.980		1.002	1.074		2.577	2.319
22127 kg	1.394	1.108		1.306	1.327		5.010	5.688
Triaxle (2.4m)								
20082 kg	0.994	0.631	0.654	0.813	0.726	0.802	1.350	1.184
26145 kg	1.121	0.707	0.710	0.995	0.909	0.986	2.083	2.625
31645 kg	1.325	0.787	0.759	1.153	1.058	1.146	3.667	4.635
Triaxle (3.7)								
20510 kg	0.917	0.856	0.833	0.764	0.828	0.900	1.773	1.518
26036 kg	1.101	0.980	0.932	0.941	1.005	1.091	3.133	3.206
31664 kg	1.190	1.096	1.038	1.058	1.143	1.253	4.506	5.257
Triaxle (4.9)								
25856 kg	1.075	1.079	0.955	0.968	1.009	1.078	3.491	3.249
31955 kg	1.223	1.233	1.146	1.143	1.221	1.343	6.044	6.864

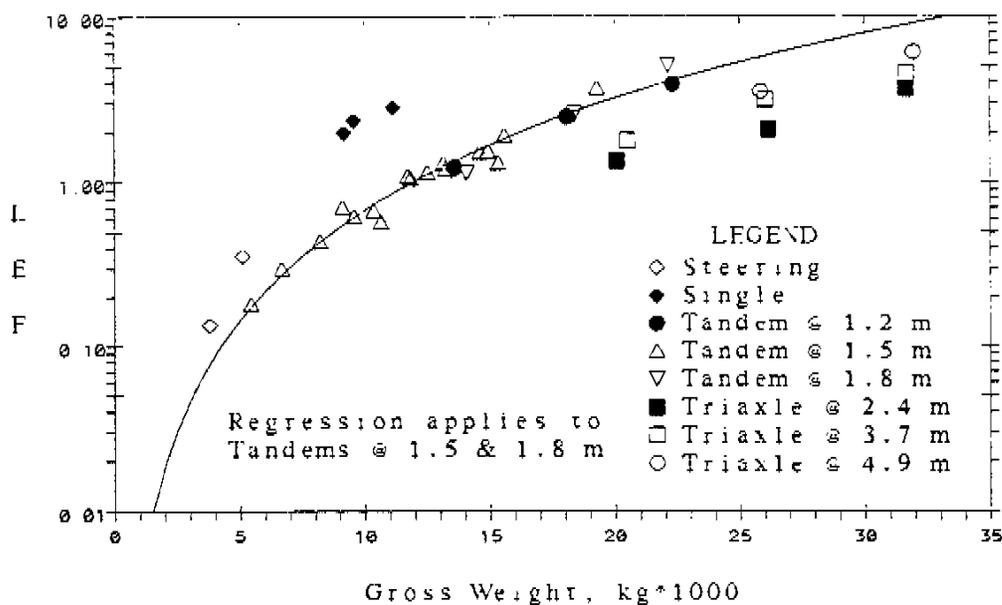


Figure 4.1: Load Equivalency Factors based on Deflections: Site 1, New Brunswick

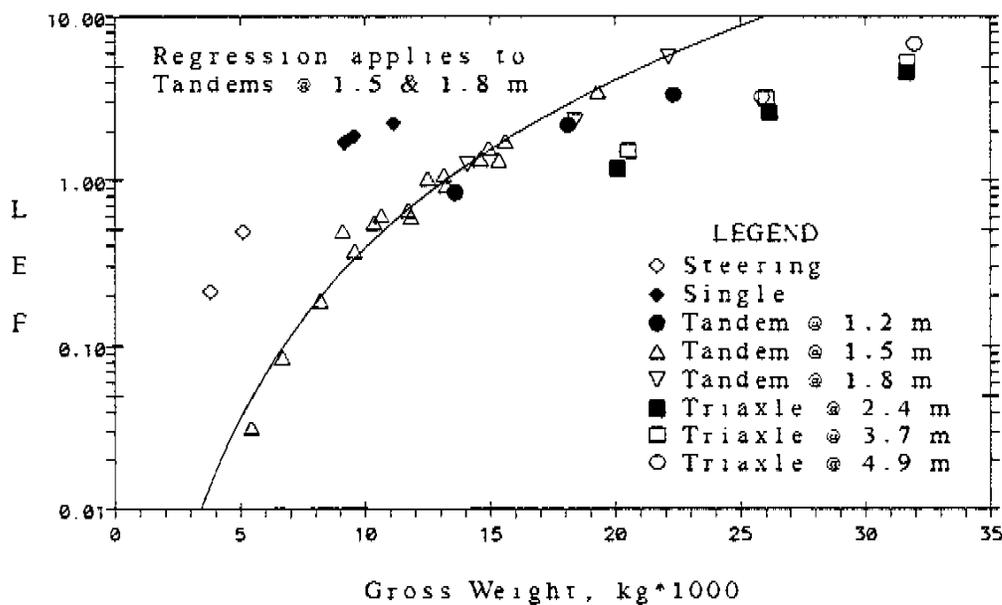


Figure 4.2: Load Equivalency Factors based on Strains: Site 1, New Brunswick

A. Gross Weight-Load Equivalency Factor Relationships

Tandem (1.5 - 1.8 m) Axles
Maximum Gross Weight = 22100 kg

Based on Deflections:

$$F = 0.0040 (GW)^{2.230} \quad r^2 = 0.90 \quad N = 20 \quad \Delta S_{ey} = 0.066$$

Based on Strains:

$$F = 0.000153 (GW)^{3.405} \quad r^2 = 0.97 \quad N = 20 \quad \Delta S_{ey} = 0.093$$

where: GW = gross weight, kg $\times 10^3$

B. Equivalent Loadings

The following summarizes results of comparisons between equivalency factors for tandem (1.5 - 1.8 m) axle loads and equivalencies for all other axle loads and configurations tested at this site.

Note: Non-bracketed and bracketed gross weights and load applications are those obtained from comparisons of equivalency factors based on deflections and strains, respectively.

1. One application of an 11900 kg (13200 kg) tandem axle (1.5 - 1.8 m) - dual tire load is approximately equivalent in potential damaging effect to one application of the standard 8160 kg single axle-dual tire load.
2. For the range of loadings tested on carrying axle configurations of the pavement test vehicle, on average:

One application of a tandem (1.5 - 1.8 m) load is equivalent in potential damaging effect to one application of a single axle-dual tire configuration having a gross weight equal to approximately 57 (62) percent of the tandem (1.5 - 1.8 m) load. Average gross weight equivalents for other carrying axle configurations are:

<u>Configuration</u>	<u>Percent of Tandem (1.5-1.8 m) GW</u>
Tandem (1.2 m)	102 (110)
Triaxle (2.4 m)	151 (148)
Triaxle (3.7 m)	133 (142)
Triaxle (4.9 m)	122 (138)

3. At comparable load magnitudes (approximately 5000 kg), one application of a single steering axle is equivalent in potential damaging effect to approximately 3 (15) applications of tandem axle (1.5 - 1.8 m) - dual tire configuration.

4.2 LOAD EQUIVALENCY FACTORS

**SITE 2
NOVA SCOTIA**

Table 4.2
Average Pavement Response Ratios and
Load Equivalency Factors,
Site 2, Nova Scotia

Loading Condition	Average Pavement Response Ratios						Load Equivalency Factors	
	Pavement Surface Deflections			Interfacial Tensile Strains			Based on	
	D_1/D_b	Δ_1/D_b	Δ_2/D_b	S_1/S_b	S_2/S_b	S_3/S_b	Deflections	Strains
Steering Axle								
3790 kg	0.743			0.766			0.323	0.363
5110 kg	0.955			0.928			0.839	0.753
Single Axle								
9182 kg	1.001			0.998			1.004	0.992
11127 kg	1.124			1.043			1.559	1.173
Tandem Axle (1.2m)								
13582 kg	0.968	0.674		0.870	0.813		1.107	1.044
18100 kg	1.058	0.626		0.947	0.935		1.408	1.568
22327 kg	1.250	0.830		1.025	0.956		2.827	1.941
Tandem Axle (1.5m)								
5445 kg	0.549	0.403		0.476	0.436		0.134	0.102
9109 kg	0.695	0.487		0.632	0.621		0.316	0.338
9555 kg	0.792	0.593		0.719	0.670		0.550	0.504
10345 kg	0.815	0.616		0.806	0.751		0.618	0.777
10645 kg	0.864	0.612		0.836	0.786		0.729	0.907
11718 kg	0.804	0.550		0.768	0.747		0.540	0.697
11817 kg	0.843	0.612		0.786	0.763		0.677	0.758
12500 kg	1.037	0.776		0.847	0.790		1.530	0.940
13136 kg	1.115	0.774		0.888	0.825		1.890	1.118
13236 kg	0.926	0.623		0.831	0.815		0.912	0.954
14582 kg	1.074	0.779		0.899	0.835		1.699	1.171
14936 kg	0.998	0.704		0.903	0.872		1.256	1.273
15336 kg	1.133	0.788		0.904	0.846		2.012	1.211
15582 kg	1.161	0.852		0.931	0.884		2.308	1.368
Tandem Axle (1.8m)								
14064 kg	0.948	0.852		0.897	0.884		1.360	1.288
18382 kg	1.000	0.860		0.956	0.980		1.564	1.769
22127 kg	1.103	0.922		1.048	1.073		2.502	2.502
Triaxle (2.4m)								
20082 kg	1.002	0.714	0.665	0.873	0.798	0.789	1.498	1.427
26145 kg	1.019	0.670	0.638	0.931	0.860	0.886	1.474	1.957
31645 kg	1.151	0.722	0.663	1.011	0.947	0.973	2.206	2.757
Triaxle (3.7m)								
20509 kg	0.819	0.763	0.769	0.786	0.817	0.825	1.195	1.346
26036 kg	0.880	0.799	0.821	0.867	0.913	0.962	1.514	2.152
31664 kg	1.027	0.939	0.944	0.948	0.944	0.931	2.697	2.382

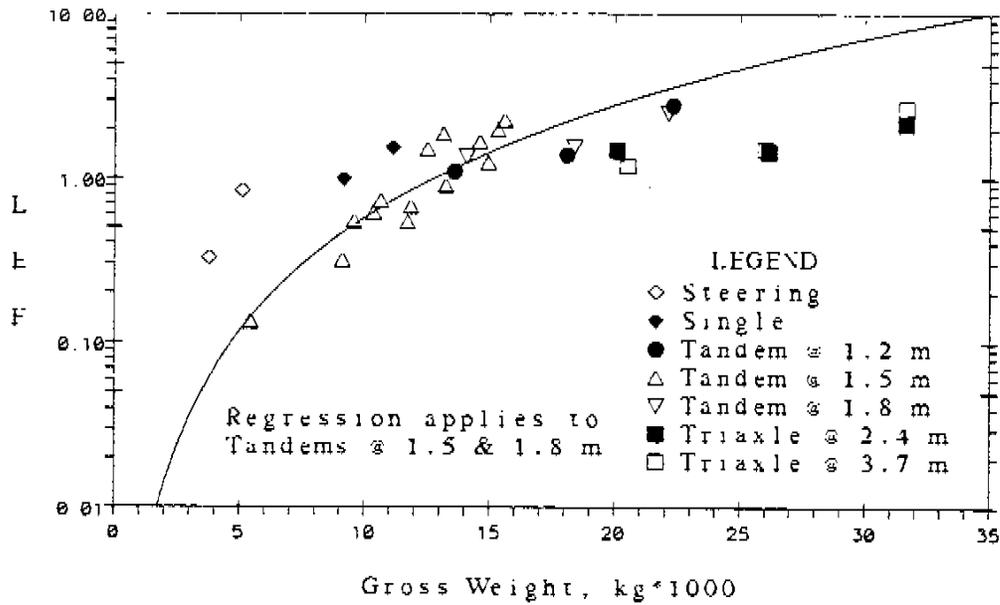


Figure 4.3: Load Equivalency Factors based on Deflections: Site 2, Nova Scotia

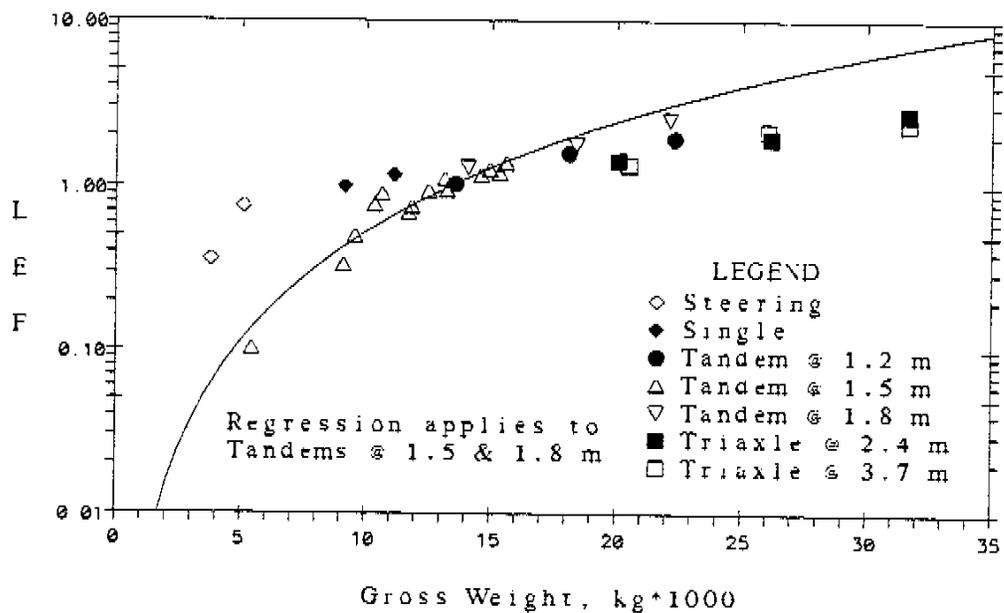


Figure 4.4: Load Equivalency Factors based on Strains: Site 2, Nova Scotia

A. Gross Weight-Load Equivalency Factor Relationships

Tandem (1.5 - 1.8 m) Axles
Maximum Gross Weight = 22100 kg

Based on Deflections:

$$F = 0.0029 (GW)^{2.296} \quad r^2 = 0.84 \quad N = 17 \quad \Delta S_{ey} = 0.134$$

Based on Strains:

$$F = 0.00318 (GW)^{2.219} \quad r^2 = 0.94 \quad N = 17 \quad \Delta S_{ey} = 0.080$$

where: GW = gross weight, kg $\times 10^3$

B. Equivalent Loadings

The following summarizes results of comparisons between equivalency factors for tandem (1.5 - 1.8 m) axle loads and equivalencies for all other axle loads and configurations tested at this site.

Note: Non-bracketed and bracketed gross weights and load applications are those obtained from comparisons of equivalency factors based on deflections and strains, respectively.

1. One application of a 12700 kg (13400 kg) tandem axle (1.5 - 1.8 m) - dual tire load is approximately equivalent in potential damaging effect to one application of the standard 8160 kg single axle-dual tire load.
2. For the range of loadings tested on carrying axle configurations of the pavement test vehicle, on average:

One application of a tandem (1.5 - 1.8 m) load is equivalent in potential damaging effect to one application of a single axle-dual tire configuration having a gross weight equal to approximately 72 (73) percent of the tandem (1.5 - 1.8 m) load. Average gross weight equivalents for other carrying axle configurations are:

<u>Configuration</u>	<u>Percent of Tandem (1.5-1.8 m) GW</u>
Tandem (1.2 m)	112 (111)
Triaxle (2.4 m)	157 (141)
Triaxle (3.7 m)	160 (144)

3. At comparable load magnitudes (approximately 5000 kg), one application of a single steering axle is equivalent in potential damaging effect to approximately 7 (8) applications of tandem axle (1.5 - 1.8 m) - dual tire configuration.

4.3 LOAD EQUIVALENCY FACTORS

SITE 3A

QUEBEC

Table 4.3
Average Pavement Response Ratios and
Load Equivalency Factors,
Site 3A, Quebec

Loading Condition	Average Pavement Response Ratios						Load Equivalency Factors	
	Pavement Surface Deflections			Interfacial Tensile Strains			Based on	
	D_1/D_b	Δ_1/D_b	Δ_2/D_b	S_1/S_b	S_2/S_b	S_3/S_b	Deflections	Strains
Single Axle								
9182 kg	1.196			1.024			1.974	1.094
9570 kg	1.193			1.115			1.955	1.512
11127 kg	1.306			1.247			2.758	2.314
Tandem Axle (1.2m)								
13582 kg	1.029	0.660		0.848	0.807		1.321	0.977
18100 kg	1.315	0.794		0.936	0.959		3.247	1.631
22327 kg	1.359	0.808		1.064	1.001		3.653	2.270
Tandem Axle (1.5m)								
5445 kg	0.523	0.415		0.355	0.356		0.121	0.039
6682 kg	0.670	0.494		0.433	0.433		0.287	0.083
8209 kg	0.756	0.599		0.606	0.598		0.488	0.291
9109 kg	0.805	0.614		0.555	0.547		0.595	0.208
9555 kg	0.804	0.629		0.656	0.641		0.608	0.385
10345 kg	0.860	0.673		0.620	0.599		0.786	0.305
10645 kg	0.909	0.700		0.618	0.639		0.954	0.343
11718 kg	0.945	0.709		0.708	0.697		1.077	0.523
11827 kg	0.920	0.715		0.602	0.593		1.008	0.283
12500 kg	0.932	0.718		0.663	0.718		1.049	0.494
13136 kg	0.965	0.741		0.755	0.814		1.193	0.801
13236 kg	1.041	0.808		0.734	0.758		1.610	0.658
14582 kg	1.043	0.818		0.834	0.819		1.640	0.970
14936 kg	1.117	0.846		0.731	0.747		2.052	0.634
15336 kg	1.016	0.780		0.801	0.783		1.451	0.825
15582 kg	1.133	0.788		0.778	0.776		2.012	0.767
19280 kg	1.235	0.868		1.027	0.974		2.814	2.011
Tandem Axle (1.8m)								
14064 kg	1.003	0.804		0.737	0.793		1.448	0.728
18382 kg	1.241	0.973		0.921	0.936		3.173	1.509
22127 kg	1.358	1.034		1.094	1.017		4.335	2.473
Triaxle (2.4m)								
20082 kg	1.051	0.601	0.617	0.727	0.692	0.709	1.152	0.815
26145 kg	1.156	0.780	0.748	0.960	0.927	0.890	2.456	2.248
31645 kg	1.420	0.850	0.848	1.063	0.974	0.993	4.864	3.140
Triaxle (3.7m)								
20509 kg	0.995	0.806	0.786	0.774	0.843	0.858	1.822	1.489
26036 kg	1.143	0.892	0.927	0.824	0.915	0.925	3.059	1.936
31664 kg	1.280	1.030	1.033	0.920	1.028	1.074	4.805	3.151
Triaxle (4.9m)								
25836 kg	1.134	1.032	0.942	0.882	0.989	0.939	3.537	2.367
31955 kg	1.354	1.263	1.111	0.883	0.973	0.962	7.084	2.388

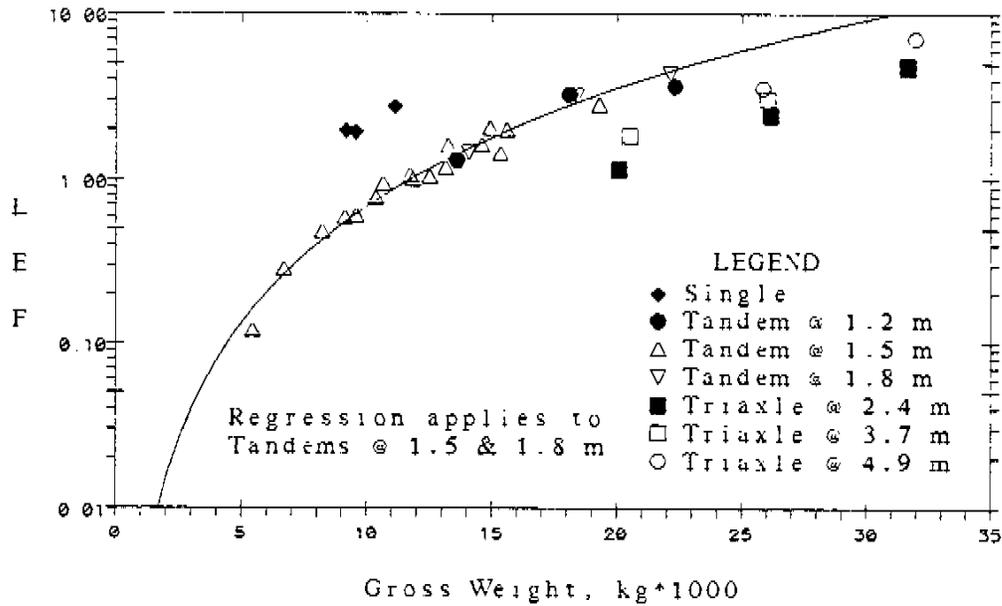


Figure 4.5: Load Equivalency Factors based on Deflections: Site 3A, Quebec

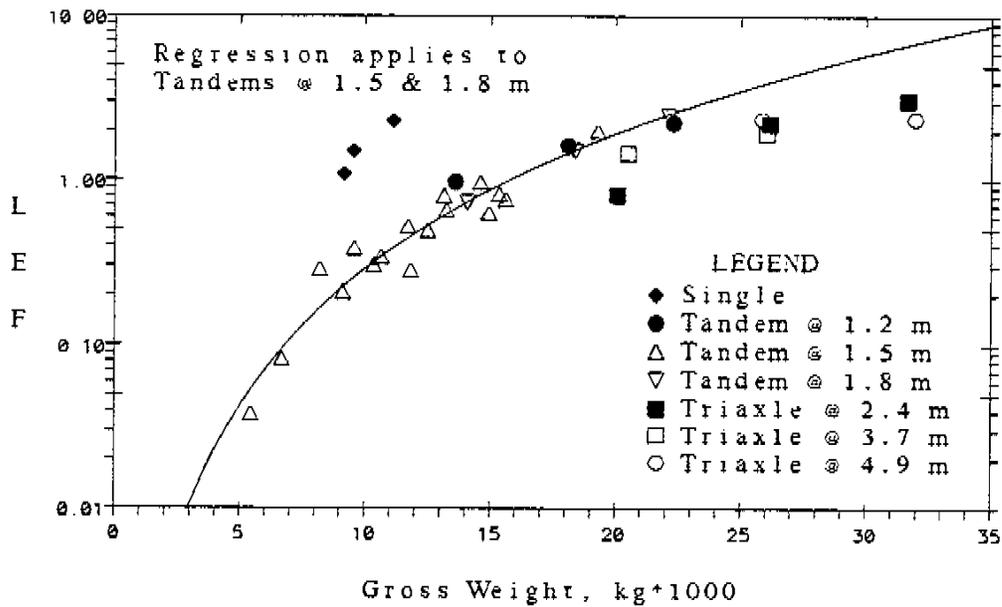


Figure 4.6: Load Equivalency Factors based on Strains: Site 3A, Quebec

A. Gross Weight-Load Equivalency Factor Relationships

Tandem (1.5 - 1.8 m) Axles
Maximum Gross Weight = 22100 kg

Based on Deflections:

$$F = 0.00294 (GW)^{2.368} \quad r^2 = 0.97 \quad N = 20 \quad \Delta S_{ey} = 0.058$$

Based on Strains:

$$F = 0.000512 (GW)^{2.748} \quad r^2 = 0.97 \quad N = 20 \quad \Delta S_{ey} = 0.108$$

where: GW = gross weight, kg x 10³

B. Equivalent Loadings

The following summarizes results of comparisons between equivalency factors for tandem (1.5 - 1.8 m) axle loads and equivalencies for all other axle loads and configurations tested at this site.

Note: Non-bracketed and bracketed gross weights are those obtained from comparisons of equivalency factors based on deflections and strains, respectively.

1. One application of an 11700 kg (15800 kg) tandem axle (1.5 - 1.8 m) - dual tire load is approximately equivalent in potential damaging effect to one application of the standard 8160 kg single axle-dual tire load.
2. For the range of loadings tested on carrying axle configurations of the pavement test vehicle, on average:

One application of a tandem (1.5 - 1.8 m) load is equivalent in potential damaging effect to one application of a single axle-dual tire configuration having a gross weight equal to approximately 60 (53) percent of the tandem (1.5 - 1.8 m) load. Average gross weight equivalents for other carrying axle configurations are:

<u>Configuration</u>	<u>Percent of Tandem (1.5-1.8 m) GW</u>
Tandem (1.2 m)	102 (96)
Triaxle (2.4 m)	151 (131)
Triaxle (3.7 m)	138 (125)
Triaxle (4.9 m)	124 (134)

4.4 LOAD EQUIVALENCY FACTORS

SITE 38

QUEBEC

Table 4.4
Average Pavement Response Ratios and
Load Equivalency Factors,
Site 3B, Quebec

Loading Condition	Average Pavement Response Ratios						Load Equivalency Factors	
	Pavement Surface Deflections			Interfacial Tensile Strains			Based on	
	D_1/D_b	Δ_1/D_b	Δ_2/D_b	S_1/S_b	S_2/S_b	S_3/S_b	Deflections	Strains
Single axle								
9182 kg	1.187			1.084			1.918	1.359
9570 kg	1.256			1.089			2.378	1.383
11127 kg	1.335			1.206			2.998	2.038
Tandem Axle (1.2m)								
13582 kg	1.089	0.695		0.996	0.939		1.634	1.772
18100 kg	1.231	0.765		1.079	1.093		2.564	2.737
22327 kg	1.404	0.791		1.140	1.079		4.041	2.980
Tandem Axle (1.5m)								
5445 kg	0.514	0.368		0.565	0.547		0.100	0.215
6682 kg	0.661	0.475		0.759	0.746		0.266	0.579
8209 kg	0.756	0.591		0.877	0.857		0.481	1.164
9109 kg	0.773	0.581		0.801	0.817		0.503	0.894
9555 kg	0.798	0.671		0.912	0.860		0.644	1.268
10345 kg	0.823	0.623		0.775	0.776		0.643	0.761
10645 kg	0.843	0.603		0.837	0.848		0.669	1.043
11718 kg	0.920	0.734		0.907	0.931		1.037	1.452
11827 kg	0.868	0.738		0.896	0.921		0.899	1.390
12500 kg	0.913	0.761		0.885	0.949		1.062	1.448
13136 kg	0.971	0.774		0.948	0.992		1.272	1.786
13236 kg	1.019	0.799		1.001	1.004		1.500	2.019
14582 kg	1.017	0.813		1.014	1.008		1.522	2.085
14936 kg	1.030	0.845		0.955	0.996		1.646	1.824
15336 kg	1.031	0.761		0.972	0.961		1.477	1.757
15582 kg	1.079	0.784		1.001	1.022		1.732	2.090
19280 kg	1.241	0.921		1.120	1.116		3.003	3.056
Tandem Axle (1.8m)								
14064 kg	1.009	0.827		0.959	0.968		1.521	1.737
18382 kg	1.195	0.990		1.076	1.082		2.930	2.670
22127 kg	1.337	1.049		1.141	1.111		4.214	3.143
Triaxle (2.4m)								
20082 kg	1.029	0.590	0.564	0.992	0.965	0.956	1.363	2.686
26145 kg	1.263	0.774	0.719	1.091	1.017	0.988	3.092	3.414
31645 kg	1.330	0.785	0.738	1.116	1.088	1.057	3.669	4.130
Triaxle (3.7m)								
20509 kg	0.998	0.849	0.875	0.965	0.954	0.966	2.131	2.686
26036 kg	1.127	0.929	0.922	1.024	1.049	1.080	3.065	3.633
31664 kg	1.232	0.956	0.936	1.054	1.095	1.101	3.830	4.074
Triaxle (4.9m)								
25836 kg	1.142	1.002	0.928	1.072	1.054	1.037	3.417	3.672
31995 kg	1.290	1.151	0.994	1.096	1.105	1.054	5.316	4.099

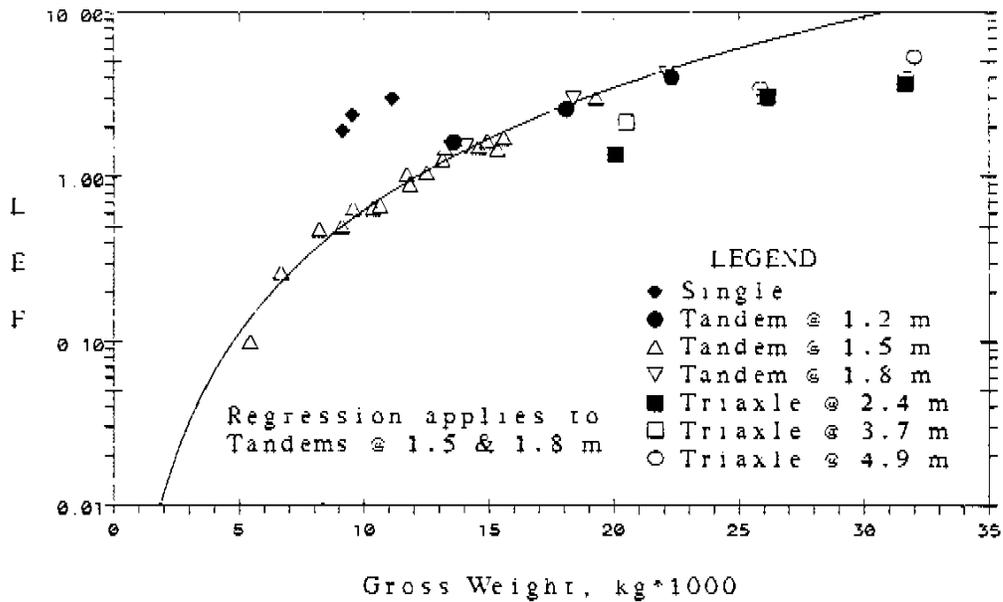


Figure 4.7: Load Equivalency Factors based on Deflections: Site 3B, Quebec

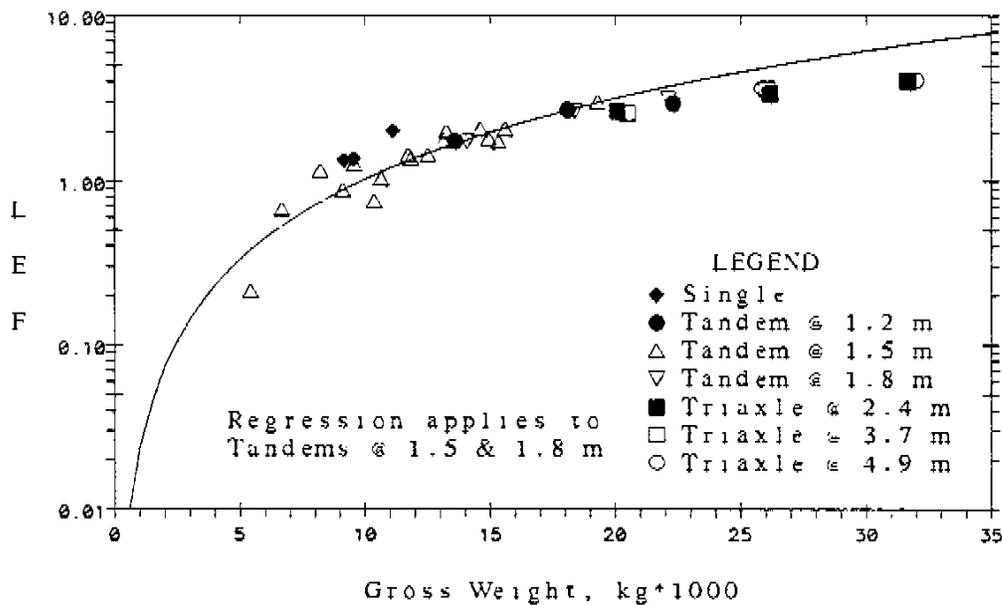


Figure 4.8: Load Equivalency Factors based on Strains: Site 3B, Quebec

A. Gross Weight-Load Equivalency Factor Relationships

Tandem (1.5 - 1.8 m) Axles
Maximum Gross Weight = 22100 kg

Based on Deflections:

$$F = 0.00216 (GW)^{2.462} \quad r^2 = 0.98 \quad N = 20 \quad \Delta S_{ey} = 0.056$$

Based on Strains:

$$F = 0.0240 (GW)^{1.631} \quad r^2 = 0.87 \quad N = 20 \quad \Delta S_{ey} = 0.097$$

where: GW = gross weight, kg x 10³

B. Equivalent Loadings

The following summarizes results of comparisons between equivalency factors for tandem (1.5 - 1.8 m) axle loads and equivalencies for all other axle loads and configurations tested at this site.

Note: Non-bracketed and bracketed gross weights are those obtained from comparisons of equivalency factors based on deflections and strains, respectively.

1. One application of a 12100 kg (9900 kg) tandem axle (1.5 - 1.8 m) - dual tire load is approximately equivalent in potential damaging effect to one application of the standard 8160 kg single axle-dual tire load.
2. For the range of loadings tested on carrying axle configurations of the pavement test vehicle, on average:

One application of a tandem (1.5 - 1.8 m) load is equivalent in potential damaging effect to one application of a single axle-dual tire configuration having a gross weight equal to approximately 57 (77) percent of the tandem (1.5 - 1.8 m) load. Average gross weight equivalents for other carrying axle configurations are:

<u>Configuration</u>	<u>Percent of Tandem (1.5-1.8 m) GW</u>
Tandem (1.2 m)	100 (104)
Triaxle (2.4 m)	146 (124)
Triaxle (3.7 m)	138 (124)
Triaxle (4.9 m)	132 (128)

4.5 LOAD EQUIVALENCY FACTORS

SITE 4

QUEBEC

Table 4.5
Average Pavement Response Ratios and
Load Equivalency Factors,
Site 4, Quebec

Loading Condition	Average Pavement Response Ratios						Load Equivalency Factors	
	Pavement Surface Deflections			Interfacial Tensile Strains			Based on	
	D_1/D_b	Δ_1/D_b	Δ_2/D_b	S_1/S_b	S_2/S_b	S_3/S_b	Deflections	Strains
Single Axle								
9182 kg	1.190			1.134			1.937	1.613
11127 kg	1.386			1.169			3.457	1.810
Tandem Axle (1.2m)								
13582 kg	1.092	0.378		1.210	1.310		1.422	4.854
18100 kg	1.367	0.467		1.134	1.197		3.336	3.593
22327 kg	1.639	0.555		1.138	1.223		6.644	3.783
Tandem Axle (1.5m)								
5445 kg	0.503	0.242		0.859	0.721		0.078	0.850
9109 kg	0.750	0.368		1.149	1.083		0.358	3.049
9556 kg	0.775	0.379		1.090	1.047		0.407	2.578
10345 kg	0.838	0.419		1.011	0.944		0.548	1.846
10645 kg	0.912	0.482		0.978	0.939		0.767	1.705
11718 kg	0.917	0.467		1.118	1.097		0.775	2.949
11827 kg	0.936	0.468		1.176	1.146		0.834	3.524
12500 kg	0.950	0.472		0.995	0.982		0.881	1.914
13136 kg	0.988	0.477		1.059	1.037		1.015	2.391
13236 kg	0.983	0.476		1.069	1.026		0.996	2.931
14582 kg	1.095	0.534		1.064	1.030		1.504	2.385
14936 kg	1.101	0.552		1.155	1.115		1.546	3.241
15336 kg	1.076	0.526		1.188	1.142		1.408	3.460
15582 kg	1.145	0.553		1.219	1.130		1.778	3.713
Tandem Axle (1.8m)								
14064 kg	1.051	0.559		1.172	1.158		1.318	3.574
18382 kg	1.301	0.697		1.189	1.237		2.972	4.175
22127 kg	1.444	0.797		1.202	1.120		4.462	3.550
Triaxle (2.4m)								
20082 kg	1.084	0.422	0.315	1.091	1.036	1.079	1.409	3.871
26145 kg	1.361	0.546	0.421	1.062	1.099	1.123	3.364	4.243
31645 kg	1.615	0.699	0.566	1.030	1.084	1.121	6.552	4.021
Triaxle (3.7m)								
20509 kg	0.971	0.610	0.538	1.107	1.223	1.154	1.142	5.344
26036 kg	1.090	0.717	0.650	1.184	1.228	1.116	1.864	5.600
31645 kg	1.319	0.839	0.793	1.128	1.192	1.180	3.791	5.405

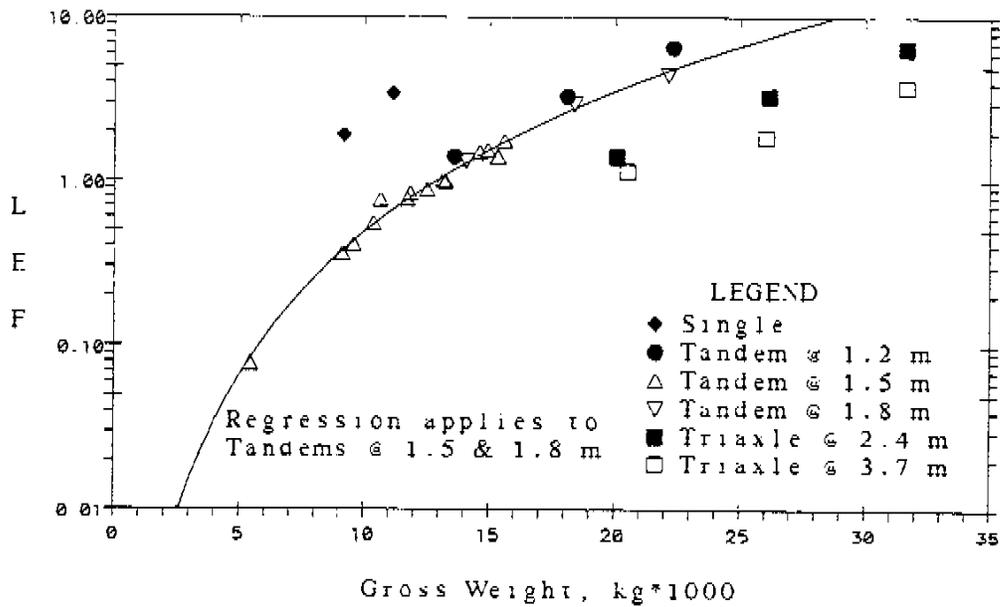


Figure 4.9: Load Equivalency Factors based on Deflections: Site 4, Quebec

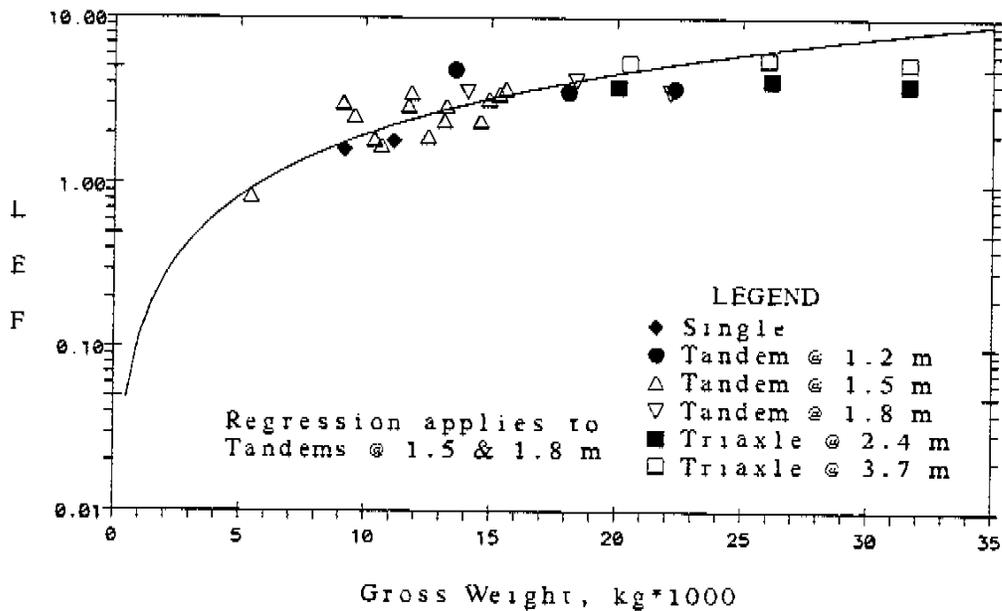


Figure 4.10: Load Equivalency Factors based on Strains: Site 4, Quebec

A. Gross Weight-Load Equivalency Factor Relationships

Tandem (1.5 - 1.8 m) Axles
Maximum Gross Weight = 22100 kg

Based on Deflections:

$$F = 0.000647 (GW)^{2.874} \quad r^2 = 0.99 \quad N = 17 \quad \sigma_{Se_y} = 0.0408$$

Based on Strains:

$$F = 0.1149 (GW)^{1.2318} \quad r^2 = 0.74 \quad N = 15 \quad \sigma_{Se_y} = 0.091$$

where: GW = gross weight, kg $\times 10^3$

B. Equivalent Loadings

The following summarizes results of comparisons between equivalency factors for tandem (1.5 - 1.8 m) axle loads and equivalencies for all other axle loads and configurations tested at this site.

Note: Non-bracketed and bracketed gross weights are those obtained from comparisons of equivalency factors based on deflections and strains, respectively.

1. One application of a 12900 kg (5800 kg) tandem axle (1.5 - 1.8 m) - dual tire load is approximately equivalent in potential damaging effect to one application of the standard 8160 kg single axle-dual tire load.
2. For the range of loadings tested on carrying axle configurations of the pavement test vehicle, on average:

One application of a tandem (1.5 - 1.8 m) load is equivalent in potential damaging effect to one application of a single axle-dual tire configuration having a gross weight equal to approximately 57 (100) percent of the tandem (1.5 - 1.8 m) load. Average gross weight equivalents for other carrying axle configurations are:

<u>Configuration</u>	<u>Percent of Tandem (1.5-1.8 m) GW</u>
Tandem (1.2 m)	92 (102)
Triaxle (2.4 m)	133 (144)
Triaxle (3.7 m)	156 (114)

4.6 LOAD EQUIVALENCY FACTORS

SITE 5

QUEBEC

Table 4.6
Average Pavement Response Ratios and
Load Equivalency Factors,
Site 5, Quebec

Loading Condition	Average Pavement Response Ratios						Load Equivalency Factors	
	Pavement Surface Deflections			Interfacial Tensile Strains			Based on	
	D_1/D_b	Δ_1/D_b	Δ_2/D_b	S_1/S_b	S_2/S_b	S_3/S_b	Deflections	Strains
Single Axle								
9182 kg	1.210			1.153			2.006	1.178
11127 kg	1.344			1.149			3.076	1.695
Tandem Axle (1.2m)								
13582 kg	1.103	0.411		1.263	1.138		1.485	4.063
18100 kg	1.324	0.516		1.218	1.173		2.986	3.949
22327 kg	1.534	0.532		1.102	1.114		5.174	2.954
Tandem Axle (1.5m)								
5445 kg	0.501	0.232		0.580	0.483		0.076	0.189
9109 kg	0.773	0.418		1.106	0.982		0.412	2.400
9555 kg	0.795	0.399		0.968	0.879		0.449	1.496
10345 kg	0.853	0.419		0.915	0.838		0.583	1.224
10645 kg	0.890	0.455		0.915	0.855		0.692	1.265
11718 kg	0.970	0.496		1.055	0.998		0.960	2.218
11827 kg	0.914	0.500		1.158	1.087		0.782	3.119
12500 kg	0.996	0.482		1.060	1.084		1.047	2.562
13136 kg	0.975	0.453		1.004	0.912		0.958	1.720
13236 kg	0.984	0.477		1.106	1.075		1.001	2.783
14582 kg	1.074	0.525		1.223	1.131		1.398	3.745
14936 kg	1.065	0.563		1.026	0.992		1.383	2.072
15336 kg	1.054	0.494		0.901	0.804		1.290	1.109
15682 kg	1.171	0.564		1.025	0.929		1.935	1.854
Tandem Axle (1.8m)								
14064 kg	1.052	0.545		1.227	1.178		1.312	4.039
18382 kg	1.243	0.610		1.188	1.170		2.438	3.740
22127 kg	1.424	0.774		1.162	1.160		4.209	3.527
Triaxle (2.4m)								
20082 kg	1.146	0.503	0.386	1.060	0.921	0.987	1.779	2.931
26145 kg	1.323	0.561	0.426	1.214	1.178	1.202	3.047	5.966
31645 kg	1.499	0.675	0.527	1.143	1.220	1.197	4.969	5.771
Triaxle (3.7m)								
20509 kg	0.928	0.568	0.512	1.063	1.118	1.023	0.948	3.835
26036 kg	1.088	0.729	0.655	1.213	1.221	1.158	1.879	5.965
31664 kg	1.255	0.781	0.691	1.173	1.213	1.151	3.007	5.623

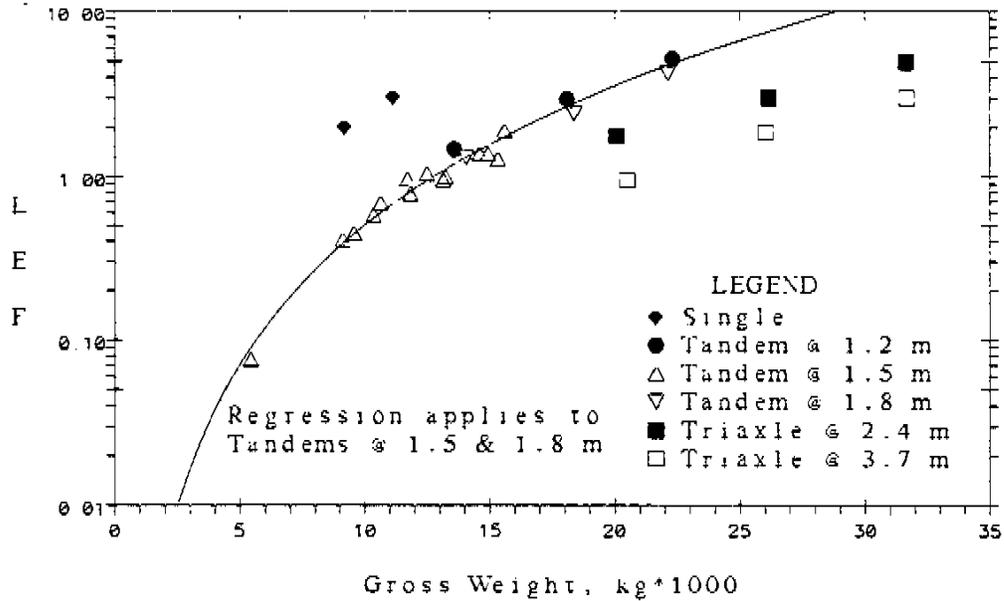


Figure 4.11 Load Equivalency Factors based on Deflections: Site 5, Quebec

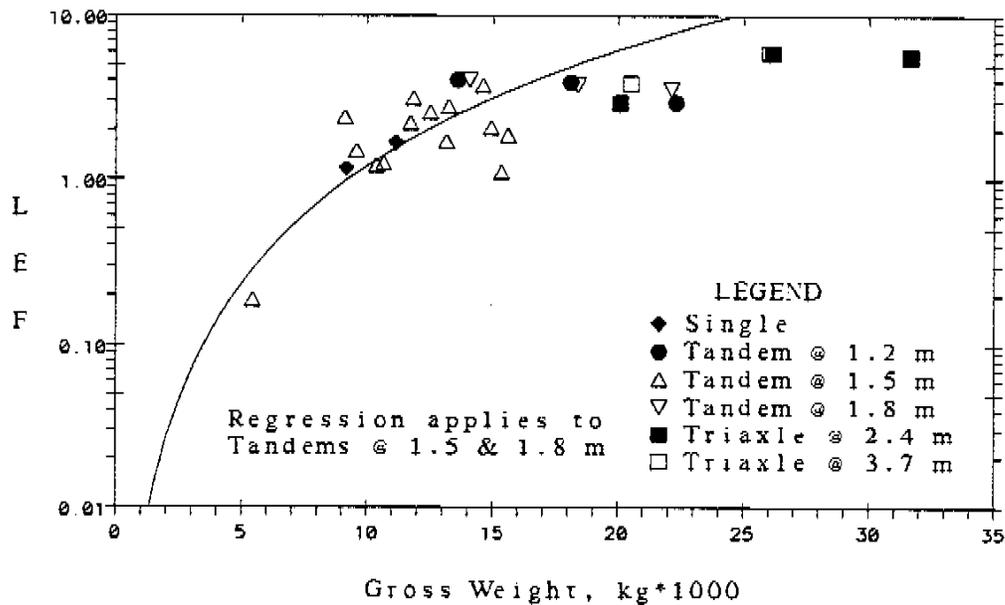


Figure 4.12 Load Equivalency Factors based on Strains: Site 5, Quebec

A. Gross Weight-Load Equivalency Factor Relationships

Tandem (1.5 - 1.8 m) Axles
Maximum Gross Weight = 22100 kg

Based on Deflections:

$$F = 0.000786 (GW)^{2.818} \quad r^2 = 0.93 \quad N = 17 \quad \Delta S_{ey} = 0.0974$$

Based on Strains:

$$F = 0.00528 (GW)^{2.358} \quad r^2 = 0.78 \quad N = 14 \quad \Delta S_{ey} = 0.156$$

where: GW = gross weight, kg $\times 10^3$

B. Equivalent Loadings

The following summarizes results of comparisons between equivalency factors for tandem (1.5 - 1.8 m) axle loads and equivalencies for all other axle loads and configurations tested at this site.

Note: Non-bracketed and bracketed gross weights are those obtained from comparisons of equivalency factors based on deflections and strains, respectively.

1. One application of a 12600 kg (9300 kg) tandem axle (1.5 - 1.8 m) - dual tire load is approximately equivalent in potential damaging effect to one application of the standard 8160 kg single axle-dual tire load.
2. For the range of loadings tested on carrying axle configurations of the pavement test vehicle, on average:

One application of a tandem (1.5 - 1.8 m) load is equivalent in potential damaging effect to one application of a single axle-dual tire configuration having a gross weight equal to approximately 58 (95) percent of the tandem (1.5 - 1.8 m) load. Average gross weight equivalents for other carrying axle configurations are:

<u>Configuration</u>	<u>Percent of Tandem (1.5-1.8 m) GW</u>
Tandem (1.2 m)	97 (114)
Triaxle (2.4 m)	137 (144)
Triaxle (3.7 m)	165 (141)

4.7 LOAD EQUIVALENCY FACTORS

SITE 6

ONTARIO

Table 4.7
Average Pavement Response Ratios and
Load Equivalency Factors,
Site 6, Ontario

Loading Condition	Average Pavement Response Ratios						Load Equivalency Factors	
	Pavement Surface Deflections			Interfacial Tensile Strains			Based on	
	D_1/D_0	Δ_1/D_0	Δ_2/D_0	S_1/S_0	S_2/S_0	S_3/S_0	Deflections	Strains
Steering Axle								
3790 kg	0.837			1.048			0.509	1.196
5110 kg	0.964			1.245			0.870	2.297
Single Axle								
9182 kg	1.130			1.090			1.591	1.387
9570 kg	1.170			1.111			1.816	1.492
11127 kg	1.260			1.165			2.409	1.787
Tandem Axle (1.2m)								
13582 kg	1.062	0.673		1.032	0.950		1.481	1.950
18100 kg	1.208	0.736		1.073	1.067		2.365	2.541
22327 kg	1.416	0.845		1.094	1.032		4.277	2.535
Tandem Axle (1.5m)								
5445 kg	0.481	0.317		0.639	0.598		0.075	0.325
6682 kg	0.583	0.395		0.784	0.719		0.158	0.682
8209 kg	0.659	0.499		0.808	0.791		0.276	0.854
9109 kg	0.661	0.521		0.782	0.754		0.292	0.735
9565 kg	0.791	0.601		1.001	0.952		0.555	1.836
10345 kg	0.783	0.605		0.920	0.879		0.543	1.339
10645 kg	0.808	0.591		0.936	0.925		0.580	1.520
11718 kg	0.842	0.610		0.961	0.930		0.674	1.620
11827 kg	0.896	0.693		1.023	0.976		0.907	2.001
12500 kg	0.984	0.723		1.049	1.010		1.234	2.241
13136 kg	0.933	0.658		0.969	0.949		0.972	1.705
13236 kg	0.941	0.674		1.018	0.990		1.016	2.034
14582 kg	1.034	0.801		1.077	1.010		1.564	2.367
14936 kg	1.032	0.767		1.109	1.056		1.492	2.710
15336 kg	1.035	0.772		1.060	1.019		1.514	2.325
15582 kg	1.088	0.818		1.139	1.055		1.842	2.869
19280 kg	1.211	0.868		1.131	1.068		2.653	2.879
Tandem Axle (1.8m)								
14064 kg	1.098	0.802		1.053	0.995		1.858	2.197
18382 kg	1.220	0.934		1.073	1.062		2.899	2.562
22127 kg	1.265	0.977		1.152	1.188		3.357	3.638
Triaxle (2.4m)								
20082 kg	1.067	0.683	0.653	1.022	0.934	0.930	1.712	2.616
26145 kg	1.182	0.724	0.688	1.007	0.972	1.006	2.425	2.946
31645 kg	1.319	0.798	0.768	1.152	1.116	1.168	3.652	5.036
Triaxle (3.7m)								
20510 kg	0.958	0.796	0.828	1.066	1.027	1.010	1.756	3.420
26036 kg	0.996	0.831	0.834	0.976	1.022	1.067	1.979	3.277
31664 kg	1.130	0.940	0.960	1.046	1.032	1.060	3.235	3.561
Triaxle (4.9m)								
25836 kg	1.010	0.888	0.940	1.076	1.015	1.057	2.467	3.615
31955 kg	1.194	1.064	0.990	1.162	1.098	1.077	4.189	4.523

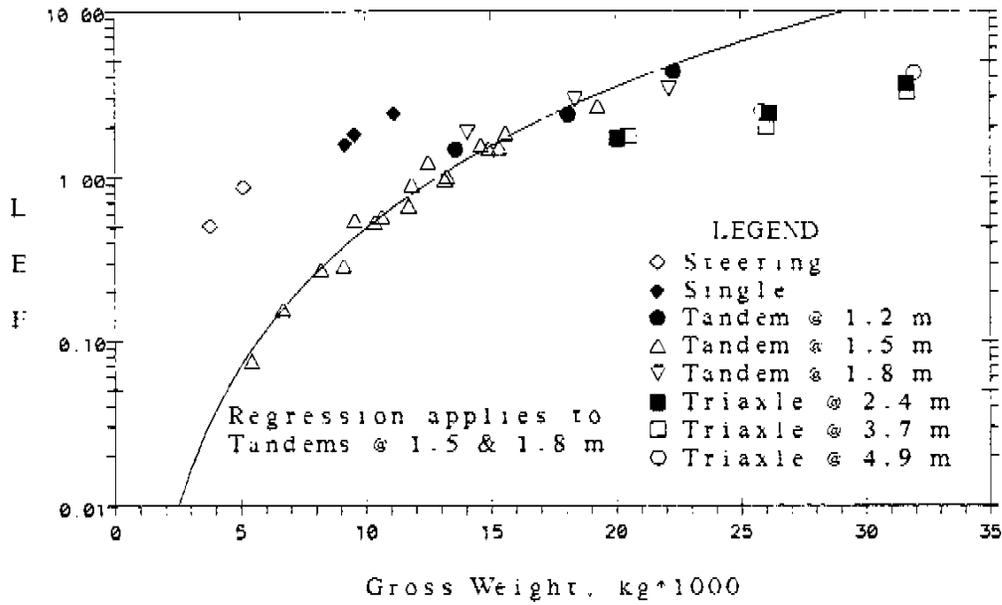


Figure 4.13: Load Equivalency Factors based on Deflections. Site 6, Ontario

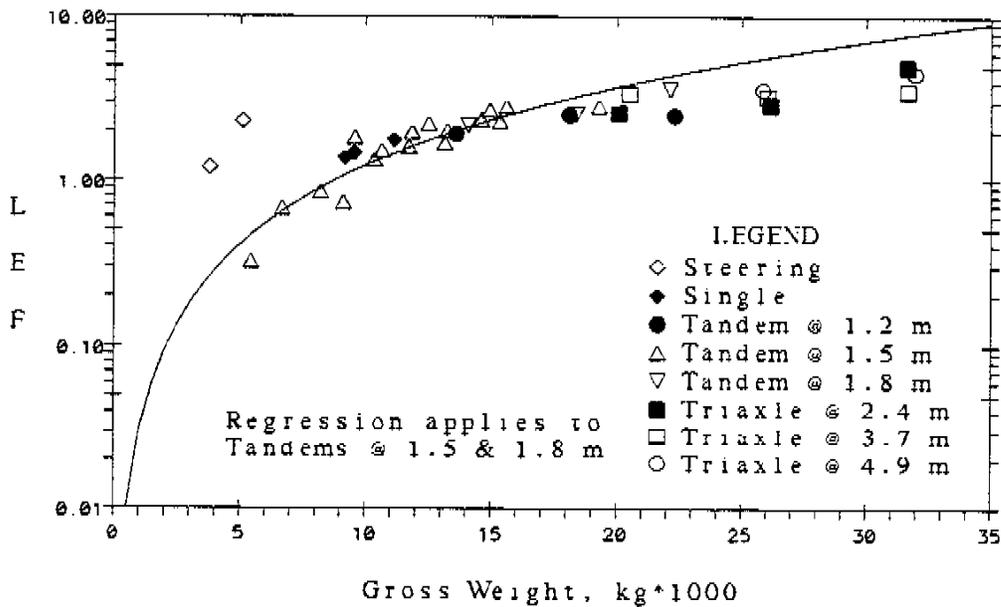


Figure 4.14: Load Equivalency Factors based on Strains: Site 6, Ontario

A. Gross Weight-Load Equivalency Factor Relationships

Tandem (1.5 - 1.8 m) Axles
Maximum Gross Weight = 22100 kg

Based on Deflections:

$$F = 0.000764 (\text{GW})^{2.809} \quad r^2 = 0.97 \quad N = 20 \quad S_{ey} = 0.076$$

Based on Strains:

$$F = 0.0307 (\text{GW})^{1.603} \quad r^2 = 0.88 \quad N = 20 \quad S_{ey} = 0.089$$

where: GW = gross weight, kg x 10³

B. Equivalent Loadings

The following summarizes results of comparisons between equivalency factors for tandem (1.5 - 1.8 m) axle loads and equivalencies for all other axle loads and configurations tested at this site.

Note: Non-bracketed and bracketed gross weights and load applications are those obtained from comparisons of equivalency factors based on deflections and strains, respectively.

1. One application of a 12900 kg (8800 kg) tandem axle (1.5 - 1.8 m) - dual tire load is approximately equivalent in potential damaging effect to one application of the standard 8160 kg single axle-dual tire load.
2. For the range of loadings tested on carrying axle configurations of the pavement test vehicle, on average:

One application of a tandem (1.5 - 1.8 m) load is equivalent in potential damaging effect to one application of a single axle-dual tire configuration having a gross weight equal to approximately 61 (85) percent of the tandem (1.5 - 1.8 m) load. Average gross weight equivalents for other carrying axle configurations are:

<u>Configuration</u>	<u>Percent of Tandem (1.5-1.8 m) GW</u>
Tandem (1.2 m)	100 (115)
Triaxle (2.4 m)	144 (136)
Triaxle (3.7 m)	150 (138)
Triaxle (4.9 m)	147 (137)

3. At comparable load magnitudes (approximately 5000 kg), one application of a single steering axle is equivalent in potential damaging effect to approximately 12 (7) applications of tandem axle (1.5 - 1.8 m) - dual tire configuration.

4.8 LOAD EQUIVALENCY FACTORS

SITE 7

ONTARIO

Table 4.8
Average Pavement Response Ratios and
Load Equivalency Factors,
Site 7, Ontario

Loading Condition	Average Pavement Response Ratios						Load Equivalency Factors	
	Pavement Surface Deflections			Interfacial Tensile Strains			Based on	
	D_1/D_b	Δ_1/D_b	Δ_2/D_b	S_1/S_b	S_2/S_b	S_3/S_b	Deflections	Strains
Single Axle								
9182 kg	1.163			1.020			1.775	1.078
11127 kg	1.294			1.137			2.663	1.629
Tandem Axle (1.2m)								
13582 kg	1.002	0.453		0.791	0.776		1.057	0.792
22327 kg	1.438	0.627		1.181	1.150		4.146	3.582
Tandem Axle (1.5m)								
5445 kg	0.452	0.247		0.376	0.361		0.054	0.045
9555 kg	0.735	0.447		0.683	0.675		0.357	0.459
10645 kg	0.795	0.449		0.683	0.666		0.466	0.448
11718 kg	0.810	0.474		0.768	0.765		0.508	0.728
12500 kg	0.830	0.546		0.841	0.826		0.593	1.002
13136 kg	0.932	0.619		0.893	0.885		0.927	1.279
13236 kg	0.945	0.624		0.899	0.866		0.973	1.246
14582 kg	1.006	0.620		0.933	0.906		1.186	1.456
15336 kg	1.024	0.600		0.958	0.934		1.238	1.621
15582 kg	1.000	0.538		0.939	0.917		1.095	1.507
Tandem Axle (1.8m)								
14064 kg	0.970	0.701		0.842	0.870		1.150	1.109
22127 kg	1.228	0.820		1.129	1.179		2.653	3.456
Triaxle (2.4m)								
20082 kg	0.937	0.414	0.366	0.759	0.660	0.755	0.838	0.901
31645 kg	1.297	0.520	0.427	1.062	0.986	1.025	2.809	3.259
Triaxle (3.7m)								
20509 kg	0.861	0.636	0.645	0.781	0.798	0.866	0.934	1.394
31664 kg	1.098	0.827	0.799	1.033	1.109	1.156	2.339	4.348

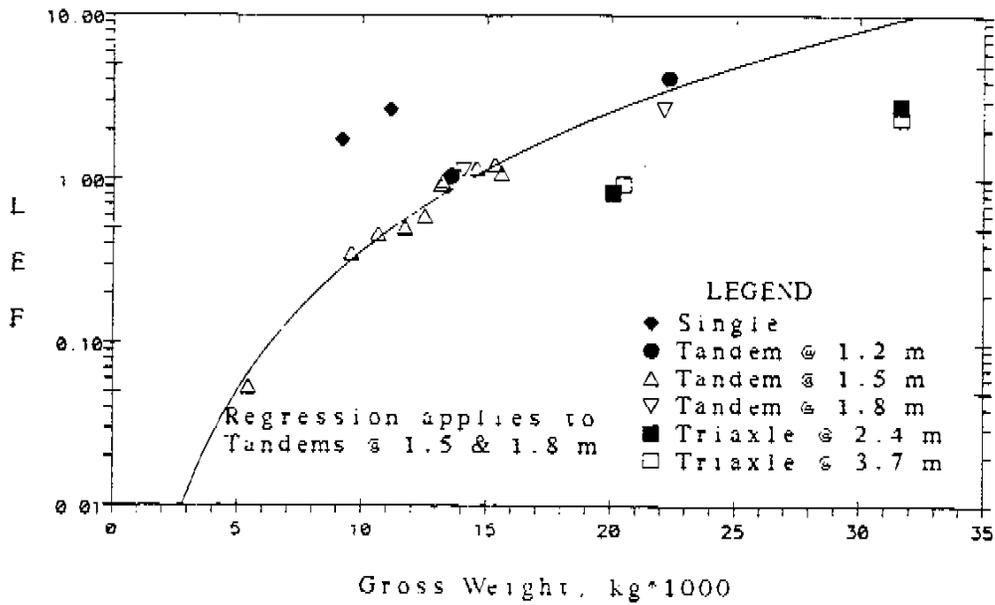


Figure 4.15: Load Equivalency Factors based on Deflections: Site 7, Ontario

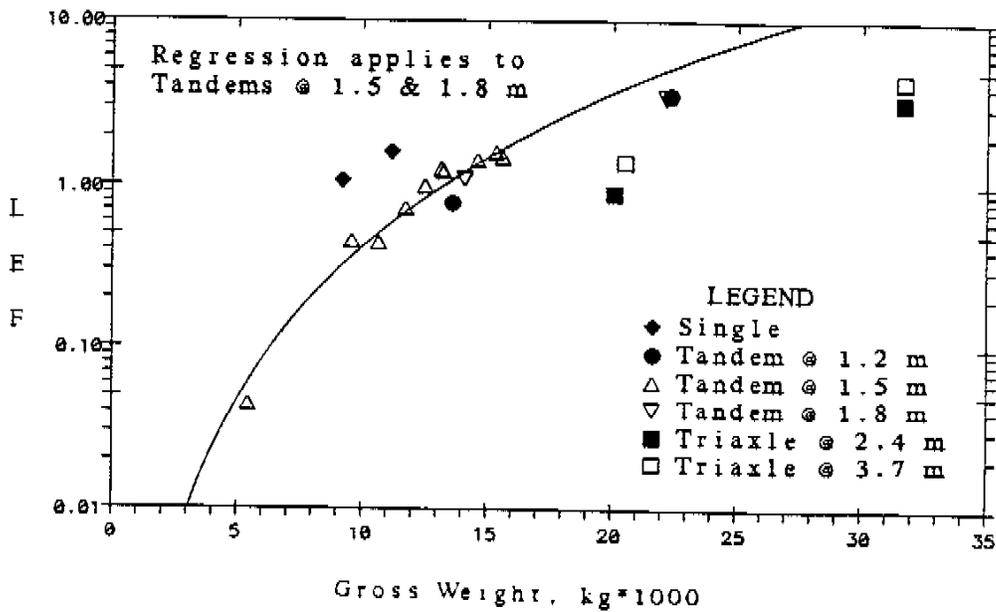


Figure 4.16: Load Equivalency Factors based on Strains: Site 7, Ontario

A. Gross Weight-Load Equivalency Factor Relationships

Tandem (1.5 - 1.8 m) Axles
Maximum Gross Weight = 22100 kg

Based on Deflections:

$$F = 0.000537 (GW)^{2.831} \quad r^2 = 0.98 \quad N = 12 \quad \Delta S_{ey} = 0.070$$

Based on Strains:

$$F = 0.0003 (GW)^{3.143} \quad r^2 = 0.96 \quad N = 12 \quad \Delta S_{ey} = 0.092$$

where: GW = gross weight, kg x 10³

B. Equivalent Loadings

The following summarizes results of comparisons between equivalency factors for tandem (1.5 - 1.8 m) axle loads and equivalencies for all other axle loads and configurations tested at this site.

Note: Non-bracketed and bracketed gross weights are those obtained from comparisons of equivalency factors based on deflections and strains, respectively.

1. One application of a 14300 kg (13200 kg) tandem axle (1.5 - 1.8 m) - dual tire load is approximately equivalent in potential damaging effect to one application of the standard 8160 kg single axle-dual tire load.
2. For the range of loadings tested on carrying axle configurations of the pavement test vehicle, on average:

One application of a tandem (1.5 - 1.8 m) load is equivalent in potential damaging effect to one application of a single axle-dual tire configuration having a gross weight equal to approximately 53 (70) percent of the tandem (1.5 - 1.8 m) load. Average gross weight equivalents for other carrying axle configurations are:

<u>Configuration</u>	<u>Percent of Tandem (1.5-1.8 m) GW</u>
Tandem (1.2 m)	94 (111)
Triaxle (2.4 m)	152 (161)
Triaxle (3.7 m)	155 (145)

4.9 LOAD EQUIVALENCY FACTORS

SITE 8

ONTARIO

Table 4.9
Average Pavement Response Ratios and
Load Equivalency Factors,
Site 8, Ontario

Loading Condition	Average Pavement Response Ratios						Load Equivalency Factors	
	Pavement Surface Deflections			Interfacial Tensile Strains			Based on	
	D_1/D_b	Δ_1/D_b	Δ_2/D_b	S_1/S_b	S_2/S_b	S_3/S_b	Deflections	Strains
Single Axle 9182 kg 11127 kg	1.016 1.215			1.010 1.159			1.063 2.098	1.040 1.754
Tandem Axle (1.2m) 13582 kg 22327 kg	0.898 1.289	0.273 0.605		0.786 1.134	0.777 1.126		0.672 2.772	0.784 3.182
Tandem Axle (1.5m) 5445 kg 9555 kg 10645 kg 11718 kg 12500 kg 13136 kg 13236 kg 14582 kg 15336 kg 15582 kg	0.420 0.636 0.710 0.788 0.766 0.839 0.824 0.907 0.924 0.990	0.228 0.294 0.411 0.433 0.361 0.390 0.410 0.464 0.603 0.477		0.384 0.607 0.706 0.734 0.745 0.785 0.774 0.876 0.882 0.941	0.390 0.581 0.689 0.733 0.738 0.781 0.775 0.879 0.887 0.969		0.041 0.188 0.306 0.445 0.385 0.542 0.513 0.743 0.886 1.024	0.054 0.277 0.509 0.615 0.641 0.789 0.757 1.217 1.254 1.645
Tandem Axle (1.8m) 14064 kg 22127 kg	0.834 1.255	0.509 0.822		0.815 1.119	0.875 1.199		0.579 2.845	1.062 3.526
Triaxle (2.4m) 20082 kg 31645 kg	0.913 1.210	0.323 0.511	0.294 0.451	0.758 1.073	0.731 1.024	0.831 1.114	0.732 2.190	1.149 3.909
Triaxle (3.7m) 20509 kg 31664 kg	0.744 1.031	0.486 0.828	0.463 0.808	0.717 0.976	0.792 1.080	0.860 1.151	0.443 2.057	1.235 3.961

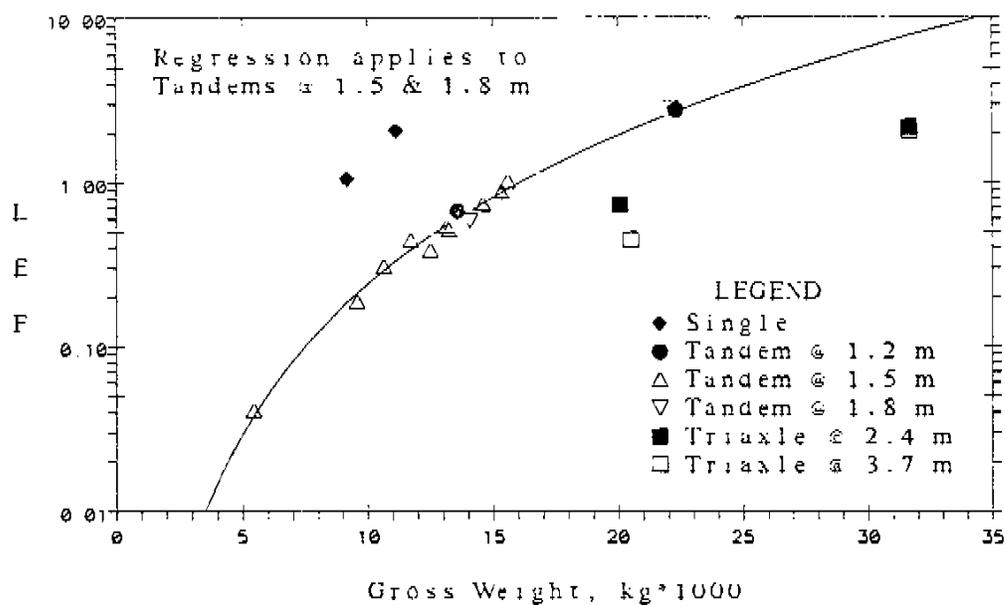


Figure 4.17 Load Equivalency Factors based on Deflections: Site 8, Ontario

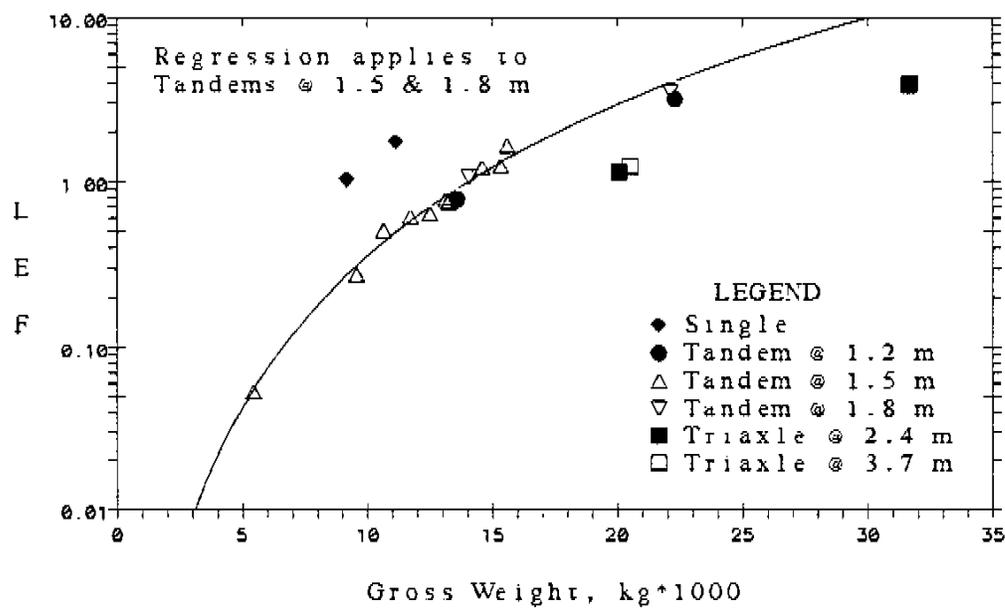


Figure 4.18 Load Equivalency Factors based on Strains: Site 8, Ontario

A. Gross Weight-Load Equivalency Factor Relationships

Tandem (1.5 - 1.8 m) Axles
Maximum Gross Weight = 22100 kg

Based on Deflections:

$$F = 0.00023 (GW)^{3.020} \quad r^2 = 0.99 \quad N = 12 \quad \Delta S_{ey} = 0.046$$

Based on Strains:

$$F = 0.000322 (GW)^{3.043} \quad r^2 = 0.99 \quad N = 12 \quad \Delta S_{ey} = 0.046$$

where: GW = gross weight, kg x 10³

B. Equivalent Loadings

The following summarizes results of comparisons between equivalency factors for tandem (1.5 - 1.8 m) axle loads and equivalencies for all other axle loads and configurations tested at this site.

Note: Non-bracketed and bracketed gross weights are those obtained from comparisons of equivalency factors based on deflections and strains, respectively.

1. One application of a 16100 kg (14100 kg) tandem axle (1.5 - 1.8 m) - dual tire load is approximately equivalent in potential damaging effect to one application of the standard 8160 kg single axle-dual tire load.
2. For the range of loadings tested on carrying axle configurations of the pavement test vehicle, on average:

One application of a tandem (1.5 - 1.8 m) load is equivalent in potential damaging effect to one application of a single axle-dual tire configuration having a gross weight equal to approximately 55 (65) percent of the tandem (1.5 - 1.8 m) load. Average gross weight equivalents for other carrying axle configurations are:

<u>Configuration</u>	<u>Percent of Tandem (1.5-1.8 m) GW</u>
Tandem (1.2 m)	98 (106)
Triaxle (2.4 m)	145 (140)
Triaxle (3.7 m)	162 (140)

4.10 LOAD EQUIVALENCY FACTORS

SITE 9

ALBERTA

Table 4.10
Average Pavement Response Ratios and
Load Equivalency Factors,
Site 9, Alberta

Loading Condition	Average Pavement Response Ratios						Load Equivalency Factors	
	Pavement Surface Deflections			Interfacial Tensile Strains			Based on	
	D_1/D_b	Δ_1/D_b	Δ_2/D_b	S_1/S_b	S_2/S_b	S_3/S_b	Deflections	Strains
Steering Axle								
3790 kg	0.590			0.895			0.135	0.656
5110 kg	0.778			1.070			0.385	1.293
Single Axle								
9182 kg	1.107			1.067			1.472	1.373
9570 kg	1.319			1.083			2.864	1.354
11127 kg	1.367			1.207			3.280	2.044
Tandem Axle (1.2m)								
13582 kg	1.106	0.334		0.984	0.814		1.482	1.398
18100 kg	1.455	0.384		1.079	0.875		4.184	1.937
22327 kg	1.657	0.449		1.223	1.035		6.862	3.289
Tandem Axle (1.5m)								
5445 kg	0.578	0.331		0.558	0.503		0.140	0.182
6682 kg	0.718	0.433		0.708	0.642		0.326	0.455
8209 kg	0.682	0.327		0.724	0.658		0.248	0.497
9109 kg	0.784	0.389		0.808	0.744		0.424	0.770
9555 kg	0.810	0.349		0.851	0.707		0.467	0.809
10345 kg	0.839	0.508		0.888	0.826		0.589	1.120
10645 kg	0.958	0.573		0.978	0.940		0.970	1.709
11718 kg	0.872	0.413		0.884	0.798		0.629	1.050
11827 kg	0.857	0.388		0.880	0.810		0.584	1.064
12500 kg	0.943	0.415		0.995	0.856		0.835	1.535
13136 kg	1.006	0.472		0.931	0.863		1.081	1.333
13236 kg	0.960	0.455		0.968	0.872		0.906	1.478
14582 kg	1.100	0.442		1.092	0.946		1.436	1.478
14936 kg	1.145	0.443		1.067	0.973		1.718	2.181
15336 kg	1.105	0.569		1.046	0.965		1.579	2.131
15582 kg	1.173	0.565		1.113	1.041		1.948	2.667
19280 kg	1.389	0.564		1.204	1.035		3.599	3.164
Tandem Axle (1.8m)								
14064 kg	1.036	0.470		1.010	0.888		1.201	1.675
18382 kg	1.219	0.564		1.080	1.023		2.236	2.430
22127 kg	1.427	0.632		1.204	1.178		4.037	3.888
Triaxle (2.4m)								
20082 kg	1.160	0.462	0.385	0.917	0.729	0.733	1.837	1.327
26145 kg	1.297	0.556	0.472	1.131	0.922	0.934	2.852	3.102
31645 kg	1.583	0.650	0.515	1.181	1.033	1.029	6.003	4.128
Triaxle (3.7m)								
20509 kg	1.015	0.557	0.458	0.903	0.881	0.821	1.218	1.769
26036 kg	1.182	0.656	0.633	0.977	0.992	0.996	2.265	2.870
31664 kg	1.328	0.805	0.788	1.123	1.151	1.117	3.782	4.783
Triaxle (4.9m)								
25836 kg	1.106	0.849	0.628	1.040	1.022	1.012	1.466	3.298
31955 kg	1.289	0.981	0.791	1.165	1.102	1.126	3.964	4.803

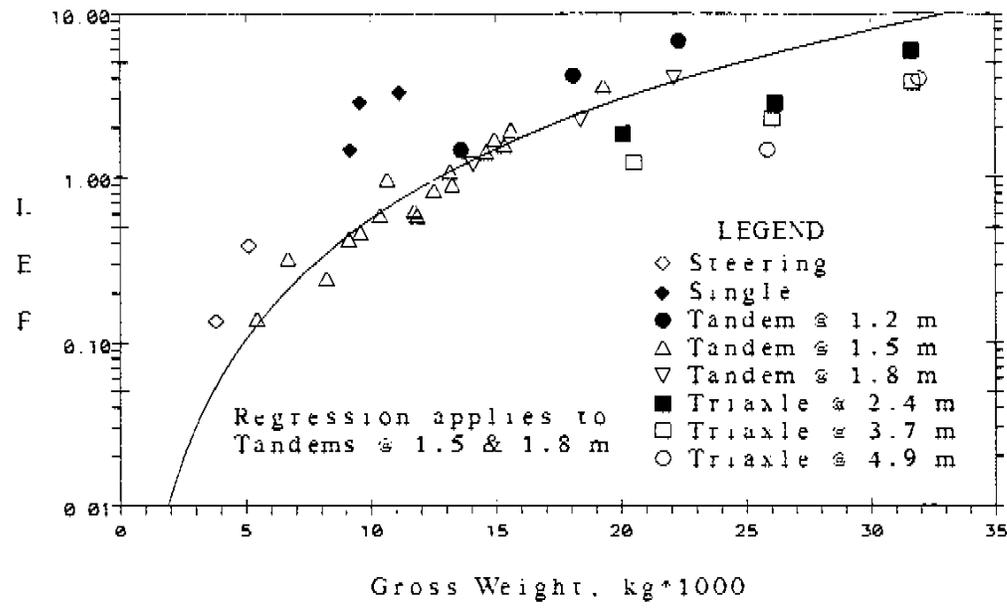


Figure 4.19 Load Equivalency Factors based on Deflections: Site 9, Alberta

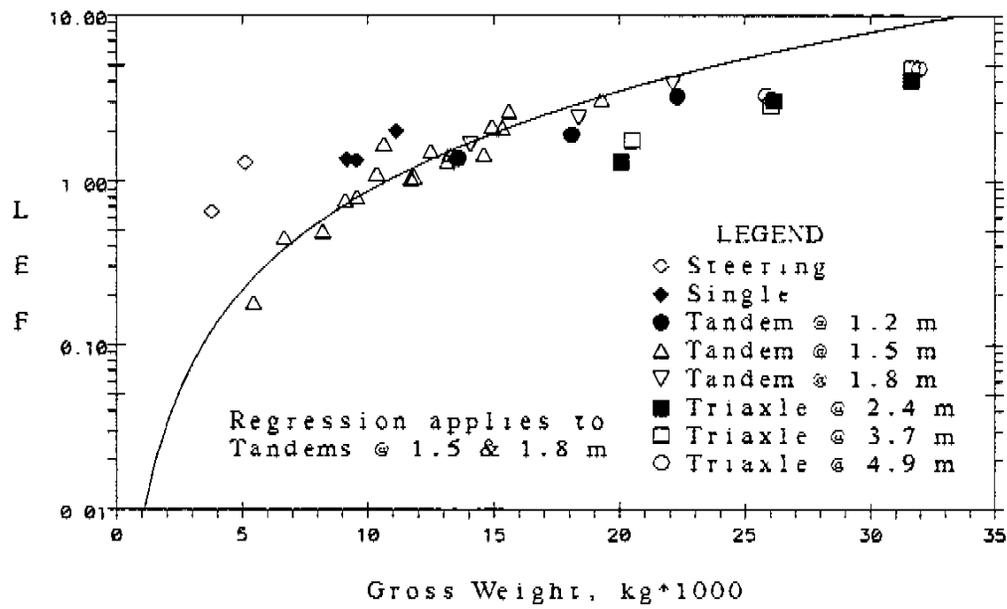


Figure 4.20: Load Equivalency Factors based on Strains: Site 9, Alberta

A. Gross Weight-Load Equivalency Factor Relationships

Tandem (1.5 - 1.8 m) Axles
Maximum Gross Weight = 22100 kg

Based on Deflections:

$$F = 0.00218 (GW)^{2.411} \quad r^2 = 0.94 \quad N = 20 \quad \epsilon_{Se_y} = 0.094$$

Based on Strains:

$$F = 0.00845 (GW)^{2.012} \quad r^2 = 0.93 \quad N = 20 \quad \epsilon_{Se_y} = 0.086$$

where: GW = gross weight, kg x 10³

B. Equivalent Loadings

The following summarizes results of comparisons between equivalency factors for tandem (1.5 - 1.8 m) axle loads and equivalencies for all other axle loads and configurations tested at this site.

Note: Non-bracketed and bracketed gross weights and load applications are those obtained from comparisons of equivalency factors based on deflections and strains, respectively.

1. One application of a 12700 kg (10700 kg) tandem axle (1.5 - 1.8 m) - dual tire load is approximately equivalent in potential damaging effect to one application of the standard 8160 kg single axle-dual tire load.
2. For the range of loadings tested on carrying axle configurations of the pavement test vehicle, on average:

One application of a tandem (1.5 - 1.8 m) load is equivalent in potential damaging effect to one application of a single axle-dual tire configuration having a gross weight equal to approximately 55 (73) percent of the tandem (1.5 - 1.8 m) load. Average gross weight equivalents for other carrying axle configurations are:

<u>Configuration</u>	<u>Percent of Tandem (1.5-1.8 m) GW</u>
Tandem (1.2 m)	83 (114)
Triaxle (2.4 m)	125 (150)
Triaxle (3.7 m)	146 (141)
Triaxle (4.9 m)	157 (135)

3. At comparable load magnitudes (approximately 5000 kg), one application of a single steering axle is equivalent in potential damaging effect to approximately 4 (7) applications of tandem axle (1.5 - 1.8 m) - dual tire configuration.

4.11 LOAD EQUIVALENCY FACTORS

SITE 10

ALBERTA

Table 4.11
Average Pavement Response Ratios and
Load Equivalency Factors,
Site 10, Alberta

Loading Condition	Average Pavement Response Ratios						Load Equivalency Factors	
	Pavement Surface Deflections			Interfacial Tensile Strains			Based on	
	D_1/D_0	Δ_1/D_0	Δ_2/D_0	S_1/S_0	S_2/S_0	S_3/S_0	Deflections	Strains
Steering Axle								
3790 kg	0.710			1.048			0.272	1.196
5110 kg	0.880			1.196			0.615	1.974
Single Axle								
9182 kg	1.154			1.103			1.723	1.451
9570 kg	1.254			1.185			2.363	1.906
11127 kg	1.268			1.313			2.465	2.815
Tandem Axle (1.2m)								
13582 kg	1.089	0.489		1.001	0.970		1.449	1.896
18100 kg	1.324	0.471		1.092	1.040		2.962	2.558
22327 kg	1.584	0.513		1.280	1.154		5.821	4.278
Tandem Axle (1.5m)								
5446 kg	0.521	0.306		0.545	0.515		0.095	0.180
6682 kg	0.597	0.383		0.655	0.654		0.167	0.399
8209 kg	0.647	0.397		0.739	0.704		0.221	0.580
9109 kg	0.689	0.401		0.779	0.739		0.274	0.704
9555 kg	0.744	0.486		0.887	0.877		0.390	1.241
10345 kg	0.825	0.450		0.767	0.762		0.530	0.721
10646 kg	0.846	0.481		0.860	0.820		0.592	1.034
11718 kg	0.832	0.431		0.867	0.833		0.538	1.081
11827 kg	0.887	0.528		0.907	0.906		0.722	1.377
12500 kg	0.969	0.602		1.030	1.007		1.033	2.146
13136 kg	0.961	0.516		0.954	0.925		0.941	1.580
13236 kg	0.959	0.508		0.940	0.884		0.929	1.416
14582 kg	1.037	0.628		1.122	1.107		1.319	3.020
14936 kg	1.071	0.540		1.061	1.028		1.394	2.319
15336 kg	1.064	0.568		1.000	0.970		1.382	1.891
15582 kg	1.140	0.592		1.102	1.045		1.782	2.628
19280 kg	1.269	0.759		1.223	1.215		2.823	4.245
Tandem Axle (1.8m)								
14064 kg	1.079	0.646		1.049	0.996		1.525	2.184
18382 kg	1.268	0.741		1.124	1.117		2.785	3.082
22127 kg	1.313	0.763		1.287	1.243		3.172	4.673
Triaxle (2.4m)								
20082 kg	1.134	0.440	0.371	0.917	0.791	0.843	1.680	1.652
26145 kg	1.346	0.589	0.472	1.044	0.897	0.974	3.284	2.744
31645 kg	1.544	0.683	0.571	1.193	1.042	1.122	5.564	4.673
Triaxle (3.7m)								
20509 kg	0.932	0.626	0.620	0.994	1.027	0.997	1.096	3.073
26036 kg	1.069	0.742	0.718	1.032	1.111	1.115	1.894	4.131
31664 kg	1.296	0.912	0.897	1.165	1.211	1.233	4.037	6.073
Triaxle (4.9m)								
25836 kg	1.044	0.887	0.682	1.066	1.117	1.135	2.045	4.416
31955 kg	1.299	1.097	0.952	1.207	1.232	1.191	4.953	6.197

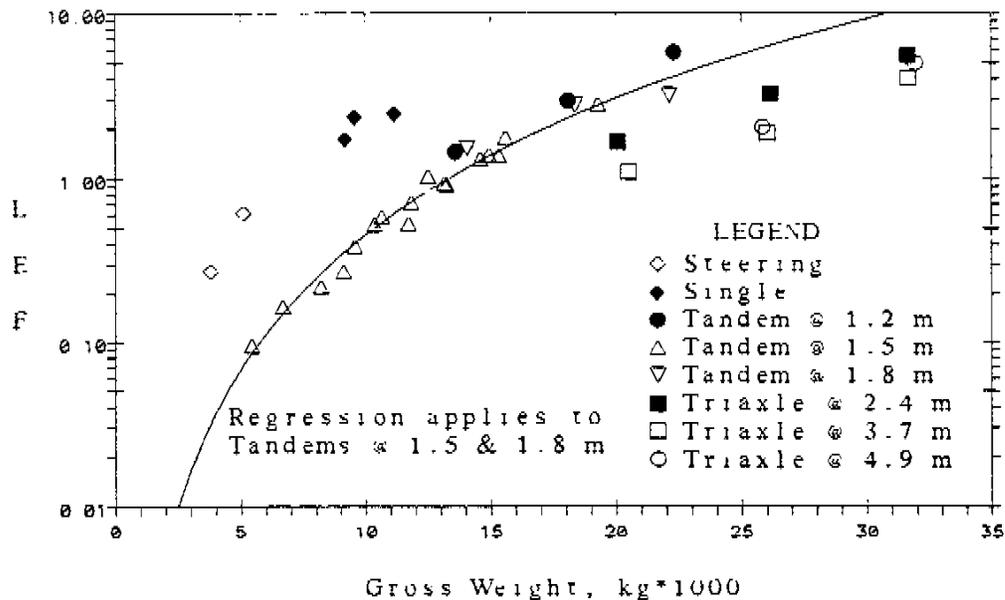


Figure 4.21: Load Equivalency Factors based on Deflections: Site 10, Alberta

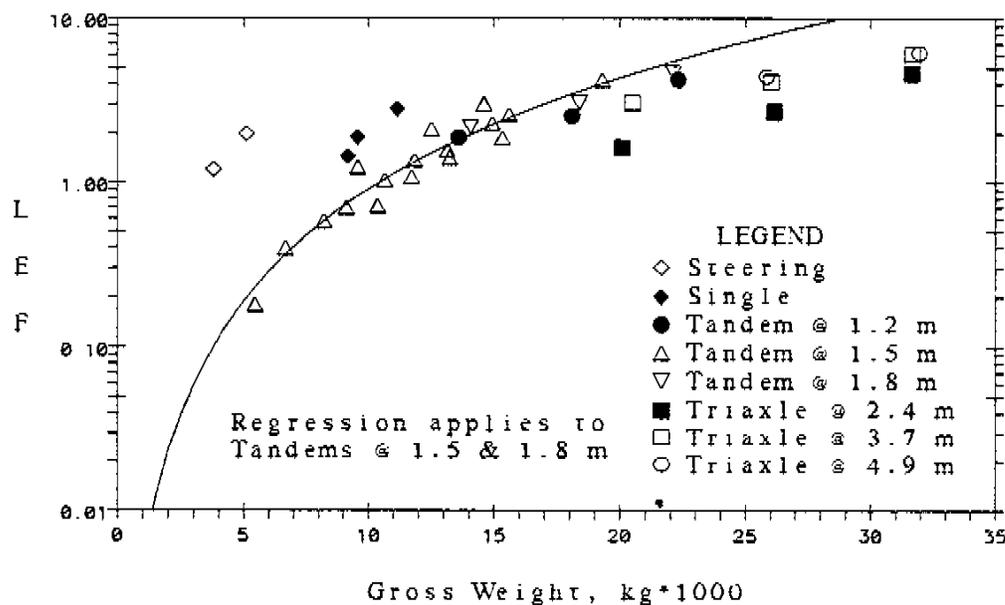


Figure 4.22: Load Equivalency Factors based on Strains: Site 10, Alberta

A. Gross Weight-Load Equivalency Factor Relationships

Tandem (1.5 - 1.8 m) Axles
Maximum Gross Weight = 22100 kg

Based on Deflections:

$$F = 0.00083 (GW)^{2.740} \quad r^2 = 0.98 \quad N = 20 \quad \Delta S_{ey} = 0.067$$

Based on Strains:

$$F = 0.0049 (GW)^{2.260} \quad r^2 = 0.94 \quad N = 20 \quad \Delta S_{ey} = 0.088$$

where: GW = gross weight, kg x 10³

B. Equivalent Loadings

The following summarizes results of comparisons between equivalency factors for tandem (1.5 - 1.8 m) axle loads and equivalencies for all other axle loads and configurations tested at this site.

Note: Non-bracketed and bracketed gross weights and load applications are those obtained from comparisons of equivalency factors based on deflections and strains, respectively.

1. One application of a 13300 kg (10400 kg) tandem axle (1.5 - 1.8 m) - dual tire load is approximately equivalent in potential damaging effect to one application of the standard 8160 kg single axle-dual tire load.
2. For the range of loadings tested on carrying axle configurations of the pavement test vehicle, on average:

One application of a tandem (1.5 - 1.8 m) load is equivalent in potential damaging effect to one application of a single axle-dual tire configuration having a gross weight equal to approximately 57 (70) percent of the tandem (1.5 - 1.8 m) load. Average gross weight equivalents for other carrying axle configurations are:

<u>Configuration</u>	<u>Percent of Tandem (1.5-1.8 m) GW</u>
Tandem (1.2 m)	89 (108)
Triaxle (2.4 m)	127 (156)
Triaxle (3.7 m)	149 (130)
Triaxle (4.9 m)	141 (133)

3. At comparable load magnitudes (approximately 5000 kg), one application of a single steering axle is equivalent in potential damaging effect to approximately 8 (10) applications of tandem axle (1.5 -1.8 m) - dual tire configuration.

4.12 LOAD EQUIVALENCY FACTORS

SITE 11

BRITISH COLUMBIA

Table 4.12
Average Pavement Response Ratios and
Load Equivalency Factors,
Site 11, British Columbia

Loading Condition	Average Pavement Response Ratios						Load Equivalency Factors	
	Pavement Surface Deflections			Interfacial Tensile Strains			Based on	
	D_1/D_b	Δ_1/D_b	Δ_2/D_b	S_1/S_b	S_2/S_b	S_3/S_b	Deflections	Strains
Single Axle								
9182 kg	1.110						1.487	
11127 kg	1.228						2.182	
Tandem Axle (1.2m)								
13582 kg	0.972	0.423					0.936	
22327 kg	1.417	0.663					3.970	
Tandem Axle (1.5m)								
5445 kg	0.455	0.368					0.073	
9555 kg	0.747	0.431					0.371	
10645 kg	0.787	0.487					0.467	
11718 kg	0.850	0.565					0.653	
12500 kg	0.893	0.530					0.740	
13136 kg	0.929	0.579					0.881	
13236 kg	0.937	0.599					0.923	
14582 kg	1.013	0.580					1.176	
15336 kg	1.007	0.633					1.203	
15582 kg	1.050	0.680					1.435	
Tandem Axle (1.8m)								
14064 kg	0.943	0.630					0.973	
22127 kg	1.249	0.908					3.021	
Triaxle (2.4m)								
20082 kg	1.027	0.531	0.506				1.272	
31645 kg	1.356	0.635	0.575				3.481	
Triaxle (3.7m)								
20509 kg	0.904	0.616	0.605				0.988	
31664 kg	1.184	0.864	0.862				3.042	

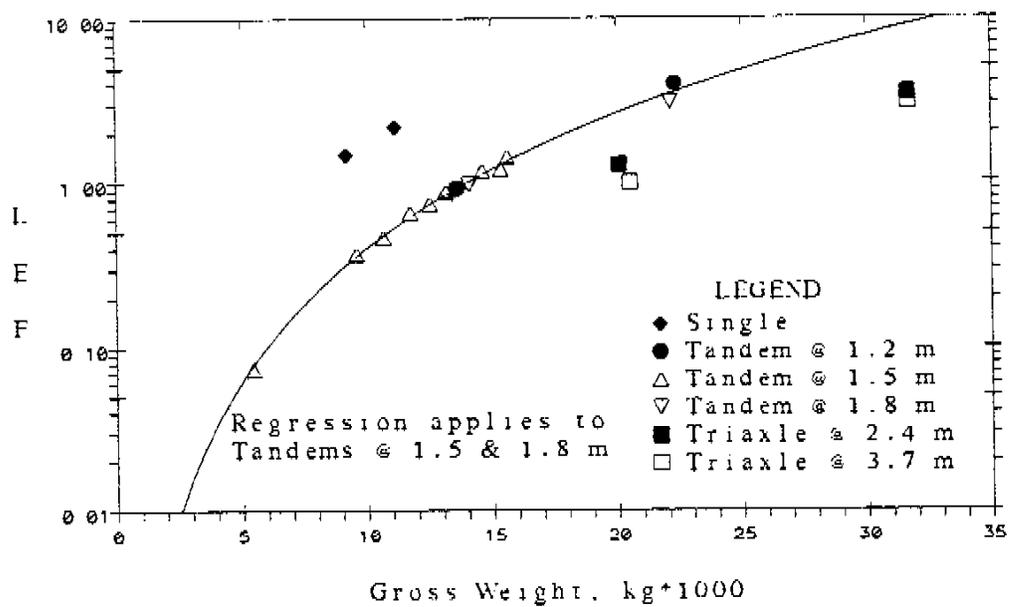


Figure 4.23: Load Equivalency Factors based on
Deflections: Site 11, British Columbia

A. Gross Weight-Load Equivalency Factor Relationships

Tandem (1.5 - 1.8 m) Axles
Maximum Gross Weight = 22100 kg

Based on Deflections:

$$F = 0.00083 (GW)^{2.687} \quad r^2 = 0.49 \quad N = 12 \quad S_{ey} = 0.028$$

where: GW = gross weight, kg x 10³

B. Equivalent Loadings

The following summarizes results of comparisons between equivalency factors for tandem (1.5 - 1.8 m) axle loads and equivalencies for all other axle loads and configurations tested at this site.

Note: Non-bracketed and bracketed gross weights are those obtained from comparisons of equivalency factors based on deflections and strains, respectively.

1. One application of a 14000 kg tandem axle (1.5 - 1.8 m) - dual tire load is approximately equivalent in potential damaging effect to one application of the standard 8160 kg single axle-dual tire load.
2. For the range of loadings tested on carrying axle configurations of the pavement test vehicle, on average:

One application of a tandem (1.5 - 1.8 m) load is equivalent in potential damaging effect to one application of a single axle-dual tire configuration having a gross weight equal to approximately 58 percent of the tandem (1.5 - 1.8 m) load. Average gross weight equivalents for other carrying axle configurations are:

<u>Configuration</u>	<u>Percent of Tandem (1.5-1.8 m) GW</u>
Tandem (1.2 m)	97
Triaxle (2.4 m)	136
Triaxle (3.7 m)	147

4.13 LOAD EQUIVALENCY FACTORS

SITE 12

BRITISH COLUMBIA

Table 4.13
Average Pavement Response Ratios and
Load Equivalency Factors,
Site 12, British Columbia

Loading Condition	Average Pavement Response Ratios						Load Equivalency Factors	
	Pavement Surface Deflections			Interfacial Tensile Strains			Based on	
	D_1/D_b	Δ_1/D_b	Δ_2/D_b	S_1/S_b	S_2/S_b	S_3/S_b	Deflections	Strains
Steering Axle								
3790 kg	1.004			1.137			1.015	1.629
5110 kg	1.069			1.216			1.289	2.103
Single Axle								
9182 kg	1.072			1.280			1.302	2.556
11127 kg	1.134			1.106			1.613	1.466
Tandem Axle (1.2m)								
13582 kg	1.018	0.777		1.254	1.307		1.453	5.129
18100 kg	1.074	0.761		1.336	1.269		1.666	5.479
22327 kg	1.241	0.882		1.246	1.243		2.692	4.592
Tandem Axle (1.5m)								
5445 kg	0.458	0.441		0.753	0.735		0.096	0.651
9109 kg	0.736	0.682		0.676	0.749		0.546	0.559
9555 kg	0.874	0.759		0.923	1.017		0.950	1.804
10346 kg	0.844	0.760		0.897	0.940		0.877	1.452
10645 kg	0.779	0.696		1.011	1.039		0.639	2.199
11718 kg	0.923	0.783		1.192	1.188		1.132	3.874
11827 kg	0.776	0.676		1.110	1.153		0.607	3.204
12500 kg	0.914	0.791		1.214	1.210		1.121	4.153
13136 kg	0.856	0.743		1.061	1.036		0.877	2.352
13236 kg	0.921	0.770		1.166	1.181		1.102	3.794
14582 kg	0.981	0.838		1.173	1.211		1.441	3.904
14936 kg	0.857	0.731		1.273	1.273		0.860	5.006
15336 kg	0.991	0.927		1.189	1.169		1.716	3.741
15582 kg	0.955	0.854		1.099	1.099		1.388	2.863
Tandem Axle (1.8m)								
14064 kg	1.040	0.885		1.234	1.218		1.789	4.339
18382 kg	1.076	0.860		1.323	1.318		1.885	5.752
22127 kg	1.229	1.017		1.071	1.020		3.255	2.376
Triaxle (2.4m)								
20082 kg	1.087	0.821	0.794	1.063	1.035	1.049	2.262	3.600
26145 kg	1.114	0.836	0.792	1.222	1.185	1.177	2.426	5.906
31645 kg	1.155	0.841	0.817	1.219	1.194	1.175	2.711	5.930
Triaxle (3.7m)								
20509 kg	1.013	0.895	0.888	1.180	1.157	1.209	2.343	5.673
26036 kg	1.063	0.957	0.937	1.105	1.118	1.124	2.888	4.549
31664 kg	1.111	1.004	1.007	1.212	1.137	1.115	3.534	5.218

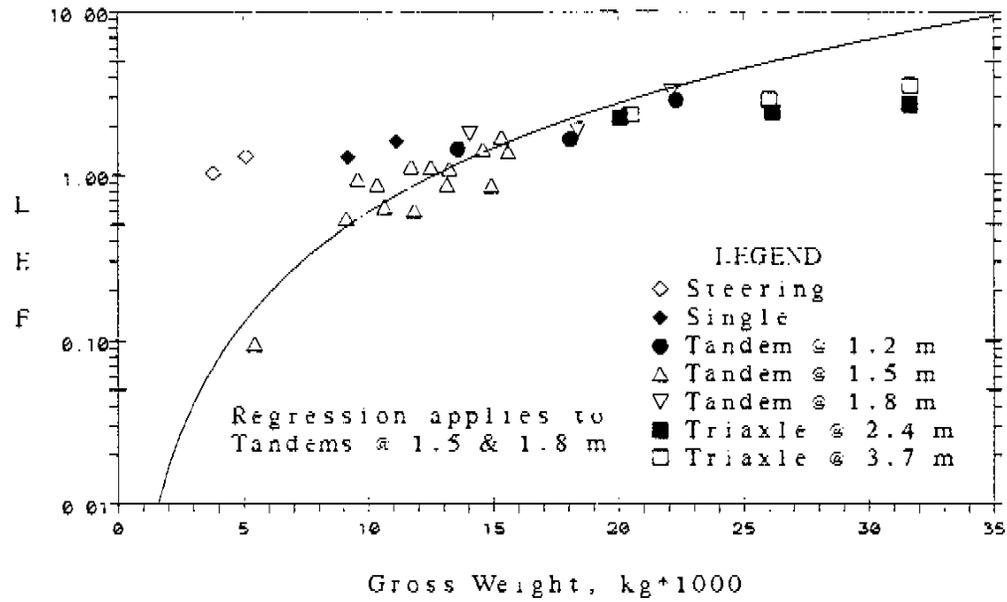


Figure 4.24: Load Equivalency Factors based on Deflections: Site 12, British Columbia

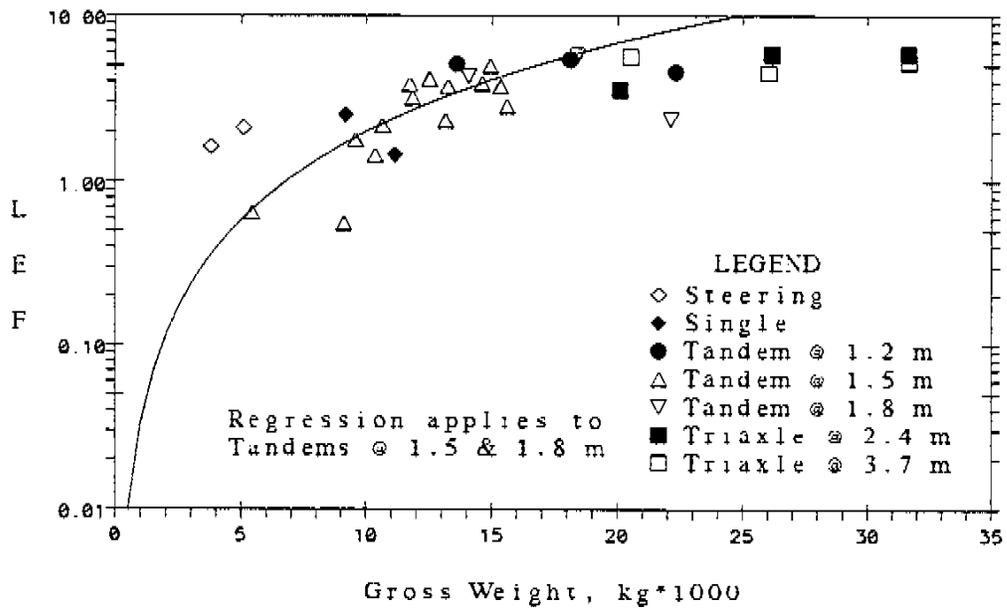


Figure 4.25: Load Equivalency Factors based on Strains: Site 12, British Columbia

A. Gross Weight-Load Equivalency Factor Relationships

Tandem (1.5 - 1.8 m) Axles
 Maximum Gross Weight = 22100 kg

Based on Deflections:

$$F = .00369 (GW)^{2.207} \quad r^2 = 0.84 \quad N = 17 \quad \Delta S_{ey} = 0.129$$

Based on Strains:

$$F = 0.0336 (GW)^{1.776} \quad r^2 = 0.81 \quad N = 15 \quad \Delta S_{ey} = 0.106$$

where: GW = gross weight, kg x 10³

B. Equivalent Loadings

The following summarizes results of comparisons between equivalency factors for tandem (1.5 - 1.8 m) axle loads and equivalencies for all other axle loads and configurations tested at this site.

Note: Non-bracketed and bracketed gross weights and load applications are those obtained from comparisons of equivalency factors based on deflections and strains, respectively.

1. One application of a 12700 kg (6800 kg) tandem axle (1.5 - 1.8 m) - dual tire load is approximately equivalent in potential damaging effect to one application of the standard 8160 kg single axle-dual tire load.
2. For the range of loadings tested on carrying axle configurations of the pavement test vehicle, on average:

One application of a tandem (1.5 - 1.8 m) load is equivalent in potential damaging effect to one application of a single axle-dual tire configuration having a gross weight equal to approximately 67 (80) percent of the tandem (1.5 - 1.8 m) load. Average gross weight equivalents for other carrying axle configurations are:

<u>Configuration</u>	<u>Percent of Tandem (1.5-1.8 m) GW</u>
Tandem (1.2 m)	104 (107)
Triaxle (2.4 m)	136 (143)
Triaxle (3.7 m)	126 (154)

3. At comparable load magnitudes (approximately 5000 kg), one application of a single steering axle is equivalent in potential damaging effect to approximately 13 (4) applications of tandem axle (1.5 -1.8 m) - dual tire configuration.

4.14 LOAD EQUIVALENCY FACTORS

SITE 13

BRITISH COLUMBIA

Table 4.14
Average Pavement Response Ratios and
Load Equivalency Factors,
Site 13, British Columbia

Loading Condition	Average Pavement Response Ratios						Load Equivalency Factors	
	Pavement Surface Deflections			Interfacial Tensile Strains			Based on	
	D_1/D_b	Δ_1/D_b	Δ_2/D_b	S_1/S_b	S_2/S_b	S_3/S_b	Deflections	Strains
Single Axle								
9182 KG	1.188			1.045			1.924	1.184
11127 KG	1.314			1.105			2.825	1.463
Tandem Axle (1.2m)								
13582 KG	1.014	0.600		0.935	0.934		1.199	1.548
22327 KG	1.403	0.773		1.082	1.081		3.994	2.696
Tandem Axle (1.5m)								
5445 KG	0.545	0.368		0.641	0.584		0.122	0.315
9555 KG	0.851	0.604		0.851	0.827		0.688	1.052
10645 KG	0.787	0.565		0.939	0.935		0.518	1.564
11718 KG	0.907	0.624		0.985	0.944		0.858	1.748
12500 KG	0.916	0.684		1.049	0.996		0.952	2.184
13136 KG	0.980	0.722		1.085	1.031		1.214	2.489
13236 KG	0.986	0.752		1.020	1.002		1.268	2.085
14582 KG	0.979	0.679		1.039	1.021		1.151	2.237
15336 KG	1.017	0.713		1.079	1.059		1.341	2.580
15582 KG	1.085	0.722		1.086	1.045		1.656	2.552
Tandem Axle (1.8m)								
14064 kg	1.020	0.759		0.991	1.014		1.431	2.020
22127 kg	1.313	0.932		1.111	1.101		3.578	2.937
Triaxle (2.4m)								
20082 kg	1.110	0.646	0.599	0.981	0.918	0.932	1.819	2.416
31645 kg	1.273	0.722	0.642	1.089	1.021	1.069	2.981	3.753
Triaxle (3.7m)								
20509 kg	1.003	0.743	0.742	0.937	0.953	0.985	1.656	2.558
31664 kg	1.131	0.887	0.876	1.114	1.072	1.081	2.839	4.152

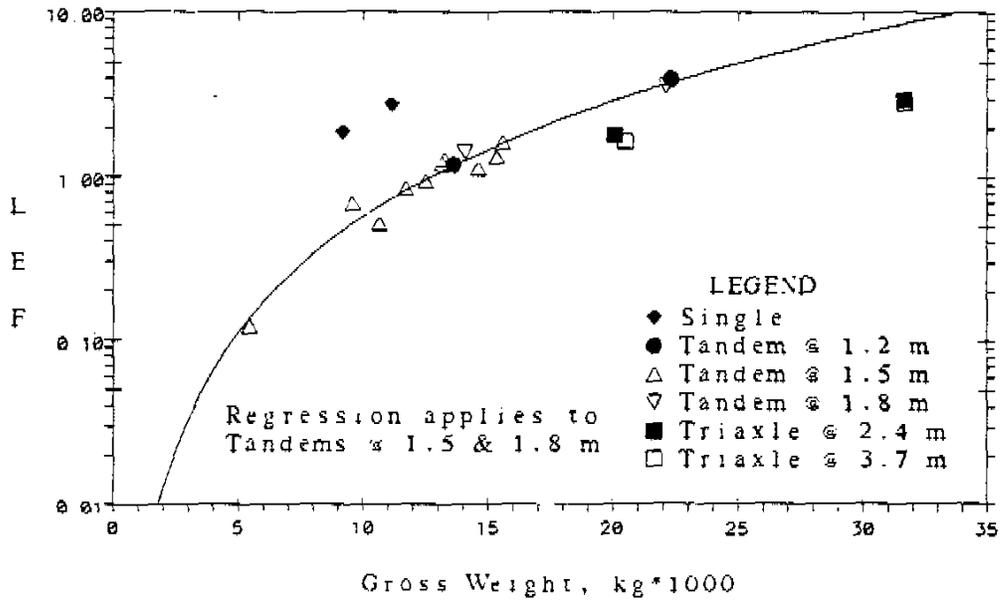


Figure 4.26: Load Equivalency Factors based on Deflections: Site 13, British Columbia

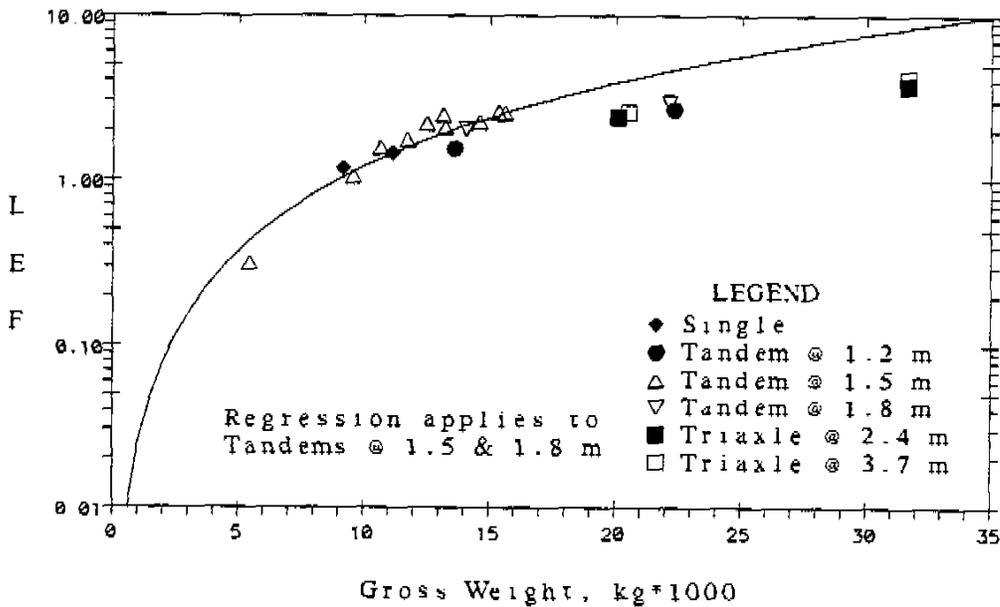


Figure 4.27: Load Equivalency Factors based on Strains: Site 13, British Columbia

A. Gross Weight-Load Equivalency Factor Relationships

Tandem (1.5 - 1.8 m) Axles
Maximum Gross Weight = 22100 kg

Based on Deflections:

$$F = 0.0025 (GW)^{2.2357} \quad r^2 = 0.96 \quad N = 12 \quad \sigma_{Se_y} = 0.068$$

Based on Strains:

$$F = 0.0243 (GW)^{1.693} \quad r^2 = 0.88 \quad N = 12 \quad \sigma_{Se_y} = 0.090$$

where: GW = gross weight, kg x 10³

B. Equivalent Loadings

The following summarizes results of comparisons between equivalency factors for tandem (1.5 - 1.8 m) axle loads and equivalencies for all other axle loads and configurations tested at this site.

Note: Non-bracketed and bracketed gross weights are those obtained from comparisons of equivalency factors based on deflections and strains, respectively.

1. One application of a 12700 kg (9000 kg) tandem axle (1.5 - 1.8 m) - dual tire load is approximately equivalent in potential damaging effect to one application of the standard 8160 kg single axle-dual tire load.
2. For the range of loadings tested on carrying axle configurations of the pavement test vehicle, on average:

One application of a tandem (1.5 - 1.8 m) load is equivalent in potential damaging effect to one application of a single axle-dual tire configuration having a gross weight equal to approximately 57 (95) percent of the tandem (1.5 - 1.8 m) load. Average gross weight equivalents for other carrying axle configurations are:

<u>Configuration</u>	<u>Percent of Tandem (1.5-1.8 m) GW</u>
Tandem (1.2 m)	98 (125)
Triaxle (2.4 m)	140 (147)
Triaxle (3.7 m)	145 (142)

4.15 Equivalent Loadings and Load Applications

Combining data from all sites, overall average tandem (1.5 m to 1.8 m) axle loads equivalent in potential damaging effect to other loading conditions included in the study are presented in table 4.15. As noted in Section 3.3, the equivalent loadings were obtained from comparisons between equivalency factors for each individual loading condition and the gross weight equivalency factor relationships for tandem axle loads. The equivalent loadings indicate, for example, that based on surface deflections, one application of a 9180 kg single axle-dual tire load is, on average, equivalent in potential damaging effect to one application of a 15 900 kg tandem (1.5 m to 1.8 m) axle-dual tire load.

Table 4.15

Average Equivalent Tandem (1.5 m to 1.8 m) Axle Loads

Loading Condition	Equivalent Tandem (1.5 m-1.8 m) Loads kgx10 ³					
	N	Based on Deflections		N	Based on Strains	
Single Axle						
9180 kg	14	15.9	(1.5)*	13	13.3	(2.3)
9570 kg	6	17.4	(1.4)	6	13.7	(3.1)
11130 kg	14	18.9	(1.8)	13	14.8	(3.2)
Tandem 1.2 m						
13582 kg	14	14.4	(0.8)	12	13.8	(1.7)
18100 kg	10	18.4	(2.2)	9	16.8	(1.3)
22327 kg	14	23.1	(2.5)	12	18.3	(2.2)
Triaxle 2.4 m						
20082 kg	14	15.3	(1.8)	12	14.6	(1.6)
26145 kg	10	17.6	(1.5)	9	18.7	(1.6)
31645 kg	14	22.1	(2.4)	12	21.1	(1.9)
Triaxle 3.7 m						
20510 kg	14	14.8	(2.0)	12	16.2	(1.6)
26036 kg	10	17.6	(1.8)	9	18.9	(1.6)
31664 kg	14	21.2	(1.5)	12	21.2	(2.1)
Triaxle 4.9 m						
25836 kg	6	18.5	(2.2)	6	20.2	(1.3)
31955 kg	6	24.2	(2.2)	6	22.9	(0.7)

*One standard deviation
N-Number of comparisons

68.

The average equivalent tandem axle loads are approximately a constant multiple of the loads on each configuration. For example, based on pavement surface deflections, average tandem (1.5 m to 1.8 m) axle-dual tire loads equivalent in potential damaging effect to single axle-dual tire loads are 1.73, 1.82 and 1.70 (15.9/9.18, 17.4/9.57 and 18.9/11.13) times the magnitude of the single axle loads. Combining the equivalent loadings by axle configuration, average equivalent tandem axle load ratios (K) for each configuration are:

Axle Configuration	Based on Deflections			Based on Strains		
	<u>N</u>	<u>K</u>	<u>σ</u>	<u>N</u>	<u>K</u>	<u>σ</u>
Single Axle	34	1.73	0.17	32	1.34	0.26
Tandem 1.2 m	38	1.04	0.10	33	0.92	0.13
Triaxle 2.4 m	38	0.72	0.08	33	0.70	0.07
Triaxle 3.7 m	38	0.69	0.08	33	0.73	0.09
Triaxle 4.9 m	12	0.73	0.08	12	0.75	0.05

The average deflection related load ratios indicate that:

- i) For the range of single axle-dual tire loads included in the study, the magnitude of the average equivalent tandem (1.5 m to 1.8 m) axle load is 1.73 times the magnitude of the single axle load. Conversely, for a given tandem load the magnitude of the equivalent single axle load is approximately 58 percent (1/1.73) of the tandem load. This percent is in close agreement with 60 percent established from previous analyses of deflections and strains recorded under single and tandem axles having gross weights ranging from 5700 to 12 000 kg and from 9700 to 20 000 kg, respectively, (Ref.1) and with the AASHO performance related load equivalency factors (Ref.5).
- ii) For a given tandem (1.2 m) axle-dual tire gross weight, the magnitude of the equivalent tandem (1.5 m to 1.8 m) axle load is, on average, 104 percent of the tandem (1.2 m) axle load. This finding indicates that, at comparable load magnitudes, increasing the centre to centre spacing between axles from 1.2 to 1.5 m decreases the relative potential damaging effect of tandem axles.

- iii) On average, for a given tandem (1.5 to 1.8 m) axle-dual tire load, equivalent triaxle (2.4 m) and (3.7 m) loads are approximately 1.39 (1/0.71) and 1.45 (1/0.69) times, respectively, the magnitude of the tandem load. At comparable gross weights, increasing the centre to centre spacing between adjacent axles of a triaxle from 1.2 m to 1.85 m decreases the relative potential damaging effect of the axle group. The average equivalent gross weight ratios are in close agreement with the value of 1.4 obtained from results of previous field studies carried out to assess the relative destructive effects of tandem and triaxle configurations (Ref.1).
- iv) Relative to a triaxle (3.7 m)-dual tire load, the equivalent gross weight of a belly-tandem axle group having a centre to centre spacing between the belly and lead tandem axle equal to 3.0 m (the triaxle 4.9 m configuration) is approximately 95 percent (0.69/0.73) of the conventional triaxle load.

With the exception of the single axle-dual tire configuration, average equivalent load ratios obtained from comparisons between predicted equivalency factors based on asphaltic concrete fatigue life-tensile strain criteria are in close agreement with those derived from deflection measurements. Reasons for the relatively low tandem/single load ratio value (1.34) have not been identified. However, an examination of the data indicated that below average ratio values were generally associated with test sites where changes in recorded strains with variations in gross axle weight were small. These sites were 4, 5, 6, 12 and 13. Deleting these sites from the analysis, the average equivalent tandem/single load ratio was found to equal 1.55.

The average strain related load ratios reveal that for a given tandem (1.2 m) axle load the equivalent tandem (1.5 m to 1.8 m) axle is, on average, 92 percent of the tandem (1.2 m) load. Similarly an equivalent triaxle (3.7 m) load is approximately 96 percent (0.70/0.73) of a triaxle (2.4 m) load. These comparisons indicate that increasing the centre to centre spacing between axles increases the relative

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potential damaging effect of the axle group. This finding is contrary to the results obtained from comparisons of the deflection based load ratios; suggesting that, for the range of axle spacing included in the study (1.2 m to 1.8 m), the influence of variations of axle spacing on potential pavement damage is dependent on the postulated, deflection or strain related, pavement distress criteria. Use of the average ratios to identify equivalent configuration gross weights beyond the limits of the loadings included in the test program is cautioned.

Relative destructive effects, expressed in terms of equivalent number of load applications, of various axle configurations at comparable gross weights are summarized below. Utilizing data from all sites, the equivalent load applications equal the overall average of individual comparisons between predicted load equivalency factors for the noted loading conditions. The non-bracketed and bracketed average equivalent load applications, together with the standard deviations σ and number of individual comparisons N , are those obtained from comparisons of the deflection and strain related equivalency factors, respectively.

- i) At comparable gross weights (9200, 9600 and 11 100 kg), one application of a single axle-dual tire is equivalent in potential damaging effect to 4.4 (3.2) applications of a tandem (1.5 m to 1.8 m) axle configuration.

$$\sigma = 1.2 (1.6), N = 34 (21)$$

- ii) One application of a 20 000 kg tandem (1.5 m to 1.8 m) axle-dual tire load is equivalent in destructive effect as 2.1 (2.2) applications of a triaxle (2.4 m) configuration, and as 2.6 (1.8) applications of a triaxle (3.7 m) configuration, having the same gross weight.

$$\sigma = 0.6 (0.9), N = 14 (13) \text{ for the triaxle (2.4 m)}$$

$$\sigma = 1.0 (0.7), N = 14 (13) \text{ for the triaxle (3.7 m)}$$

- iii) At comparable gross weights (13 600, 18 100 and 22 300 kg), one application of a tandem (1.2 m) axle-dual tire is equivalent in

potential damaging effect to 1.2 (0.9) applications of a tandem (1.5 m to 1.8 m) axle.

$$\sigma = 0.3 (0.3), N = 38 (33)$$

- iv) At comparable load magnitudes (25 800 and 32 000 kg), one application of a belly-tandem axle grouping, the triaxle (4.9 m) configuration, is equivalent in destructive effect as 1.2 (1.1) applications of a triaxle (3.7 m)-dual tire.

$$\sigma = 0.2 (0.1), N = 12 (12)$$

- v) For gross weights ranging from 20 000 to 32 000 kg, one application of a triaxle (2.4 m) axle-dual tire is equivalent in potential damaging effect to 1.2 (0.9) applications of a triaxle (3.7 m) axle-dual tire.

$$\sigma = 0.4 (0.2), N = 38 (33)$$

5.0 INFLUENCE OF STRUCTURE ON PREDICTED LOAD EQUIVALENCY FACTORS

The following presents results of analyses carried out to assess the effects of pavement structure on the magnitude of the predicted load equivalency factors. The analyses were conducted using the gross weight-equivalency factor relationships developed for tandem (1.5 m to 1.8 m) axle loads. A brief description of each instrumented pavement structure is presented in table 5.1.

5.1 Deflection Related Equivalency Factors

The gross weight versus load equivalency factor relationships derived from deflections recorded under the tandem (1.5 m and 1.8 m) axle configurations are shown in figure 5.1. The predicted factors are highly dependent on the magnitude of the relative deflection ratio D_1/D_0 . Based on the assumed pavement distress criteria and selected exponent coefficient of 3.8 (Section 2.1), a 10 percent variation in D_1/D_0 results in approximately a 40 percent change in the magnitude of the predicted equivalencies. From figure 5.1, maximum predicted factors, site 3A, were approximately twice the magnitude of those for site 8. This extreme site to site difference reflects a 20 percent difference between the magnitude of average deflection ratios for the two sites. Excluding site 8, average deflection ratios for a given load at any one site were within ± 7 percent of the mean ratios for all sites. Compared to differences in component layer thicknesses and materials comprising the various structures, these site to site variations in relative response measurements are small. The old road bed subbase at site 8 appears to be the main structural component difference between this and other sites.

Using an asphalt concrete/base/subbase equivalent layer thickness ratio equal to 2:1:0.5, an equivalent base layer thickness was calculated for each structure. A plot of equivalent base layer thicknesses versus predicted equivalency factors for 10 000 kg and 20 000 kg tandem axle loads is shown in figure 5.2. The predicted factors show no measurable trend with changes in equivalent base thickness.

Table 5.1 Pavement Test Sites

Site No.	Province	Location	Structure			
			A.C. Thick.(mm)	Base Thick.(mm)-Material	Sub-Base Thick.(mm)-Material	Subgrade Material
1	New Brunswick	Hwy.15 - 10 km. E. of Moncton	225	76 - Crushed rock	460 - Crushed sandstone	Silty-sand
2	Nova Scotia	Hwy.102 - 6 km. S. of Truro	160	275 - Granular	200 - Granular	Gravelly-clay
3A	Quebec	Hwy.40 - 55 km. W. of Quebec City	135	200 - Crushed limestone	625 - Granite sand	Granitic-gravel
3B	Quebec	Hwy.40 - 55 km. W. of Quebec City	130	375 - Crushed limestone	450 - Granitic sand	Granitic-gravel
4	Quebec	Rte.363 - 73 km. W. of Quebec City	56	150 - Granitic gneiss	450 - Granitic sand	Clay
5	Quebec	Rte.363 - 73 km. W. of Quebec City	56	200 - Granitic gneiss	550 - Granitic sand	Clay
6	Ontario	Hwy.7-Peterborough Bypass	110	150 - Granular A	350 - Granular C	Silty-sand
7	Ontario	Hwy.403 - 19 km. W. of Brantford	170	200 - Granular A	250 - Granular B	Sand
8	Ontario	Hwy.55 - 8 km. E. of St. Catharines	190	300 - Granular A	90 - Old road	Clay
9	Alberta	Hwy.21 - 8 km. N. of Three Hills	136	170 - Cement Stab. Sand	- -	Clay
10	Alberta	Hwy.21 - 8 km. N. of Three Hills	136	250 - Granular	- -	Clay
11	British Columbia	Hwy.97 - 110 km. W. of Chetwynd	75	145-Asphalt bnd.gran. 200 - Granular	610 - Granular 1000 - Shot rock	Peat/Silty Sand
12	British Columbia	Hwy.97 - 112 km. W. of Chetwynd	85	155-Asphalt bnd.gran. 210 - Granular	610 - Granular 975 - Silty gravel	Silty-sand
13	British Columbia	Hwy.16 - 16 km. N.W. of Tete Jaune Cache	100	545 - Granular	50 - Clay and sand 450 - Pit run gravel	Clay

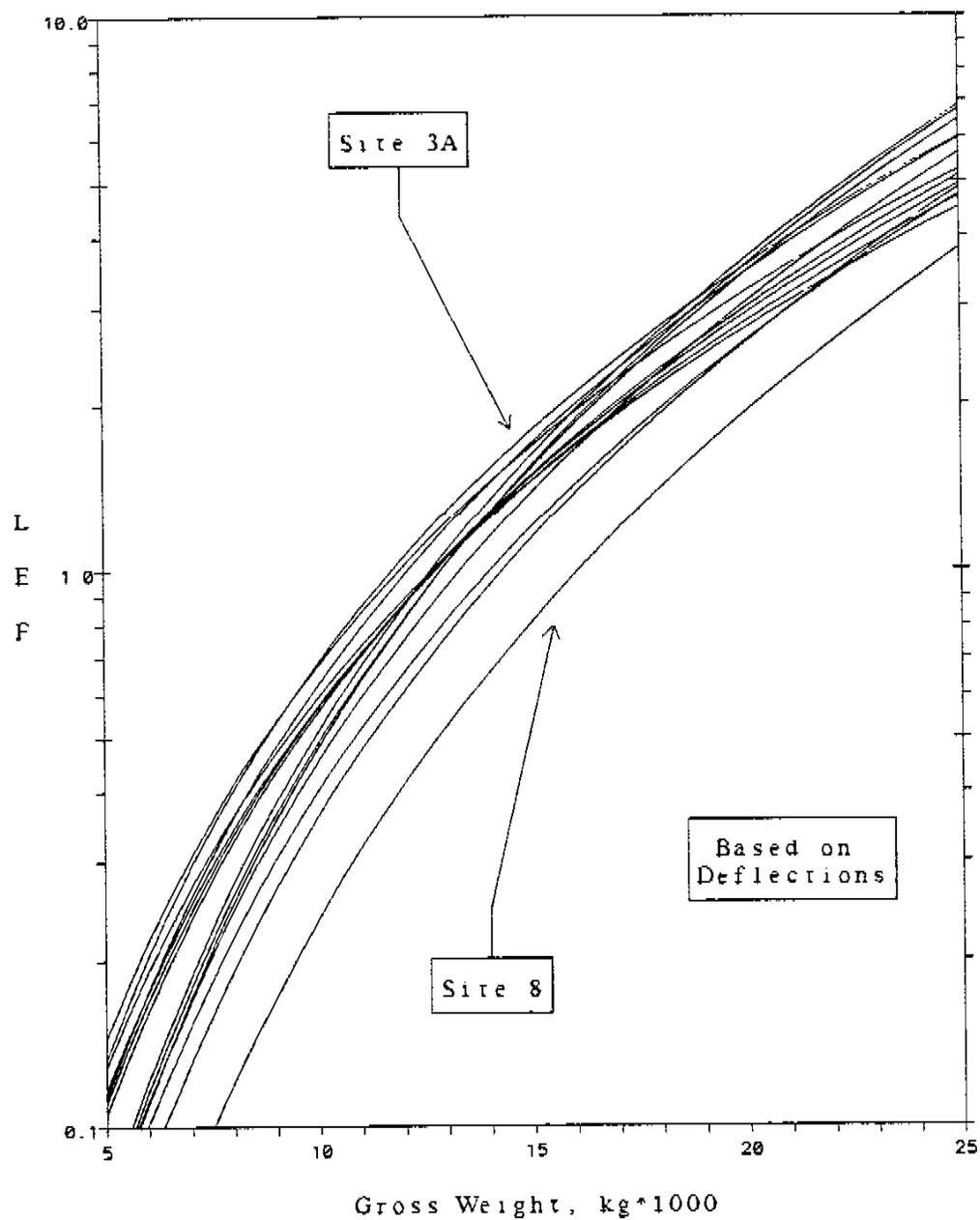


Figure 5.1: Gross Weight-Load Equivalency Factor Relationships for Tandem (1.5-1.8 m) Axles for all Test Sites

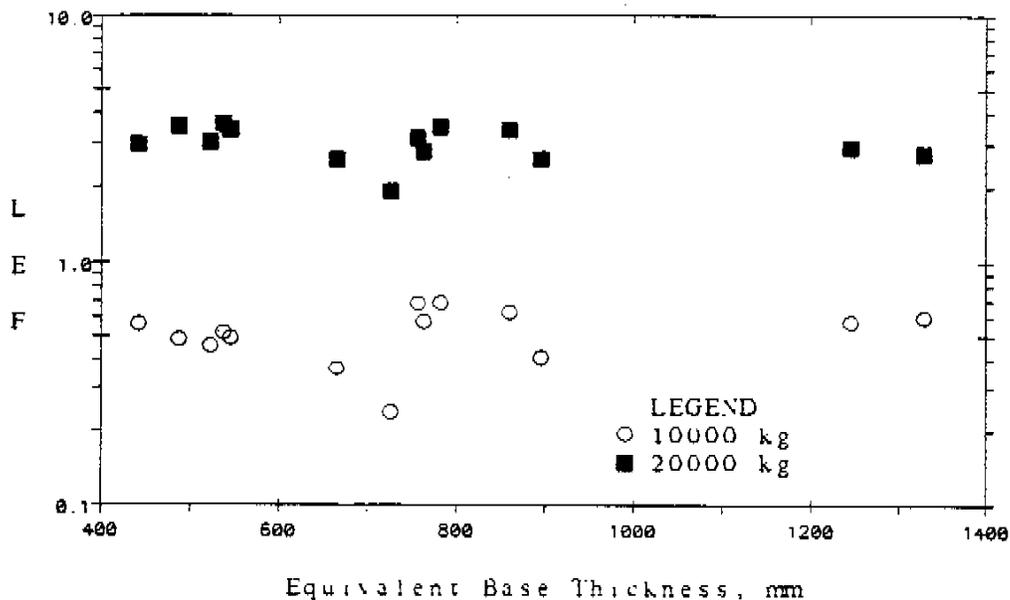


Figure 5.2: Influence of Equivalent Base Thickness on Predicted Load Equivalency Factors

5.2 Strain Related Equivalency Factors

Gross weight-load equivalency factor relationships derived from tensile strains recorded under tandem (1.5 m and 1.8 m) axle configurations at each site are presented in figure 5.3. At a gross weight equal to 10 000 kg the equivalencies ranged from approximately 0.3 to 2.0, at 15 000 kg from 1.0 to 4.0, and at 20 000 kg from approximately 2.0 to 7.0. That is, site to site variations in the magnitude of the predicted equivalencies tended to decrease with increasing load.

An examination of the average axle weight-strain ratio relationships for leading axles of tandem and triaxle configurations, presented in the Appendix, indicated that the magnitude of the strain ratios tended to decrease with increasing asphalt concrete thickness. From this observation, predicted equivalencies for tandem gross weights equal

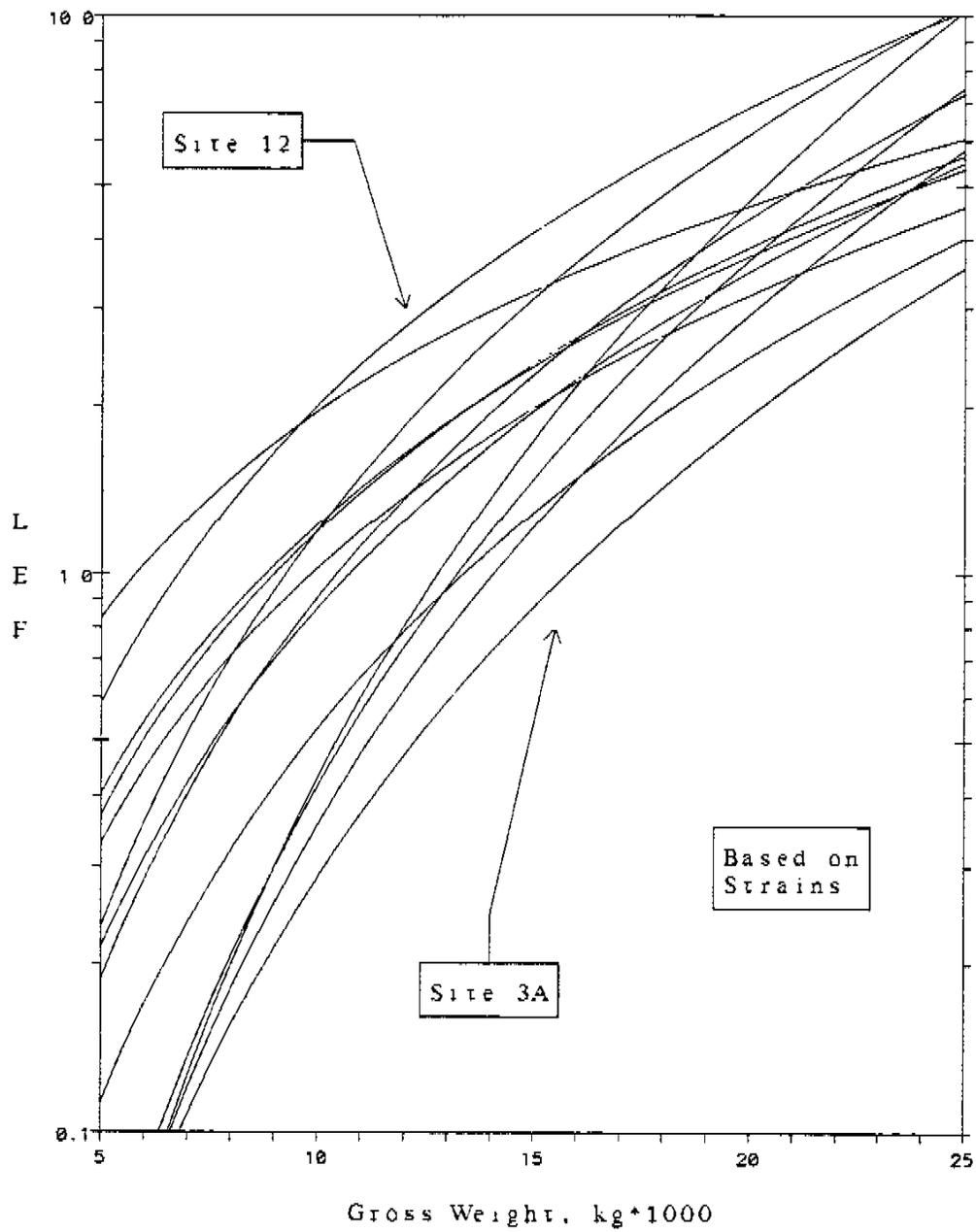


Figure 5.3: Gross Weight-Load Equivalency Factor Relationships for Tandem (1.5-1.8 m) Axles for all Test Sites

to 10 000 kg and 20 000 kg at each site are shown as a function of asphalt concrete thickness in figure 5.4. These plots reveal that, at the lighter load, equivalency factors decreased as asphalt concrete thickness increased from approximately 85 mm to 190 mm and, thereafter, remained relatively constant with increasing asphalt concrete thickness. At the heavier load, and based on limited test results, the factors were less sensitive to variations in pavement surface thickness. (A maximum of two tests/site were carried out at this load level.)

Combining test site data, regression analyses relating the predicted tandem (1.5 m and 1.8 m) equivalency factors to gross weight (GW,kg) and asphalt concrete thickness (T,mm) yielded the expression:

$$\log_{10}(F) = 0.578 + 0.0155(T) (\log_{10}GW) - 0.0669(T)$$

$$r^2 = 0.86 \quad 1Sey = 0.144 \quad N = 204$$

Using this expression, equivalencies for an 16 000 kg tandem axle load (approximating present maximum allowable loadings) increase from approximately 1.8 to 2.6 as asphalt concrete thickness decreases from 200 mm to 100 mm. That is, based on asphalt concrete fatigue life-tensile strain criteria, one application of an 16 000 kg tandem axle load on the thinner pavement is equivalent in potential damaging effect as 1.4 (2.6/1.8) applications of the same load on the thicker pavement. Similarly, the equivalent load application ratio (F,100mm/F,200mm) for an 10 000 kg tandem axle load equals 3.0(1.2/0.4). (Due to the limited number of tests conducted at heavier loadings, use of the above expression for estimating load factors for tandem (1.5 m - 1.8 m) axles exceeding 16 000 kg is cautioned.)

The results of the above analyses reveal that the site to site variations in load equivalency factors predicted from the in situ tensile strain measurements can be attributed, in part, to variations in asphalt concrete thicknesses. The equivalency-asphalt thickness dependency lends support to load equivalency factors for fatigue cracking developed using mechanistic pavement models (Ref. 7).

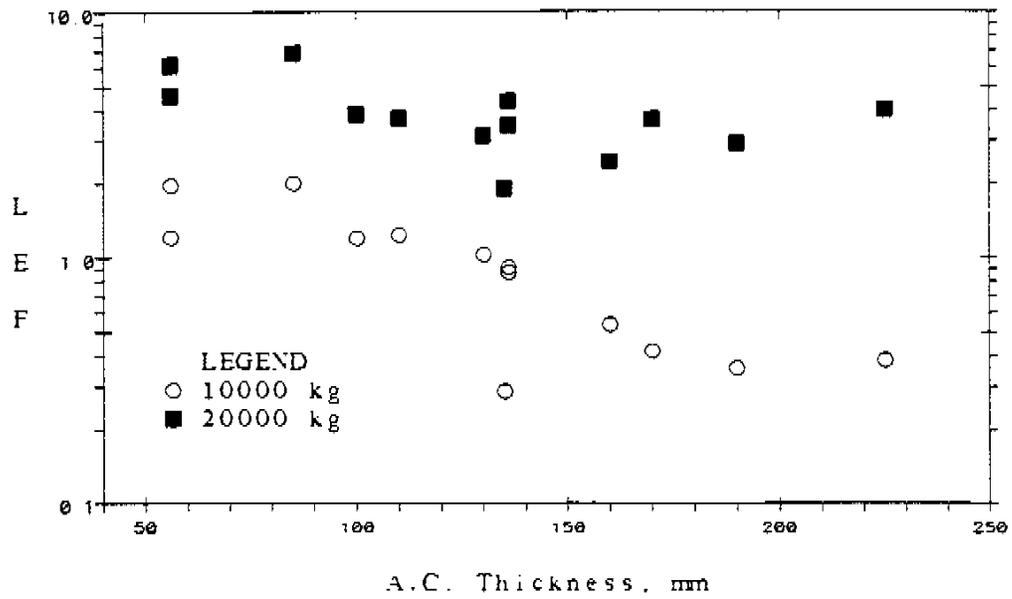


Figure 5.4: Influence of A.C. Thickness on Predicted Load Equivalency Factors

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APPENDIX
AXLE WEIGHT-PAVEMENT RESPONSE RELATIONSHIPS

Table A1
Axle Weight - Pavement Response Relationships

Pavement Response Ratio = $K (AW)^C$
 where: AW = Axle Weight; kg x 10³

Site No.	Deflection Ratio D_1/D_b (Axles @ 1.5 & 1.8 m Spacing)					Strain Ratio S_1/S_b (Axles @ 1.2, 1.5 & 1.8 m Spacing)				
	K	C	N	r ²	$\pm S_{ey}$	K	C	N	r ²	$\pm S_{ey}$
1	0.299	0.624	23	0.94	0.023	0.153	0.886	29	0.98	0.020
2	0.311	0.546	20	0.78	0.037	0.309	0.525	26	0.91	0.022
3A	0.280	0.672	23	0.98	0.014	0.175	0.764	29	0.93	0.030
3B	0.274	0.670	23	0.98	0.014	0.419	0.431	29	0.87	0.024
4	0.226	0.787	20	0.99	0.008	0.814	0.157	26	0.34	0.028
5	0.242	0.747	20	0.98	0.012	0.515	0.377	26	0.49	0.049
6	0.231	0.741	23	0.95	0.023	0.498	0.365	29	0.78	0.023
7	0.220	0.745	14	0.97	0.017	0.189	0.775	18	0.94	0.028
8	0.180	0.803	14	0.98	0.015	0.178	0.781	18	0.99	0.012
9	0.271	0.698	23	0.96	0.021	0.354	0.529	29	0.94	0.019
10	0.226	0.768	23	0.98	0.017	0.314	0.593	29	0.94	0.021
11	0.217	0.763	14	0.98	0.013					
12	0.268	0.649	20	0.84	0.036	0.536	0.389	24	0.66	0.030
13	0.296	0.624	14	0.94	0.021	0.443	0.426	17	0.86	0.022

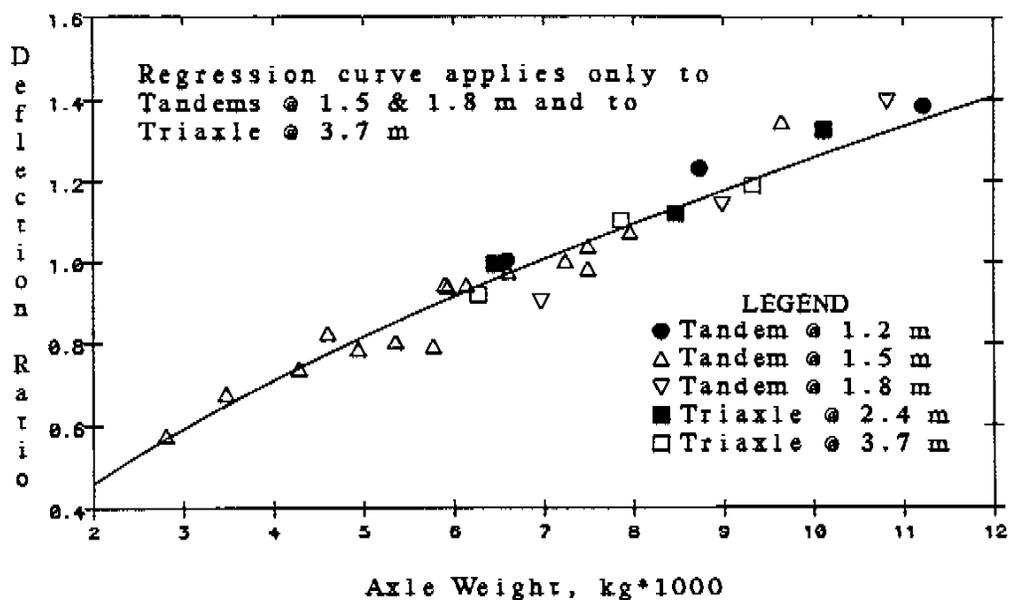


Figure A1: Deflection Ratios for Lead Axle
Site 1, New Brunswick

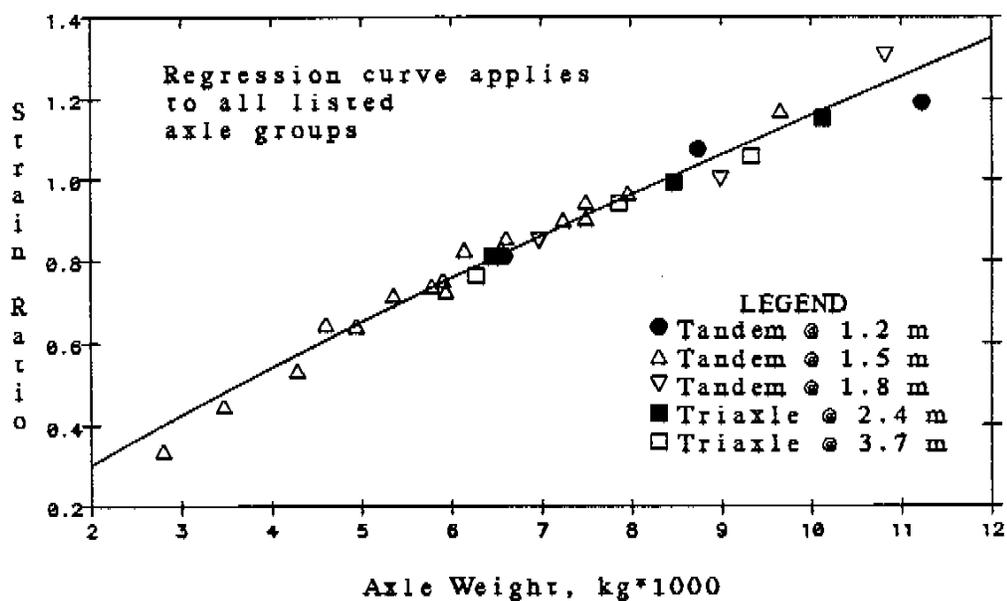


Figure A2: Strain Ratios for Lead Axle
Site 1, New Brunswick

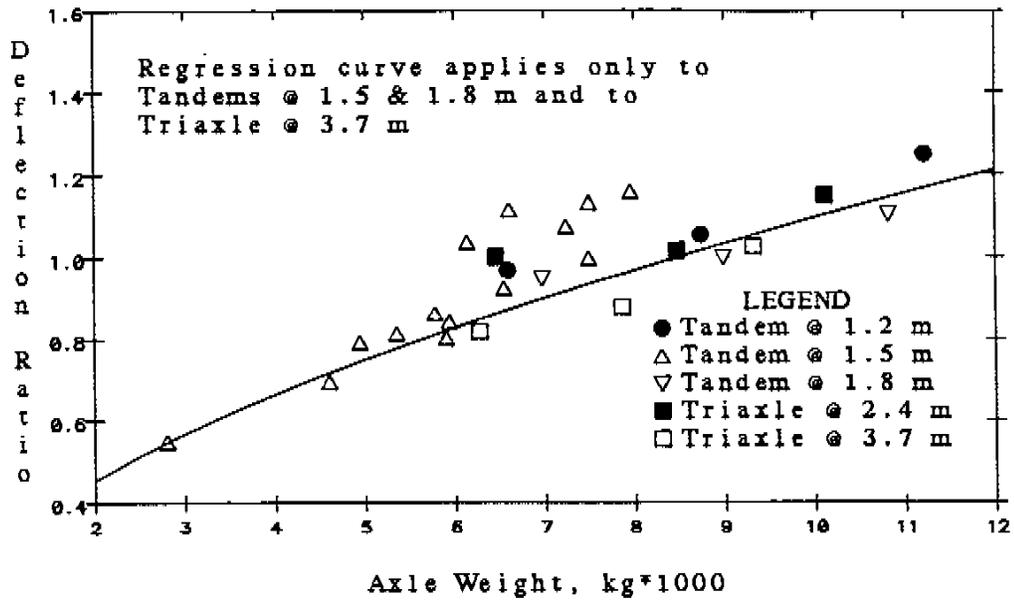


Figure A3: Deflection Ratios for Lead Axle Site 2, Nova Scotia

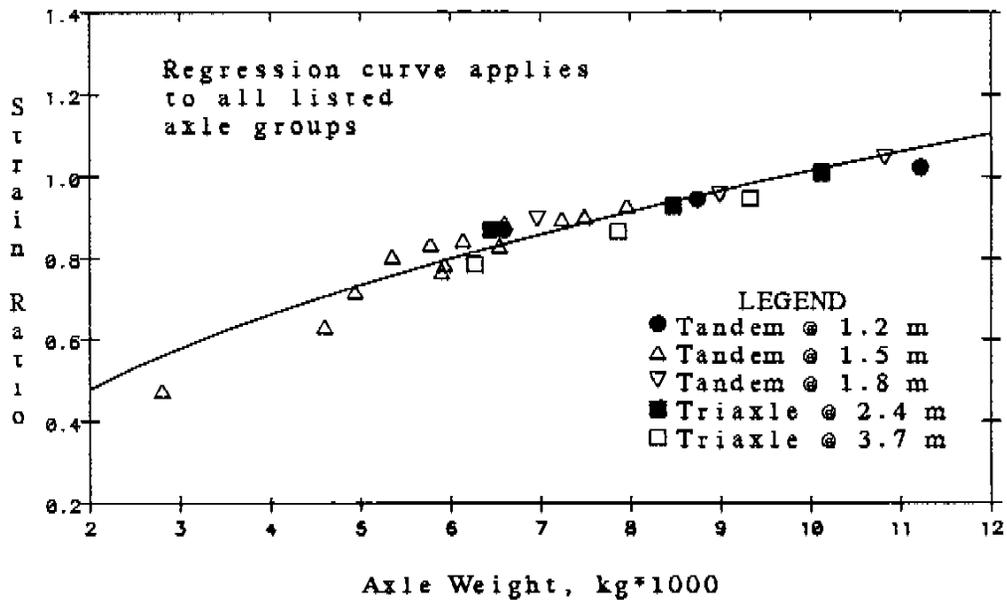


Figure A4: Strain Ratios for Lead Axle Site 2, Nova Scotia

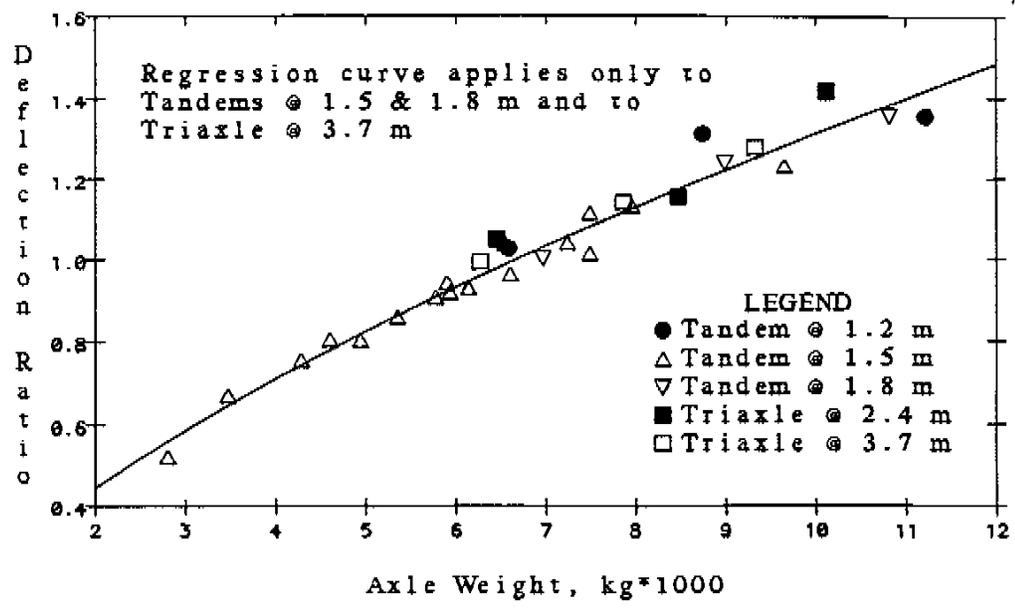


Figure A5: Deflection Ratios for Lead Axle Site 3A, Quebec

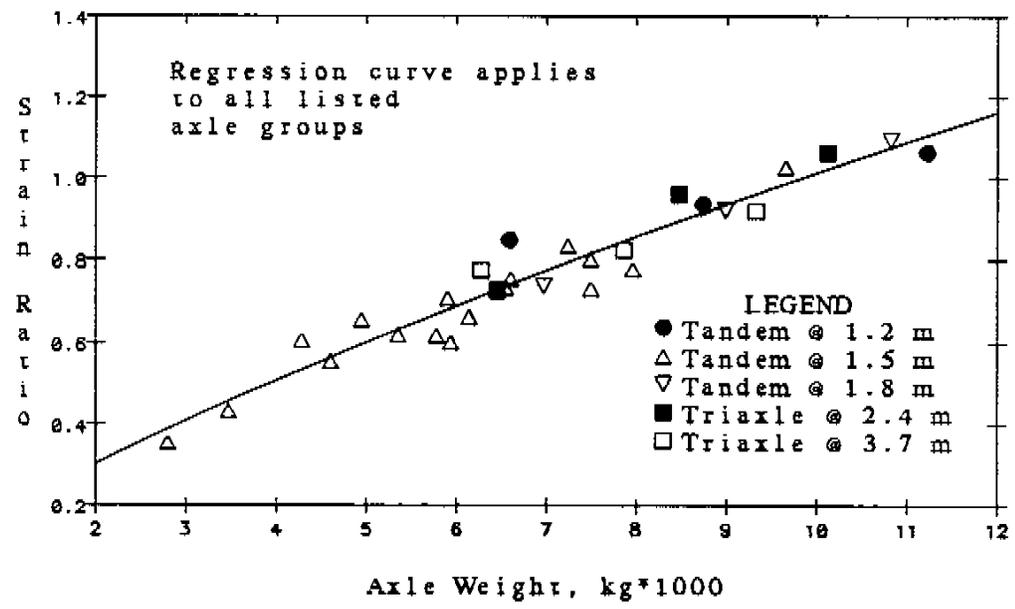


Figure A6: Strain Ratios for Lead Axle Site 3A, Quebec

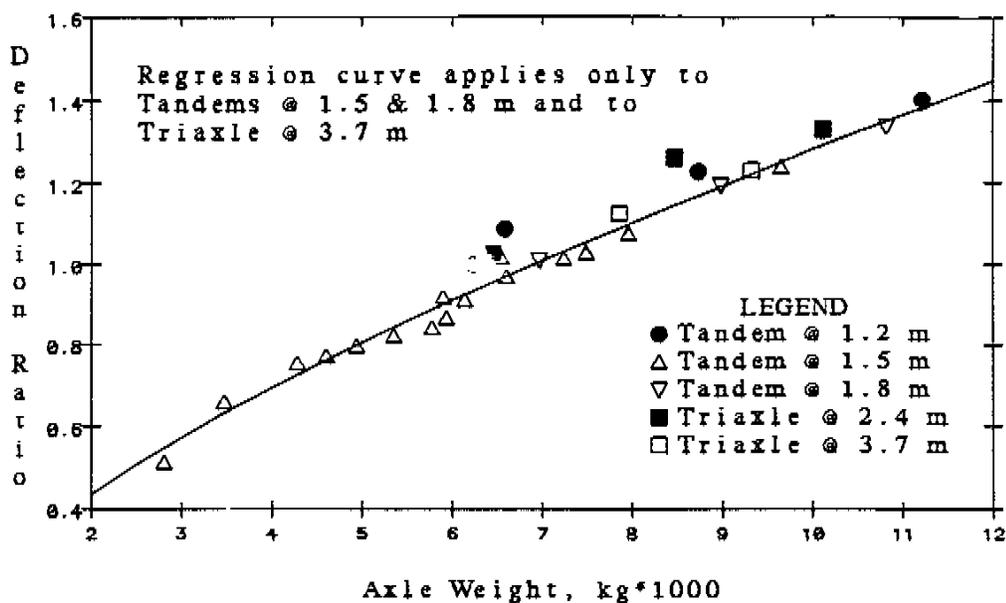


Figure A7: Deflection Ratios for Lead Axle
Site 3B, Quebec

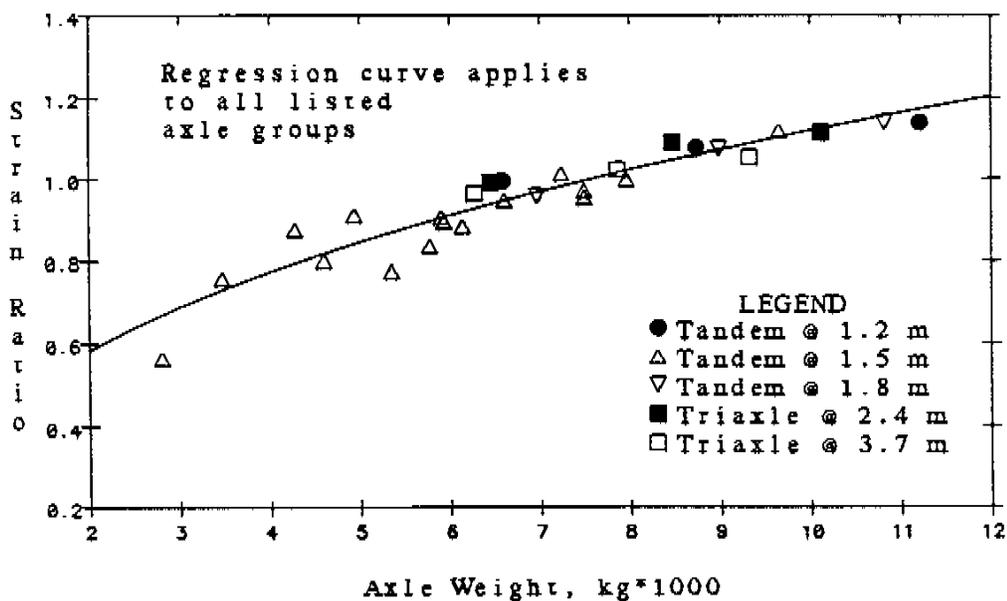


Figure A8: Strain Ratios for Lead Axle
Site 3B, Quebec

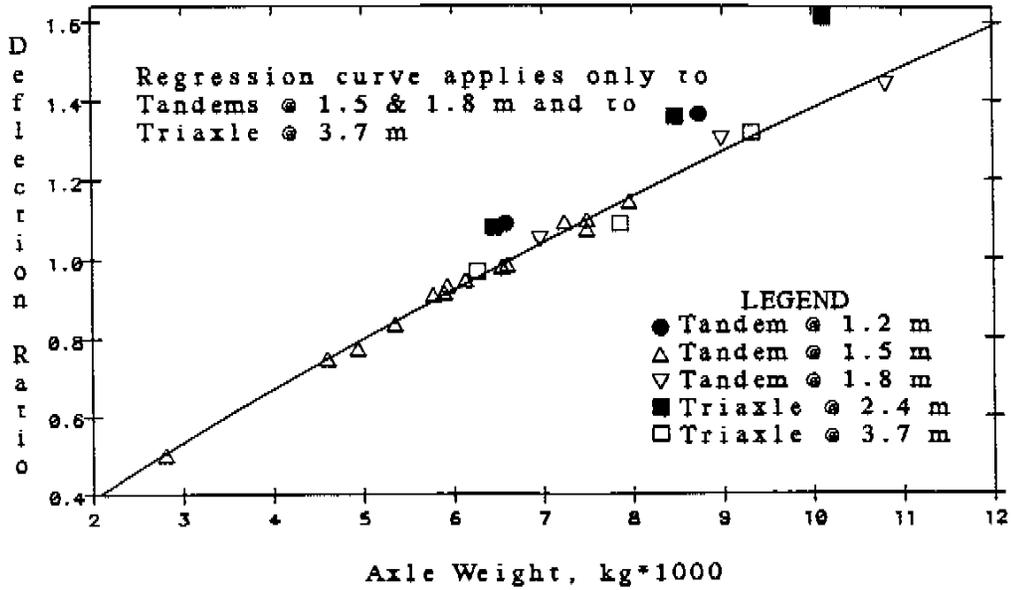


Figure A9: Deflection Ratios for Lead Axle Site 4, Quebec

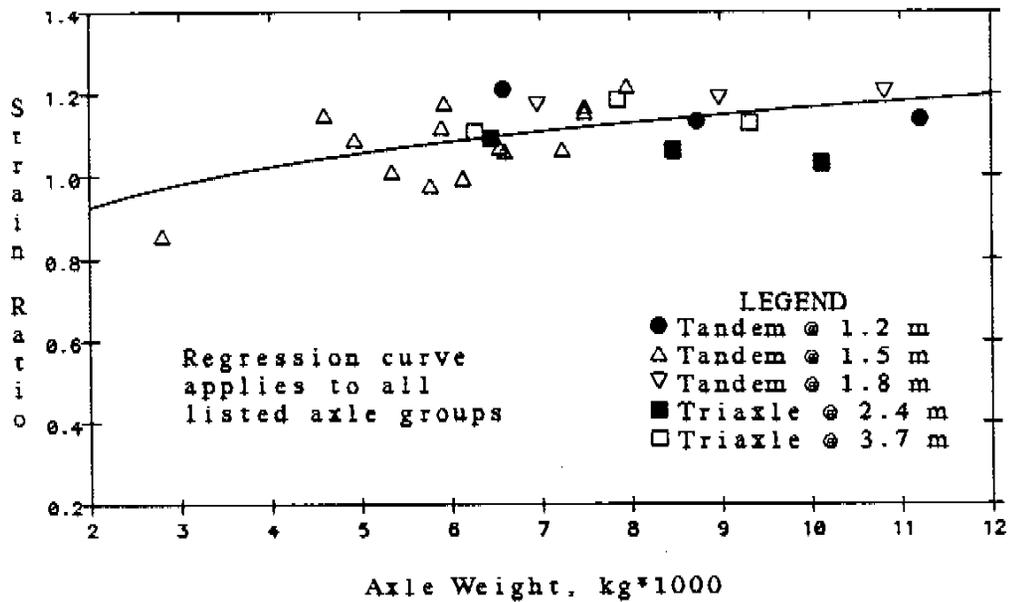


Figure A10: Strain Ratios for Lead Axle Site 4, Quebec

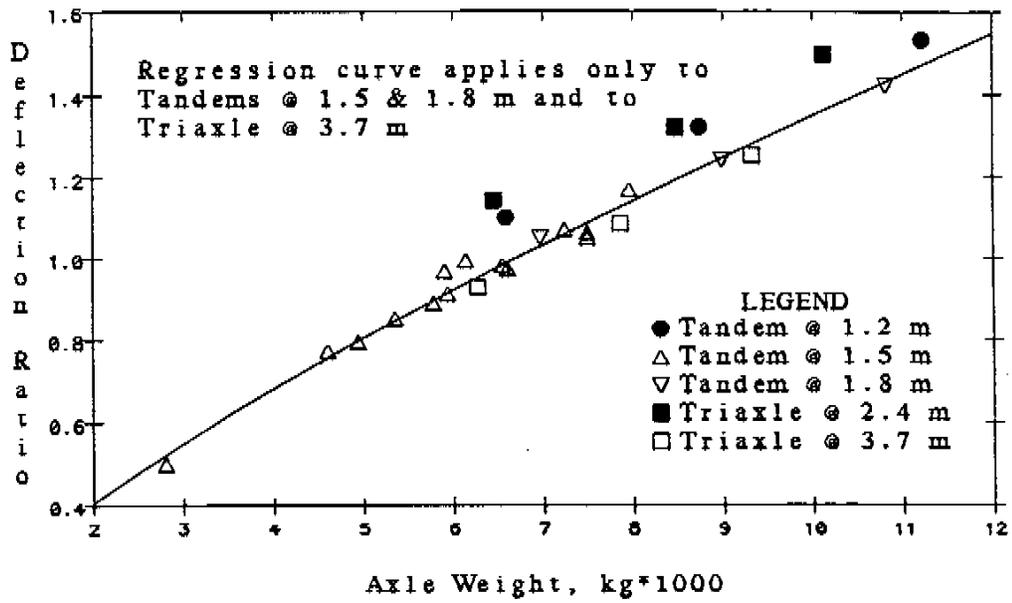


Figure A11: Deflection Ratios for Lead Axle Site 5, Quebec

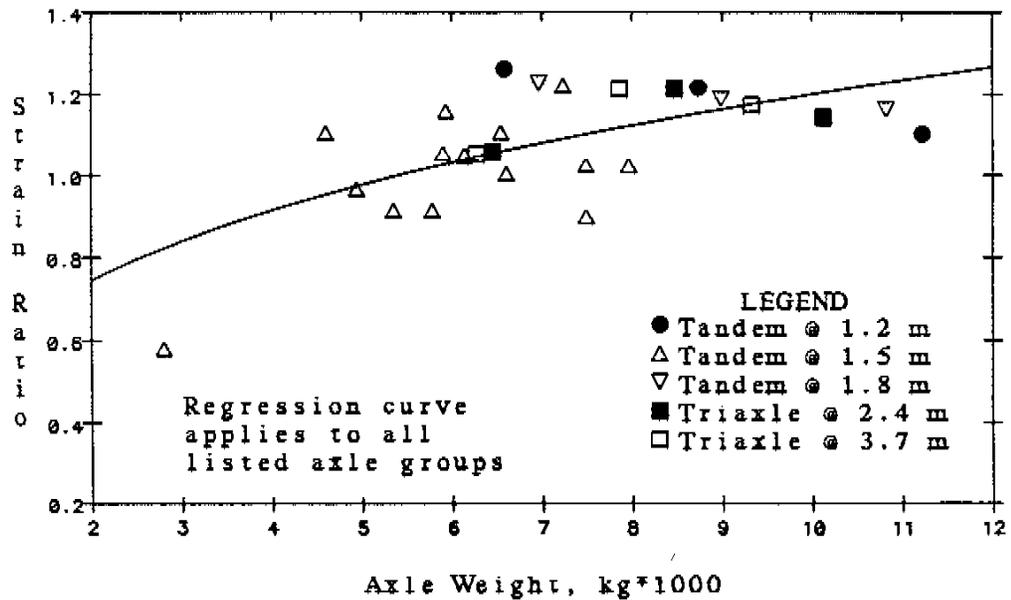


Figure A12: Strain Ratios for Lead Axle Site 5, Quebec

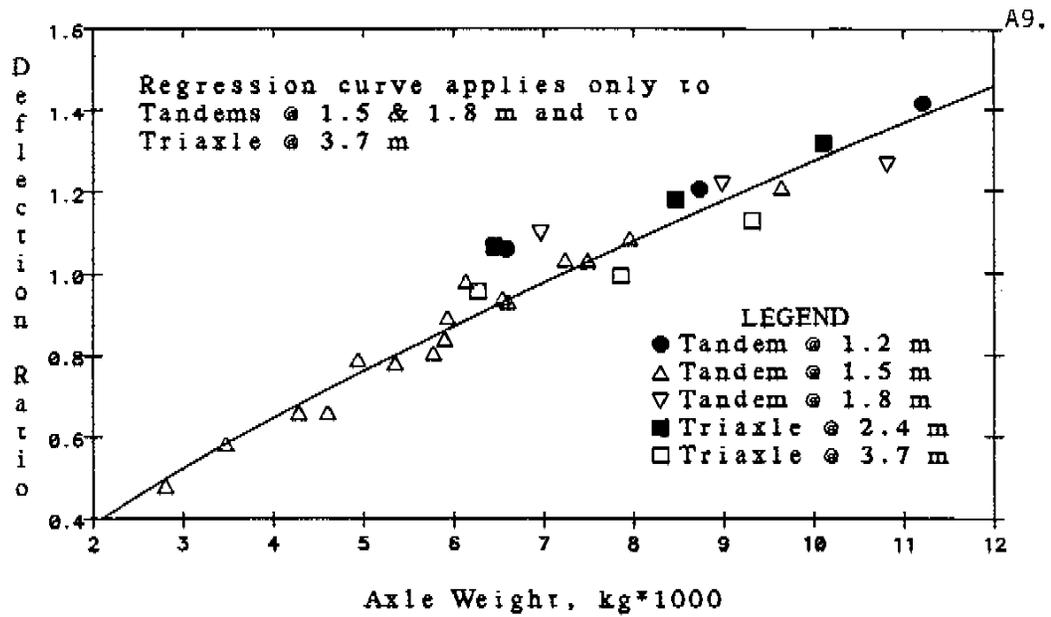


Figure A13: Deflection Ratios for Lead Axle Site 6, Ontario

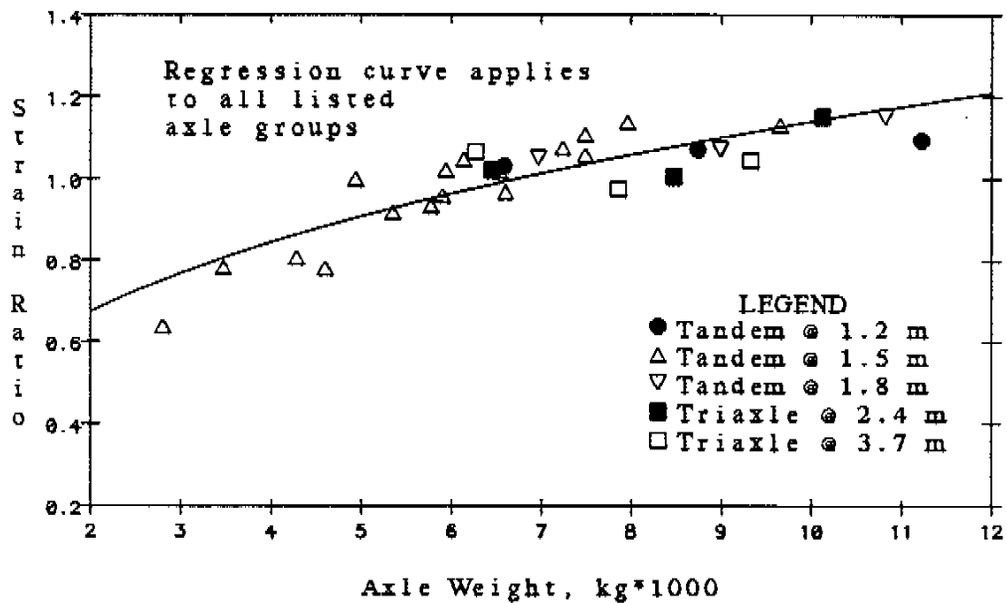


Figure A14: Strain Ratios for Lead Axle Site 6, Ontario

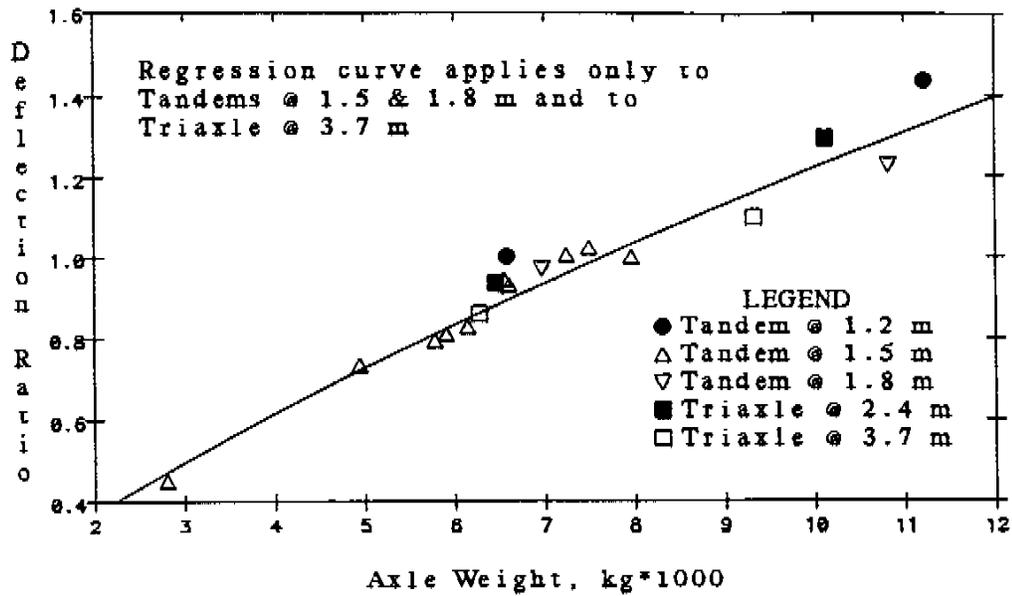


Figure A15: Deflection Ratios for Lead Axle Site 7, Ontario

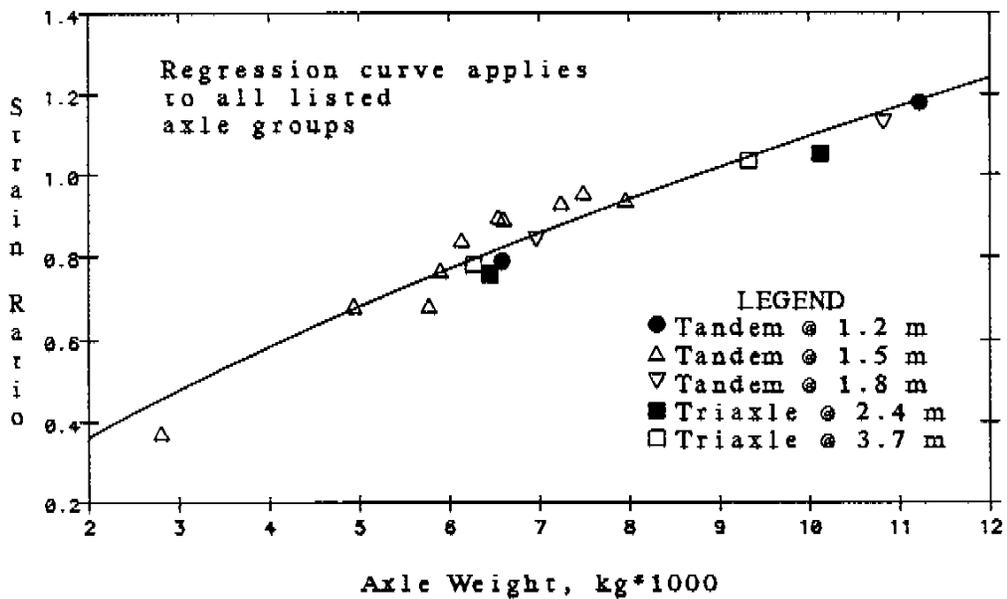


Figure A16: Strain Ratios for Lead Axle Site 7, Ontario

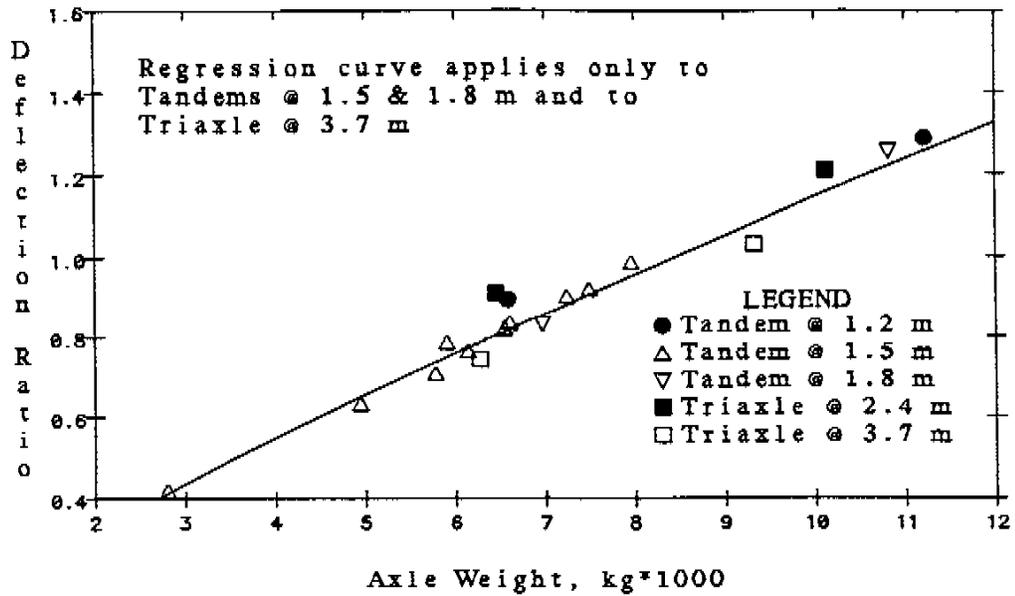


Figure A17: Deflection Ratios for Lead Axle Site 8, Ontario

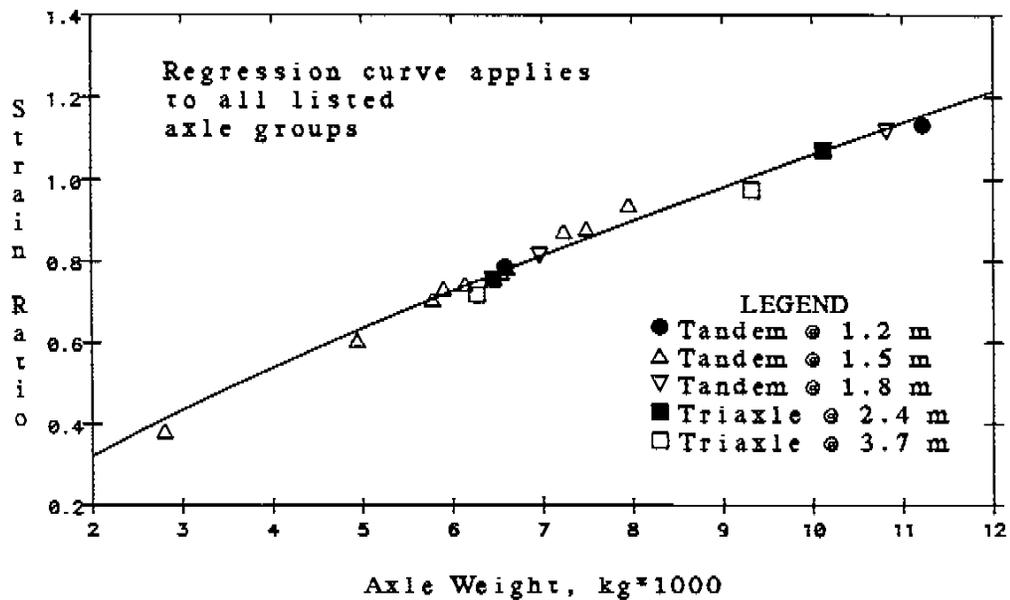


Figure A18: Strain Ratios for Lead Axle Site 8, Ontario

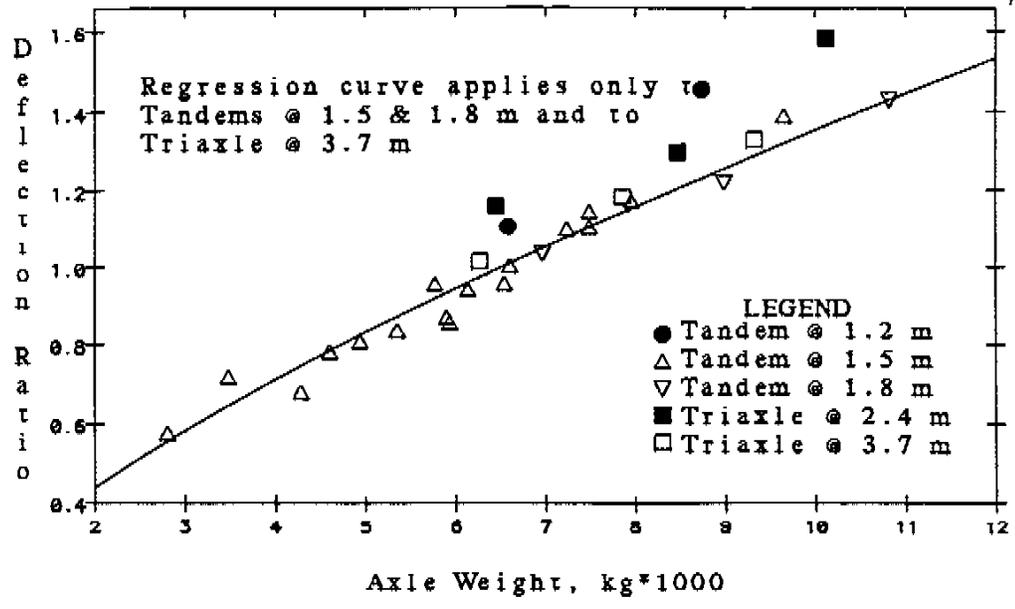


Figure A19: Deflection Ratios for Lead Axle Site 9, Alberta

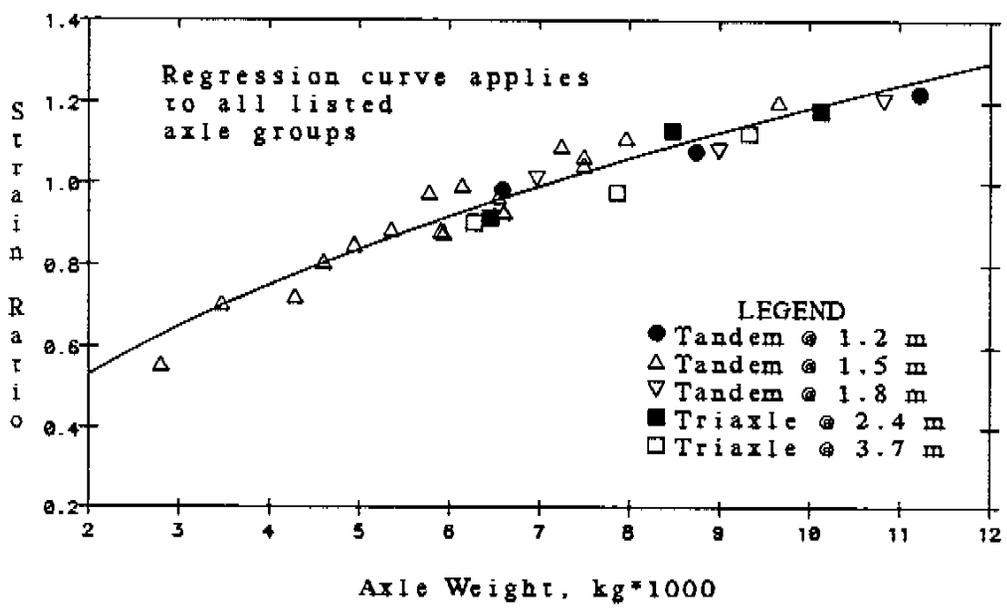


Figure A20: Strain Ratios for Lead Axle Site 9, Alberta

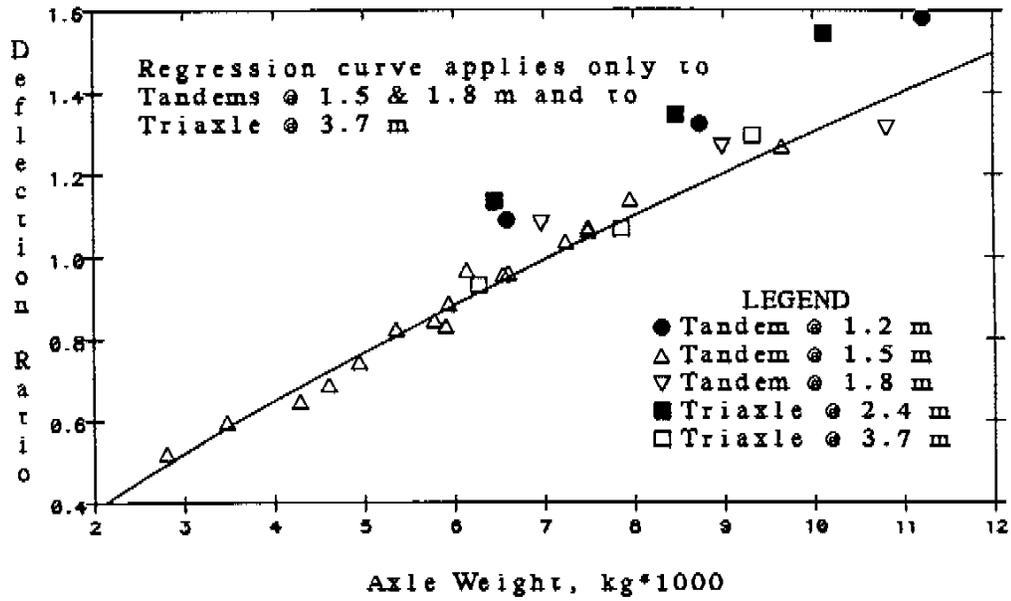


Figure A21: Deflection Ratios for Lead Axle Site 10, Alberta

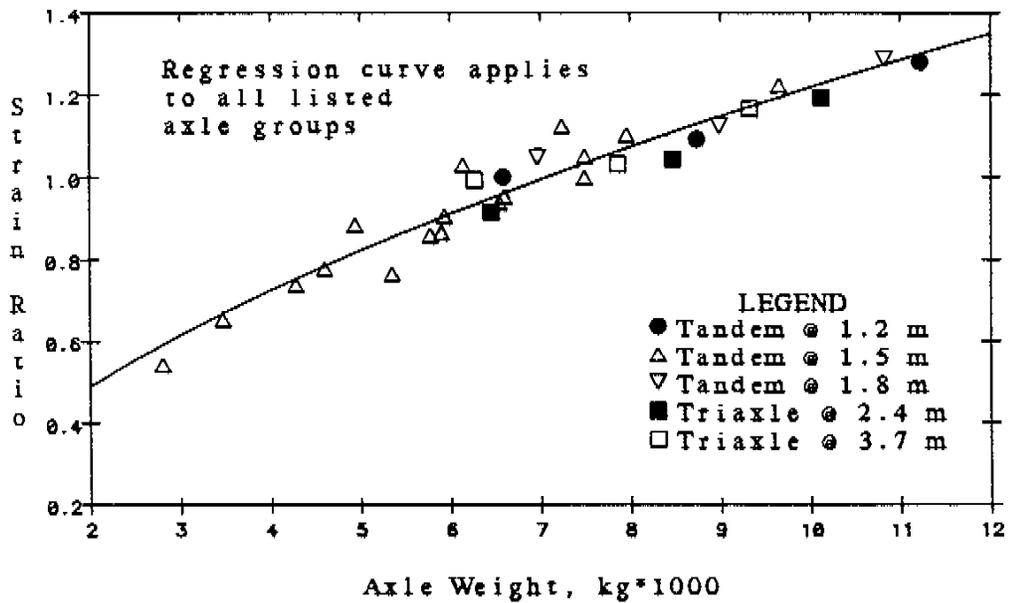


Figure A22: Strain Ratios for Lead Axle Site 10, Alberta

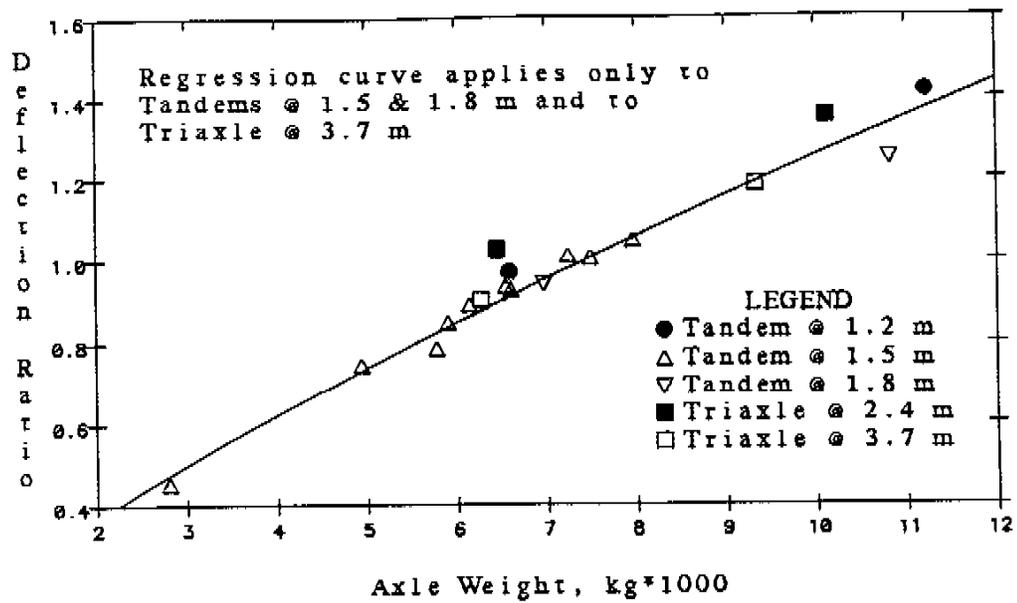


Figure A23: Deflection Ratios for Lead Axle
Site 11, British Columbia

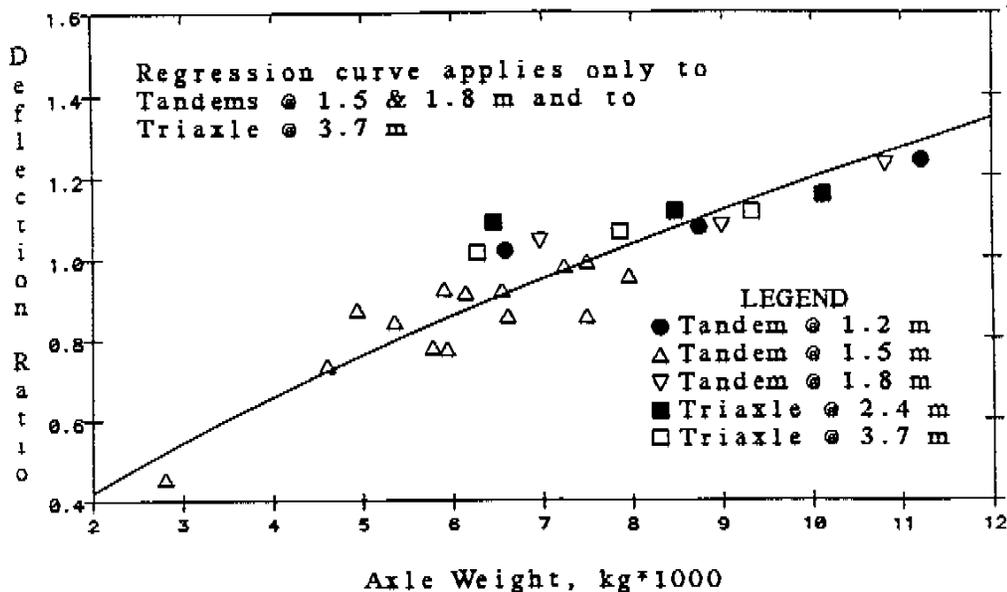


Figure A24: Deflection Ratios for Lead Axle Site 12, British Columbia

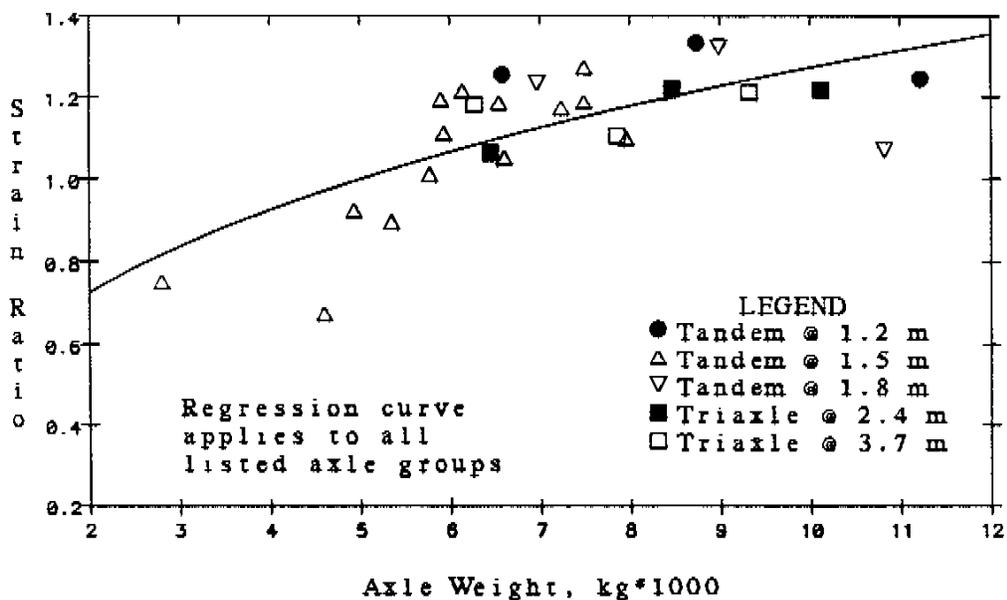


Figure A25: Strain Ratios for Lead Axle Site 12, British Columbia

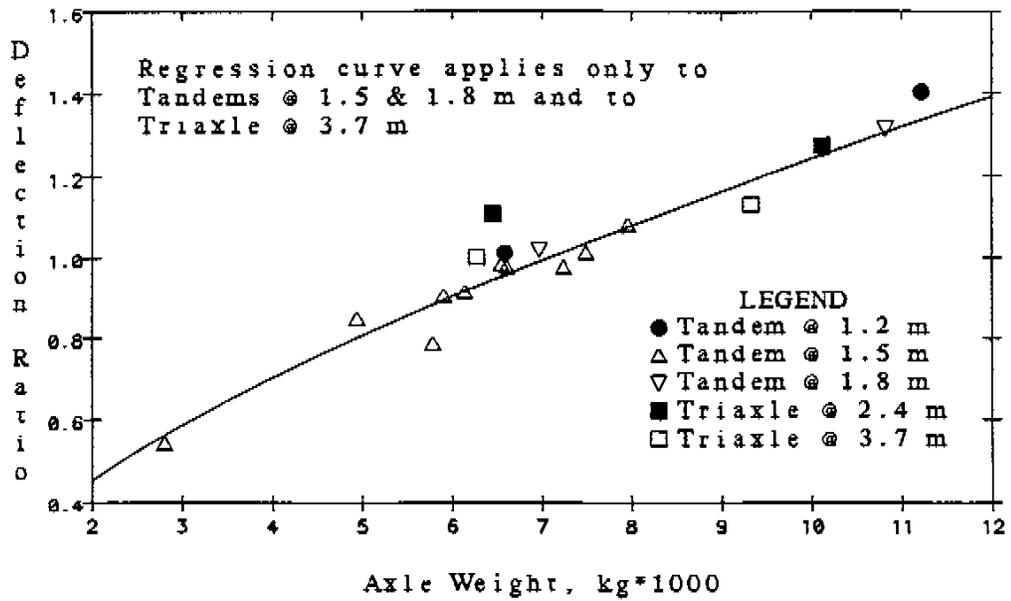


Figure A26: Deflection Ratios for Lead Axle Site 13, British Columbia

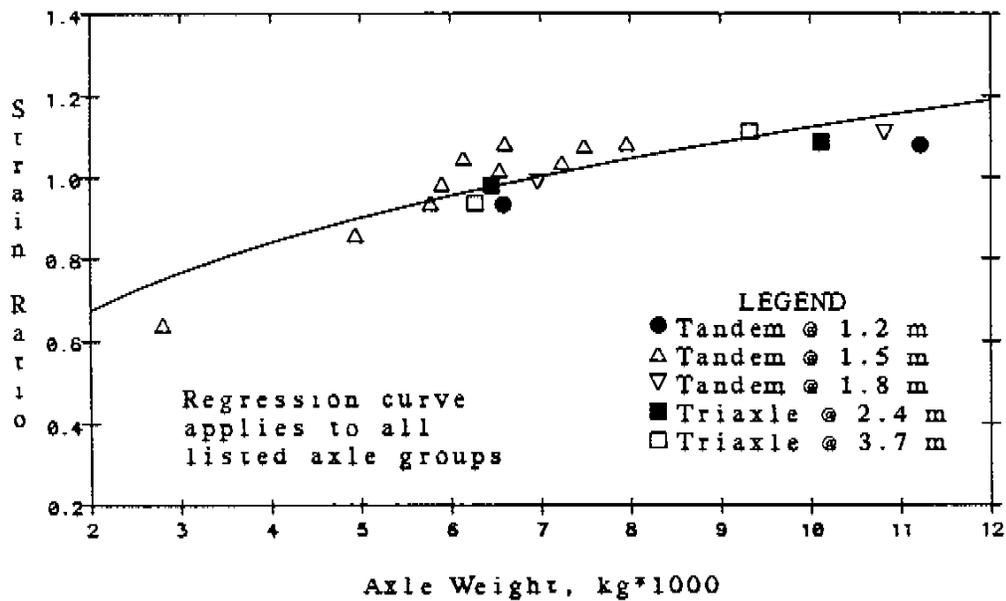


Figure A27: Strain Ratios for Lead Axle Site 13, British Columbia