Effect Of Heavy Vehicle Weights On Pavement Performance

Chhote L. Saraf, George J. Ilves, and Kamran Majidzadeh
Resource International, Inc., USA

ABSTRACT

A study was conducted to determine the effect of heavy vehicle weights on the performance of rigid, flexible and composite pavements. Detailed traffic measurements were made twice a year for two years using weigh-in-motion equipment. Distress measurements, consisting of cracking, faulting, Mays roughness, and PSI for rigid pavements and cracking, rutting, Mays roughness, and PSI for flexible and composite pavements, were made at the same time. These measurements were analyzed to determine the effect of heavy axle loads on measured distresses. Dynaflect deflections were taken four (4) times during the monitoring period; the analysis of this data showed only minor deterioration of pavement's structural strength.

The analysis of data showed that for rigid pavements, heavy axle loads may contribute toward cracking and faulting development, whereas, rutting is most influenced by heavy axle loads for flexible and composite pavements. Different load equivalency factors for each distress type are, therefore, required for estimating the effect of heavy vehicles on the performance of pavements.

INTRODUCTION

Load equivalency factors currently used to convert mixed traffic into 18,000 lb. single axle loads (E-18) were developed from AASHTO Road data collected in 1959-60. The design of heavy vehicles, their tire pressures and weights have changed since that time. Therefore, the equivalent single axle loads estimated from current load equivalency factors may not be able to predict the performance of pavements accurately. Keeping this in mind, a study to determine the effect of heavy vehicles on the performance of pavements was sponsored by the Ohio Department of Transportation (ODOT) and The Federal Highway Administration (FHWA) in 1985. The results of this study were published in a report submitted to ODOT in 1991 [1]. The data collected for this study was analyzed to determine the effect of heavy vehicle weights on the performance of flexible, composite and rigid pavements. The results of data analysis along with other relevant information are described in this paper.

SITE SELECTION

The Ohio special Permit data for overloaded vehicles showed that the weight limits for trucks traveling from neighboring states, such as Michigan, to northern Ohio cities are substantially heavier than the loads permitted in Ohio. Therefore, four sites were selected for the study near Toledo, Ohio where these heavy vehicles use the roadways. The selected sections were approximately ½ mile long and included all three different types of pavements, viz., flexible, composite and rigid. The data in Table 1 lists the locations and some important features of each site. All sites are located in Lucas County of Ohio.

FIELD DATA

The following field data was collected for this study:
1. Traffic,
2. Rutting measurements,
3. Faulting measurements,
4. Cracking measurements,
5. Roughness using Mays meter and K.J. Law non-contact profilometer, and
6. Dynaflect deflection measurements.

A brief description of data collection method and the data collected is as follows. The traffic lanes were numbered 1-4 for the 4-lane divided highways. According to ODOT conventions, lane 1 is the driving lane of south or west bound traffic and lane 4 is the driving lane of north or east bound traffic.

Table 1. Features of site selected for the study (all sites in Lucas County)

Feature	Site #1	Site #2	Site #3	Site #4
Location	I-475	US-23	I-75	I-280
Approx. limits, from mile post - mile post	6.80-7.20	10.90-11.40	7.00-7.50	4.20-4.65
No. of lanes/ directions	4/North and South Bound	2/South Bound only	4/East and West Bound	2/South Bound only
Pavement type	Flexible	Comp., reinf.	Rigid, reinf.	Comp., reinf.
Joint Spacing	-	60'	40'	60'
Pavement layer thicknesses, inches	10" AC 4" Agg	2.5" AC 9" Conc 6" Agg	9" Conc 6" Agg	3.25" AC 9" Conc 6" Agg
Subgrade (ODOT Class)	A-4B	A-3	A-6	A-6

1. TRAFFIC DATA

Traffic data was collected with the help of a weigh-in-motion (WIM) equipment. A preliminary study of available WIM equipment indicated that the Golden Weighman (TM) could be used to meet the traffic analysis needs of this study. This WIM system consists of a capacitive weighmat to sense the axle loads (only ½ of an axle is measured and this measurement is doubled to get the axle load) and two inductive loops that act as axle detectors. The loops were installed in grooves cut into the pavement surface (about 1 inch deep) and functioned well over the 18 month monitoring period.

At the outset of the project it was felt that at least three (3) days of traffic measurements per project would be needed to get an accurate estimate of the traffic mix and that each project should be monitored twice per year. Since one working day would be required for system installation and distress measurements, and allowing for bad weather (ODOT policy was not to close off lanes during wet weather, nor could the weighmat be installed when the pavement was wet), it was decided to only monitor one project per week. The general procedure was to install the WIM equipment on Wednesday, start the recording at 4 p.m. and continue collecting data until 8 p.m. on the following Tuesday; it was necessary to stop recording the night before in order to recharge the Weighman (TM) batteries. This period was chosen because traffic in the Toledo area is very similar on Tuesdays and Wednesday, and to some extent also on Thursdays. However, this pattern could not always be followed due to wet weather, equipment malfunction and on a few occasions, the availability of the traffic control crew.

The field monitoring had to be conducted between April 1 and October 31 each year. These dates were selected because studded snow tires were legal on Ohio highways between November 1 and March 31 and the WIM weighmat cannot long survive under studded tires. Further, the weighmat is temperature sensitive; it is temperature compensated for temperatures above freezing but not well compensated for temperatures below freezing. Therefore, April through October period represents the practical time span available for monitoring. The system was calibrated before using it at the study sites.

The data collected was analyzed and stored in the Weighman (TM) which is programmed to retain data in various modes using a programmer/retriever which also acts as an interface with a computer. The data measured included vehicle speed, load and length, axle load, spacing and type (steering, single, multiple) and time of arrival. All this data could be stored but this is impractical since in this configuration the 128k memory would be filled in a few hours; furthermore, such detail is not necessary for most purposes. The data storage mode selected was that which segregated the vehicles by the FHWA vehicle classification scheme F, and axles by type (steering, single, multiple), as well as storing axle weights in twelve (12) user-defined weight bins. Gross vehicle weight was also categorized into twelve bins (whose limits are fixed at four (4) times that of the axle load bins). [2] A recording interval of four (4) hours was selected.

The results of the traffic measurements are shown in Table 2. In this table the day factor (this factor converts traffic measurements made on a specific day into ADT values) has been derived from ODOT's permanent traffic counting stations that have been operational for several years in the Toledo area (although not at the same locations). Type C vehicles represent medium weight trucks belonging to FHWA Classes 4-7, Type B vehicles represent heavy trucks in Classes 8-13 and Class 13 vehicles (7 or more axles, multi-units) represent the "Michigan Train."[2] The road identification consists of: Road No.-Lane.Monitoring Period, e.g. 475-1.2 represents I-475, Lane 1, and Monitoring Period 2.

The average traffic volume measurements (ADT/lane) shown in Table 2 were in general quite accurate and that vehicle classification (at least as far as Type B and Type C vehicles are concerned) was also satisfactory, especially when

Table 2. Summary of traffic survey data

Road Number	Length, Days	Day Factor	ADT/ Lane	No. of C Trucks/Day	No. of B Trucks/Day	Class 13 Vehicles	
						No. Per Day	% Over 80 KIP
475-1.1	1.0	1.03	10887	186	1623	32	50
475-1.2	6.2	0.99	11372	241	1350	11	69
475-1.3	6.2	0.91	12952	209	947	6	97
475-1.4	6.0	0.85	9815	334	945	83	37
475-2.1	3.7	1.04	5134	25	254	1	25
475-2.2*	6.0	0.91	6637	49	301	16	8
475-2.3*	3.3	0.95	6626	142	459	63	20
475-2.4	6.0	0.85	6615	31	196	1	16
475-3.1	5.2	0.99	7711	42	415	2	64
475-3.2	0.7	0.85	6273	91	357	33	4
475-3.3	0.5	0.90	6456	158	301	36	11
475-3.4	6.0	0.99	8026	61	307	17	3
475-4.1	4.8	0.90	11341	202	1144	8	16
475-4.2	6.2	0.99	12058	327	1431	152	4
475-4.3	5.3	0.99	11907	252	1521	15	30
475-4.4	6.0	0.85	11843	246	1048	54	18
23-1.1	5.0	1.03	8962	147	1208	16	51
23-1.2	7.2	0.85	8267	152	893	12	66
23-1.3	5.7	0.90	7885	121	793	9	65
23-1.4	6.0	0.99	7928	163	713	24	28
23-2.1	4.5	1.04	5806	196	536	6	27
23-2.2	6.2	0.85	6085	108	703	10	45
23-2.3	5.8	0.91	7379	110	846	28	58
23-2.4*	1.2	0.86	4690	354	657	60	34
75-1.1	Equipment	Malfunctn.					
75-1.2	5.3	0.89	10809	749	975	19	17
75-1.3	4.0	0.83	12476	1447	288	4	23
75-2.1	6.8	0.86	7338	282	176	2	13
75-2.2	6.2	1.02	7418	300	289	3	47
75-2.3	6.0	0.86	6882	296	138	2	17
75-3.1	6.7	0.90	11540	234	1655	11	53
75-3.2	6.2	0.99	9686	218	1608	16	49
75-3.3	6.0	0.98	9772	238	1066	9	50
75-3.4							
75-4.1	4.8	0.85	6378	173	315	6	25
75-4.2	6.2	0.99	7222	298	626	3	48
75-4.3	6.0	0.90	6715	479	563	3	75
280-1.1	6.5	0.86	12770	425	1486	191	14
280-1.2	6.2	1.01	13746	357	1887	12	56
280-2.1	5.7	0.85	8516	293	703	86	2
280-2.2	6.7	1.01	9071	100	832	4	33

*Weighmat failed

monitoring times were greater than 4 days. However, small discrepancies were noted in classifying vehicles. For instance, it was noticed during visual cross-checks that the equipment tended to mis-classify vehicles when two vehicles traveled close together (one after the other). This is especially true for Class 13 vehicles where two vehicles with a combined total of more than 6 axles were classified as one Class 13 vehicle. In most cases where a high number of Class 13 vehicles has been found, the percent of these vehicles weighing over 80 kips is low, indicating a high probability of misclassification. The Weighmat on I-280 was located just upstream from a draw bridge; consequently traffic tends to move close together during the times when the draw bridge was operated. This most probably explains why I-280 has a significant variation in the number of Class 13 vehicles accompanied by a significant change in the percentage of heavy Class 13 vehicles.

2. RUTTING MEASUREMENTS

The extent of rutting was measured in both wheel paths at 100 feet (30m) intervals using a 7 feet straight edge and a combination square. The location of maximum rut depth was determined by sight and measured to the nearest 1/64th of an inch. Care was taken to place the straight edge so that it was not on the painted edge lines as the wear in these cause measurements error. Measurements were always taken at the same locations; the pavement was marked with spray paint to ensure this. Average rutting measurements of all sites are listed in Table 3.

Table 3. Average rutting and total cracking measurements, Project site I-475, US-23 and I-280

Route Number	Date	No. of 18-kip Load Applications	Total Cracking (Ft.)	Average Rutting (In.)
I-475-1.1	07/05/86	5,695,480	414	0.126
I-475-1.2	20/08/86	5,872,022	412	0.126
I-475-1.3	02/06/87	6,415,360	466	0.095
I-475-1.4	26/08/87	6,454,782	651	0.133
I-475-2.1	14/04/86	1,346,896	632	0.079
I-475-2.2	28/08/86	1,400,684	637	0.064
I-475-2.3	05/05/87	1,501,836	668	0.074
I-475-2.4	19/08/87	1,538,754	755	0.085
I-475-3.1	22/04/86	1,412,708	499	0.081
I-475-3.2	10/09/86	1,478,562	497	0.058
I-475-3.3	15/04/87	1,583,546	534	0.070
I-475-3.4	12/08/87	1,624,585	621	0.097
I-475-4.1	29/04/86	4,160,056	147	0.130
I-475-4.2	03/09/86	4,394,044	152	0.141
I-475-4.3	06/04/87	4,805,410	188	0.145
I-475-4.3	05/08/87	4,934,544	245	0.167
US-23-1.2	01/04/86	1,456,785	736	0.108
US-23-1.2	12/08/86	1,582,770	739	0.098
US-23-1.3	14/07/87	1,914,417	738	0.103
US-23-1.4	03/09/87	1,963,417	744	0.103
US-23-2.1	02/04/86	1,176,784	686	0.120
US-23-2.2	28/07/86	1,267,017	703	0.115
US-23-2.3	16/06/87	1,522,085	682	0.105
US-23-2.4	10/09/87	1,590,797	686	0.114
I-280-1.2	22/07/86	10,412,966	612	0.337
I-280-1.2	15/10/86	10,619,220	626	0.310
I-280-2.1	16/07/86	2,945,354	578	0.268
I-280-2.2	22/10/86	3,012,708	625	0.318

Table 4. Total cracking and average faulting measurements, Project site I-75

Route Number	Date	No. Of 18-kip Load Applications	Total Cracking (Ft.)	Average Faulting (In.)
I-75-1.1	15/07/86	7,367,617	1,588	0.081
I-75-1.2	02/10/86	7,556,544	1,857	0.090
I-75-1.3	21/07/87	8,277,903	1,884	0.074
I-75-1.4	09/09/87	8,388,315	1,920	0.090
I-75-2.1	07/07.86	1,566,081	1,343	0.011
I-75-2.2	10/10/86	1,605,746	1,423	0.016
I-75-2.3	21/07/86	1,727,725	1,444	0.032
I-75-2.4	09/09/87	1,746,917	1,464	0.013
I-75-3.1	24/06/86	6,699,692	1,409	0.065
I-75-3.2	24/09/86	6,859,982	1,423	0.070
I-75-3.3	14/07/87	7,367,567	1,446	0.072
I-75-3.4	23/09/87	7,502,923	1,506	0.069
I-75-4.1	01/07/86	3,768,668	1,408	0.068
I-75-4.2	17/09/86	3,844,668	1,471	0.081
I-75-4.3	01/07/87	4,133,668	1,488	0.089
I-75-4.4	23/09/87	4,212,668	1,644	0.076

3. FAULTING MEASUREMENTS

Faulting measurements were made on the outside edges of the slab at about 12 inches in from the edge. The 12 inch distance was selected to be away from the painted edge lines and also to avoid any excess joint filler and/or significant joint spalling; however, measurements sometimes had to be shifted slightly to clear the obstacles. A combination square was used, with faulting values recorded to the nearest 1/64th of an inch; every joint was measured. Average faulting measurement at project site I-75 are listed in Table 4.

4. CRACKING MEASUREMENTS

Cracking measurements consisted of estimating the length of each crack to the nearest foot. To facilitate this, a sketch was made of each project during the first survey showing the location and approximate length of each crack. This allowed the changes in cracking to be recorded on these figures during subsequent surveys and resulted in much more accurate estimate of the extent of cracking than would otherwise have been possible. Total cracks measured at all sites are listed in Tables 3 and 4.

5. ROUGHNESS MEASUREMENTS

Pavement roughness was measured using a Mays Meter mounted on a midsize car and also by a K.J. Law non-contact profilometer, which provided PSI values. Measurements were always made over the entire project length; the start and end points of each project were painted on the sides of the road for easy visibility. The roughness measurements are summarized in Table 5.

6. DYNAFLECT DEFLECTION MEASUREMENTS

Dynaflect deflection measurements were made by ODOT at about 100 feet intervals on all lanes of I-475 (flexible pavement) and at about 50 feet (15 m) intervals on the south bound lanes of US 23 (composite pavement); no measurements were made at joint locations because very few joints had reflected through the overlay. Measurements were made at each joint and at each location for all four lanes of I-75 and for the southbound lanes of I-280. The joint measurements consisted of "approach" and "leave" measurements. In the approach case the loading wheels and number 1 sensor are placed about 6 inches (150 mm) on the upstream slab, with the remainder being on the downstream slab, and in the leave case all sensors are on the downstream slab with the loading wheels being about 6 inches (150 mm) downstream from the joint.

Air and pavement surface temperature were also recorded, along with weather information. Due to limited space in this paper, deflection data is not included here. The results of data analysis, however, are discussed later in this paper.

ANALYSIS OF DATA

The data collected for this study was analyzed to determine the effect of heavy loads on various pavement performance parameters measured for this study. For this purpose, the traffic data was analyzed to estimate the total number of 18-kip single axle load applications (E-18) for each lane of the road section using the conventional load equivalency factors. The estimated number of E-18 are listed in Tables 3, 4 and 5 along with the performance measurements. The WIM data listed in Table 2 was used to estimate the averages of ADT and number of B, C and Class 13 trucks for each lane of the study section. The results of this analysis are summarized in Table 6. These traffic data were used to relate the performance measurements with the number of E-18 and/or heavy trucks (Class 13). The following paragraphs describe the analysis of data and the results.

Table 5. Summary of roughness measurements.

Route Number	Date	No. of 18-kip Load Appl..	Mays, in./ 0.2 mile	Date	No. of 18-kip Load Appl..	PSI (ODOT)
I-475-1.1	18/08/86	5,868,594	4.57	09/86	5,914,872	3.74
I-475-1.2	16/12/86	6,026,282	7.27	12/86	6,024,568	4.02
I-475-1.3	31/08/87	6,463,352	5.90	02/87	6,178,828	3.63
I-475-1.4	10/02/88	6,597,809	6.56	12/87	6,669,032	3.57
				03/88	6,657,799	3.70
I-475-2.1	18/08/86	1,393,046	5.50	09/86	1,403,884	3.74
I-475-2.2	16/12/86	1,441,214	5.96	12/86	1,440,813	3.99
I-475-2.3	31/08/87	1,543,571	6.80	02/87	1,476,939	3.64
I-475-2.4	10/02/88	1,607,795	7.12	12/87	1,591,739	none
				03/88	1,621,844	3.57
I-475-3.1	18/08/86	1,468,063	6.58	09/86	1,480,948	3.48
I-475-3.2	16/12/86	1,511,966	5.80	12/86	1,511,488	3.97
I-475-3.3	31/08/87	1,633,652	4.58	02/87	1,554,436	3.47
I-475-3.4	10/02/88	1,642,273	6.73	12/87	1,690,916	none
				03/88	1,658,975	3.57
I-475-4.1	18/08/86	4,275,981	6.25	09/86	4,326,930	3.73
I-475-4.2	16/12/86	4,502,421	9.15	12/86	4,500,534	4.00
I-475-4.3	31/08/87	4,983,606	5.19	02/87	4,670,364	3.64
I-475-4.4	10/02/88	5,285,526	7.55	12/87	5,210,046	3.69
				03/88	5,351,571	3.74
US-23-1.1	18/08/86	1,618,488	4.80	09/86	1,648,107	3.48
US-23-1.2	16/12/86	1,705,180	6.80	12/86	1,704,083	3.73
US-23-1.3	31/08/87	1,960,329	5.09	02/87	1,802,813	3.69
US-23-1.4	10/02/88	2,125,279	4.53	12/87	2,135,204	3.68
				03/88	2,233,934	3.38
US-23-2.1	18/08/86	1,306,566	5.88	09/86	1,329,114	3.56
US-23-2.2	16/12/86	1,376,551	6.03	12/86	1,375,716	3.91
US-23-2.3	31/08/87	1,582,526	5.75	02/87	1,450,875	3.66
US-23-2.4	10/02/88	1,715,687	5.49	12/87	1,703,910	None
				03/88	1,779,069	3.52
I-75-1.1	18/09/86	7,514,833	11.87	09/86	7,507,472	2.82
I-75-1.2	16/12/86	7,740,564	16.93	12/86	7,738,111	3.05
I-75-1.3	31/08/87	8,366,232	10.90	02/87	7,885,327	2.81
I-75-1.4				12/87	8,628,767	2.82
I-75-1.5				03/88	8,849,591	2.80
I-75-2.1	18/09/86	1,595,083	11.09	09/86	1,593,804	3.28
I-75-2.2	16/12/86	1,634,321	14.57	12/86	1,663,895	3.54
I-75-2.3	31/08/87	1,743,079	9.31	02/87	1,659,485	3.42
I-75-2.4				12/87	1,788,714	none
I-75-2.5				03/88	1,827,099	3.40
I-75-3.1	18/09/86	6,843,953	13.47	09/86	6,838,610	2.72
I-75-3.2	16/12/86	7,007,805	17.49	12/86	7,006,024	3.03
I-75-3.3	31/08/87	7,461,960	11.27	02/87	7,112,884	2.84
I-75-3.4				12/87	7,652,527	none
I-75-3.5				03/88	7,812,817	2.73

Table 5. Summary of Roughness Measurements (continued)						
Route Number	Date	No. Of E-18	Mays	Date	No. Of E-18	PSI
I-75-4.1	18/09/86	3,842,668	12.87	09/86	3,839,668	3.10
I-75-4.2	16/12/86	3,934,668	16.34	12/86	3,933,668	3.17
I-75-4.3	31/08/87	4,189,668	11.06	02/87	3,993,668	2.20
I-75-4.4				12/87	4,296,668	2.71
I-75-4.5				03/88	4,386,668	3.07
I-280-1.1	18/08/86	10,550,088	8.13	09/86	10,621,368	3.37
I-280-1.2	16/12/86	10,767,455	10.66	12/86	10,764,815	3.51
I-280-1.3				02/87	11,002,415	3.38
I-280-1.4				12/87	11,802,335	3.64
I-280-2.1	18/08/86	2,988,221	6.27	09/86	3,007,607	3.49
I-280-2.2	16/12/86	3,049,788	8.76	12/86	3,049,070	3.80
I-280-2.3				02/87	3,113,690	3.40
I-280-2.4				12/87	3,331,244	none

Table 6. Averages of traffic data listed in Table 2.

Road	Lane	ADT/ Lane	No. Of C/Day	No. Of B/Day	No. Of Class 13/Day	Total Trucks (B + C + Class 13)/Day
I-475	1	11,257	243	1,216	33	1,492
	2	6,253	62	303	20	385
	3	7,117	88	345	22	495
	4	11,787	257	1,282	57	1,596
US-23	1	8,261	146	902	15	1,063
	2	5,990	192	686	26	904
I-75	1	11,643	1,098	632	12	1,742
	2	7,213	293	201	2	496
	3	10,333	230	1,443	12	1,685
	4	6,771	317	501	4	822
I-280	1	13,258	391	1,687	102	2,180
	2	8,794	197	768	45	1,010

1. ANALYSIS OF CRACKING DATA

The cracking data for flexible pavement (I-475 road section) is listed in Table 3. This data indicates that total cracking for each lane increased with time and number of E-18. However, no clear trend was observed when total cracking data was combined for all 4 lanes. Coincidentally, it was observed that lane #4 developed the least amount of total cracking and lane #2 developed the highest amount of total cracking (see Table 3). Also, lane #4 carried the highest number of Class 13 trucks and lane #2 carried the least number of Class 13 truck (see Table 6). The cracking for lanes 3 and 1 also follow this trend. This indicated that E-18 obtained from load equivalency factors may not be representative of cracking related performance of flexible pavements.

Cracking data for rigid pavement (I-75) is shown in Table 4. This data indicated that cracking in each lane increased with time and E-18. But, as was the case with flexible pavements, no relation between E-18 and total cracking was observed when data for all 4-lanes was combined. Presence of greater number of Class 13 vehicles in lanes 1 and 3 did not cause greater cracking in these lanes when compared with lanes 2 and 4.

Cracking data for composite pavements (I-280 and US-23 roadway segments) is listed in Table 3. This data shows that total cracking in these pavements did not change significantly during the observation period of approximately 17 months.

There is a significant difference in the traffic (E-18 as well as Class 13 vehicles) in lane 1 and lane 2 of route I-280.However, no such difference in total cracking in these lanes was observed for this pavement.

2. ANALYSIS OF RUTTING DATA

Rutting measurements were recorded for flexible and composite pavements. The data for flexible pavement (I-475) indicated that rutting in any given lane generally increased with time and E-18. Among the two highest rutting lanes (1 and 4), lane #4 rutted most but lane #1 carried the most E-18 (see Table 3). A comparison with Class 13 data (see Table 6), however, showed that lane #4 carried the most Class 13 vehicles and also rutted the most. A regression analysis of this data (flexible pavement) was, therefore, performed to obtain a relationship between the observed rutting (RUTF) and the number of Class 13 vehicles (C13) per day and the combined B and C trucks (B&C). Another independent variable (months) was added to this equation which represented the month of testing. The count for month of testing started with January 1986 as month = 1. Data collected during any given month was recorded as a whole number. For example May 1986 was recorded as 5 months and June 1987 was recorded as 13 months and so on. The equation derived from the data is as follows:

$$RUTF = 0.035 + 0.984\,(C13) + 0.03\,(B \,\&\, C) + 0.0007\,(months) \quad (1)$$

where,

RUTF = Rutting in flexible pavement, in,
C13 = No. of Class 13 vehicles in the lane per day in thousands,
B & C = Total number of B & C trucks combined per day in thousands, and
months = number of months since January, 1986 as explained above.

The correlation coefficient (r) square of this data was 0.86. However, the relationship is limited to the data range used and it is not intended to be an universal equation. It is evident from this equation that heavy vehicles (C13) contribute significantly more to rutting of flexible pavement than other trucks (B & C). The coefficient for C13 is about 33 times larger than the coefficient for B&C.

The rutting data for composite pavements (US-23 and I-280) indicated that lane #1 of US-23 (see Table 3) carried slightly more E-18 than lane #2. But the rutting in lane #1 was slightly less than lane #2. A substantial difference in E-18 in lane #1 and #2 of I-280 showed only a slight difference between the rutting in lane #1 and #2 of this road. On the other hand, the summary of traffic data shown in Table 6 indicated that lane #2 of US-23 carried slightly more C13 vehicles than lane #1, which may explain slightly more rutting in lane #2 than lane #1. Also, the difference in rutting in lanes 1 and 2 of I-280 is consistent with the slight difference in C13 vehicles in these lanes rather than a significant difference between E-18 values listed in Table 3 for this road. These observations indicate that rutting in composite pavements is also affected by heavy vehicles(C13).

3. ANALYSIS OF FAULTING DATA

Faulting data was collected for rigid pavement (I-75) only. The data listed in Table 4 indicates that in any given lane, faulting increased with time and E-18. Also, when data for lanes 1 and 2 is combined, there is a clear trend between the faulting and E-18 due to significant difference between the E-18 in these lanes. However, the difference in E-18 of lane #3 and #4 does not show similar trends. The number of C13 vehicles listed in Table 6 for this route also do not indicate any consistent trend with this parameter. However, relatively higher percentage of B and C and Class 13 trucks in lanes 1, 3 and 4 were observed to develop more faulting than lane 2 which carried lesser percentage of trucks (percent of ADT/day). These percentages for lanes 1, 3, 4 and 2 are 15, 16, 12 and 7 respectively.

These results indicate that faulting in rigid pavement is affected by all types of trucks but the effect of heavy vehicles in this case may have been shadowed by their small number in the traffic mix.

4. ANALYSIS OF ROUGHNESS DATA

Roughness data was collected by two different devices; Mays Meter and K.J. Law non-contact profilometer. The data collected by these devices is summarized in Table 5. The flexible pavement data (I-475) shows that the roughness measured by May Meter increased with time and E-18 for any given lane. However, no correlation could be found between E-18 and May Meter roughness when data for all 4-lanes was combined together. This roughness did not show any correlation with the number of heavy vehicles (C13) in different lanes. The PSI data also did not correlate with either E-18 or heavy vehicles (C13).

The data from two composite pavements (US-23 and I-280) showed some increase in Mays Meter roughness with time and E-18 in only one case (I-280). However, the number of heavy vehicles in individual lanes of both pavements increased the roughness with increase in their numbers. PSI did not show noticeable change in either case.

The rigid pavement roughness (I-75) did not show any noticeable trend for either Mays Meter data or PSI data with E-18 and C13 traffic.

5. ANALYSIS OF DEFLECTION DATA

The deflection data collected for this study was analyzed to determine the effect of heavy vehicles on this parameter. Although, it was observed that the maximum deflection (W1) generally increased during the study period, yet this increase in (W1) did not indicate significant deterioration in pavement structurally. The total cracking in sections of I-75, I-280 and I-475 changed more than the cracking in US-23. Therefore, these sections may have undergone slight structural strength change than US-23 section. This was evident from the deflection data for US-23 section.

RESULTS OF DATA ANALYSIS

The results of data analysis (described in the previous section) are as follows:

1. The presence of heavy vehicles in the traffic mix did not alter the cracking of pavements of all three types.
2. The effect of heavy vehicles on rutting in flexible and composite pavements was significant when compared with other trucks (B & C) as indicated by Equation (1).
3. Faulting in rigid pavement did not show any significant effect of Class 13 vehicles only. However, a greater percentage of all trucks (B, C and Class 13) carried by lanes 1, 3 and 4 of I-75 section developed more faulting in these lanes than lane #1 which carried lesser percentage of all trucks.
4. Effect of heavy vehicles on roughness of pavements was no different than the effect of other trucks (B&C) on roughness.
5. The presence of heavy vehicles did not alter the trends in structural deterioration of pavements as observed from the deflection data. Slight deterioration in structural strength of pavements as observed from the Dynaflect deflection data may be due to the presence of cracks in these pavements

CONCLUSIONS

Based on the results of this study it was observed that in general the traffic affected the performance (as measured by various parameters) of all types of pavements. When data from each lane of the roadway was considered, all distresses increased with time and/or E-18. However, the presence of different number of heavy vehicles in the mix of traffic in each lane of a roadway, the effect of heavy vehicles on the performance of pavement was not clearly delineated except in case of rutting in flexible and composite pavements and to some extent faulting in rigid pavement. Different load equivalency factors (different than currently used) for different pavement distresses are, therefore, required to determine the effect of heavy vehicles on various pavement distresses.

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