The 1986 International Conference on Bearing Capacity of Roads and Airfields.

September 16th - 18th 1986, Plymouth, England.

MAINTENANCE AND REHABILITATION TECHNOLOGEIS OF HEAVY TRAFFIC ROAD PAVEMENTS IN TOKYO

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ABSTRACT

This paper describes maintenance and rehabilitation technologies developed in Tokyo for the past ten years laying emphasis on the heavy traffic road. Vibration caused by traffic is discussed initially. Experimental results show that surface roughness is related to the level of vibration and that stiff structures of pavement are effective for preventing vibration. The relationship between pavement structures and type of failures are discussed secondly. Japan has succeeded in preventing cracking from the bottom of asphaltic leyares, but rutting caused by plastic flow of asphalt mixtures has become serious especially in major roads. Circumstances which cause plastic flow and recently developed high viscosity asphalt against it are also introduced. Field recycling has been widely used in Japan. The method and cost are stated briefly. Most of pavement engineers are studying pavement management systems in Japan in order to use unvestments effectively, or rehabilitation will not catch up with failure. Automatic condition survey devices have been developed recently for the purpose of structuring systems. These are introduced finally.

1. INTRODUCTION

Tokyo Metropolitan Government has a public road network of 2 thousand kilometers in total length. As Tokyo is industrially and geographically situated in the center of Japan, roads are always busy even at night. Figure 1 shows such concentrated circumstances of Tokyo. The number of commercial vehicles passing through major roads often exceeds 10,000 per day / direction. Therefore, the pavement engineers in Tokyo have to consider not only pavement rehabilitation technologies but also minimizing the complaints of inhabitants around roads, whose houses are generally within 5 meters from road shoulders. Subjects going to be discussed hereafter are largely influenced by these special circumstances of Tokyo.

Table 1. Concentration index in Tokyo (1984)

	JAPAN (A)	TOKYO (B)	B/A (%)
Area	377,780 km^2	2,161 km^2	0.6
Road Length	1,121,782 km	22,451 km	2.0
Number of motor vehicle	61.8 million	4.6 million	7.4
Population	120.2 million	11.8 million	9.8
Number of college and university	460	102	22.2
Number of major company	726	422	58.1

2. FACTORS INFLUENCING VIBRATION

As Tokyo has such a big population in a small area, land price at ordinary bed towns is more than 1,000 dollars / m^2. So there is almost nothing but houses besides roads. Heavy traffic roads are not exceptional, either. Vibration caused by commercial vehicles has been the strongest complaint of all from these inhabitants against the Government. A lot of field experiments were carried out by pavement engineers to find out main parameters influencing the vibration and the following conclusions were obtained:

(i) Surfaces roughness is the most important factor among pavement failures. Figure 1 shows one of the relations between level of vibration on the edge of road and surface roughness index. Based on the conclusion, the criteria of surface roughness index was decided as less than 2.5mm just after construction.

(ii) Stiffer structures of pavement cause less vibration. So stabilization of base materials with portland cement or asphalt is recommendable. Figure 2 and 3 show the results of experiments concerning vibration and stiffness of pavement for various structures.

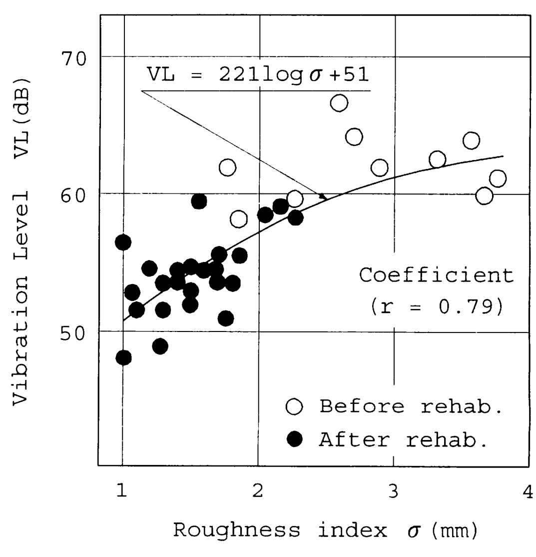


Fig.1 The relationship between VL and σ

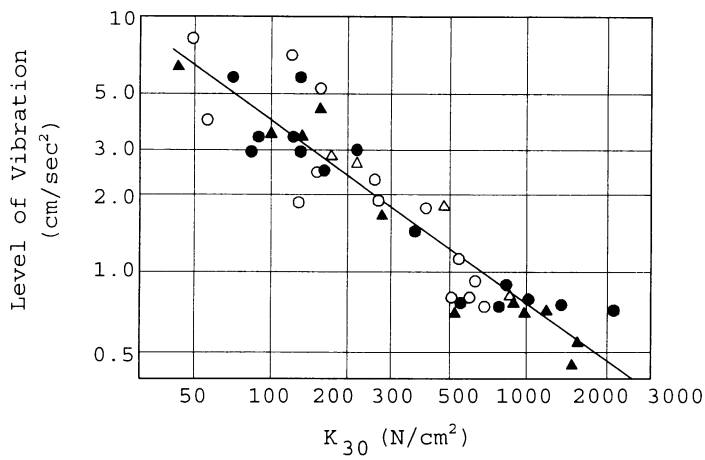


Fig.2 Vibration level vs K value

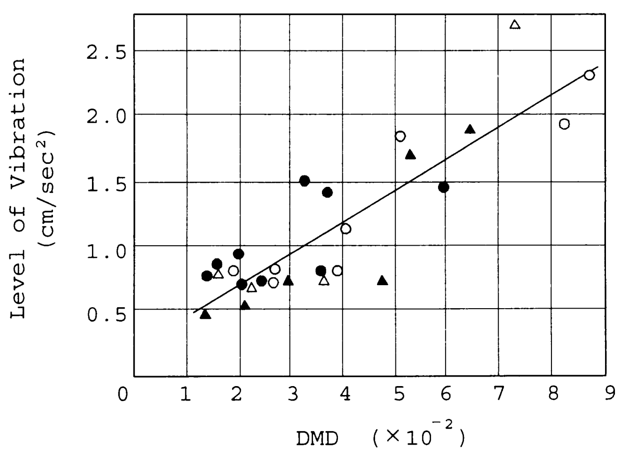


Fig.3 Vibration level vs Dynaflect DMD

3. PAVEMENT STRUCTURES

Figure 4(a) shows one of standard structures for busy road before 1967. It was found that this type of structures was not strong enough for increasing commercial vehicles and consequently cracking occured from the bottom of cementitious layer.

A new design methods was developed in 1967 based on AASHO Road Test results and a lot of field experiments in Japan. The thickness of pavement is calculated by the following formula[1]:

$$T_A = \frac{3.84N^{0.16}}{CBR^{0.3}}$$

where T_A and N are the design thickness (ie. the required thickness of a full depth hot mix asphalt pavement having an equivalent strength) and the number of equivalent 5-ton wheel-loads in one direction to be expected during the 10-year period following construction.

One of standard structures which has been used since then is shown in Figure 4(b). Damaged old structures have been replaced according to the formula.

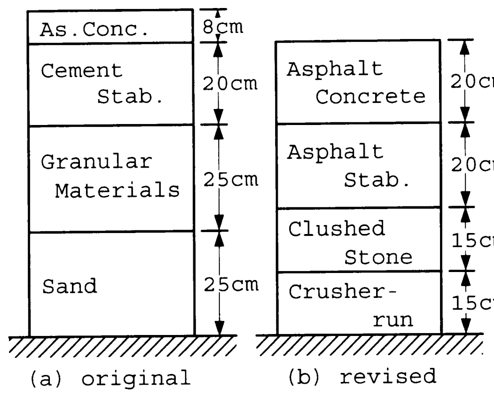


Fig.4 Pavement structures

4. FAILURES AND REHABILITATION METHODS

There have been two kinds of pavement failures which are serious but difficult to avoid both at one time in Tokyo. One is cracking and the other is rutting. Cracking can be found usually in the old type of structures (Figure 4(a)) and it is apparent that the thickness is not sufficient to carry traffic loads any longer. Partial replacing of 35cm from the surface or whole replacing is used for this type of failure. Though cracking seldom occurs to the structures of Figure 4(b), another failure occurs. It is rutting caused by plastic flow of asphalt mixtures. In this case, overlay was first applied but gradually it has become difficult to level up the formation considering houses around roads. Therefore cut and overlay method has been developed and simple overlay has almost disappeared. This trend of rehabilitation methods and yearly investment are shown Figure 5 and 6.

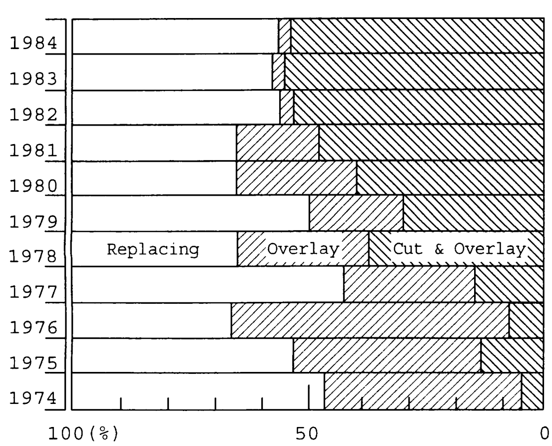


Fig.5 Proportion of methods by areas

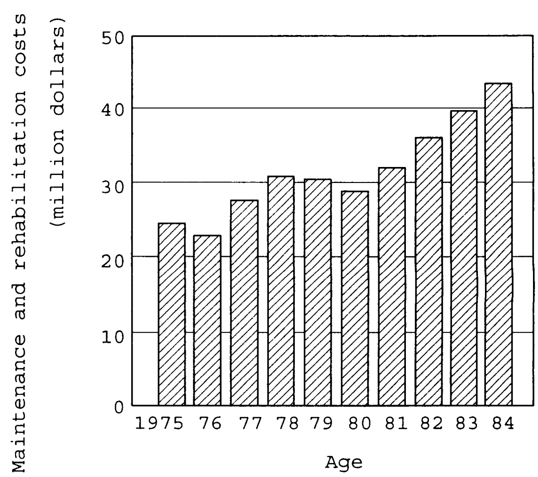


Fig.6 Change of investment

5. PREVENTION OF RUTTING

Plastic flow of asphalt mixtures in Tokyo results from high temperature, lane regulation, traffic jam and etc. Table 2 explains one of such circumstances. Pavement engineers have tried to minimize plastic flow by changing asphalt mixtures as follows:

(i) Use of harder straight asphalt

(ii) Use of modified asphalt or semi-blown asphalt (Table 3)

(iii) Changing gradation of aggregate from dense to coarse or open

These methods have been successful to some extent, but the heavy snow fall in 1984 after an interval of ten years exposed a weak point of such mixtures. Pavement surface was considerably damaged by chain and stud of tire. Engineers had known the risk of course, but inhabitants would not accept noisy surfaces. They may have to change mix design method again.

Table 2. Number of Hot days in Summer (1982)

	Over 20°C	Over 25°C	Over 30°C	Continueing Over 20°C	Continueing Over 25°C	Continueing Over 30°C
London	82	25	1	18	6	1
Paris	114	48	12	77	11	4
San Fransisco	41	7	1	12	3	1
Tokyo	119	81	24	96	38	8
Tokyo (30years average)	122	106	34	122	106	34

Note: These figures show number of days from June to September concerning dayly maximum air temperature mentioned above.

Table 3. Requirements for semi-brown asphalt[2)]

The semi-blown asphalt shall be homogeneous and free of water, shall not foam when heated to 180°C, and shall satisfy all the following requirements.

	Grade : AC 140
Viscosity at 60°C, poise.	14,000±4,000
Kinematic viscosity at 180°C, max., cSt	200
Mass change by thin-film oven test, max., %	0.6
Penetration at 25°C, 100g, 5sec., min.	40
Solubility in trichloroethane, min., %	99.0
Flash point, COC, min., °C	260
Specific gravity at 25°C, min.	1,000
$\text{Ratio} = \dfrac{\text{Viscosity at 60°C after thin film oven test}}{\text{Viscosity at 60°C before thin film oven test}}$, max	6

6. <u>DEVELOPMENT OF RECYCLING METHODS</u>

Recycling of asphalt mixtures was first tried after the energy crisis of 1973 and has been developed eagerly according to following reasons:

(i) Insufficient place for dumping

(ii) Shortage and high cost of good granular materials

(iii) Little influence of aged asphalt on the rutting

The standard of material properties for central plant mixes has been authorized and they are sold widely now. Field recycling is one of the most expected methods for rehabilitation not only in Tokyo but also in whole Japan. As pavement structures have become stiffer and stiffer especially in the major road, there are a lot of cases that failures are limited to several sentimeters of surface course. Those failures include wearing, surface roughness, rutting and cracking which comes from the surface. Field recycling has been applied for them and is being used widely. Japan has more than thirty sets of field recycling machine. One of the typical sets is illustrated in Figure 7. Pavement materials are heated first, sculified, coverd by fresh mixtures and compacted. Nearly 100 thousand square meters of road were repaired for the past three years in Tokyo. There are three methods of using the machine.

Type I : heating, sculifying, compacting

Typw II : heating, sculifying, adding modifier, compacting

Typw III : heating, sculifying, adding fresh mixtures, compacting

The costs of these methods are compared with other traditional methods in Table 4.

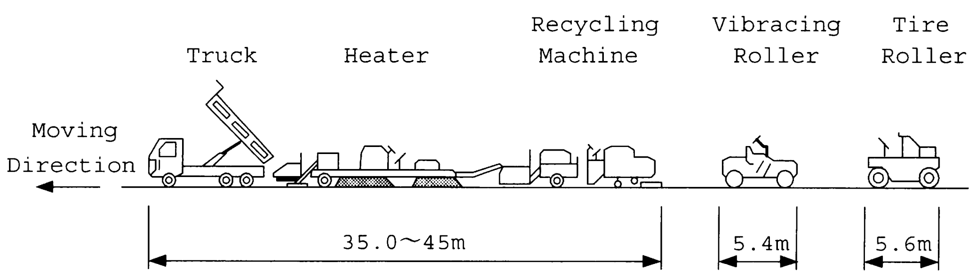


Fig.7 Field Recycling Machine[3)]

Table 4. Comparion of Cost

Method	Depth (cm)	Cost ($/m²)
Cut and Overlay	5 10	14.6 27.9
Replacing	35 70	66.7 87.5
Recycling Type I Type II Type III	5 5 5	5.0 7.1~ 9.0 8.2~10.2

7. FAILURE CRITERIA FOR REHABILITATION

Pavement rehabilitation generally follows the "Manual for Maintenance and Rehabilitation of Roads"[2) issued by the Japan Road Association. In it methods of repairing pavement are classified as in Table 5 in accordance with PSI values calculated by the following formula:

$$PSI = 4.53 - 0.518\log k - 0.371C^{0.5} - 0.174D^2$$

where PSI : Present Serviceability Index

K : Surface Roughness Index in cm

C : Percentage of cracked area

D : Rut depth in cm

Another formula has been presented recently by the Ministry of Construction based on serveys of national roas (Table 5). It is :

$$MCI = 10 - 0.47K^{0.2} - 1.48C^{0.3} - 0.29D^{0.7}$$

$$MCI_1 = 10 - 2.23C^{0.3}$$

$$MCI_2 = 10 - 0.54D^{0.7}$$

where MCI : Maintenance Control Index

MCI_1 : MCI when cracking is major factor

MCI_2 : MCI when rutting is major factor

Figure 8 shows the limit of these indices requiring overlay. Instead of those formula mentioned above we have decided to use following simple one.

$$TMI = C + D$$

where TMI : Tokyo Maintenance Index

This represents the diagonal line connecting 40% (cracking) with 40mm (rutting) In this case the value of TMI is 40. This simple formula is based on the fact that more than 90% of surface roughness index ranges 2.3mm - 2.6mm and that it can be considered as constant (Figure 9). TMI value of 30 is recommendable for major roads in Tokyo. Figure 10 shows the limit and distribution of cracking and rutting measured in actual roads.

Table 5. Target Values for Rehabilitation

PSI	Methods		
3~2.1	Surface Treatment		
2~1.1	Overlay	MCI=4	Rehabilitation is recommended
1~ 0	Replacing		

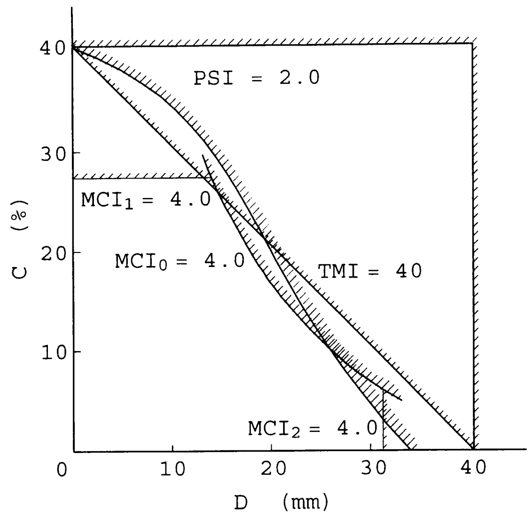


Fig.8 Limit Line for rehabilitation

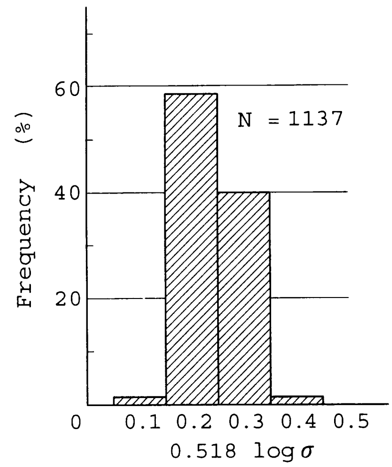


Fig.9 Distribution of $0.518\log\sigma$ in major roads

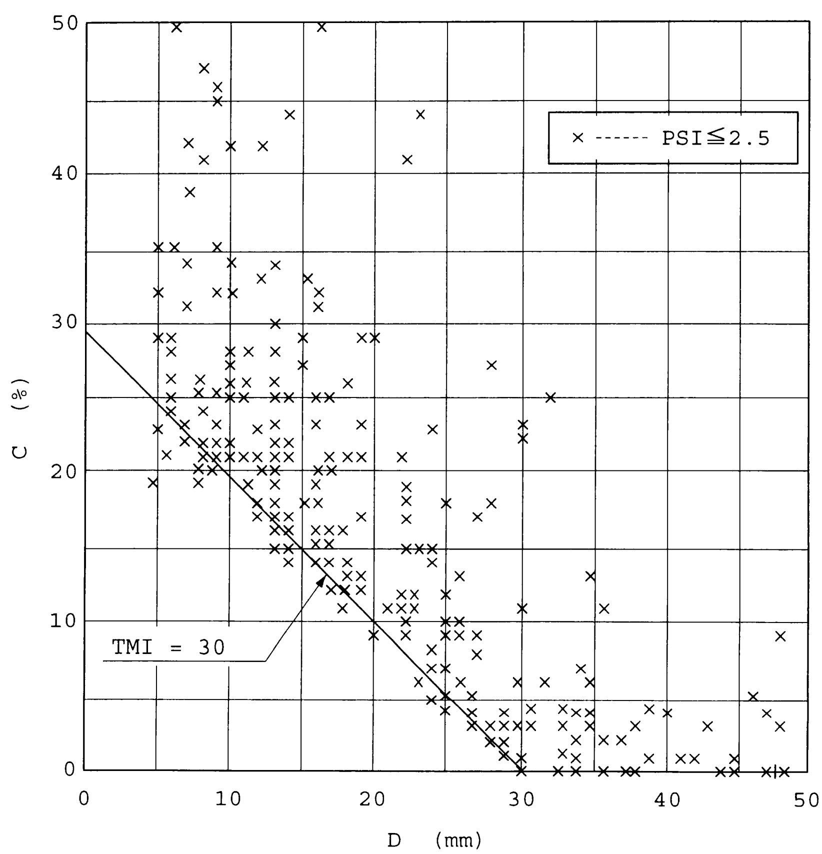
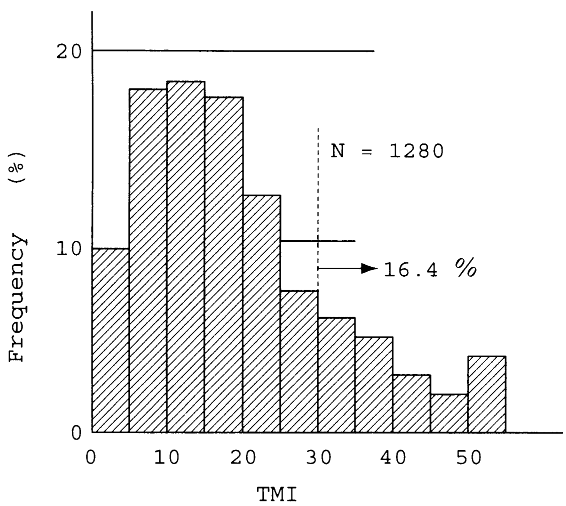


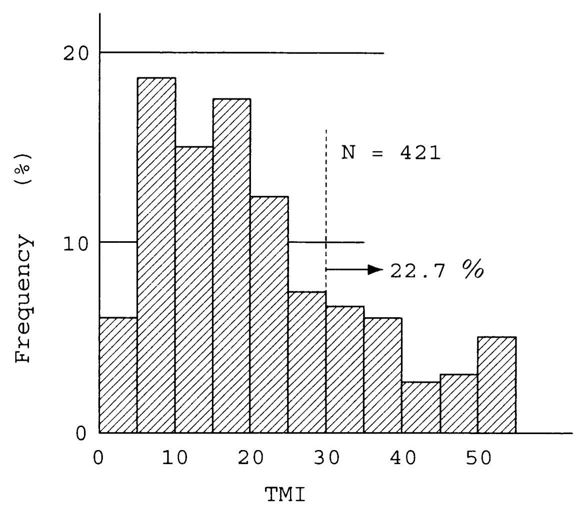
Fig.10 Recommendable limit for Rehabilitation in Tokyo

8. CONDITION SURVEY FOR PAVEMENT MANAGEMENT

Tokyo Metropolitan Government and pavement engineers have been interested in developing the pavement management systems. It has been concluded that the most important factor controling a system is the history of pavement performance. Industrial copanies were advises to develop new devices to measure pavement conditions automatically. In 1985, five companies were authorized to use their devices by the Ministry of Construction. According to these, the speed of measurement is more than 50 km/hour. Some examples measured by the devices are shown in Figure 11. The costs are about $75 (cracking), $75 (rutting) and $45 (roughness) per kilometer. They have been getting cheaper year by year.



(a) Average major roads



(b) The busiest road

Fig.11 Distribution of TMI

ACKNOWLEDGEMENT

The authors wish to acknowledge the may co-worker who assisted in field measurements and collecting necessary data. This support is greatly appreciated.

REFFERENCES

1. Manual for Design and Construction of Asphalt Pavement, the Japan Road Association, 1967
2. Manual for Maintenance and Rehabilitation of Roads, the Japan Road Association, 1978
3. A Report on the Surface Recycling , Express Highway Research Foundation of Japan, 1984